KIRK-OTHMER CHEMICAL TECHNOLOGY OF COSMETICS

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PREFACE

Cosmetic preparations and usage are rooted in antiquity, when suspensions of natural pigments in lipids were used to enhance appearance, and fragrant plant concoctions were widely traded.

Cosmetics represent a large group of consumer products designed to improve the health, cleanliness, and physical appearance of the human exterior and to protect a body part against damage from the environment. Cosmetic products are promoted to the public and are available without prescription.

A large number of raw materials—ingredients—are used to prepare cosmetics. Some of these ingredients are active component, for example, have moisturizing or conditioning effects, and are typically used in limited quantities, whereas other ingredients are used to formulate the products and are used in relatively larger amounts. The combination of various substances determines the nature of the finished cosmetic. Several specialized technologies have been perfected for cosmetic products. Among these, emulsification, stick technology, and powder blending are prominent.

Different laws and regulations apply to prescription drugs, over-the-counter drugs and cosmetics. The use of ingredients in cosmetics is essentially unrestricted and may include new or not well-known substances.

This volume contains carefully selected articles from Wiley's renowned ***Kirk-Othmer Encyclopedia of Chemical Technology,*** which have been updated and revised for this volume***,*** as well as new contributions. The articles cover key topics related to product groups, ingredients, formulation technology and related regulatory aspects. This book will be of interest to chemists, perfumers, R&D, and other professionals in the cosmetic and personal care industry, as well as advanced students who intend to enter this multi-billion dollar global industry.

PART I

PRODUCTS

1

COSMETICS

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1.1. INTRODUCTION

Cosmetics are products created by the cosmetic industry and marketed directly to consumers. The cosmetic industry is dominated by manufacturers of finished products, but also includes manufacturers who sell products to distributors as well as suppliers of raw and packaging materials. Cosmetics represent a large group of consumer products designed to improve the health, cleanliness, and physical appearance of the human exterior and to protect a body part against damage from the environment. Cosmetics are promoted to the public and are available without prescription.

The difference between a cosmetic and a drug is often confusing. In the United States, the inclusion of a drug constituent, as defined by the Food and Drug Administration (FDA), in a cosmetic product may make the product a drug; whenever there is a claim for pharmacological activity of one of a product's constituents, the product is a drug. Some products are identified as quasi or over-the-counter (OTC) drugs according to each country's regulations. The composition, claim structure, and distribution of OTC products may be more tightly regulated than those of pharmacologically inactive cosmetics. The difference between an ordinary cosmetic and a quasi or OTC drug may not be readily apparent; it is based on statutory regulations. Certain types of products, such as hair-growth products and skin rejuvenators, are not cosmetics, and OTC claims for hair growth or skin rejuvenation are not allowed in the United States. These products have been referred to as cosmeceuticals.

Cosmetics, regardless of form, can be grouped by product use into the following seven categories: (*1*) skin care and maintenance, including products that soften (emollients and lubricants), hydrate (moisturizers), tone (astringents), protect (sunscreens), etc., and repair (antichapping, antiwrinkling, antiacne agents); (*2*) cleansing, including soap, bath preparations, shampoos, and dentrifices; (*3*) odor improvement by use of fragrance,

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deodorants, and antiperspirants; (*4*) hair removal, aided by shaving preparations, and depilatories; (*5*) hair care and maintenance, including waving, straightening, antidandruff, styling and setting, conditioning, and coloring products; (*6*) care and maintenance of mucous membranes by use of mouthwashes, intimate care products, and lip antichapping products; and (*7*) decorative cosmetics, used to beautify eyes, lips, skin, and nails.

Reference 1 gives formulations for products in all of the categories listed above.

1.2. HISTORY

Cosmetic preparations and usage are rooted in antiquity, when suspensions of natural pigments in lipids were evidently used to enhance appearance, and fragrant plant concoctions were widely traded. The use of cosmetics for adornment is recorded in biblical writings, and the use of soap, probably a hydrolysate of animal lipids by wood ashes, was encouraged for cleanliness. The benefits of bathing were fully known to the ancients, who built elaborate bathhouses. Bathing became less popular in Western cultures during the Middle Ages but again became accepted during the eighteenth and nineteenth centuries.

The use of fragrant substances has been continuous, and the use of lipids or emollients for anointing is fully documented in historical writings. However, it is probably not justifiable to identify the recipes passed on from antiquity as cosmetics. The compositions based on folklore and mysticism were replaced by more scientifically acceptable products beginning about 1875. The first edition of a handbook of cosmetic chemistry published in 1920 included a foreword noting that scientific cosmetic chemistry did not exist prior to that publication (2). A few years later, texts on cosmetic chemistry and other formularies became available (3, 4).

The Society of Cosmetic Chemists, with individual memberships, was founded in the United States after World War II, based on the belief that scientific expertise and exchange were the foundations for future expansion of the cosmetic industry. Prior to that time, knowledge of cosmetic formulation was jealously guarded. Related scientific societies emerged in other countries and have since joined to form the International Federation of Societies of Cosmetic Chemists.

1.3. REGULATION OF THE COSMETIC INDUSTRY

In the United States, the 1938 revision of the Federal Food and Drug Act regulates cosmetic products and identifies these materials as:

> (1) articles intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body or any part thereof for cleansing, beautifying, promoting attractiveness, or altering the appearance, and (2) articles intended for use as a component of any such articles, except that such term shall not include soap.

This definition establishes the legal difference between a drug and a cosmetic. It is clearly the purpose of, or the claims for, the product, not necessarily its performance, that legally classifies it as a drug or a cosmetic in the United States. For example, a skin-care product intended to beautify by removing wrinkles may be viewed as a cosmetic because it alters the appearance and a drug because it affects a body structure. Different laws and regulations apply to each type of product. Firms sometimes violate the law by marketing a

cosmetic with a drug claim or by marketing a drug as a cosmetic without adhering to requirement for drug. The term cosmeceutical used to mean a product that has two functions has no meaning under the law (5).

The FDA is responsible for enforcing the 1939 act as well as the Fair Packaging and Labeling Act. In light of the difficulty of differentiating between cosmetics and drugs, the FDA has in recent years implemented its regulatory power by concluding that certain topically applied products should be identified as OTC drugs. As a group, these OTC drugs were originally considered cosmetics and remain among the products distributed by cosmetic companies. They include acne, antidandruff, antiperspirant, astringent, oral-care, skin-protectant, and sunscreen products.

The use or presence of poisonous or deleterious substances in cosmetics and drugs is prohibited. The presence of such materials makes the product "adulterated" or "misbranded" and in violation of good manufacturing practices (GMP), which are applicable to drugs and, with minor changes, to cosmetics (6).

In contrast to prescription drugs, OTC drugs and cosmetics are not subject to preclearance in the United States. However, the rules covering OTC drugs preclude introduction of untested drugs or new combinations. A "new chemical entity" that appears suitable for OTC drug use requires work-up via the new drug application (NDA) process. In contrast, the use of ingredients in cosmetics is essentially unrestricted and may include less well-known substances.

1.3.1. Color Additives

The FDA has created a unique classification and strict limitations on color additives. Certified color additives are synthetic organic dyes that are described in an approved color additive petition. Each manufactured lot of a certified dye must be analyzed and certified by the FDA prior to usage. This regulation is covered by the Federal Food Drug and Cosmetic Act. Color lakes are pigments that consist of an insoluble metallic salt of a certified color additive deposited on an inert substrate. Lakes are subject to the color additive regulations of the FDA and must be certified by FDA prior to use. Noncertified color additives require an approved color additive petition, but individual batches need not be FDA certified prior to use.

Hair colorants, the fourth class of color additives, may be used only to color scalp hair and may not be used in the area of the eye. Use of these colorants is exempt, that is, coal-tar hair dyes may be sold with cautionary labeling, directions for preliminary (patch) testing, and restrictions against use in or near the eye. The FDA diligently enforces the rules governing color additives and limits the use of, or even delists colorants deemed unsafe. The list of substances specifically prohibited for use in cosmetics is short.

Under the Fair Packaging and Labeling Act, the FDA has instituted regulations for identifying components of cosmetics on product labels. To avoid confusion, the Personal Care Products Council (PCPC)(formerly CTFA) has established standardized names for about 6000 cosmetic ingredients (1). Rigid U.S. labeling requirements mandate that ingredients be listed in order of descending concentration.

1.3.2. European Regulations

Regulations for cosmetics differ from country to country but, in general, are similar to or patterned after U.S. regulation. Thus, the identification of a cosmetic in the

European Community differs only marginally from that in the United States. A 1991 European Economic Community (EEC) [now the European Union (EU)] directive defines a cosmetic as:

> any substance or preparation intended for placing in contact with the various external parts of the human body (epidermis, hair system, nails, lips and external genital organs) or with the teeth and the mucous membranes of the oral cavity with a view to cleaning them, perfuming them, protecting them, keeping them in good condition, changing their appearance and/or correcting body odours.

The EU Directive asserts that cosmetic products must not damage human health when applied under normal or reasonably foreseeable conditions of use. Also, the Directive states that the label of a cosmetic should include a list of ingredients in descending order of weight at the time of manufacture.

The 27 EU members have transposed the European Union Directive enacted in 1976 into law. Each member state has health authorities that can regulate cosmetics within the state's boundaries. The EU Scientific Committee on Consumer Products (SCCP) is responsible for reviewing all special and active ingredients and assessing conditions for safe use. The results are published on the SCCP website. Today Annex II of the Directive lists 1300 banned ingredients, although some would never be used in cosmetics, e.g., jet fuel. The EU allows the marketing of cosmetic products with certain medicinal properties. In the United States, these products would be regulated as over-the-counter drugs (7).

1.3.3. Japanese Regulation

Cosmetics in Japan are defined as externally used articles for cleaning, beautifying, promoting attractiveness, and altering the appearance of the human body and for keeping the skin and hair healthy, provided that the action of the article on the human body is mild. Articles intended for use in diagnosis, treatment of disease, and those intended to affect the structure or any function of the body are identified as quasi drugs and are excluded. Japanese law identifies the following as quasi drugs: products for the prevention of foul breath or body odor; products for the prevention of prickly heat; products for the prevention of hair loss, promotion of hair growth, or removal of hair; hair dyes; agents for permanent waving of hair; and agents combining cosmetic effects with the purpose of preventing acne, chapping, itchy skin rashes, chilblains, or disinfection of the skin or mouth.

The Japanese government regulates the cosmetic industry through its Ministry of Health Labor and Welfare according to the Pharmaceutical Affairs law (Law 145) established August 10, 1960. Japan has adopted a list of prohibited ingredients, a list of restricted ingredients, a positive list of UV filters, and a positive list of preservatives (8). Other than these restrictions, the burden ensuring product safety has been shifted to the cosmetic manufacturers. Any product shown to be safe can be used. Until recently, a manufacturer or importer of cosmetics was required to obtain pre-market approval. Since 2001, Japan cosmetic companies are required to produce notification of product brand prior to manufacturing or importing.

Japan is an example of a country replacing costly pre-market registration with manufacturer responsibility for product safety and post-market surveillance without compromising consumer safety.

Regulatory changes and discussions of the impact of regulations on the manufacture and import of cosmetic products are available in manuals published by the PCPC (9, 10).

1.3.4. Canadian Regulations

The Canadian government regulates cosmetics through Health Canada's Cosmetic Program. The basis for regulation comes through the Food and Drug Act and Cosmetic Regulations. The program has the mandate of protecting the Canadian people by minimizing the risk associated with cosmetics. The program defines requirements for manufacturing, labeling, distribution, and sales of cosmetics. Manufacturers are responsible for demonstrating the product is safe for its intended use. Regulations are enforced by Health Canada and its officers who manage all aspects of product safety (7).

1.4. PRODUCT REQUIREMENTS

1.4.1. Safety

Cosmetic products must meet acceptable standards of safety during use, must be produced under sanitary conditions, and must exhibit stability during storage, shipment, and use. Cosmetics are not lifesaving or life-prolonging drugs, and the requirements for innocuousness are absolute. In the United States, the manufacturer bears the responsibility for not using injurious or questionable ingredients. The safety of each ingredient used in each finished cosmetic product must be adequately substantiated prior to marketing. In countries that have positive lists of ingredients that may be used in cosmetics, the burden for testing each finished cosmetic products is reduced. Positive listing assumes, without requiring evidence, that no adverse effects result from the use of a mixture of safe ingredients.

For many years the safety of cosmetic ingredients has been established using a variety of animal safety tests. The use of animal testing has declined dramatically in recent years. Animal welfare organizations have urged that this type of safety testing be abandoned. Despite widespread use of cosmetics without professional supervision, the incidence of injury from cosmetic products is rare. In part, this is the result of extensive animal safety testing of components as well as of finished products. Such animal testing was considered mandatory from about 1945 to about 1985. Since the mid-1980s animal testing has been significantly reduced. The cosmetic industry has invested in the search for valid alternative tests. Today the PCPC supports limited and ethical use of animal and *in vitro* tests for new or novel ingredients (11).

In vitro safety testing technology is becoming more common. Validation of these methods is based on comparisons with early animal safety data. In the United States, the PCPC created the Cosmetic Ingredient Review (CIR) for the purpose of evaluating existing *in vitro* and *in vivo* data and reviewing the safety of the ingredients used in cosmetics. The CIR is an independent nonprofit body. The review of ingredients is prioritized based on frequency of use, concentration used, the area of use, and consumer complaints. The CIR conclusions are available from the PCPC.

California law prohibits animal testing when alternatives have been scientifically validated and adopted by appropriate agencies. To date, validated and alternative test methods are not available to replace all types of safety testing. The industry supports various groups that are involved in evaluating alternative methods of testing. Among them are

The Scientific Advisory Committee on Alternative Toxicological Methods, Interagency Coordinating Committee on the Validation of Alternative Toxicological Methods (http://ccyam.nieh.nih.gov), and the National Toxicology Program Interagency for the Evaluation of Alternative Toxicological Methods.

Many cosmetic companies have made efforts to find new testing methods. In addition to the CIR process, the cosmetic industry has instituted a second, important, self-regulatory procedure: the voluntary reporting of adverse reactions, which is intended to provide data on the type and incidence of adverse reactions noted by consumers or by their medical advisors. This reporting procedure creates early awareness of problems handled outside hospital emergency facilities or centers for acute poisoning.

Many consumers now look for the "no animal testing" label as part of their decision to purchase a product. The PCPC advises that individual companies be contacted for information on their testing techniques.

Safety testing of a finished cosmetic product should be sufficient to ensure that the product does not cause irritation when used in accordance with direction, neither elicits sensitization nor includes a sensitizer, and does not cause photoallergic responses.

A particularly critical test for establishing the safety of cosmetics is the exaggerated-use test, in which panelists, often under medical supervision, use a product at frequencies that exceed the normally expected usage. Any adverse reactions, including subjective reports of burning or itching without clinical symptoms, suggest that the product should be examined further. This test also can be used to elicit comments concerning product acceptability.

Repeated usage of certain common cosmetic ingredients can elicit a response within the sebaceous gland apparatus that generates comedos. The cause of this phenomenon is not entirely clear, but an animal (rabbit ear) test purportedly measures the comedogenic potential of cosmetic ingredients or finished products (12). Controversy surrounds the identity of comedogenic substances and the concentration required to elicit the response. Thus use of cosmetic ingredients that have been suspected of causing comedogenicity are generally avoided.

The FDA reports that there is no federal regulation regarding hypoallergenic products. Cosmetic manufacturers claim fewer allergic reactions, but can have little meaning for dermatologists. The FDA suggests that the consumer can use a product with hypoallergenic claims and compare against another product that does not report such claims (13).

1.4.2. Production Facilities

The manufacture of acceptable cosmetic products requires not only safe ingredients but also facilities that maintain high standards of quality and cleanliness. Most countries have established regulations intended to assure that no substandard product or batch is distributed to consumers. Good Manufacturing Practices (GMP) represent workable standards that cover every aspect of drug manufacture, from building construction to distribution of finished products. GMPs in the United States that have been established for drug manufacture are commonly used in cosmetic production (6).

1.4.3. Contamination

Manufacturers of cosmetics must be careful to guard against chemical and microbial contamination. Chemical contamination, which may result from the presence of undesirable

impurities in raw materials, is avoidable by adhering to rigid specifications for raw materials. Compendial specifications and publications by the PCPC and other professional societies form the basis of most intracompany raw material specifications. Moreover, all packaging components must meet not only physical and design specifications but also such chemical requirements as extractables and absence of dust and similar contaminants.

Chemical contamination arising from overheating or other decomposition reactions during processing or from improper storage of incoming supplies must also be avoided. For these reasons, adherence to documented production processes and periodic reassays of stored supplies are required. Additionally, final chemical or physical examinations of the finished and filled products are required to ascertain that no inadvertent chemical contamination has occurred during manufacture and that no undesirable ingredients are present.

An entirely different type of contamination arises from the presence of microbiota in a product. As in the case of chemical contamination, compendial requirements for microbiological purity exists. Pharmacopoeial standards vary from country to country, and manufacturers must use the specifications and kill times that meet local requirements.

1.4.4. Stability

An additional mandatory requirement for cosmetic products is chemical and physical stability. Interactions between ingredients that lead to new chemical entities or decomposition products are unacceptable. Stability testing becomes particularly critical if the product includes an active or drug constituent for which a specific performance claim is made. In the absence of an expiration date, a cosmetic product or an OTC drug should be stable for 60 months at ambient temperature. This temperature is a function of climatic zones. Therefore, controlled temperature storage, sometimes at controlled relative humidity, is universally recognized as ideal despite its attendant cost. In order to demonstrate long-term chemical stability on the basis of short- or intermediate-term studies, formulations are stored routinely at elevated temperatures, normally 37, 45, or 50°C. Changes are extrapolated to ambient temperatures using the Arrhenius equation for reaction rates.

Another type of chemical change is initiated by light, which may trigger autolytic, that is, free radical (Type I) or singlet oxygen (Type II) reactions. These changes are routinely classified as oxidation. Rancidity in cosmetics, especially those containing unsaturated lipids, is commonly prevented by use of antioxidants.

Requirements for physical stability in cosmetics are not as rigid as those for chemical stability. As a rule, minor changes in viscosity or appearance are acceptable to users. More drastic changes, resulting from separation of an emulsion because of creaming or oiling, are not acceptable. Short-term physical, or viscosity, changes cannot be extrapolated to long-term performance. Changes observed during static viscosity tests have little predictive value for long-term viscosity or emulsion stability. Short-term dynamic viscosity tests also do not allow prediction of long-term viscosity changes, but these can sometimes be used to predict changes in the nature of emulsions. Zeta potential and particle size determination can provide predictive information on emulsion behavior.

1.4.5. Performance

Consumer acceptance is a criterion on which cosmetic marketers cannot compromise. Whereas the likes and dislikes of consumers are in a state of constant flux, some

product features are critical. A deodorant that does not deodorize or a hair coloring that fades in sunlight is unacceptable. Performance is tested by *in vitro* techniques during formulation, but the ultimate test of a product's performance requires in-use experience with consumers and critical assessment by trained observers. Performance tests can sometimes be combined with in-use safety tests, and protocols for such programs have been developed.

1.5. INGREDIENTS

Manufacturers of cosmetics employ a surprisingly large number of raw materials. Some of these ingredients are active constituents that have purported beneficial effects on the skin, hair, or nails, for example, acting as moisturizers or conditioners. These substances are generally used in limited quantities. Other ingredients are used to formulate or create the vehicle. These are bulk chemicals used in comparatively large amounts. The resulting combination of various substances affects the nature (viscosity, oiliness, etc.) of the finished cosmetic. As a rule, numerous combinations and permutations are tested to optimize textural characteristics and to match these to consumers' preferences. Finally, cosmetics may include substances added primarily to appeal to consumers. These ingredients need not contribute appreciably to product performance.

About 6000 different cosmetic ingredients have been identified (1). These can be divided into smaller groups according to chemical similarity or functionality. Table 1.1 represents a breakdown by functionality on the skin or in the product. The chemical identity of only one ingredient that performs the desired function is given. In most cases, other equally effective substances exist. The diversity of functions required in cosmetics is evident, and cosmetic ingredients may perform more than one function or belong to more than one chemical class. A typical example is sodium DL-2-pyrrolidinone-5-carboxylate (sodium PCA) [28874-51-3], $NaC_5H_7NO_3$. Chemically, this compound may be viewed as an amide, a heterocyclic compound, or an organic salt; functionally, it is a humectant and skin-conditioning agent.

Ingredients exhibiting certain functions are required in many types of cosmetic products. Antioxidants and preservatives are especially critical for product shelf life and quality during usage. Shelf life is defined herein as that period of time during which a product in an unopened package maintains its quality and performance and shows no physical or chemical instability. Antioxidants and preservatives do not contribute to physical stability but are included in cosmetic products to ensure oxidative stability and to control microbial contamination. Once a package has been opened, oxidative processes may cause the product to deteriorate, and microbial species may gain access to the product. These additives are expected to impart some protection even under these circumstances.

1.5.1. Antioxidants

Some antioxidants useful in cosmetics are listed in Table 1.2. The operant mechanisms are interference with radical propagation reactions, reaction with oxygen, or reduction of active oxygen species. Antioxidants are intended to protect the product but not the skin against oxidative damage resulting from ultraviolet radiation or singlet oxygen formation.

TABLE 1.1. Cosmetic Functions and Representative Ingredients[a]

Function	Ingredient[b]	Molecular Formula	CAS Registry Number
	Biologically active agents		
Antiacne	Salicylic acid	$C_7H_6O_3$	[69-72-7]
Anticaries	Monosodium fluorophosphate	Na_2HPO_3F	[10163-15-2]
Antidandruff	Zinc pyrithione	$C_{10}H_8N_2O_2S_2Zn$	[13463-41-7]
Antimicrobial	Benzalkonium chloride		[8001-54-5]
Antiperspirant	Aluminum chlorohydrate	$Al_2ClH_5O_5$	[12042-91-0]
Biocides	Triclosan	$C_{12}H_7Cl_3O_2$	[3380-34-5]
Sunscreen	Octyl methoxycinnamate	$C_{18}H_{26}O_3$	[5466-77-3]
Skin protectant	Dimethicone	$(C_2H_6OSi)_nC_4H_{12}Si$	[9006-65-9] [63148-62-9]
		$(C_2H_6OSi)_n$	[9016-00-6]
External analgesic	Methyl salicylate	$C_8H_8O_3$	[119-36-8]
	Nonbiologically active agents		
Abrasive			
Skin	Oatmeal		
Teeth	Dicalcium phosphate	$Ca_2(HPO_4)_2$	[7757-93-9]
Antifoam	Simethicone		[8050-81-5]
Antioxidant	Ascorbic acid	$C_6H_8O_6$	[50-81-7]
Antistatic agent	Dimethylditallow alkylammonium chlorides		[68783-78-8]
Binder	Hydroxypropylcellulose		[9004-64-2]
Chelator	Hydroxyethyl ethylenediamine triacetic acid (HEDTA)	$C_{10}H_{18}N_2O_7$	[150-39-0]
Colorant			
Pigment	Ultramarine	$Na_7Al_6Si_6O_{24}S_2$	[1317-97-11]; [1345-00-2]; [12769-96-9]
Dye	FD&C Red No. 4	$C_{18}H_{16}N_2O_7S_2{\cdot}2Na$	[4548-53-2]
Emulsion stabilizer	Xanthan gum		[11138-66-2]
Film former	PVP	$(C_6H_9NO)_x$	[9003-39-8]
Hair colorant	*p*-Phenylenediamine	$C_6H_8N_2$	[106-50-3]
Hair conditioner	Sodium lauroamphoacetate	$Na_2C_{18}H_{35}N_2O_3{\cdot}HO$	[14350-96-0]

(*continued*)

TABLE 1.1. (*Continued*)

Function	Ingredient[b]	Molecular Formula	CAS Registry Number
Humectant	Glycerol	$C_3H_8O_3$	[56-81-5]
Deodorant			
Mouth	Zinc chloride	$ZnCl_2$	[7646-85-7]
External	Cetylpyridinium chloride	$C_{21}H_{38}ClN$	[123-03-5]
Preservative	Propylparaben	$C_{10}H_{12}O_3$	[94-13-3]
Emollient	Octyl stearate	$C_{26}H_{52}O_2$	[22047-49-0]
Skin-conditioning agent			
General	Pyrrolidinone carboxylic acid (PCA)	$C_5H_7NO_3$	[98-79-3]
Occlusive	Petrolatum	C_nH_{2n+2}	[8009-03-8]
Film forming	Hyaluronic acid		[9004-61-9]
Solvent	Ethanol	C_2H_6O	[64-17-5]
Cleansing agent	Sodium lauryl sulfate	$C_{12}H_{25}NaO_4S$	[151-21-3]
Emulsifying agent	Polysorbate 65		[9005-71-4]
Foam booster	Cocamide DEA		[68140-00-1]
Suspending agent	Sodium lignosulfonate		[8061-51-6]
Hydrotrope	Sodium toluenesulfonate		[12068-03-0]
Viscosity-controlling agent			
Decrease	Propylene glycol	$C_3H_8O_2$	[57-55-6]
Increase	Hydroxypropylmethyl-cellulose		[9004-65-3]

[a]Additional functions may be found in Ref. 1.
[b]PCPC adopted names are used; this notation is used for cosmetic labeling.

TABLE 1.2. Free-Radical-Inhibiting Antioxidants or Reductants Useful in Cosmetics[a,b]

Antioxidant	CAS Registry Number	Molecular Formula
Ascorbic acid	[50-81-7]	$C_6H_8O_6$
Ascorbyl palmitate	[137-66-6]	$C_{22}H_{38}O_7$
Butylated hydroxyanisole (BHA)	[25013-16-5]	$C_{11}H_{16}O_2$
Butylated hydroxytoluene (BHT)	[128-37-0]	$C_{15}H_{24}O$
t-Butyl hydroquinone	[1948-33-0]	$C_{10}H_{14}O_2$
Cysteine	[52-90-4]	$C_3H_7NO_2S$
Dilauryl thiodipropionate	[123-28-4]	$C_{30}H_{58}O_4S$
Dodecyl gallate	[1166-52-5]	$C_{19}H_{30}O_5$
Ellagic acid	[476-66-4]	$C_{14}H_6O_8$
Erythorbic acid	[98-65-6]	$C_6H_8O_6$
Kaempferol	[520-18-3]	$C_{15}H_{10}O_6$
Nordihydroguaiaretic acid	[500-38-9]	$C_{18}H_{22}O_4$
Propyl gallate	[121-79-9]	$C_{10}H_{12}O_5$
Quercetin	[117-39-5]	$C_{15}H_{10}O_7$
Sodium ascorbate	[134-03-2]	$C_6H_7NaO_6$
Sodium sulfite	[7757-83-7]	Na_2SO_3
Thioglycolic acid	[68-11-1]	$C_2H_4O_2S$
Tocopherol	[59-02-9]; [1406-18-4]	$C_{28}H_{48}O_2$

[a]Ref. 1 includes a more comprehensive listing.
[b]Use levels are normally about 0.1% and rarely exceed 0.2%.

1.5.2. Preservatives

Several micro-organisms can survive and propagate on unpreserved cosmetic products. Preservatives are routinely added to all preparations that can support microbial growth. The choice of a preservative for a given product is difficult. Anhydrous preparations and products containing high levels of ethanol or *i*-propanol may not require the addition of preservatives.

Contamination during manufacture is common, even when microbially clean ingredients are used. Water, which is almost ubiquitous in cosmetic products, is especially troublesome and must be free from contaminating micro-organisms. All other ingredients should be screened for the presence of microbial species and batches of raw materials of dubious purity may have to be rejected. Cleanliness during manufacture, processing, and filling must be strictly maintained. Despite these precautions, microbial integrity of products may require the presence of one or more preservatives that are compatible with the product's ingredients. Products should not support the growth or viability of any microbial species that may have been accidentally introduced. Preservatives are also required to reduce contamination by consumers during normal use. Powerful preservative action to create self-sterilizing products is required. Whereas production of sterile cosmetics may be practicable, maintenance of sterility during use is problematical, because fingers and cosmetic applicators are not sterile.

Pharmacopoeias and PCPC publications provide guidelines for challenge test procedures and limits on microbial counts (1). The compendial requirements for kill of micro-organisms vary significantly, and alternative test methods may be required (14). As a general rule, pathogenic organisms should be absent (15). Table 1.3 lists a number of antimicrobial preservatives used in cosmetic products. Experience has shown that some

TABLE 1.3. Antimicrobial Preservatives Useful in Cosmetics[a,b]

Name	CAS Registry Number	Molecular Formula
Benzoic acid[c]	[65-85-0]	$C_7H_6O_2$
Benzyl alcohol	[100-51-6]	C_7H_8O
5-Bromo-5-nitro-1,3-dioxane	[30007-47-7]	$C_4H_6BrNO_4$
2-Bromo-2-nitropropane-1,3-diol	[52-51-7]	$C_3H_6BrNO_4$
Butylparaben	[94-26-8]	$C_{11}H_{14}O_3$
Calcium propionate	[4075-81-4]	$CaC_6H_{10}O_4$
Chlorobutanol	[57-15-8]	$C_4H_7Cl_3O$
m-Cresol	[108-39-4]	C_7H_8O
o-Cresol	[95-48-7]	C_7H_8O
p-Cresol	[106-44-5]	C_7H_8O
DEDM hydantoin	[26850-24-8]	$C_9H_{16}N_2O_4$
Dehydroacetic acid	[520-45-6]	$C_8H_8O_4$
Diazolidinyl urea	[278-92-2]	$C_{11}H_8O_2$
Dimethyl oxazolidine	[51200-87-4]	$C_5H_{11}NO$
DMDM hydantoin	[6440-58-0]	$C_7H_{12}N_2O_4$
7-Ethylbicyclooxazolidine	[7747-35-5]	$C_7H_{13}NO_2$
Ethylparaben	[120-47-8]	$C_9H_{10}O_3$
Formaldehyde	[50-00-0]	CH_2O
Glutaral	[111-30-8]	$C_5H_8O_2$
Glyoxal	[107-22-2]	$C_2H_2O_2$
Imidazolidinyl urea	[39236-46-9]	$C_{11}H_{16}N_8O_8$
Iodopropynyl butylcarbamate	[55406-53-6]	$C_8H_{12}INO_2$
Isobutylparaben	[4247-02-3]	$C_{11}H_{14}O_3$
Isopropylparaben	[4191-73-5]	$C_{10}H_{12}O_3$
MDM hydantoin	[116-25-6]	$C_6H_{10}N_2O_3$
Methylchloroisothiazolinone	[26172-55-4]	C_4H_4ClNOS
Methyldibromoglutaronitrile	[35691-65-7]	$C_6H_6Br_2N_2$
Methylisothiazolinone	[2682-20-4]	C_4H_5NOS
Methylparaben	[99-76-3]	$C_8H_8O_3$
Phenethyl alcohol	[200-456-2]	$C_8H_{10}O$
Phenol	[108-95-2]	C_6H_6O
Phenoxyethanol	[122-99-6]	$C_8H_{10}O_2$
Phenylmercuric acetate	[62-38-4]	$HgC_8H_8O_2$
Phenylmercuric benzoate	[94-43-9]	$HgC_{13}H_{10}O_2$
Phenylmercuric borate	[102-98-7]	$HgC_6H_7BO_3$
o-Phenylphenol	[90-43-7]	$C_{12}H_{10}O$
Propylparaben	[94-13-3]	$C_{10}H_{12}O_3$
Quaternium-14	[27479-28-3]	$C_{23}H_{42}N{\cdot}Cl$
Quaternium-15	[51229-78-8]	$C_9H_{16}ClN_4{\cdot}Cl$
Sodium dehydroacetate	[4418-26-2]	$NaC_8H_7O_4$
Sodium phenolsulfonate	[1300-51-2]	$NaC_6H_5O_4S$
Sodium phenoxide	[139-02-6]	NaC_6H_5O
Sodium pyrithione	[3811-73-2]	NaC_5H_5NOS
Sorbic acid[c]	[110-44-1]	$C_6H_8O_2$
Thimerosal	[54-64-8]	$NaHgC_9H_9O_3S$
Triclocarban	[101-20-2]	$C_{13}H_9Cl_3N_2O$
Triclosan	[3380-34-5]	$C_{12}H_7Cl_3O_2$
Zinc pyrithione	[13463-41-7]	$ZnC_{10}H_8N_2O_2S_2$

[a]Ref. 1 includes a more comprehensive listing.
[b]Use levels are product dependent but generally do not exceed 0.25%.
[c]The acid salts are also used.

of the most commonly used preservatives are inactivated by a variety of surfactants. For example, the parabens (esters of *p*-hydroxybenzoic acid) are exceptionally sensitive to the presence of nonionic surfactants, presumably as a result of micellization of the antimicrobial by the surfactant. Over the years, preservation problems have resulted in the introduction into cosmetics of unusual substances that exhibit suitable antimicrobial spectra. However, some of these ingredients reportedly are irritants or sensitizers. Controversies in the scientific literature over the use of these substances are aggravated by regulatory acceptance or prohibition, which may differ from country to country. Table 1.3 includes preservatives that may be barred in certain countries.

Local restrictions concerning the inclusion of preservatives and other constituents are dependent on the cosmetic product's method of use. Products that are allowed to remain on the skin are differentiated from those that are meant to be rinsed off. Components of products left on the skin can be expected to penetrate the viable epidermis and to be systematically absorbed. Products that are rinsed off shortly after skin contact, such as shampoos, can, if properly labeled, contain preservatives that might elicit adverse reactions if left on the skin. Typical examples of such preservatives are formaldehyde, formaldehyde releasers such as Quaternium 15 or MDM hydantoin, and the blend of methylchloroisothiazolinone and methylisothiazolinone.

Decorative eye cosmetic products have been reported to be subject to pathogenic microbial contamination. Regulatory agencies in several countries, therefore, permit the use of mercury-containing preservatives in eye makeups. The infections reported were to a large extent caused by contamination during use, and the introduction of self-sterilizing preparations seems warranted.

1.5.3. Lipids

Natural and synthetic lipids are used in almost all cosmetic products. Lipids serve as emollients or occlusive agents, lubricants, binders for creating compressed powders, adhesives to hold makeup in place, and hardeners in such products as lipsticks. In addition, lipids are used as gloss-imparting agents in hair-care products. The primary requirements for lipids in cosmetics are absence of excessive greasiness and ease of spreading on skin. Oily lipids, principal constituents of emulsions (creams and lotions), are well suited for inclusion in massage products, oils used to treat the skin (bath oils), ointments, suntan oils, and the like. Selection for a specific application is made on the basis of chemical inertness and physical properties. Petrolatum, mineral oils, polymeric silicones, polybutenes, and related substances are ingredients used for skin and hair conditioning. Conditioning is cosmetic jargon for describing a substance's beneficial effect on the substrate. For example, quaternary compounds are substantive to skin and hair proteins and thus can produce conditioning effects. Similarly, lipidic compounds without substantive functional groups, for example, tricaprin, condition skin merely by their presence on the surface. A selected listing of cosmetically useful lipids is provided in Table 1.4.

1.5.4. Solvents

Solvents can be added to cosmetics to help dissolve components used in cosmetic preparations. Water is the most common solvent and is the continuous phase in most suspensions and water/oil (w/o) emulsions. Organic solvents are required in the preparation of colognes, hair fixatives, and nail lacquers. Selected solvents are used to remove soil,

TABLE 1.4. Cosmetically Useful Lipids[a]

Material	CAS Registry Number	Molecular Formula
	Emollients	
Butyl oleate	[142-77-8]	$C_{22}H_{42}O_2$
Caprylic/capric glycerides	[65381-09-1]	
Cetyl lactate	[35274-05-6]	$C_{19}H_{38}O_3$
Dibutyl sebacate	[109-43-3]	$C_{18}H_{34}O_4$
Diisobutyl adipate	[141-04-8]	$C_{14}H_{26}O_4$
Ethyl linoleate	[544-35-4]	$C_{20}H_{26}O_2$
Glyceryl isostearate	[32057-14-0]	$C_{21}H_{42}O_4$
Hydrogenated palm kernel glycerides[b]		
Isodecyl myristate	[17670-91-6]	$C_{24}H_{48}O_2$
Isopropyl stearate	[112-10-7]	$C_{21}H_{42}O_2$
Lauryl lactate	[6283-92-7]	$C_{15}H_{30}O_3$
Mineral oil	[8012-95-1]	C_nH_{2n}
Myristyl myristate	[3234-85-3]	$C_{24}H_{56}O_2$
Oleyl oleate	[3687-45-4]	$C_{36}H_{68}O_2$
PPG-10 cetyl ether	[9035-85-2]	$(C_3H_3O)_2C_{16}H_{34}O$
Propylene glycol dicaprylate	[7384-97-6]	$C_{15}H_{19}NOS{\cdot}HCl$
Squalene	[111-02-4]	$C_{30}H_{50}$
Wheat germ glycerides	[58990-07-8]	
	Occlusive agents	
Acetylated lanolin	[61788-48-5]	
Butyl stearate	[123-95-5]	$C_{22}H_{44}O_2$
Caprylic/capric triglyceride	[65381-09-1]	
Dimethicone	[9006-65-9]	$(C_2H_6OSi)_nC_4H_{12}Si$
Hydrogenated rice bran wax[c]		
Lauryl stearate	[5303-25-3]	$C_{30}H_{60}O_2$
Paraffin	[8002-74-2]	C_nH_{2n+2}
Pentarerythritol tetrastearate	[115-83-3]	$C_{77}H_{148}O_8$
Petrolatum	[8009-03-8]	C_nH_{2n+2}
Propylene glycol dipelargonate	[225-350-9]	$C_{21}H_{40}O_4$
Stearyl erucate[d]		$C_{40}H_{78}O_2$
Trilinolein	[537-40-6]	$C_{57}H_{98}O_6$
	Natural lipids	
Apricot kernel oil	[72869-69-3]	
Beeswax	[8006-40-4]	
Carnauba	[8015-86-9]	
Castor oil	[8001-79-4]	
Coconut oil	[8001-31-8]	
Japan wax	[8001-39-6]	
Jojoba wax	[66625-78-3]	
Lanolin	[8006-54-0]	
Mink oil[e]		
Olive oil	[8001-25-0]	
Ozokerite	[8021-55-4]	
Rice bran oil	[68553-81-1]; [84696-37-7]	

Sesame oil	[8008-74-0]
Sunflower seed oil	[8001-21-6]
Vegetable oil	[68956-68-3]
Walnut oil	[8024-09-7]

[a]Ref. 1 includes a more comprehensive listing.
[b]This is a hydrogenated mixture of mono-, di-, and triglycerides derived from palm kernel oil.
[c]Prepared by partial hydrogenation of rice bran wax.
[d]Erucic acid, *n*-octadecanol ester.
[e]Oil obtained from subdermal fatty tissue of genus *Mustela.*

sebum, and makeup from skin. Solvents used in cosmetics include acetone, denatured alcohol, butoxyethanol (ethylene glycol monobutylether), diethylene glycol, dimethyl isosorbide, ethyl acetate, heptane, isopropyl alcohol, mineral spirits (boiling range 110–155°C), polyethylene glycol (mol. wt. from 200 up to 15,000), propylene glycol, toluene, and tricaprin (glyceryl tri-*n*-decanoate). A comprehensive listing may be found in Ref. 1. The selection of solvents for use in cosmetics is a complex task because of odor as well as topical and inhalation toxicities.

1.5.5. Surfactants

Substances commonly classified as surfactants or surface active agents are required in a wide variety of cosmetics. These are often categorized on the basis of ionic character but are grouped in Table 1.5, which includes at least one member from each of the various chemical types of surfactants, on the basis of utility in cosmetics. Prolonged contact with anionic surfactants can cause some swelling of the skin. Although this is a temporary phenomenon, skin in this swollen condition allows permeation of externally applied substances. Nonionic surfactants as a group are generally believed to be mild even under exaggerated conditions. The more hydrophobic nonionics, those that are water dispersible (not water-soluble), can enhance transdermal passage. Amphoteric surfactants as a group exhibit a favorable safety profile. Finally, cationic surfactants are commonly rated as more irritating than the anionics, but the evidence for generalized conclusions is insufficient.

TABLE 1.5. Cosmetic Surfactants[a]

Material[b]	CAS Registry Number	Molecular Formula
	Cleansing agents	
Ammonium laureth sulfate[c,d]	[32612-48-9]	$(C_2H_4O)_nC_{12}H_{26}O_4S{\cdot}H_3N$
Cetalkonium chloride	[122-18-9]	$C_{25}H_{46}N{\cdot}Cl$
DEA myristate	[53404-39-0]	$C_{14}H_{28}O_2{\cdot}C_4H_{11}NO_2$
Decyl polyglucose[d,e]		
Dioctyl sodium sulfosuccinate[c,d]	[577-11-7]	$C_{20}H_{38}O_7S{\cdot}Na$
Disodium cocoamphodiacetate[d]	[68650-39-5]	
Disodium laurimino dipropionate[d]	[3655-00-3]	$C_{18}H_{35}NO_4{\cdot}2Na$
Lauryl betaine[c,d]	[683-10-3]	$C_{16}H_{33}NO_2$
Lauryl pyrrolidone[d]	[2687-96-9]	$C_{16}H_{31}NO$
Nonoxynol-12	[9016-45-9]	$(C_2H_4O)_nC_{15}H_{24}O$
Myristamine oxide[c,d]	[3332-27-2]	$C_{16}H_{35}NO$
PEG-50 stearate	[9004-99-3]	$(C_2H_4O)_nC_{18}H_{36}O_2$
Potassium dodecylbenzenesulfonate[d]	[27177-77-1]	$KC_{18}H_{30}O_3S$

(*continued*)

TABLE 1.5. (*Continued*)

Material[b]	CAS Registry Number	Molecular Formula
Potassium oleate	[143-18-0]	$KC_{18}H_{34}O_2$
Sodium cocoyl glutamate[d]	[68187-32-6]	
Sodium C_{14-16} olefin sulfonate[d]	[68439-57-6]	
Sodium laureth phosphate[c,d]	[42612-52-2]	
Sodium lauryl sulfate[c,d]	[151-21-3]	$NaC_{12}H_{26}O_4S$
Sodium methyl oleoyl taurate[c,d]	[137-20-2]	$NaC_{21}H_{41}NO_4S$
Sodium nonoxynol-25 sulfate	[9014-90-8]	$(C_2H_4O)_nC_{15}H_{24}O_4S{\cdot}Na$
Sodium oleoyl isethionate[d]	[142-15-4]	$NaC_{20}H_{38}O_5S$
Sodium stearate[c]	[822-16-2]	$NaC_{18}H_{36}O_2$
TEA-abietoyl hydrolyzed collagen[d]	[68918-77-4]	
TEA-lauryl sulfate[d]	[139-96-8]	$C_{12}H_{26}O_4S{\cdot}C_6H_{15}NO_3$
TEA-oleoyl sarcosinate[c]	[17736-08-2]	$C_{21}H_{39}NO_3{\cdot}C_6H_{15}NO_3$
Emulsifying agents		
Ceteareth-10	[68439-49-6]	
Cetrimonium bromide	[57-09-0]	$C_{19}H_{42}N{\cdot}Br$
Laneth-5	[3055-95-6]	$C_{22}H_{46}O_6$
Lecithin	[8002-43-5]	
Nonoxynol-9	[14409-72-4]	$C_{33}H_{60}O_{10}$
PEG-20 dilaurate	[9005-02-1]	$(C_2H_4O)_nC_{24}H_{46}O_3$
PEG-8 oleate	[9004-96-0]	$(C_2H_4O)_nC_{18}H_{34}O_2$
Poloxamer 407	[9003-11-6]	$(C_3H_6O{\cdot}C_2H_4O)_x$
Polyglyceryl-8 oleate	[9007-48-1]	
Polysorbate 60	[9005-67-8]	
Sorbitan sequioleate	[8007-43-0]	
Sucrose stearate	[25168-73-4]	$C_{30}H_{56}O_{12}$
Foam boosters		
Cocamine oxide	[61788-90-7]	
Lauramide DEA	[120-40-1]	$C_{16}H_{33}NO_3$
Myristamide MIPA	[10525-14-1]	$C_{17}H_{35}NO_2$
Myristaminopropionic acid	[14960-08-8]	$C_{17}H_{35}NO_2$
Hydrotropes		
Ammonium xylenesulfonate	[26447-10-9]	$C_8H_{10}O_3S{\cdot}H_3N$
Potassium toluenesulfonate	[16106-44-8]	$C_7H_8O_3S{\cdot}K$
Sodium methyl naphthalene sulfonate	[26264-58-4]	$C_{11}H_{10}O_3S{\cdot}Na$
Solubilizing agents		
Cetareth-40	[68439-49-6]	
Oleth-44	[9004-98-2]	$(C_2H_4O)_nC_{18}H_{36}O$
PEG-40 stearate	[9004-99-3]	$(C_2H_4O)_2C_{18}H_{36}O_2$
Suspending agents		
Behentrimonium chloride	[17301-53-0]	$C_{25}H_{54}N{\cdot}Cl$
Benzethonium chloride	[121-54-0]	$C_{27}H_{42}NO_2{\cdot}Cl$
Sodium lignosulfonate	[8061-51-6]	
Sodium polystyrene sulfonate	[9003-59-2]	$(C_8H_8O_3S{\cdot}Na)_x$

[a] Ref. 1 includes a comprehensive listing.
[b] PCPC names are used.
[c] Belongs to a chemical class especially useful in facial and body washes.
[d] Belongs to a chemical class especially useful in shampoos.
[e] Decyl ether of a glucose oligomer.

1.5.6. Colorants

Color is used in cosmetic products for several reasons: the addition of color to a product makes it more attractive and enhances consumer acceptance; tinting helps hide discoloration resulting from use of a particular ingredient or from age; and finally, decorative cosmetics owe their existence to color.

Organic Colorants The importance of coal-tar colorants cannot be overemphasized. The cosmetic industry, in cooperation with the FDA, has spent a great deal of time and money in efforts to establish the safety of these dyes. Contamination, especially by heavy metals, and other impurities arising from the synthesis of permitted dyes are strictly controlled. Despite this effort, the number of usable organic dyes and of pigments derived from them has been drastically curtailed by regulatory action.

In addition to the U.S. certified coal-tar colorants, some noncertified naturally occurring plant and animal colorants, such as alkanet, annatto [1393-63-1], carotene [36-88-4], $C_{40}H_{56}$, chlorophyll [1406-65-1], cochineal [1260-17-9], saffron [138-55-6], and henna [83-72-7], can be used in cosmetics. In the United States, however, natural food colors, such as beet extract or powder, turmeric, and saffron, are not allowed as cosmetic colorants.

The terms FD&C, D&C, and External D&C (Ext. D&C), which are part of the name of colorants, reflect the FDA's colorant certification. FD&C dyes may be used for foods, drugs, and cosmetics; D&C dyes are allowed in drugs and cosmetics; and Ext. D&C dyes are permitted only in topical products. Straight colorants include both the organic dyes and corresponding lakes, made by extending the colorant on a substrate such as aluminum hydroxide or barium sulfate. The pure dye content of these lakes varies from 2 to 80%; the organic dyes contain over 80% pure dye. Colorants certified for cosmetic use may not contain more than 0.002% of lead, not more than 0.0002% of arsenic, and not more than 0.003% of heavy metals other than lead and arsenic.

Inorganic Colorants In addition to various white pigments, other inorganic colorants such as those listed in Table 1.6 are used in a number of cosmetic products. These usually exhibit excellent lightfastness and are completely insoluble in solvents and water.

Naturally occurring colored minerals that contain oxides of iron are known by such names as ochre [1309-37-1], umber [12713-03-0], sienna [1309-37-1], etc. These show greater variation in color and tinting power than the synthetic equivalents, and the nature and amount of impurities in the national products is also variable. Most of the pigments identified in Table 1.6 are, therefore, manufactured synthetically. They are primarily used in skin-makeup products and in eye-area colorants.

Nacreous Pigments For many years nacreous pigments were limited to guanine (from fish scales) and bismuth oxychloride. Mica, gold, copper, and silver, in flake form, can also provide some interesting glossy effects in products and on the face. Guanine is relatively costly, and bismuth oxychloride darkens on exposure to light and is difficult to suspend because of its high specific gravity. An entirely new set of colored, iridescent, inorganic pigments, which may be described as mixtures of mica and titanium dioxide (sometimes with iron oxides), has been created by coating mica flakes with titanium dioxide. The wavelengths of light reflected from these compositions can produce a complete range of colored interference patterns. The particle size of the mica must be controlled

TABLE 1.6. Inorganic Pigments Useful in Makeups

Material	Molecular Formula	Color
Titanium dioxide	TiO_2	White
Zinc oxide	ZnO	White
Talc	Steatite	Whitish
Barium sulfate	$BaSO_4$	White
Mica		Glossy, colorless
Titanium dioxide–ferric oxide coated mica	[a]	Glossy, nacreous, multicolored
		Multicolored
Guanine[b]	$C_5H_5N_5O$	Nacreous
Bismuth oxychloride	BiOCl	White, nacreous
Iron oxides	85% Fe_2O_3	Yellow to orange
Umber	Fe_2O_3/Fe_3O_4	Brown
Sienna	Fe_2O_3 (ignited)	Red
	Fe_3O_4	Black
Chrome hydroxide green	$Cr_2O(OH)_4$	Bluish green
Chrome oxide greens	Cr_2O_3	Green
Ferric ammonium ferrocyanide	$Fe(NH_4)[Fe(CN)_6]$	Blue
Ferric ferrocyanide	$Fe_4[Fe(CN)_6]_3$	Blue
Manganese violet	$Mn(NH_4)P_2O_7$	Violet
Ultramarines[c]		Blue, violet, red, pink, green

[a] Material is a mixture.
[b] Guanine [73-40-5], an organic dye, is also known as CI 75170 [73-40-5].
[c] Materials are fusion mixtures.

and may not exceed 150 μm, at least in the United States. Additional color effects can be created by sandwiching the mica, TiO_2, and Fe_2O_3.

1.5.7. Botanicals

Plant derived ingredients were among the first cosmetics and their use has always had continuous interest. New discoveries of the benefits of botanicals, greater standardization and control of raw material specifications, and new formulation techniques have resulted in an explosion of interest in botanicals. Today many consumers prefer products made with natural ingredients. In the case of cosmetics, this is because good skin health is associated with natural ingredients. For this reason, essential oils extracted from plants are often added as preservatives (16). This new interest has resulted in the need for the industry to formulate rules for identifying the ingredients in consumer products. The earliest rules for identifying botanical ingredients for cosmetic labeling purposes were developed in the United States. Initially, it made sense to call them by their common name, e.g., apple, orange, etc. As more ingredients entered the market, it became necessary to formulate new rules. Other countries became interested in labeling botanical formulations, but were worried that the names of their plant derivatives would not be understood by the rest of the world. After many meetings, The Personal Care Products Council's (formerly the CTFA) International Nomenclature Committee recommended new rules that recognize

the advantage of using scientific terminology, Latin genus, and species name as the base for botanical nomenclature. These names would be recognized by the scientific and medical community. At first in the Council's *International Cosmetic Ingredient Dictionary and Handbook* (1995), the botanicals were listed as common name first and then their Latin names. In 1999, the Council considered that the familiarization of the names would be advanced enough so that they could list the names in Latin first in updated volumes of the Handbook. The Council is working to ensure that botanicals with possible health effects will continue to have their common name provided. The Council has prepared a cross reference of Latin binomials with English common names (17).

1.6. SPECIALIZED COSMETIC TECHNOLOGIES

Several specialized technologies have been perfected for cosmetic products. Among these, emulsification, stick technology, and powder blending are prominent.

1.6.1. Emulsification

Emulsification is essential for the development of all types of skin- and hair-care preparations and a variety of makeup products. Emulsions are fine dispersions of one liquid or semisolid in a second liquid (the continuous phase) with which the first substance is not miscible. Generally, one of the phases is water and the other phase is an oily substance: oil-in-water emulsions are identified as o/w; water-in-oil emulsions as w/o. When oil and water are mixed by shaking or stirring in the absence of a surface-active agent, the two phases separate rapidly to minimize the interfacial energy. Maintenance of the dispersion of small droplets of the internal phase, a requirement for emulsification, is practical only by including at least one surface-active emulsifier in the oil-and-water blend.

The addition of emulsifiers (see Table 1.5) lowers the energy of the large interfacial area created by forming a huge number of small droplets from a single large drop. In practical emulsification technology, this thermodynamic emulsion stabilization is augmented by two other features. One is the formation of a rigid interfacial film on the surface of the droplets of the internal phase (18). This film, sometimes exhibiting the optical characteristics of a liquid crystal, acts as a mechanical barrier to the coalescence of the droplets of the internal phase. Finally, the droplets may be stabilized by the formation of an electric double layer, which favors the electrical repulsion between charged particles. The latter requires the presence of an electrolyte or an ionized emulsifier.

The coalescence of internal phase droplets can be further decreased by raising the viscosity of the external continuous phase through addition of gums or synthetic polymers, for example, cellulosic gums such as hydroxypropyl methyl cellulose [9004-65-3], fermentation gums such as xanthan gum [11138-66-2], or cross-linked carboxyvinyl polymers such as carbomer [39007-16-3]. The increased viscosity also counteracts changes in the emulsion resulting from differences in the specific gravity of the two phases as mandated by Stokes' law. An advance in cosmetic emulsification technology has resulted from the development of cross-linked carboxyvinyl polymers, in which some of the carboxylic acid residues are esterified with various fatty alcohols. These polymers possess the ability to act as primary emulsifiers and thicken the system when some of the remaining carboxylic groups are neutralized with alkali.

The selection of emulsifiers, auxiliary emulsifiers, gums, and other components is complicated and largely empirical. Despite the lack of a rigid theoretical basis, the hydrophile/lipophile balance (HLB) is the most useful approach for the selection of nonionic emulsifiers (19). The inclusion of ionic emulsifiers was not contemplated in the original formulation of the HLB system. The HLB system also does not account for the effect of low HLB viscosity increasing ingredients, such as cetyl alcohol or glyceryl monostearate. The precise selection of the desired blend from commercial nonionics for emulsification is often frustrating (20). Methods for selecting suitable blends of emulsifiers and stabilizers (21, 22), for preparing emulsions (23, 24), and for studying stability (25) have been published. Stability is important for skin care products from the point of view of functional shelf life. Stability against aggregation is important but failry easy to deal with sine most products are formulated to have a yield stress. Stability against coalescence is very important, but less straightforward. Most cosmetics require a useful life of 2–5 years (16). The technical literature also includes publications dealing with the theory of emulsification and the structure of emulsions and of microemulsions (26, 27).

Conventional cosmetic emulsions (macroemulsions) normally contain about 70% or more of the external phase, which may be a mixture of components. The internal phase is routinely introduced into the external phase at an elevated temperature with vigorous agitation. The emulsifiers are distributed according to their solubility between the two phases. The level of emulsifiers (rarely more than about 10%) is kept low, since excessive amounts may destabilize emulsions or form a clear solubilizate. Auxiliary emulsifiers and other components are included in the phases in which they are soluble.

The term multiple emulsion describes a w/o emulsion in an o/w emulsion. For example, when a w/o emulsion is added to water, no dispersion is expected unless the aqueous phase is fortified with a suitable emulsifier. The resulting dispersion may then be a blend of a w/o and an o/w emulsion, or it may be a multiple emulsion of the w/o/w type. In this latter case, the initial w/o emulsion becomes the internal phase of the final product. Generally, these preparations are not very stable unless they are produced under rigidly controlled conditions (21, 28, 29).

Microemulsions or solubilized or transparent systems are very important in the marketing of cosmetic products to enhance consumer appeal (21, 30). As a rule, large quantities of hydrophilic surfactants are required to effect solubilization. Alternatively, a combination of a solvent and a surfactant can provide a practical solution. In modern clear mouthwash preparations, for example, the flavoring oils are solubilized in part by the solvent (alcohol) and in part by the surfactants. The nature of solubilized systems is not clear. Under normal circumstances, microemulsions are stable and form spontaneously. Formation of a microemulsion requires little or no agitation. Microemulsions may become cloudy on heating or cooling, but clarity at intermediate temperatures is restored automatically.

Nanoemulsioms are transparent or translucent systems. Due to their small droplet size, nanoemulsions are stable against creaming, or seimentation, flocculation, and coalescence. A main advantage is that high occlusive film may be formed on application to the skin. Another useful application is the ability to enhance penetration of actives (e.g., vitamins) into skin. This is due to their much higher surface area when compared to coarser emulsions (31).

Formation of liposomal vesicles under controlled conditions of emulsification of lipids with phospholipids has achieved prominence in the development of drugs and cosmetics (32). Such vesicles are formed not only by phospholipids but also by certain nonionic

emulsifying agents. Formation is further enhanced by use of specialized agitation equipment known as microfluidizers. The almost spontaneous formation of liposomal vesicles arises from the self-assembly concepts of surfactant molecules (33). Vesicles of this type are unusual sustained-release disperse systems that have been widely promoted in the drug and cosmetic industries.

1.6.2. Stick Technology

Cosmetic sticks can be divided into three categories: sticks molded in the container; sticks molded separately and then encased; and sticks formed by compression.

Container Molding Antiperspirant, deodorant, sunscreen, and antiacne sticks are container molded. The amount of dispersed ingredients makes them brittle and difficult to handle mechanically.

The required solids are suspended in a wax–emollient blend at about 60–80°C and milled. The liquid suspension is then cooled to about 55°C, and the more volatile ingredients are added. The mass is placed into containers, which are commonly provided with a threaded shaft for raising or lowering the product.

Antiperspirant sticks based on this molding technique have become more popular since volatile low mol. wt. cyclomethicones [69430-24-6] have been used successfully as the lipids and fatty alcohols as the waxes. This type of product delivers the active antiperspirant to the site as a clinging powder without excessive oiliness.

Deodorant and cologne sticks are formed by allowing sodium stearate to gel in a suitable organic solvent, usually ethanol or propylene glycol. The soap and the solvent are heated under reflux until the soap is dissolved. The solution is cooled to about 60°C; fragrance, color, and the like are added; and the mass is placed into suitable containers.

Stick Molding Various types of lipsticks and eye-shadow sticks are stick molded. A wax-containing lipid mass is milled with the pigment at elevated (about 75°C) temperatures until it is uniform. The lipid mass, at a temperature about 10°C above its melting point, is then poured into metallic molds. Deaeration is essential to prevent unsightly depressions on the molded sticks. To avoid sudden congealing, the molds are customarily heated to a temperature above room temperature before filling; after filling, they are chilled to temperatures well below room temperature. After unmolding, the sticks may be inserted into various types of containers (swivel, metal, or plastic). In order to formulate acceptable molded sticks, slowly developing surface anomalies or defects must be avoided. Foremost are the excrescence of solid fatty substances (also called bloom) and the exudation of liquid substances (also called sweating). Both of these defects are attributed to polymorphic transformation. The selection of the proper blend of lipids to create an acceptable makeup stick is complex. Some of the lipids used in such products and their primary characteristics are listed in Table 1.7. Other types of sticks, for example, eyebrow pencils and lip liners, are molded similarly but may be inserted into wooden pencil stock, trimmed, and appropriately finished.

The criteria for a good cosmetic makeup stick are manifold: the sticks must pay off, that is, deliver the desired amount when used at or near room temperature; sticks must withstand exposure to moderately elevated temperatures; they should not break during

TABLE 1.7. Lipids Used in Cosmetic Molded Sticks[a]

Lipid	CAS Registry Number	Characteristics
	oils	
Castor oil	[8001-79-4]	High gloss; high viscosity
Mineral oil	[8012-95-1]	High gloss
	Esters/alcohols	
Butyl stearate	[123-95-5]	Rapid wetting of pigments; controls sweating at elevated temperatures
Guerbet alcohols		
Decyl tetradecanol	[58670-89-6]	Satiny gloss
Octyl dodecanol	[5333-42-6]	Satiny gloss
Isocetyl alcohol	[36311-34-9]	Similar to castor oil
Isopropyl myristate	[110-27-0]	Same as butyl stearate
Isopropyl palmitate	[142-91-6]	Same as butyl stearate
Oleyl alcohol	[143-28-2]	High gloss; turns rancid
	Fats	
Cocoa butter	[8002-31-1]	Tendency to bloom
Glyceryl monostearate	[31566-31-1]	High melting
Hydrogenated cocoglycerides[b]		Variable properties
Hydrogenated vegetable oil	[68334-28-1]	Greasy
Lanolin	[8006-54-0]	Wets pigments
	Waxes	
Beeswax	[8006-40-4]	Low gloss
Candelilla	[8006-44-8]	Low melting
Carnauba	[8015-86-9]	Very hard
Ozokerite	[8021-55-4]	Thermally stable
	Dye solvents	
Ethoxydiglycol acetate	[112-15-2]	Bitter
Polyethylene glycols	[25322-68-3]	
Propylene glycol	[57-55-6]	

[a]Ref. 1 includes comprehensive listings.
[b]These are blends of mono-, di-, and triglycerides of hydrogenated coconut oil.

normal use; stick components must not elicit unpleasant, for example, oily or warming, sensations after application; pigments must be uniformly distributed and must not react photochemically with the remaining stick components to cause rancidity or photoirritation; and finally, the film produced on the body site must be resistant to rubbing off or transferring to eating utensils or clothing.

Compressed-Powder Sticks Compression of a blend of solids using a suitable binder or by extruding a water containing magma results in compressed-powder sticks.

1.6.3. Powder Blending

Cosmetic powders serve two primary functions. One group, commonly called body powders or talcs, is applied to the skin to provide lubricity and to absorb excessive moisture. The second group, commonly referred to as face powders, exists in both loose and compressed forms and is used to impart some color to the skin and to dull excessive oiliness.

Most powders, including medicated powders, depend on talc to provide lubricity and a matte finish on the skin. Talc is generally blended with other constituents, such as those listed in Table 1.8. The plate-like nature of mined talc makes this hydrous magnesium silicate (steatite) an important skin-care constituent. Loose body and makeup powders utilize additional bulk ingredients. The products can also include antimicrobial agents, dyes, and pigments. The selection of a fragrance must be made with great care; some bulk ingredients are alkaline, and the perfume oil on the surface of particles is subject to oxidation, especially if pigmented ingredients are included.

The basic manufacturing process involves thorough blending of the components, especially the pigments, and comminution with the aid of a variety of mills to reduce the particle size. Loose powders are filled without additional processing.

If compression is required to provide a stick or pan-type of product, the bulk components must be held together with a binder. Common binders are various lipids, polymers, polysaccharides, and waxes. Some binder compositions include water, which is removed by drying the compact. The amount of binder must be carefully controlled to yield a solid, nonfragile compact that is soft enough to pay off. Excessive amounts of or improperly compounded binders glaze during use because of transfer of skin lipids to the compact.

When the bulk containing the binder is uniform, it is compressed on pneumatic, hydraulic, or ram-type presses. Compression can be carried out in presses provided with suitably designed cavities or in metallic pans. The pans are filled with the powder mass, and a plunger with a cross-sectional shape similar to that of the pan is used to compress the tablet. The resulting tablets are commonly used with powder puffs or cosmetic brushes.

TABLE 1.8. Powder Ingredients Used for Cosmetics

Ingredient	Chemical Identity	CAS Registry Number	Comment
Chalk		[13397-25-6]	Opaque, alkaline
Kaolin (clay)	Aluminum silicate	[1332-58-7]	
	Attapulgite	[1337-76-4]	
	Fuller's earth	[8031-18-3]	Opaque, low gloss
	Hectorite	[12173-47-6]	
	Montmorillonite	[1318-93-0]	
Magnesium carbonate		[546-93-0]	Absorbent
Metallic soaps	Magnesium stearate	[557-704-0]	Hydrophobic, lubricant
	Zinc ricinoleate	[13040-19-2]	
Silica	Fumed	[7631-86-9]	Absorbent
	Xerogel	[112945-52-5]	
Starch	Corn starch	[9005-25-6]	Hygroscopic
	Rice starch	[9005-25-8]	
Talc	Hydrated magnesium silicate (steatite)	[14807-96-6]	Opaque lubricant
Titanium dioxide		[13463-67-7]	Opaque, white
Zinc oxide		[1314-13-2]	Opaque, adherent
Zirconium silicate		[10101-52-7]	Opaque, white

1.7. ECONOMIC ASPECTS

Economic summaries of the cosmetic industry, commonly documented by sales volume, are sometimes based on unit sales, sometimes on manufacturers' sales in monetary units, and sometimes on consumer spending. Figures normally include contributions by private labeling operations but do not necessarily reflect the value of the industry service sector, which includes suppliers of raw materials, beauticians, testing laboratories, and other specialists. Moreover, product categories cannot be rigidly defined. For example, the differentiation between a deodorant (a cosmetic) and an antiperspirant (an OTC drug) is often obscured by its trade name.

Numerous cosmetic trade organizations exist. Foremost among them are the Personal Care Products Council (PPC) formerly CTFA; the European Cosmetics Industries Federation (COLIPA); and the Japanese Cosmetic Industry Association (JCIA). These organizations provide member companies with regulatory and technical information and supply documentation on the industry's practices to governments and consumers. The cosmetic industry supports a number of trade journals. Comprehensive annual listings of companies and individual products are available (34).

Euromonitor International reports that world sales of cosmetics in 2007 was $\$290{,}786.9 \times 10^6$ compared to $\$241{,}626.8 \times 10^6$ in 2004. North America accounted for $\$57{,}187.4 \times 10^6$ in 2007 as compared to $52{,}599.1 \times 10^6$ in 2004. The European Union reports an output of more than 35×10^9 euros (35).

1.8. SKIN PREPARATION PRODUCTS

Products for use on the skin are designed to improve skin quality, to maintain (or restore) skin's youthful appearance, and to aid in alleviating the symptoms of minor diseases of the skin. Many of these products are subject to different regulations in different countries. Skin products are generally formulated for a specific consumer purpose.

1.8.1. Skin-Care Products

Preparations are generally classified by body part and purpose (see Table 1.9).

The smoothing or emollient properties of creams and lotions are critical for making these emulsions the preferred vehicles for facial skin moisturizers, skin protectants, and rejuvenating products. On the body, emollients provide smoothness and tend to reduce the sensation of tightness commonly associated with dryness and loss of lipids from the skin. Although a wide variety of plant and animal extracts have been claimed to impart skin benefits, valid scientific evidence for efficacy has been provided only rarely.

Emulsion components enter the stratum corneum and other epidermal layers at different rates. Most of the water evaporates, and a residue of emulsifiers, lipids, and other nonvolatile constituents remains on the skin. Some of these materials and other product ingredients may permeate the skin; others remain on the surface. If the blend of nonvolatiles materially reduces the evaporative loss of water from the skin, known as the transepidermal water loss (TEWL), the film is identified as occlusive. Application of a layer of petrolatum to normal skin can reduce the TEWL, which is normally about 4–8 $g/(m^2 \cdot h)$, by as much as 50–75% for several hours. The evaporated water is to a large extent trapped under the occlusive layer hydrating or moisturizing the dead cells of the stratum corneum.

TABLE 1.9. Classification of Skin-Care Products

Product	Purpose
Baby preparations	
Oils and lotions	Cleansing, soothing
Diaper-rash Products	Prevention, cure drying
Powders	Drying
Foot preparations	
Antifungals	Antiinfective
Emollients	Soothing, crack-prevention
Powders	Drying
Facial preparations	
Lotions and creams	Smoothing, protecting, rejuvenating
Body preparations	
Lotions and creams	Smoothing, protecting
Oils	Smoothing, protecting
Powders	Drying
Hand preparations	
Lotions and creams	Smoothing, protecting
Gels	Antichapping

The flexibility of isolated stratum corneum is dependent on the presence of water: dry stratum corneum is brittle and difficult to stretch or bend. Thus, any increase in the water content of skin is believed to improve the skin quality.

The ability to moisturize the stratum corneum has also been claimed for the presence of certain hydrophilic polymers, for example, guar hydroxypropyl trimonium chloride [65497-29-2], on the skin. By far the most popular way to moisturize skin is with humectants, some of which are listed in Table 1.10. It is claimed that humectants attract water from the environment and thereby provide moisture to the skin.

Studies of the interactions between water and the lipid constituents of the stratum corneum suggest that the supply of water *per se* is not responsible for skin quality and condition. Water vapor from lower layers provides a constant supply of moisture to the epidermis. Instead, the ability of the skin to retain the moisture is critical, and this ability depends on the lipid lamellar bilayers that occupy the spaces between the cells of the stratum corneum (36, 37).

In the United States, products claimed to reverse or alleviate the stigmata of facial skin aging are considered drugs. Claims for improvement of fine wrinkling, mottled hyperpigmentation, and roughness associated with photodamage, on the part of products containing all *trans*-retinoic acid [302-79-4], have received some favorable comments from regulatory advisory panels. Other approaches for antiaging products are based on desquamation by α-hydroxyacids, for example, lactic acid [50-21-5]. Finally, a number of substances, such as hyaluronic acid [9004-61-9] and collagen [9007-34-5], have been claimed to improve the appearance of wrinkled skin.

The amounts and types of lipids used in skin-care products control their application properties. Methods for assessing these characteristics using expert panelists have been described (38).

The ability of skin-care products to supply moisture to the skin remains in question. In the United States, however, the OTC panel has sanctioned the use of skin-protectant

TABLE 1.10. Skin Conditioners and Moisturizers[a]

Material	CAS Registry Number	Molecular Formula
Glycerol	[56-81-5]	$C_3H_8O_3$
2-Pyrrolidinone-5-carboxylic acid (PCA)	[98-79-3]	$C_5H_7NO_3$
Sodium lactate	[72-17-3]	$C_3H_5NaO_3$
Urea	[57-13-6]	CH_4N_2O
Cholesterol	[57-88-5]	$C_{27}H_{46}O$
Hydrolyzed glycosaminoglycans[b]		
Hydrolyzed soy protein	[68607-88-5]	
Linoleic acid	[60-33-3]	$C_{18}H_{32}O_2$
Tocopheryl acetate	[7695-91-2]	$C_{31}H_{52}O_3$
Witch hazel distillate[c]		
Sodium hyaluronate[d]		
Myristyl betaine	[2601-33-4]	$C_{18}H_{37}NO_2$

[a]Ref. 21 includes a more comprehensive listing.
[b]Mixed polysaccharides from animal connective tissue.
[c]Nonalcoholic steam distillate of parts of *Hamamelis virginiana*.
[d]Sodium salt of hyaluronic acid [9004-61-9].

ingredients such as glycerin, which may play roles in the skin's water ecology. Products for the care of body skin are similar to preparations formulated for the care of facial skin. Products for overall body care should leave a dry, satinlike finish even though relatively high levels of unctuous lipids are used. Facial night creams may leave the skin somewhat oily, whereas facial day creams must provide a dry finish.

Hand-care products are designed to reduce chapping and cracking, especially prevalent during cold, dry, winter weather. Hand-care products are commonly fortified with various humectants, and products for the elbows and feet may include abrasives. Bath powders impart lubricity to body skin, absorb moisture, and provide some fragrance. These are formulated without pigments to preclude the staining of clothing.

1.8.2. Antiacne Preparations

Antiacne products are designed to alleviate the unsightly appearance and underlying cause of juvenile acne. Generally, acne is a mild disease of the follicular duct in which sebaceous secretion is not readily allowed to pass to the surface of the skin because of a hyperkeratotic restriction in the duct. The retained sebum may undergo chemical changes or be altered by microbial species, with consequent inflammatory responses. In the past, cosmetic preparations were designed to remove sebum from the skin surface with solvents or cleansers and work against micro-organisms with antibacterials. In addition, acne was cosmetically treated with abrasives in the hope that scrubbing would relieve the ductal blockage.

As of 1991 in the United States, OTC antiacne preparations may contain only a few active drugs, for example, sulfur [7704-34-9], resorcinol acetate [102-29-4], resorcinol [108-46-3], salicylic acid [69-72-7], and some combinations (39). OTC antiacne constituents may be included in a variety of conventional cosmetic preparations, which then become OTC drugs. These include lotions, creams, solutions, facial makeups, facial