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ENHANCED SKIN PENETRATION SYSTEM FOR IMPROVED TOPICAL DELIVERY OF DRUGS

TECHNICAL FIELD

The present invention relates to compositions for the topical administration of drugs, especially such compositions having enhanced penetration of the drug through the skin.

BACKGROUND OF THE INVENTION

Because of the accessibility and large area of the skin, it has long been considered a promising route for the administration of drugs, whether dermal, regional, or systemic effects are desired.

The advantages of the topical route of drug administration include: avoidance of the risks and inconvenience of parenteral treatment; avoidance of the variable absorption and metabolism associated with oral treatment; continuity of drug administration, permitting use of pharmacologically active agents with short biological half-lives; potential reduction of gastrointestinal irritation in systemic administration; and treatment of curtaneous manifestations of diseases usually treated systemically.

However, the impermeability of skin is well-known, serving as a barrier to ingress of pathogens and toxic chemicals, and egress of physiologic fluids. This impermeability is the result of normal physiologic changes in developing skin. A typical cell in the epidermis is formed in the basal layer. It typically takes approximately thirty days for a cell to migrate from the basal layer of the epidermis to sloughing off and discarding at the outer layers of the stratum corneum. As the cell migrates outward from the basal layer, it progressively keratinizes until it is relatively impermeable. The result is the stratum corneum, an extremely thin surface layer (10 microns) with substantial barrier properties. The cell envelopes of the cells in the stratum corneum tend to be mainly polar lipids, such as ceramides, sterols, and fatty acids while the cytoplasm of stratum corneum

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cells remains polar and aqueous. Despite the close packing of the cells, some 15% of the stratum corneum is intercellular and, generally, lipid based. It is generally recognized that over the very short term, penetration occurs through the hair follicles and the sebaceous apparatus; long-term penetration occurs across cells (non-polar route). Poor penetration of many drugs across the epidermal lipid barrier has, until now, frustrated attempts to deliver clinically significant doses of many drugs by the topical route.

One route of internal delivery of drugs is by transdermal administration. Transdermal administration of drugs can be used in many instances to achieve therapeutic levels of the drugs in the systemic circulatory system, as well as for more localized internal dosing of drugs. Where such therapeutic levels of drugs can be achieved by transdermal administration, several potential advantages exist over other routes of administration. Sustained systemic delivery of drug controlled at therapeutic but below toxic levels over long periods of time with a single continuous application is often an advantage of transdermal drug administration. Potential contamination of internal tissues with undesired foreign substances or microbes, often associated with parenteral administration of drugs, is avoided with transdermal drug administration. Oral administration of many drugs is undesirable or unfeasible because the drug decomposes in the harsh environment of the gastrointestinal tract, lacks sufficient absorption from the gastrointestinal tract, or causes gastrointestinal upset or tissue damage in the gastrointestinal tract. First-pass metabolism of orally administered drugs can increase the dosage required to achieve therapeutic levels and thereby increase undesirable side effects either from the primary drug or the metabolites. Maintenance of uniform, optimal systemic levels of drugs for long periods of time is often difficult through oral administration. Such problems can often be reduced or avoided by transdermal drug administration.

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Despite the substantial potential advantages for transdermal administration of drugs, relatively few drugs are so administered. The skin is a formidable barrier to the passage of most drugs. It is often necessary to provide a composition containing a skin penetration enhancing vehicle in order to provide sufficient transdermal penetration of the drug to achieve therapeutic levels of the drug at the target internal tissue. A number of skin penetration enhancing vehicles for drugs have been disclosed, including those in the following references: U.S. Patent No. 3,536,816 issued to Kellner on October 27, 1970; U.S. Patent No. 4,006,218 issued to Sipos on February 1, 1977; U.S. Patent No. 4,124,720 issued to Wenmaekers on November 7, 1978; U.S. Patent No. 4,126,681 issued to Reller on November 21, 1978; U.S. Patent No. 4,299,826 issued to Luedders on November 10, 1981; U.S. Patent No. 4,305,936 issued to Klein on December 15, 1981; U.S. Patent No. 4,309,414 issued to Inagi, Muramatsu & Nagai on January 5, 1982; U.S. Patent No. 4,338,306 issued to Kitao & Nishimura on July 6, 1982; U.S. Patent No. 4,442,090 issued to Kakeya, Kitao & Nishimura on April 10, 1984; U.S. Patent No. 4,485,033 issued to Kitao & Nishimura on November 27, 1984; U.S. Patent No. 4,537,776 issued to Cooper on August 27, 1985; U.S. Patent No. 4,552,872 issued to Cooper, Loomans & Fawzi on November 12, 1985; U.S. Patent No. 4,557,934 issued to Cooper on December 10, 1985; U.S. Patent No. 4,573,995 issued to Chen, Chun & Enscore on March 4, 1986; U.S. Patent No. 4,626,539 issued to Aungst & DiLuocio on December 2, 1986; U.S. Patent No. 4,637,930 issued to Konno, Kawata, Aruga, Sonobe & Mitomi issued January 20, 1987; U.S. Patent No. 4,695,465 issued to Kigasawa, Ohtani, Tanaka & Hayashida on September 22, 1987; European Patent Application No. 0,043,738 of The Procter & Gamble Company in the names of Wickett, Cooper & Loomans, published on June 13 1982; European Patent Application No. 0,095,813 of The Procter & Gamble Company in the name of Cooper, published December 7, 1983; PCT International Patent Application No. WO 87/03490 of Key Pharmaceuticals, Inc. in the names of Bodor and Loftson, published on June 18, 1987;

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Washitake, M., T. Anmo, I. Tanaka, T. Arita & M. Nakano, "Percutaneous Absorption of Drugs from Oily Vehicles", Journal of Pharmaceutical Sciences, Vol. 64, No. 3 (March, 1975), pp. 397-401; Shahi, V., & J. L. Zatz, "Effect of Formulation Factors on Penetration of Hydrocortisone through Mouse Skin", Journal of Pharmaceutical Sciences, Vol. 67, No. 6 (June, 1978), pp. 789-792; Cooper, E.R., "Increased Skin Permeability for Lipophilic Molecules", Journal of Pharmaceutical Sciences, Vol. 73, No. 8 (August, 1984), pp. 1153-1156; Aungst, B.J., N. J. Rogers & E. Shefter, "Enhancement of Naloxone Penetration through Human Skin In Vitro Using Fatty Acids, Fatty Alcohols, Surfactants, Sulfoxides and Amides", International Journal of Pharmaceutics, Vol. 33 (1986), pp. 225-234; Green, P.G., & J. Hadgraft, "Facilitated Transfer of Cationic Drugs Across a Lipoidal Membrane by Oleic Acid and Lauric Acid", International Journal of Pharmaceutics, Vol. 37 (July, 1987), pp. 251-255.

It is an object of the present invention to provide novel compositions for enhancing the skin penetration of drugs.

It is a further object of the present invention to provide such compositions which provide sufficient skin penetration enhancement to achieve therapeutic levels of the drugs in target internal tissues.

It is a further object of the present invention to provide such compositions with low dermal irritation, especially in compositions requiring a low pH.

It is a still further object of the present invention to provide such compositions having good stability and good cosmetics.

SUMMARY OF THE INVENTION

The present invention relates to pharmaceutical compositions for topical application having enhanced penetration through the skin comprising:

(a) a safe and effective amount of a pharmaceutical active; and

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(b) from about 0.1% to about 10.0% of a high molecular weight crosslinked cationic polymer of the formula: $(A)_l(B)_m(C)_n$ wherein (A) is a dialkylaminoalkyl acrylate monomer or its quaternary ammonium or acid addition salt, (B) is a dialkylaminoalkyl methacrylate monomer or its quaternary ammonium or acid addition salt, (C) is a monomer having one carbon-carbon double bond, l is an integer of 0 or greater, m is an integer of 1 or greater, and n is an integer of 0 or greater, wherein said polymer contains a crosslinking agent.

In further embodiments the crosslinked cationic polymer is of the formula wherein (C) is acrylamide.

In further embodiments the crosslinked cationic polymer is of the formula wherein (C) is acrylamide and l is zero.

In yet further embodiments the crosslinked cationic polymer is a homopolymer wherein both l and n are zero.

All concentrations and ratios herein are by weight of total composition and all measurements are at 25°C, unless otherwise specified.

DETAILED DESCRIPTION OF THE INVENTION

The present invention involves compositions comprising certain specific cationic polymers which may be applied topically to the skin and which result in improved transdermal penetration of the drugs through the skin. These compositions also have a high solvent tolerance, i.e., high level of solvents such as alcohol and other water-soluble components which may be necessary to solubilize the active can be included in the compositions.

Drug Active

The compositions of the present invention comprise a safe and effective amount of a drug active. The phrase "safe and effective amount", as used herein, means an amount of a drug high enough to significantly positively modify the condition to be treated, but low enough to avoid serious side effects (at a reasonable benefit/risk ratio), within the scope of sound medical judgement. A safe and effective amount of the drug will vary with the

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specific drug, the ability of the composition to penetrate the drug through the skin, the amount of composition to be applied, the particular condition being treated, the age and physical condition of the patient being treated, the severity of the condition, the duration of the treatment, the nature of concurrent therapy, and like factors.

The drug compounds present in the compositions of the present invention preferably comprise from about 0.1% to about 20% by weight of the compositions, more preferably from about 0.1% to about 10%, and most preferably from about 0.1% to about 5%. Mixtures of drug actives may also be used.

Useful drug actives in the compositions of the present invention include anti-acne drugs. Anti-acne drugs preferred for use in the present invention include the keratolytics such as salicylic acid, sulfur, lactic acid, glycolic, pyruvic acid, urea, resorcinol, and N-acetylcysteine; retinoids such as retinoic acid and its derivatives (e.g., cis and trans); antibiotics and antimicrobials such as benzoyl peroxide, octopirox, erythromycin, zinc, tetracyclin, triclosan, azelaic acid and its derivatives, phenoxy ethanol and phenoxy proponol, ethylacetate, clindamycin and meclocycline; sebostats such as flavinoids; alpha and beta hydroxy acids; and bile salts such as scymnol sulfate and its derivatives, deoxycholate, and cholate. Preferred for use herein is salicylic acid.

Useful drug actives in the compositions of the present invention include non-steroidal anti-inflammatory drugs (NSAIDS). The NSAIDS can be selected from the following categories: propionic acid derivatives; acetic acid derivatives; fenamic acid derivatives; biphenylcarboxylic acid derivatives; and oxicams. All of these NSAIDS are fully described in the U.S. Patent 4,985,459 to Sunshine et al., issued January 15, 1991, incorporated by reference herein. Most preferred are the propionic NSAIDS including but not limited to aspirin, acetaminophen, ibuprofen, naproxen, benoxaprofen, flurbiprofen, fenoprofen, fenbufen, ketoprofen, indoprofen, pirprofen,

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carprofen, oxaprozin, pranoprofen, miroprofen, tioxaprofen, suprofen, alminoprofen, tiaprofenic acid, fluprofen and bucloxic acid. Also useful are the steroidal anti-inflammatory drugs including hydrocortisone and the like.

Useful drug actives in the compositions of the present invention include antihistaminic drugs. Antihistaminic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of chlorpheniramine, triprolidine, diphenhydramine, doxylamine, pyrilamine, phenindamine, promethazine, cyproheptadine, azatadine, clemastine, carbinoxamine, tripelennamine, terfenadine, dexchlorpheniramine, brompheniramine, chlorcyclizine, diphenylpyraline, pheniramine and phenyltoloxamine, and mixtures thereof.

Useful drug actives in the compositions of the present invention include antitussive drugs. Antitussive drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of dextromethorphan, codeine, caramiphen and carbetapentane.

Useful drug actives in the compositions of the present invention include antipruritic drugs. Antipruritic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of methdilizine and trimeprazine.

Useful drug actives in the compositions of the present invention include anticholinergic drugs. Anticholinergic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of scopolamine, atropine, homatropine, levodopa, dicyclomine, hyoscyamine, procyclidine, trihexyphenidyl and ethopropazine.

Useful drug actives in the compositions of the present invention include anti-emetic and antinauseant drugs. Anti-emetic and antinauseant drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of cyclizine, meclizine, chlorpromazine, buclizine, metoclopramide, prochlorperazine and trimethobenzamide.

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Useful drug actives in the compositions of the present invention include anorexic drugs. Anorexic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of benzphetamine, phentermine, chlorphentermine, fenfluramine, diethylpropion and phendimetrazine.

Useful drug actives in the compositions of the present invention include central stimulant drugs. Central stimulant drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of amphetamine, methamphetamine, dextroamphetamine and methylphenidate.

Useful drug actives in the compositions of the present invention include antiarrhythmic drugs. Antiarrhythmic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of propranolol, procainamide, disopyramide, quinidine, encainide, flecanaide, mexiletine and tocainide. Other antiarrhythmic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of the quinidine derivatives disclosed in U.S. Patent No. 4,716,171 issued to Jarreau and Koenig on December 29, 1987, which is hereby incorporated herein in its entirety by reference. Highly preferred compounds included in this class include pharmaceutically-acceptable salts of 3S-hydroxy-10,11-dihydroquinidine, 3R-hydroxy-10,11-dihydroquinidine, 3R-hydroxy-O-acetyl-10,11-dihydroquinidine, and 3S-hydroxy-O-acetyl-10,11-dihydroquinidine, especially 3S-hydroxy-10,11-dihydroquinidine.

Useful drug actives in the compositions of the present invention include β-adrenergic blocker drugs. β-Adrenergic blocker drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of metoprolol, acebutolol, betaxolol, labetalol and timolol. β-Adrenergic blocker drugs more preferred for inclusion in compositions of the present invention include metoprolol tartrate,

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acebutolol hydrochloride, betaxolol hydrochloride, labetalol hydrochloride and timolol maleate.

Useful drug actives in the compositions of the present invention include cardiotonic drugs. Cardiotonic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of milrinone, amrinone and dobutamine. Other cardiotonic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of 14-amino steroid derivatives, some of which are disclosed in U.S. Patent Nos. 4,325,879, 4,552,868 and 4,584,289, issued to Jarreau and Koenig on April 20, 1982, November 12, 1985 and April 22, 1986, respectively, each of which are hereby incorporated herein in their entirety by reference.

Useful drug actives in the compositions of the present invention include antihypertensive drugs. Antihypertensive drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of enalapril, clonidine, hydralazine, minoxidil (which is also a hair growth stimulator drug), guanadrel, guanethidine, guanfacine, mecamylamine, methyldopate, pargyline, phenoxybenzamine and prazosin.

Useful drug actives in the compositions of the present invention include diuretic drugs. Diuretic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of amiloride and hydrochlorothiazide. Diuretic drugs more preferred for inclusion in compositions of the present invention include amiloride hydrochloride.

Useful drug actives in the compositions of the present invention include vasodilator drugs. Vasodilator drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of diltazem, amiodarone, isoxsuprine, nylidrin, tolazoline and verapamil.

Useful drug actives in the compositions of the present invention include vasoconstrictor drugs. Vasoconstrictor drugs preferred for inclusion in compositions of the present invention

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include pharmaceutically-acceptable salts of dihydroergotamine, ergotamine and methysergide.

Useful drug actives in the compositions of the present invention includes anti-ulcer drugs. Anti-ulcer drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of ranitidine and cimetidine.

Useful drug actives in the compositions of the present invention include include anesthetic drugs. Anesthetic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of lidocaine, bupivacaine, chlorprocaine, dibucaine, etidocaine, mepivacaine, tetracaine, dyclonine, hexylcaine, procaine, cocaine, ketamine, pramoxine and phenol.

Useful drug actives in the compositions of the present invention include antidepressant drugs. Antidepressant drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of imipramine, desipramine, amitriptyline, nortriptyline, protriptyline, doxepin, maprotiline, phenelzine, tranylcypromine, trazodone and trimipramine.

Useful drug actives in the compositions of the present invention include tranquilizer and sedative drugs. Tranquilizer and sedative drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of chlordiazepoxide, benactyzine, benzquinamide, flurazepam, hydroxyzine, loxapine and promazine.

Useful drug actives in the compositions of the present invention include antipsychotic drugs. Antipsychotic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of chlorprothixene, fluphenazine, haloperidol, molindone, thioridazine and trifluoperazine.

Useful drug actives in the compositions of the present invention include antimicrobial drugs (antibacterial, antifungal, antiprotozoal and antiviral drugs). Antimicrobial drugs preferred

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for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of β-lactam drugs, quinolone drugs, ciprofloxacin, norfloxacin, tetracycline, erythromycin, amikacin, triclosan, doxycycline, capreomycin, chlorhexidine, chlortetracycline, oxytetracycline, clindamycin, ethambutol, metronidazole, pentamidine, gentamicin, kanamycin, lineomycin, methacycline, methenamine, minocycline, neomycin, netilmicin, paromomycin, streptomycin, tobramycin, miconazole and amanfadine. Antimicrobial drugs preferred for inclusion in compositions of the present invention include tetracycline hydrochloride, erythromycin estolate, erythromycin stearate (salt), amikacin sulfate, doxycycline hydrochloride, capreomycin sulfate, chlorhexidine gluconate, chlorhexidine hydrochloride, chlortetracycline hydrochloride, oxytetracycline hydrochloride, clindamycin hydrochloride, ethambutol hydrochloride, metronidazole hydrochloride, pentamidine hydrochloride, gentamicin sulfate, kanamycin sulfate, lineomycin hydrochloride, methacycline hydrochloride, methenamine hippurate, methenamine mandelate, minocycline hydrochloride, neomycin sulfate, netilmicin sulfate, paromomycin sulfate, streptomycin sulfate, tobramycin sulfate, miconazole hydrochloride, amanfadine hydrochloride, amanfadine sulfate, triclosan, octopirox, parachlorometa xylenol, nystatin, tolnaftate and clotrimazole.

Useful drug actives in the compositions of the present invention include antineoplastic drugs. Antineoplastic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of bleomycin, daunorubicin, doxorubicin, mechlorethamine, procarbazine, quinacrine, tamoxifen, vinblastine and vincristine.

Useful drug actives in the compositions of the present invention include antimalarial drugs. Antimalarial drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of chloroquine, hydroxychloroquine primaquine and quinine.

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Useful drug actives in the compositions of the present invention include muscle relaxant drugs. Muscle relaxant drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of cinnamedrine, cyclobenzaprine, flavoxate, orphenadrine, papaverine, mebeverine, idaverine, ritodrine, dephenoxylate, dantrolene and azumolene.

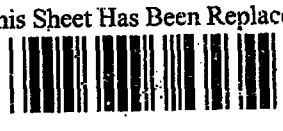
Useful drug actives in the compositions of the present invention include antispasmodic drugs. Antispasmodic drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of the compounds disclosed in U.S. Patent Number 3,856,825 issued to Wright, Burch and Goldenburg on December 24, 1974, which is hereby incorporated herein in its entirety by reference.

Useful drug actives in the compositions of the present invention include antidiarrheal drugs. Antidiarrheal drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of loperamide.

Useful drug actives in the compositions of the present invention include bone-active drugs. Bone-active drugs preferred for inclusion in compositions of the present invention include pharmaceutically-acceptable salts of diphosphonate drug compounds and phosphonoalkylphosphinate drug compounds, including the prodrug esters thereof. Such compounds are disclosed, for example, in U.S. Patent Nos. 3,683,080 issued to Francis on August 8, 1972; 4,304,734 issued to Jary, Rihakova & Zobacova on December 8, 1981; 4,687,768 issued to Benedict & Johnson on August 18, 1987; 4,711,880 issued to Stahl & Schmitz on December 8, 1987; and 4,719,203 issued to Bosies & Gall on January 12, 1988; copending U.S. patent application Serial Nos. 808,584,* of Benedict & Perkins filed December 13, 1985; 945,069* of Ebetino, Buckingham & McOsker filed December 19, 1986; 945,068* of Ebetino & Benedict filed December 19, 1986; and 069,666* of Ebetino filed July 6, 1987; and European Patent Application Nos. 0,001,584 of Blum, Hempel & Worms, published May 2, 1979; 0,039,033 published April 11, 1981; 0,186,405 of Benedict & Perkins, published July 2, 1986; and

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0,243,173 of Oku, Todo, Kasahara, Nakamura, Kayakiri & Hashimoto, published October 28, 1987; all of which are hereby incorporated herein in their entirety by reference.

Also useful in the present invention are sunless tanning agents including dihydroxyacetone, glyceraldehyde, indoles and their derivatives, and the like.These sunless tanning agents may also be used in combination with conventional sunscreen agents such as those disclosed in Segarin, et al., at Chapter VIII, pages 189 et seq., of Cosmetics Science and Technology, incorporated by reference herein, as well as wound healing agents such as peptide derivatives, yeast, panthenol, Iamin and kinetin.

Other usefulskin actives include skin bleaching (or lightening) agents including but not limited to hydroquinone, ascorbic acid, kojic acid and sodium metabisulfite.

Water-Soluble Polymer The polymers useful in the present invention are certain cationic polymers. These polymers are generally described in U.S. Patent 5,100,660, to Hawe et al., issued March 31, 1992; U.S. Patent 4,849,484, to Heard, issued July 18, 1989; U.S. Patent 4,835,206, to Farrar et al., issued May 30, 1989; U.S. Patent 4,628,078 to Glover et al. issued December 9, 1986; U.S. Patent 4,599,379 to Flesher et al. issued July 8, 1986; and EP 228,868, to Farrar et al., published July 15, 1987; all of which are incorporated by reference herein.

The compositions of the instant invention comprise from about 0.1% to about 10%, preferably from about 0.1% to about 7.5%, and most preferably from about 0.1% to about 5% of the polymer.

In general these polymers are high molecular weight materials containing cationic, usually quaternized, nitrogen moieties. These polymers can be characterized by the general formula: $(A)_l(B)_m(C)_n$ wherein (A) is a dialkylaminoalkyl acrylate monomer or its quaternary ammonium or acid addition salt, (B) is a dialkylaminoalkyl methacrylate monomer or its quaternary ammonium or acid addition salt, (C) is a monomer having one carbon-carbon double bond, l is an integer of 0 or greater, m is an integer of 1 or greater, and n is an integer of 0 or greater. The (C) monomer

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can be selected from any of the commonly used monomers. Nonlimiting examples of these monomers include ethylene, propylene, butylene, isobutylene, eicosene, maelic anhydride, acrylamide, methacrylamide, maleic acid, acrolein, cycohexene, ethyl vinyl ether, and methyl vinyl ether. In the cationic polymers of the present invention, (C) is preferably acrylamide.

In highly preferred embodiments, these polymers also contain a crosslinking agent, which is most typically a material containing one or more unsaturated functional groups. Nonlimiting examples of suitable crosslinking agents include those selected from the group consisting of methylenebisacrylamides, diallyldialkyl ammonium halides, polyalkenyl polyethers of polyhydric alcohols, allyl acrylates, vinyloxyalkylacrylates, and polyfunctional vinylidenes. Specific examples of crosslinking agents useful herein include those selected from the group consisting of methylenebisacrylamide, ethylene glycol di-(meth)acrylate, di-(meth)acrylamide, cyanomethylacrylate, vinyloxyethylacrylate, vinyloxyethylmethacrylate, allyl pentaerythritol, trimethylolpropane diallylether, allyl sucrose, butadiene, isoprene, divinyl benzene, divinyl naphthalene, ethyl vinyl ether, methl vinyl ether, and allyl acrylate. Other crosslinkers include formaldehyde and glyoxal. Preferred for use herein as a cosslinking agent is methylenebisacrylamide.

When the croslinking agent is present, widely varying amounts can be employed depending upon the properties desired in the final polymer, e.g. viscosifying effect. Without being limited by theory, it is believed that incorporation of a crosslinking agent into these cationic polymers provides a material that is a more effective viscosifying agent without negatives such as stringiness and viscosity breakdown in the presence of electrolytes. The crosslinking agent, when present, can comprise from about 1 ppm to about 1000 ppm, preferably from about 5 ppm to about 750 ppm, more preferably from about 25 ppm to about 500 ppm, even more preferably from about 100 ppm to about 500 ppm, and most

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preferably from about 250 ppm to about about 500 ppm of the total weight of the polymer on a weight/weight basis.

In one group of embodiments, these cationic polymers are made from processes which generally require polymerisation of a solution containing from about 20% to about 60%, generally from about 25% to about 40%, by weight monomer, in the presence of an initiator (usually redox or thermal) until the polymerization terminates. The temperature generally starts low, e.g. 0° to 95°C. The polymerization can be conducted by forming a reverse phase dispersion of an aqueous phase of the monomers into a nonaqueous liquid, e.g. mineral oil and the like.

When the polymer contains acrylamide, the molar proportion of acrylamide, based on the total molar amount of acrylamide, dialkylaminoalkyl acrylate and dialkylaminoalkyl methacrylate, is generally from about 20% to about 99%. Preferably, the amount of acrylamide is at least 50%, often at least 60% to below about 95%. All percentages describing the polymer herein are molar, unless otherwise specified.

Where monomer A is present, the ratio of monomer A:monomer B used in this process, and thus the ratio of groups A and B in the final polymer, on a molar basis is preferably about 80:20 to about 20:80. In one class of processes, the ratio is about 5:95 to 50:50, i.e., the cationic monomer is mainly methacrylate. In these processes, the ratio is generally being achieved in the range of from about 25:75 to about 5:95.

In another class of processes, the ratio A:B is from about 50:50 to about 85:15, the cationic monomers being mainly acrylate. Preferably the ratio A:B is about 60:40 to 85:15, most preferably about 75:25 to 85:15.

Preferred is where monomer A is not present and the ratio of monomer B:monomer C is from about 30:70 to about 70:30, preferably from about 40:60 to about 60:40 and most preferably from about 45:55 to about 55:45.

The polymerisation is preferably conducted under known conditions such that the polymers are water soluble and have a

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high molecular weight, generally about 1 million, for instance up to 30 million. The intrinsic viscosity, measured in molar sodium chloride solution at 25° C., is generally above 6, for instance from 8 to 14.

A cationic polymer useful herein is one conforming to the general structure $(A)_l(B)_m(C)_n$ wherein l is zero, B is methyl quaternized dimethylaminoethyl methacrylate, the ratio of B:C is about 45:55 to about 55:45, and the optional crosslinking agent is methylenebisacrylamide. This polymer which has the proposed CTFA designation, Polyquaternium 32 and Mineral Oil, is commercially available as Salcare SC92 from Allied Colloids Ltd. (Norfolk, VA).

Alternatively in another group of preferred embodiments, these cationic polymers do not contain the acrylamide monomer, that is, n is zero. In these polymers the (A) and (B) monomer components are as described above. An especially preferred group of these non-acrylamide containing polymers is one in which l is also zero. In this instance the polymer is essentially a homopolymer of a dialkylaminoalkyl methacrlyate monomer or its quaternary ammonium or acid addition salt. These diaklylaminoalkyl methacrylate copolymers and homopolymers preferably contain a crosslinking agent as described above.

A cationic homopolymer useful herein is one conforming to the general structure $(A)_l(B)_m(C)_n$ wherein l is zero, B is methyl quaternized dimethylaminoethyl methacrylate, n is zero, and the crosslinking agent is methylenebisacrylamide. This polymer, which does not as yet have a CTFA designation, will be referred to herein as crosslinked methyl quaternized dimethylaminoethyl methacrylate and mineral oil. This polymer is commercially available as Salcare SC95 from Allied Colloids Ltd. (Norfolk, VA).

Vehicle The compositions of the present invention are used along with pharmaceutically-acceptable carrier (or vehicle) components. The term "pharmaceutically-acceptable carrier components", as used herein, means compatible solid or liquid filler diluents which are suitable for administration to a human or lower animal. The term "compatible", as used herein, means

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that the components are capable of being commingled with the drug compounds, and other components of the compositions of the present invention, in a manner such that there is no interaction which would substantially reduce the pharmaceutical efficacy of the compositions of the present invention under ordinary use situations.

Pharmaceutically-acceptable carrier components must, of course, be of sufficiently high purity and sufficiently low toxicity to render them suitable for administration to the human or lower animal being treated.

Some examples of substances which can serve as pharmaceutically-acceptable carrier components are glycerol; ethanol; water; antioxidants; surfactants; chelating agents; preservatives; thickeners; anti-bacterial agents; as well as other non-toxic compatible substances used in pharmaceutical formulations.

These compositions can also contain one or more additional humectants/moisturizers, many of which may also be useful as actives. A variety of humectants/moisturizers can be employed and can be present at a level of from about 0.5% to about 30%, more preferably from about 2% to about 8%, and most preferably from about 3% to about 5%. These materials include polyhydroxy alcohols such as sorbitol, glycerin, hexanetriol, hexylene glycol and the like; sugars and starches; sugar and starch derivatives (e.g. alkoxylated glucose); D-panthenol and its derivatives; hyaluronic acid; lactamide monoethanolamine; acetamide monoethanolamine; and mixtures thereof.

Preferred humectants/moisturizers for use in the compositions of the present invention are the C_3-C_6 diols and triols. Especially preferred is the triol, glycerin.

The compositions of the present invention can also optionally comprise at least one emollient. Examples of suitable emollients include, but are not limited to, volatile and non-volatile silicone oils, highly branched hydrocarbons, and mixtures thereof. Emollients useful in the instant invention are further described

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in U.S. Patent No. 4,919,934, to Deckner et al., issued April 24 1990, which is incorporated herein by reference in its entirety.

The emollients can typically comprise in total from about 1% to about 50%, preferably from about 1% to about 25%, and more preferably from about 1% to about 10% by weight of the compositions of the present invention.

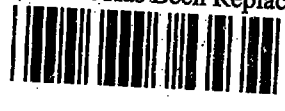
The compositions of this invention may also contain pharmaceutically acceptable optional components that modify the physical and/or therapeutic effects of the compositions. Such optional components may include, for example, additional solvents, gelling agents, fragrances, preservatives, anti-bacterial agents, and stabilizers. However, such optional materials must not unduly interfere with the transdermal delivery of the drug active. Optional components useful in the compositions of this invention are described in the following patent documents, incorporated by reference herein: European Patent Publication 43,738, Wickett et al., published January 13, 1982; and U.S. Patent 4,552,872, Cooper et al., issued November 12, 1985.

Most preferred compositions herein are gel-type compositions.

Another optional material is a solvent or co-solvent material. Such solvent materials include, for example, short chain alcohols and ethers. Preferred optional solvent materials include polyethylene glycols, dipropylene glycol, ethylene glycol monoethyl ether, ethanol, isopropanol, and dimethyl isosorbide. Water may also be used as a solvent or co-solvent in the compositions of this invention. If water is used in a saturated system, a gel or emulsion is preferably formed.

Most preferred compositions herein have a pH of below about 5, preferably below about 4, and most preferably below about 3. Without being limited by theory, the pH of a formulation can be an important factor in the delivery and availability of an active ingredient. For example, for the active ingredient salicylic acid, at pH values above its pK_a in a particular matrix, the salicylic acid would exist primarily in its ionized form and would not as readily penetrate into the skin. Thus, an acidic

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formulation range is preferred for salicylic acid compositions in order to supress ionization and enhance its penetration into the stratum corneum.

A wide variety of acids, bases, and buffers can be utilized to adjust and/or maintain the pH of the compositions useful in the instant invention. Materials useful for adjusting and/or maintaining the pH include sodium carbonate, sodium hydroxide, hydrochloric acid, phosphoric acid, sulfuric acid, acetic acid, sodium acetate, sodium hydrogen phosphate, sodium dihydrogen phosphate, citric acid, sodium citrate, sodium bicarbonate, triethanolamine, and the like.

While particular embodiments of the present invention have been described, it will be obvious to those skilled in the art that various changes and modifications to the compositions disclosed herein can be made without departing from the spirit and the scope of the invention. It is intended to cover, in the appended claims, all such modifications that are within the scope of this invention.

Test Method

Transdermal penetration of drugs is conveniently determined and compared from various vehicles using the apparatus and procedure described below.

Full thickness excised human thigh skin is obtained from cadavers after all hair had been clipped and the skin washed. The skin samples are then bathed in 10% glycerin and stored frozen. The glycerin prevents the formation of ice crystals which could possibly damage the keratinized cells and/or the intercellular lipid matrix. After a rapid thawing, the skin is conditioned for 24 hours in Hank's Balanced Salt Solution with 1% antibacterial-antimycotic solution. Then the skin is washed with distilled water. A single skin donor is used for each experiment, and individual sections for use are selected based on integrity of the stratum corneum (visual determination). Selected areas are cut to $1cm^2$ using a scalpel.

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Tests are conducted using glass diffusion cells placed in temperature-regulated stirring modules. Skin sections are mounted in the cells, and the receptor phase is added. The receptor phase is 50% Hank's Balance Salt Solution with 1% antibiotic-antimycotic solution. Each diffusion cell has an exposed area of 0.79cm^2 and a receptor capacity of 5ml. Sufficient formulation is applied (750ul) to the surface of the skin to ensure infinite dose conditions, and the diffusion cell is covered with plastic wrap or parafilm to prevent product evaporation. At each sampling time the receptor phase is removed for analysis of drug content. The receptor phase is removed for analysis of drug content. The receptor phase is replenished at each sampling time in order to maintain sink conditions. Preferably 3 to 6 replicates are run with sampling intervals occurring at 1, 2, 4 & 6 hours.

Penetration rate (Flux) is determined as the quantity of drug penetrating a measured area of skin per hour during the 5 hour interval between 1 hour and 6 hours. Generally steady state is reached before 1 hour. Penetration rate is usually expressed as ug drug per cm^2 skin per hour.

The following examples further describe and demonstrate embodiments within the scope of the present invention. The examples are given solely for the purpose of illustration and are not to be construed as limitations of the present invention, as many variations thereof are possible without departing from the spirit and scope of the invention.

Ingredients are identified by chemical or CTFA name.

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EXAMPLES

Example I

An anti-acne composition is made by combining the following components using conventional mixing technology.

Ingredient	(%W/W)
Water, Purified	54.0
Alcohol SD 40	40.0
Polyquaternium-32 and Mineral Oil[1]	4.0
Salicylic Acid	2.0

[1]SalCare SC92 available from Allied Colloids, Suffolk, VA

Water is added to a suitable size container. While mixing at a moderate speed (300 rpm), the polyquaternium-32 and mineral oil is added to the water. Separately, the alcohol is placed in a container and covered. Using a Lightnin' Mixer with a 3 blade paddle prop, the salicylic acid is added to the alcohol and mixed at a low speed (100 rpm) until all salicylic acid is dissolved. The alcohol is slowly added to the water phase to form a gel. The resulting gel is mixed at moderate speed until uniform.

The compositions display skin penetration of the salicylic acid active as well as improved skin feel and residue characteristics together with excellent moisturizing, emolliency, rub-in and absorption characteristics.

Alternatively, the above composition is prepared by substituting the polyquaternium-32 and mineral oil with crosslinked methyl quaternized dimethylaminoethyl methacrylate and mineral oil, available as SalCare SC95 from Allied Colloids (Suffolk, VA).

Example II

An anti-acne and/or analgesic composition is made by combining the following ingredients utilizing conventional mixing techniques as described above in Example I.

Ingredient	(%W/W)
Water, Purified	55.0

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Ibuprofen	2.0
Alcohol SDA 40	40.0
Polyquaternium-32 and Mineral Oil	4.0

The compositions display skin penetration of the Ibuprofen active as well as improved skin feel and residue characteristics together with excellent moisturizing, emolliency, rub-in and absorption characteristics.

Alternatively, the above composition is prepared by substituting the polyquaternium-32 and mineral oil with crosslinked methyl quaternized dimethylaminoethyl methacrylate and mineral oil, available as SalCare SC95 from Allied Colloids (Suffolk, VA).

Example III

A keratolytic composition for dermatological disorders is made by combining the following ingredients utilizing conventional mixing techniques as described above in Example I.

Ingredient	(%W/W)
Water	56.5
Urea	10.0
Benzyl Alcohol	0.5
Polyquaternium-32 and Mineral Oil	4.0

The compositions display skin penetration of the Urea active as well as improved skin feel and residue characteristics together with excellent moisturizing, emolliency, rub-in and absorption characteristics.

Alternatively, the above composition is prepared by substituting the polyquaternium-32 and mineral oil with crosslinked methyl quaternized dimethylaminoethyl methacrylate and mineral oil, available as SalCare SC95 from Allied Colloids (Suffolk, VA).

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Example IV

A composition for sunless tanning is made by combining the following ingredients utilizing conventional mixing techniques as described above in Example I.

Ingredient	(%W/W)
Water	91.5
Benzyl Alcohol	0.5
Polyquaternium-32 and Mineral Oil	3.0
Dihydroxyacetyone	3.0
Glycerin	2.0

The compositions display improved skin penetration of the dihydroxyacetone as well as improved skin feel and residue characteristics together with excellent moisturizing, emolliency, rub-in and absorption characteristics.

Alternatively, the above composition is prepared by substituting the polyquaternium-32 and mineral oil with crosslinked methyl quaternized dimethylaminoethyl methacrylate and mineral oil, available as SalCare SC95 from Allied Colloids (Suffolk, VA).

(*Equivalent Applications: USSN 808584 equivalent to US Patent Appln. 4,902,679; USSN 945069 equivalent to US Patent Appln. 4,868,164; USSN 945068 equivalent to European Patent 0,274,158; and USSN 069666 equivalent to EP Appln. 298,553.)

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CLAIMS:

1. A topical pharmaceutical composition having enhanced penetration through the skin characterized in that it comprises:
   (a) a safe and effective amount of a pharmaceutical active; and
   (b) from 0.1% to 10.0% of a high molecular weight crosslinked cationic polymer of the formula: $(A)_l(B)_m(C)_n$ wherein (A) is a dialkylaminoalkyl acrylate monomer or its quaternary ammonium or acid addition salt, (B) is a dialkylaminoalkyl methacrylate monomer or its quaternary ammonium or acid addition salt, (C) is acrylamide, l is an integer of 0 or greater, m is an integer of 1 or greater, and n is an integer of 0 or greater, wherein said polymer contains a crosslinking agent.

2. The composition of Claim 1 wherein the crosslinking agent is selected from the group consisting of methylene bisacrylamide, ethylene glycol di-(meth)acrylate, di-(meth)acrylamide, cyanomethylacrylate, vinyloxy-ethylacrylate, vinyloxyethylmethacrylate, allyl pentaerythritol, trimethylolpropane diallylether, allyl sucrose, butadiene, isoprene, divinyl benzene, divinyl naphthalene, allyl acrylate, and mixtures thereof, preferably wherein the crosslinking agent is methylenebisacrylamide.

3. The composition of Claim 2 wherein said pharmaceutical active is selected from the group consisting of anti-acne drugs, non-steroidal anti-inflammatory drugs, steroidal anti-inflammatory drugs, sunless tanning agents, sunscreen agents, wound healing agents, skin bleaching or lightening agents, antihistaminic drugs, antitussive drugs, antipruritic drugs, anticholinergic drugs, anti-emetic and antinauseant

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drugs, anorexic drugs, central stimulant drugs, antiarrhythmic drugs, β-adrenergic blocker drugs, cardiotonic drugs, antihypertensive drugs, diuretic drugs, vasodilator drugs, vasoconstrictor drugs, anti-ulcer drugs, anesthetic drugs, antidepressant drugs, tranquilizer and sedative drugs, antipsychotic drugs, antimicrobial drugs, antineoplastic drugs, antimalarial drugs, muscle relaxant drugs, antispamadic drugs, antidiarrheal drugs and bone-active drugs and mixtures thereof.

4. The composition of Claim 3 wherein said pharmaceutical active is an anti-acne drug selected from the group consisting of salicylic acid, sulfur, resorcinol, N-acetylcysteine, octopirox, retinoic acid and its derivatives, benzoyl peroxide, erythromycin, zinc, tetracyclin, azelaic acid and its derivatives, phenoxy ethanol and phenoxy proponol, ethylacetate, clindamycin and meclocycline, flavinoids, lactic acid, glycolic acid, pyruvic acid, urea, scymnol sulfate and its derivatives, deoxycholate and cholate and mixtures thereof, preferably wherein said anti-acne drug is salicylic acid.

5. The composition of Claim 4 wherein the amount of (C) in the cationic polymer is from 50% to 90% molar.

6. The composition of Claim 4 wherein l in the cationic polymer is zero and the ratio of (B):(C) is from 45:55 to 55:45.

7. The composition of Claim 4 wherein both l and n are zero in the cationic polymer.

8. The composition of Claim 7 which further comprises from 3% to 5% glycerin.

9. The composition of Claim 3 wherein said antihistaminic drug is selected from the group consisting of chlorpheniramine

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maleate, chlorpheniramine tannate, triprolidine hydrochloride, triprolidine oxalate, diphenhydramine hydrochloride, diphenhydramine ascorbate, diphenhydramine citrate, doxylamine succinate, pyrilamine maleate, pyrilamine hydrochloride, pyrilamine tannate, phenindamine tartrate, promethazine hydrochloride, cyproheptadine hydrochloride, azatadine maleate, clemastine fumarate, carbinoxamine maleate, carbinoxamine hydrochloride, tripelennamine hydrochloride, tripelennamine citrate, dexchlorpheniramine maleate, brompheniramine maleate and chlorcyclizine hydrochloride and mixtures thereof; wherein said antitussive drug is selected from the group consisting of dextromethorphan hydrobromide, carbetapentane citrate, codeine phosphate and codeine N-oxide hydrochloride and mixtures thereof; wherein said anticholinergic drug is selected from the group consisting of scopolamine hydrobromide, scopolamine hydrochloride, atropine sulfate, atropine mucate, homatropine hydrobromide and homatropine hydrochloride and mixtures thereof; wherein said anti-emetic or antinauseant drug is selected from the group consisting of cyclizine hydrochloride, meclizine hydrochloride, chlorpromazine hydrochloride and chlorpromazine maleate and mixtures thereof; wherein said anorexic drug is selected from the group consisting of benzphetamine hydrochloride, phentermine hydrochloride, chlorphentermine hydrochloride and fenfluramine hydrochloride and mixtures thereof; wherein said antimicrobial drug is selected from the group consisting of β-lactam drugs, quinolone drugs, ciprofloxacin, norfloxacin, tetracycline, erythromycin, amikacin, triclosan, doxycycline, capreomycin, chlorhexidine, chlortetracycline, oxytetracycline, clindamycin, ethambutol, metronidazole, pentamidine, gentamicin, kanamycin, lineomycin, methacycline, methenamine, minocycline, neomycin, netilmicin, paromomycin, streptomycin, tobramycin, miconazole and amanfadine, pharmaceutically-acceptable salts thereof and mixtures

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thereof; wherein said antiarrhythmic drug is selected from the group consisting of propranolol hydrochloride, procainamide hydrochloride, quinidine sulfate and quinidine gluconate and mixtures thereof; wherein said antihypertensive drug is selected from the group consisting of enalapril maleate, clonidine hydrochloride, hydralazine hydrochloride and hydralazine sulfate and mixtures thereof; wherein said anesthetic or antipruritic drug is selected from the group consisting of lidocaine hydrochloride, bupivacaine hydrochloride, chlorprocaine hydrochloride, dibucaine hydrochloride, etidocaine hydrochloride, mepivacaine hydrochloride, tetracaine hydrochloride, dyclonine hydrochloride and hexylcaine hydrochloride and mixtures thereof; wherein said bone-active drug is selected from the group consisting of 6-amino-1-hydroxy-hexanel,1-diphosphonic acid, 3-amino-1-hydroxy-propane-1,1-diphosphonic acid, octahydro-1-pyridine-6,6-diphosphonic acid, 2-(2'-piperidinyl)-ethane-1,1-diphosphonic acid, 2-(3'-piperidinyl)-ethane-1,1-diphosphonic acid, 2-(2'-piperidinyl)-1-hydroxy-ethane-1,1-diphosphonic acid, 2-(3'-piperidinyl)-1-hydroxy-ethane-1,1-diphos-phonic acid, N-(2'-(3'-methyl)-piperidinylidene)-amino- methane diphosphonic acid, N-(2'-(1',3'-diazinylidene))- aminomethane diphosphonic acid, and N-(2-(3-methyl-piperidinylidene))-aminomethanephosphonomethylphosphinic acid, or esters thereof and mixtures thereof; wherein said non-steroidal anti-inflammatory drug is selected from the group consisting of propionic acid derivatives, acetic acid derivatives, fenamic acid derivatives, biphenylcarboxylic acid derivatives, and oxicams and mixtures thereof, preferably wherein said non-steroidal anti-inflammatory drug is a propionic acid derivative selected from the group consisting of aspirin, acetaminophen, ibuprofen, naproxen, benoxaprofen, flurbiprofen, fenoprofen, fenbufen, ketoprofen, indoprofen, pirprofen, carprofen, oxaprozin, pranoprofen,

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miroprofen, tioxaprofen, suprofen, alminoprofen, tiaprofenic acid, fluprofen and bucloxic acid and mixtures thereof; and wherein said sunless tanning agent is selected from the group consisting of dihydroxyacetone, indole derivatives and mixtures thereof.

10. The composition of claim 9 which further comprises a sunscreen active.



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