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(54) **METHODS OF MAKING BIMETAL COMPLEXES**

ation-in-part of application No. 11/647,623, filed on Dec. 29, 2006, now Pat. No. 7,687,650.

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(57) **ABSTRACT**

Related U.S. Application Data

(60) Division of application No. 11/668,020, filed on Jan. 29, 2007, now Pat. No. 7,897,800, which is a continu-

Methods of forming bimetal complexes including reacting polyfunctional compounds with two or more coordination elements and recovering a bimetal complex.

METHODS OF MAKING BIMETAL COMPLEXES

CROSS REFERENCE TO RELATED APPLICATION

[0001] This Application is a divisional application of U.S. application Ser. No. 11/668,020 filed Jan. 29, 2007 which is a continuation-in-part of U.S. application Ser. No. 11/647,623 filed Dec. 29, 2006, now U.S. Pat. No. 7,687,650 which claims priority benefit to U.S. Provisional Application No. 60/764,968 filed Feb. 3, 2006 the entire disclosures of which are incorporated herein by this reference.

BACKGROUND

[0002] 1. Technical Field

[0003] The present disclosure relates compositions that contain bimetal complexes. The bimetal complexes can be prepared by reacting a polyfunctional compound with two or more coordination elements.

[0004] 2. Background of the Invention

[0005] Polycarboxylic acids are polyfunctional acids used in many products. The ion form of carboxylic acids, as well as its esters and salts, are known as carboxylates. Various copper carboxylates are known through the extensive use of the carboxylate ion in crystal engineering to explore the structural chemistry of copper (II) carboxylates, which exist, for example as copper (II) malonates, copper (II) coppergiutamates, copper citrates and other copper complexes known.

[0006] However, the study of copper (II) reaction products of polyfunctional acids and the formation of carboxylates are problematic in that the conditions of synthesis, stoichiometry and temperature should be known and applied in order to synthesize the desired product. For example, the mixture of copper carbonate and malonic acid in a 1:2 molar ratio kept at 5° C. for weeks results in the formation of deep blue copper (II) malonate trihydrate crystals.

[0007] It would be desirable to provide compositions containing reaction products of polyfunctional carboxylic acid compounds with two or more coordination elements. For example, it would be desirable to provide malonates having both copper and at least one other metallic constituent, such as zinc. These can be obtained by reacting a mixture of malonic and a 3:1:1 molar ratio with the metallic components resulting in the formation of greenish-blue copper II zinc II malonate crystals.

[0008] Polyamines are polyfunctional bases used in many products. When combined with metallic constituent, the ion form of amines as well as their amides and salts, can produce amino complexes. Various copper amine complexes are used extensively in crystal engineering to explore the structural chemistry of amine complexes, such as, for example, copper (II) amine complexes. Copper (II) amine complexes exist in numerous forms, many of which have an intense blue color. For example, intense blue various copper (II) ethylenediamine complexes are known.

[0009] However, the study of reaction products of polyfunctional amines and the formation of amine complexes are problematic in that conditions of synthesis, stoichiometry and temperature should be known and applied in order to synthesize the desired product. For example, a mixture of butylene diamine, copper chloride, zinc chloride in a 3:1:1 molar ratio results in the formation of dry, blue crystals.

[0010] It would be desirable to provide compositions containing reactions products of polyfunctional amine compounds with two or more coordination elements. For example, it would be desirable to provide amines complexes having both copper and at least one other metallic constituent, such as zinc.

[0011] Poly-functional organic compounds having a carboxyl group and an amine group are known as amino acids. The ionic form of amino acids vary with the pH of the media, with ionic forms of the acid being known as carboxylates and the ionic forms of the amine as being known as ammonium complexes.

[0012] Various copper amino acid complexes are known through the extensive use of the amino acids in crystal engineering to explore the structural chemistry of copper (II) amino acid complexes. They exist in numerous forms such as copper (II) glycinate, copper II glutamate, etc. However, one study of reaction products of polyfunctional amino acids and the formation of amino acid complex is problematic in that conditions of synthesis, stoichiometry and temperature should be known and applied in order to synthesize the desired product.

[0013] It would also be desirable to provide compositions containing reaction products of amino acid compounds with two or more coordination elements. For example, it would be also desirable to provide amino acid complexes having copper and at least one other metallic constituent, such as zinc. For example in a mixture of glutamic acid, zinc carbonate and copper carbonate in a 3:1:1 molar ratio results in the formation of greenish-blue crystals. It would be desirable to provide compositions containing reaction products of polyfunctional compounds with two or more coordination elements. It would also be desirable to provide glutamates having both copper and at least one other metallic constituent, such as zinc.

SUMMARY

[0014] Compositions in accordance with the present disclosure contain a bimetal complex. The bimetal complex can be the reaction product of a polyfunctional compound with two or more coordination elements. The polyfunctional compound can be, for example, a polyfunctional acid or an amino acid. The coordination elements can be selected from the elements listed in Groups IIIA to VIIIA, Groups IB to IIIB, of periods 4 and 5 and aluminum in Group IIIB, period 3 of The Periodic Table of the Elements.

[0015] Methods of making such reaction products are also described. In embodiments, bimetal complexes are made by 1) contacting one or more polyfunctional compounds with two or more coordination elements, wherein the molar ratio of polyfunctional compound to two or more coordination elements is at least 3:2; and 2) isolating the reaction product.

[0016] In embodiments, copper-zinc malonate complexes are synthesized from malonic acid and copper and zinc constituents. Methods of making copper-zinc dual salts are also described. In embodiments, copper-zinc malonate compositions are made by:

[0017] 1) contacting malonic acid with one or more bases containing copper and zinc constituents in an aqueous solution, wherein the molar ratio of malonic acid to copper to zinc is about 3:1:1; and 2) recovering the copper-zinc malonate product.

[0018] Excess malonic acid in the manufacturing process may drive the formation of copper-zinc malonates which precipitate in the reaction solution.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0019] The preparation of reaction products of polyfunctional compounds with two or more coordination elements and compositions containing such reaction products are described.

[0020] The polyfunctional compound can be any compound that contains at least two functional groups that may complex with metal cations in solution. Among the functional groups that may be present include carboxylic acid groups and amino groups. Suitable polyfunctional compounds include, but are not limited to polyfunctional acids, polyfunctional amines and amino acids. Other suitable polyfunctional compounds will be readily envisioned by those skilled in the art reading the present disclosure. It should of course be understood that mixtures of polyfunctional compounds may be used.

[0021] Polyfunctional acids are primarily monomeric compositions having two or more carboxylic acid groups. Non-limiting examples of polyfunctional acids include maleic acid, fumaric acid, citraconic acid, itaconic acid, glutaconic acid, phthalic acid, isophthalic acid, terephthalic acid, cyclohexane dicarboxylic acid, succinic acid, adipic acid, sebacic acid, azealic acid, malonic acid, dodecanedioic acid, 1,18-octadecanedioic acid, dimer acids (prepared from a mono-, di- or triunsaturated fatty acid, acid wax, acid anhydride grafted wax, or other suitable polycarboxylic acid reacting compound), alkenyl succinic acids (such as n-dodecenylsuccinic acid, docecylsuccinic acid and octadecenylsuccinic acid). The polyfunctional acid can be present in acidic form, anhydride form, salt form, or mixtures thereof.

[0022] Amino acids may also be used as the polyfunctional compound. Amino acids are known to those skilled in the art and include at least a carboxylic acid functionality and an amino functionality. Suitable amino acids include naturally occurring amino acids and synthetic amino acids. Non-limiting examples of amino acids include, but are not limited to: glycine; aminopolycarboxylic acids (e.g., aspartic acid, β -hydroxyaspartic acid, glutamic acid, β -hydroxyglutamic acid, β -methylaspartic acid, β -methylglutamic acid, β,β -dimethylaspartic acid, γ -hydroxyglutamic acid, β,γ -dihydroxyglutamic acid, β -phenylglutamic acid, γ -methyleneglutamic acid, 3-aminoadipic acid, 2-aminopimelic acid, 2-aminosuberlic acid and 2-aminosebacic acid); amino acid amides such as glutamine and asparagine; polyamino- or polybasic-monocarboxylic acids such as arginine, lysine, β -aminoalanine, γ -aminobutyric acid, ornithine, citrulline, homoarginine, homocitrulline, hydroxylysine, allohydroxylysine and diaminobutyric acid; other basic amino acid residues such as histidine; diaminodicarboxylic acids such as α,α' -diaminosuccinic acid, α,α' -diaminoglutaric acid, α,α' -diaminoadipic acid, α,α' -diaminopimelic acid, α,α' -diamino- β -hydroxypimelic acid, α,α' -diaminosuberlic acid, α,α' -diaminoazelaic acid, and α,α' -diaminosebacic acid; imino acids such as proline, hydroxyproline, allohydroxyproline, γ -methylproline, pipercolic acid, 5-hydroxypipercolic acid, and azetidine-2-carboxylic acid; mono- or dialkyl (typically C_1 - C_8 branched or normal) amino acids such as alanine, valine, leucine, allylglycine, butyric acid, norvaline, norleucine, heptyline, α -methylserine, α -amino- α -methyl- γ -hydroxyvaleric acid,

α -amino- α -methyl- δ -hydroxyvaleric acid, α -amino- α -methyl- ϵ -hydroxycaproic acid, isovaline, α -methylglutamic acid, α -aminoisobutyric acid, α -aminodiethylacetic acid, α -aminodiisopropylacetic acid, α -aminodi-n-propylacetic acid, α -aminodiisobutylacetic acid, α -aminodi-n-butylacetic acid, α -aminoethylisopropylacetic acid, α -amino-n-propylacetic acid, aaminodiisoamyacetic acid, α -methylaspartic acid, α -methylglutamic acid, 1-aminocyclopropane-1-carboxylic acid, isoleucine, alloisoleucine, tert-leucine, β -methyltryptophan and α -amino- β -ethyl- β -phenylpropionic acid; β -phenylserinyl; aliphatic α -amino- β -hydroxy acids such as serine, β -hydroxyvaleric acid, β -hydroxynorvaline, β -hydroxynorvaline, and α -amino- β -hydroxystearic acid; α -Amino, α -, γ -, δ - or ϵ -hydroxy acids such as homoserine, γ -hydroxynorvaline, δ -hydroxynorvaline and epsilon-hydroxynorvaline residues; canavine and canaline; γ -hydroxyornithine; 2-hexosaminic acids such as D-glucosaminic acid or D-galactosaminic acid; α -Amino- β -thiols such as penicillamine, β -thiolnorvaline or β -thiolbutyric acid; other sulfur containing amino acid residues including cysteine; homocystine, β -phenylmethionine, methionine, S-allyl-L-cysteine sulfoxide, 2-thiolhistidine, cystathionine, and thiol ethers of cysteine or homocysteine; phenylalanine, tryptophan and ring-substituted α amino acids such as the phenyl- or cyclohexylamino acids α -aminophenylacetic acid, aminocyclohexylacetic acid and α -amino- β -cyclohexylpropionic acid; phenylalanine analogues and derivatives comprising aryl, lower alkyl, hydroxy, guanidino, oxyalkylether, nitro, sulfur or halo-substituted phenyl (e.g., tyrosine, methyltyrosine and o-chloro-, p-chloro-, 3,4-dichloro-, o-, m- or p-methyl-, 2,4,6-trimethyl-, 2-ethoxy-5-nitro-, 2-hydroxy-5-nitro- and p-nitrophenylalanine); furyl-, thienyl-, pyridyl-, pyrimidinyl-, purinyl- or naphthylalanines; and tryptophan analogues and derivatives including kynurenine, 3-hydroxykynurenine, 2-hydroxytryptophan and 4-carboxytryptophan; α -Amino substituted amino acids including sarcosine (N-methylglycine), N-benzylglycine, N-methylalanine, N-benzylalanine, N-methylphenylalanine, N-benzylphenylalanine, N-methylvaline and N-benzylvaline; and α -Hydroxy and substituted α -hydroxy amino acids including serine, threonine, allothreonine, phosphoserine and phosphothreonine. glycine, alanine, valine, leucine, isoleucine, serine, threonine, cysteine, methionine, glutamic acid, aspartic acid, lysine, hydroxylysine, arginine, histidine, phenylalanine, tyrosine, tryptophan, proline, asparagine, glutamine and hydroxyproline. Aminopolycarboxylic acids, e.g., aspartic acid, β -hydroxyaspartic acid, glutamic acid, β -hydroxyglutamic acid, β -methylaspartic acid, β -methylglutamic acid, β,β -dimethylaspartic acid, γ -hydroxyglutamic acid, β,γ -dihydroxyglutamic acid, β -phenylglutamic acid, γ -methyleneglutamic acid, 3-aminoadipic acid, 2-aminopimelic acid, 2-aminosuberlic acid and 2-aminosebacic acid. Polyaminoacids may also be used provided they form complexes with the coordination elements employed.

[0023] The polyfunctional compound is reacted with two or more coordination elements. The coordination elements can be chosen from the elements listed in Groups IIIA to VIIIA, Groups IB to IIIB, of periods 4 and 5 and aluminum in Group IIIB, period 3 of The Periodic Table of the Elements. Suitable non-limiting examples of elements listed in group IB of The Periodic Table of Elements include copper, silver, and gold. Suitable non-limiting examples of coordination elements include aluminum, scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, gallium,

yttrium, zirconium, niobium, molybdenum, technetium, ruthenium, rhodium, palladium, silver, cadmium, and indium. Tin may also be used. Those skilled in the art will readily envision suitable compounds for providing the coordination elements in solution.

[0024] For example, water soluble salts containing the coordination element may be used. The salts may be organic or inorganic. Suitable water-soluble silver salts include silver nitrate, silver acetate, silver propionate, silver sulfate, silver butyrate, silver isobutyrate, silver benzoate, silver tartrate, silver salicylate, silver malonate, silver succinate and silver lactate. Suitable water-soluble aluminum salts include aluminum potassium sulfate, aluminum chloride, aluminum sodium sulfate, aluminum sodium phosphate, aluminum sulfate, aluminum nitrate, and sodium aluminate. Suitable water-soluble copper salts include copper sulfate, fluoroborate, hydroxide, borate, fluoride, carbonate, oxychloride, formate or acetate. Suitable water-soluble zinc salts include zinc chloride, zinc bromide, zinc iodide, zinc chlorate, zinc bromate, zinc chlorite, zinc perchlorate, zinc sulfate, zinc nitrate, zinc nitrite, zinc borate, zinc metaborate, basic zinc borate, zinc hexafluorosilicate, zinc hypophosphite, zinc glycerophosphate, zinc bichromate, zinc citrate, zinc thionate, zinc dithionate, zinc tetrathionate, zinc pentathionate, zinc thiocyanate, zinc benzoate, zinc acetate, zinc salicylate, zinc picrate, zinc permanganate, zinc hydrogen phosphate, zinc formate, zinc ethylsulfate and zinc phenolsulfonate. Examples of suitable water soluble nickel salts that may be used include nickel sulfate hexahydrate and nickel chloride hexahydrate. It should be understood that the listed salts are only a small portion of the salts suitable for use in accordance with the present disclosure. For example, inorganic salts are suitable provided that they provide coordination element cations when placed in an aqueous solution. Thus, the foregoing list of salts should be considered a non-limiting, illustrative list.

[0025] For carrying out the process, a reaction solution can be prepared by mixing the various ingredients in water. Water in the mixture may advantageously be added in limited amounts sufficient to allow the reaction product to precipitate from solution upon formation. Accordingly, the reaction mixture is not so dilute as to prevent product precipitate formation. Where necessary, mixing and heating can be used to bring the reactants to 40-100° C. in order to solubilize the reactants. As a result, reactant solubility may be enhanced through energy input such as microwave heating or addition of boiling water. The input of the energy may take place through any instrument capable of heating the aqueous reaction mixture. The reaction products formed in solution may be immediately separated so that their production can take place in a continuous process. Where a short reaction time and rapid crystallization of the reaction product occur, the conversion may be carried out continuously, and the recovery of the resultant solid product may take place by any conventional manner such as filtering, centrifugation, or sedimentation.

[0026] The polyfunctional compound is present in the reaction mixture in amounts that will contact metal cations in an aqueous solution. Suitable amounts of polyfunctional compound also include excess amounts in relation to the amount of metal cations. In embodiments, polyfunctional compound is present in a 3:1:1 molar ratio in relation to the metal constituents. In embodiments, the polyfunctional compound is malonic acid which can be present in acidic form, salt form, or

mixtures thereof. In embodiments, the process parameters are especially advantageous if the polyfunctional compound is added to excess in comparison to the metal counter cation constituents. Depending on the desired complex, the latter are added so that the molar ratio of polyfunctional compound to metal ions is approximately 3:2.

[0027] In embodiments, the coordination elements may be present as one or more ionic compounds formed by joining one or more independent coordination element molecules or ions of a first type and coordination element molecules or ions of a second type to a central unit by ionic bonds. For example, the reaction product may be in the form of a trinuclear cation, where structurally independent coordination element hydrates are bridged by a central unit. However, various coordination modes are possible depending on the source of the coordination elements and synthesis conditions. In embodiments, the central unit may be a multi-membered ring such as eight-membered ring, six-membered ring, and four-membered metalocycle for bridging or chelating functions between the coordination element constituents. Accordingly, the crystal structures of the reaction products can be very diverse, from ionic to three-dimensional polymers. In embodiments, the reaction products are present in several hydrate, and polymorphic forms.

[0028] In embodiments, suitable reaction products can be non-toxic bimetal complexes that include copper, zinc, aluminum and/or silver constituents. Such copper, zinc, aluminum and/or silver reaction products include, but are not limited to water soluble compounds that contain copper, zinc, aluminum and/or silver. Non-limiting examples of water-soluble bimetal complexes include copper-zinc citrate, copper-silver citrate, silver-zinc citrate, copper-zinc oxalate, copper-silver oxalate, silver-zinc oxalate, copper-zinc tartarate, copper-silver tartarate, silver-zinc tartarate, copper-zinc malate, copper-silver malate, silver-zinc malate, copper-zinc succinate, copper-silver succinate, silver-zinc succinate, copper-zinc malonate, copper-silver malonate, silver-zinc malonate, copper-zinc maleate, copper-silver maleate, silver-zinc maleate, copper-zinc aspartate, copper-silver aspartate, silver-zinc aspartate, copper-zinc glutamate, copper-silver glutamate, silver-zinc glutamate, copper-zinc glutarate, copper-silver glutarate, silver-zinc glutarate, copper-zinc fumarate, copper-silver fumarate, silver-zinc fumarate, copper-zinc glucarate, copper-silver glucarate, silver-zinc glucarate, copper-zinc polyacrylic acid, copper-silver polyacrylic acid, silver-zinc polyacrylic acid, and combinations thereof. In embodiments, copper, zinc, aluminum and silver salts of organic multi carboxylic acids are suitable for use in accordance with the present disclosure. In embodiments, suitable salts can be doped such that the unit cell of the salt has zinc or silver constituents dispersed therein. Such zinc or silver constituents may either substitute another metallic constituent or fill a preexisting void in the unit cell.

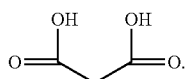
[0029] In embodiments, suitable reaction products can be copper salts having zinc or silver constituents therein. For example, zinc or silver may either substitute a copper constituent or fill a preexisting void in the copper salt's unit cell. Suitable non-limiting examples of copper salts which may be used to form bimetallic complexes include copper (II) malonate and any hydrated form thereof such as copper (II) malonate dihydrate, copper (II) malonate trihydrate, and copper malonate tetrahydrate. Other suitable non-limiting examples of suitable copper salt active ingredients include copper citrate, copper oxalate, copper tartarate, copper

malate, copper succinate, copper malonate, copper maleate, copper aspartate, copper glutamate, copper glutarate, copper fumarate, copper glucarate, copper polyacrylic acid, and combinations thereof. In embodiments, suitable copper salts can be doped such that the unit cell of the salt has zinc or silver constituents dispersed therein. Such zinc or silver constituents may either substitute a copper constituent or fill a preexisting void in the unit cell.

Cu/Zn Malonate Preferred Embodiments

[0030] In embodiments, malonic acid may be reacted with salts containing copper and zinc constituents in an aqueous solution. It has been found that where the malonic acid, copper and zinc constituents are present in at least about a 3:1:1 molar ratio, copper-zinc malonates may be produced in good yield and high crystalline purity.

[0031] Malonic acid refers to 1,3-propanedioic acid, a dicarboxylic acid with structure $\text{CH}_2(\text{COOH})_2$ or:



[0032] The ion form of malonic acid, as well as its esters and salts, are known as malonates. For example, diethyl malonate is ethyl ester of malonic acid. As used herein, the term copper-zinc malonate applies to any salt substances formed from malonic acid having copper and zinc constituents.

[0033] Suitable ingredients for the formation of copper-zinc malonates include malonic acid, one or more bases of copper and zinc, and water. In an aqueous reaction solution, suitable salt forms provide copper and zinc cations capable of bonding to malonate anions. Other suitable ingredients for the formation of copper-zinc malonates will include the replacement of bases of copper and zinc with the metallic form of copper and zinc. The elemental form of copper and zinc are known as copper and zinc metals and will be dissolved in the acidic water media as they react with malonic acid.

[0034] One or more salts containing copper and zinc constituents are present in amounts that will contact malonic acid in an aqueous solution. Suitable salts for making copper-zinc malonate compositions in accordance with this disclosure include metal salts containing complex-forming metal ions of copper and/or zinc. Non-limiting examples of suitable metal salts are copper (I) and (II) salts such as copper chloride, copper bromide, copper fluoride, copper nitrate, copper fluoroborate, copper sulfate, copper acetate, copper trifluoroacetate, copper stearate, copper octoate, copper methacrylate, copper malonate, copper benzoate; zinc salts such as zinc bromide, zinc chromate, zinc chloride, zinc stearate, zinc octoate, and zinc ethylhexoate. In embodiments, the aqueous solution may include one or more metallic salts, such as cupric carbonate ($\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$), zinc carbonate ($3\text{Zn}(\text{OH})_2 \cdot 2\text{ZnCO}_3$), metallic copper, metallic zinc and combinations thereof. Basic salts such as basic zinc salts, basic copper salts, and combinations thereof are also suitable for use in accordance with the present disclosure. In embodiments, suitable metal basic salts are: copper (I) and (II) salts such as copper carbonate, copper oxide, and copper hydroxide; and zinc salts such as zinc carbonate, zinc oxide, and zinc hydroxide.

[0035] It should be understood that the listed salts are only a small portion of the salts suitable for use in accordance with the present disclosure. For example, inorganic salts are suitable provided that they provide copper and zinc cations when placed in an aqueous solution. Thus, the foregoing list of salts should be considered a non-limiting, illustrative list.

[0036] For carrying out the process, the reaction solution can be prepared by mixing the various ingredients in water where malonic acid and the salts may ionize and become more reactive. Water in the mixture is added in limited amounts sufficient to allow copper-zinc malonates to precipitate from solution upon formation. Accordingly, the reaction mixture is not so dilute as to prevent product precipitate formation. Where copper and zinc salts in the reaction mixture are insoluble and form dispersions (such as at cooler temperatures), mixing and heating steps can be applied to bring the reactants to 40-100° C. in order to solubilize the reactants. As a result, reactant solubility may be enhanced through energy input such as microwave heating or addition of boiling water dissolver. The input of the energy may take place through any instrument capable of heating the aqueous reaction mixture. The copper-zinc malonate complexes formed in solution may be immediately separated so that their production can take place in a continuous process. Due to the short reaction time and the rapid crystallization of the copper-zinc malonate product, the conversion may be carried out continuously, and the recovery of the resultant solid product may take place by any conventional manner such as filtering, centrifugation, or sedimentation.

[0037] In the production of the reaction mixture, the concentration of the polyfunctional compound and that of the copper and zinc constituents may be pre-selected so that the total concentration of product formed exceeds the solubility equilibrium. This will result in product precipitating from solution in solid form for easy collection.

[0038] In embodiments, the final composition may be a deep blue crystal having good yield and substantial crystalline purity. Suitable copper-zinc malonate forms in accordance with the present disclosure include any salt formed from the neutralization of malonic acid by one or more copper containing molecules and one or more zinc containing molecules. Illustrative examples include salt formed by the neutralization of malonic acid by cupric carbonate ($\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$), and zinc carbonate ($3\text{Zn}(\text{OH})_2 \cdot 2\text{ZnCO}_3$) in an aqueous solution. Here copper may be added first, followed by zinc in order to obtain the salts of the present disclosure.

[0039] In embodiments, the copper-zinc malonates may be one or more ionic compounds formed by joining one or more independent copper molecules or ions and one or more independent zinc molecules or ions to a central unit by ionic bonds. For example, the copper-zinc malonate may be in the form of a trinuclear cation, where structurally independent copper and zinc hydrates are bridged by a central unit such as an octahedral diaquadimalonatocopper (II) unit. However, various coordination modes are possible depending on the source of the copper and zinc and synthesis conditions. In embodiments, the central unit malonate ion may be a multi-membered ring such as eight-membered ring, six-membered ring, and four-membered metalocycle for bridging or chelating functions between the copper and zinc constituents. Accordingly, the crystal structures of copper-zinc malonates can be very diverse, from ionic to three-dimensional polymers. In embodiments, the copper-zinc malonates can be found in several hydrate, and polymorphic forms.

[0040] In embodiments, the process parameters are especially advantageous if the polyfunctional compound is added to excess in comparison to the metal counter cation constituents. Depending on the desired complex, the latter are added so that the molar ratio of polyfunctional compound to metal ions is approximately 3:2.

Embodiments of Compositions Containing the Reaction Products

[0041] In embodiments, the resulting reaction products may serve as active ingredients in compositions suitable for contact with a subject. Such active ingredients may be combined with numerous ingredients to form products of numerous chemical applications, such as catalytical agents, crosslinking of polymers, superconducting electrical materials, pharmaceutical drugs, food supplements, etc. The active ingredients in suitable toxicological compositions can be applied to the skin, or other tissues of humans or other mammals. Such products may include a dermatologically or pharmaceutically acceptable carrier, vehicle or medium, for example, a carrier, vehicle or medium that is compatible with the tissues to which they will be applied. The term "dermatologically or pharmaceutically acceptable," as used herein, means that the compositions or components thereof so described are suitable for use in contact with these tissues or for use in patients in general without undue toxicity, incompatibility, instability, allergic response, and the like. In embodiments, compositions in accordance with the present disclosure can contain any ingredient conventionally used in cosmetics and/or dermatology. In embodiments, active ingredients may be formulated to provide crystals in solution, as well as solid forms.

[0042] In embodiments, products containing a reaction product in accordance with the present disclosure as an active ingredient can be in the form of solutions, emulsions (including microemulsions), suspensions, creams, lotions, gels, powders, or other typical solid or liquid compositions used for treatment of age related skin conditions. Such compositions may contain, in addition to the reaction product in accordance with this disclosure, other ingredients typically used in such products, such as antimicrobials, moisturizers and hydration agents, penetration agents, preservatives, emulsifiers, natural or synthetic oils, solvents, surfactants, detergents, gelling agents, emollients, antioxidants, fragrances, fillers, thickeners, waxes, odor absorbers, dyestuffs, coloring agents, powders, viscosity-controlling agents and water, and optionally including anesthetics, anti-itch actives, botanical extracts, conditioning agents, darkening or lightening agents, glitter, humectants, mica, minerals, polyphenols, silicones or derivatives thereof, sunblocks, vitamins, and phytochemicals.

[0043] As an illustrative example, products can be formulated to contain copper-zinc malonate in amounts from about 0.001 to about 5% by weight of the total composition. In embodiments, products can be formulated to contain copper-zinc malonate in an amount from about 0.05 to about 1.0% by weight of the total composition. In other embodiments, the amount of copper-zinc malonate is from about 0.1 to about 0.5% by weight of the total composition. Here, the copper-zinc malonate present may be in a pharmaceutically acceptable salt form. Other active ingredients may be provided in the formulations at the same concentrations.

[0044] In embodiments, compositions in accordance with the present disclosure can be topically applied to skin in need

of improvement such as the reduction or elimination of an undesirable dermatological condition. As used herein the word "treat," "treating" or "treatment" refers to using the actives or compositions of the present disclosure prophylactically to prevent outbreaks of undesirable dermatological conditions, or therapeutically to ameliorate an existing dermatological condition, and/or extend the duration of the aesthetic benefit of a skin procedure. A number of different treatments are now possible, which reduce and/or eliminate undesirable skin conditions.

[0045] As used herein "undesirable skin condition" refers to any skin condition that may require treatment of any sort, including skin having one or more undesirable appearances and/or disagreeable tactile sensations. The term further refers to any cosmetically undesirable skin condition, as well as any undesirable diseased or damaged skin condition.

[0046] Non-limiting examples of undesirable skin conditions which can be treated with the topical application of compositions in accordance with the present disclosure include: acne vulgaris (pimples); atopic dermatitis; birthmarks; cafe-au-laits spots; common benign skin tumors or growths; common diseases of the nail such as nail infections caused by bacteria, fungi, yeast and/or virus; paronychia; nail disorder due to skin disease such as psoriasis, and/or nail injury; common skin conditions around the eyes such as eyelid contact dermatitis, atopic dermatitis, bacterial skin infection (impetigo or conjunctivitis), xanthelasma, syringoma, skin tags, milia, Naevus, and/or portwine stains; common skin condition associated with housework such as irritant contact dermatitis, allergic contact dermatitis, contact urticaria, fungal infections, paronychia, and/or viral warts; common diseases of the scalp such as seborrhoeic dermatitis, psoriasis of the scalp, lichen planus, discoid lupus erythematosus (DLE), alopecia areata, seborrhoeic keratoses (seborrhoeic warts, age spots), solar keratoses, angiosarcoma, fungal infection (ringworm, tinea Capitis), bacteria infections of the hair follicles (folliculitis, boils), and/or shingles (Herpes Zoster); common diseases in children such as atopic dermatitis, atopic eczema, discoid eczema, pityriasis alba, vitiligo, and/or alopecia areata; common diseases of the mouth and lips such as oral candidiasis, oral leukoplakia, aphthous ulcers, and/or oral lichen planus; common skin problems in elderly such as appearance and texture changes, senile purpura, xerosis/asteatotic eczema, skin infections/infestations, pigmentary changes, blistering disorders, non-cancerous skin growths, cancerous skin growths, adverse drug reaction, and/or stasis dermatitis; common viral warts; contact allergy; diaper candidiasis, drug allergy, folliculitis; freckles; fungal infections of the skin such as white spot, athlete's foot, jock itch, and/or moniliasis/candidiasis; guttate hypomelanosis; hair loss; hand eczema; impetigo; lines, crow's feet, wrinkles, etc.; melasma; molluscum contagiosum; occupational skin disease such as irritation and/or allergy; post-inflammatory pigmentation; psoriasis; rosacea; shingles; skin cancers; skin diseases in diabetes mellitus; skin diseases in pregnancy; skin disorders caused by cosmetics such as irritant contact dermatitis and/or allergic contact dermatitis, cosmetic induced pimples (acne), sunscreens allergy, and/or special cosmetic allergies, solar lentigenes; tinea capitis; viral warts; vitiligo; and combinations of these undesirable skin conditions.

[0047] In embodiments, compositions in accordance with the present disclosure are suitable for treating diseased skin,

or any condition which can result from the excessive amount of pathogens such as fungi, viruses, and or bacterium affecting the skin in any way.

[0048] In embodiments, an undesirable skin condition is skin that has a rough texture or uneven appearance such as psoriasis, bumps, razor burns, and/or patches.

[0049] The particular active ingredient or ingredients employed, and the concentration in the compositions, generally depends on the purpose for which the composition is to be applied. For example, the dosage and frequency of application can vary depending upon the type and severity of the skin condition.

[0050] Treatments in accordance with the present disclosure contact skin with one or more active ingredients such as those containing copper, zinc and/or silver in an effective amount to improve the undesirable skin conditions. In embodiments, patients are treated by topically applying to skin suffering a condition, one or more copper-zinc malonates. In embodiments, patients are treated by topically applying to skin suffering from a condition, one or more salts in accordance with the present disclosure. The active ingredient is applied until the treatment goals are obtained. However, the duration of the treatment can vary depending on the severity of the condition. For example, treatments can last several weeks to months depending on whether the goal of treatment is to reduce or eliminate the skin condition.

[0051] In treatment embodiments, the compositions and methods in accordance with the present disclosure can be combined with other skin treatment systems. For example, the bimetallic salt complexes and be applied to skin in combination with skin treatment systems such as the Obagi NuDerm® skin treatment system and related Obagi skin care products from O.M.P. Inc. of Long Beach Calif. More specifically copper-zinc malonate compositions can be combined with the Obagi Nuderm® skin treatment system in order to promote the beneficial affects of that system. The active ingredients and formulations in accordance with the present disclosure may either be incorporated into other product formulations, or applied to the skin before, after, and/or during other skin treatments.

[0052] In embodiments, the compositions may contain any active ingredient or be formulated and applied as described in commonly owned U.S. Patent Application entitled Anti-aging Treatment Using Copper-Zinc Compositions (U.S. Ser. No. 11/452,642 filed Jun. 14, 2006) herein incorporated by reference in its entirety.

[0053] The following non-limiting examples further illustrate compositions and methods in accordance with this disclosure.

EXAMPLE 1

[0054] Example 1 below shows suitable ingredients of a reaction mixture for forming copper-zinc malonates in accordance with the present disclosure.

Ingredient	Amount
Malonic acid	1.8 g
cupric carbonate	0.632 g
zinc carbonate	0.626 g
Water	100 ml

EXAMPLE 2

[0055] 1.8 g of malonic acid ($\text{CH}_2(\text{COOH})_2$) was combined with 0.632 grams of cupric carbonate ($\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$), 0.626 g of zinc carbonate ($3\text{Zn}(\text{OH})_2 \cdot 2\text{ZnCO}_3$), and 100 ml of water to form a dispersion. The solution was heated until the reactants went into solution. Well-defined deep-blue crystals precipitated and were separated from the aqueous solution of malonic acid, cupric carbonate, and zinc carbonate (3:1:1 molar ratio) that had been kept at room temperature. Dual salt was formed by replacing acid groups with copper and zinc cations in the same molecule. The deep blue crystals were found to have a melting point of about 210° C.

[0056] Sample prepared as per ASTM-D-1971-95 (herein incorporated by reference in its entirety) and analyzed by method 6010 (I.C.P.) (herein incorporated by reference in its entirety) showed 16.5% copper and 12.4% zinc.

EXAMPLE 3

[0057] 1.8 g of malonic acid ($\text{CH}_2(\text{COOH})_2$) was combined with 0.632 grams of cupric carbonate ($\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$), 0.626 g of zinc carbonate ($3\text{Zn}(\text{OH})_2 \cdot 2\text{ZnCO}_3$), and 100 ml of boiling water. Well-defined deep-blue crystals were separated from the aqueous solution of malonic acid, cupric carbonate, and zinc carbonate (3:1:1 molar ratio) that had been kept at room temperature for 1 week.

EXAMPLE 4

[0058] 3 moles of malonic acid is thoroughly mixed with 1 mole of copper as cupric carbonate and 1 mole of zinc as zinc carbonate in a stirred tank reactor containing 100 ml of heated water (approximately 95-100° C.). After a short reaction time, copper-zinc malonate precipitates out of solution with a high yield. A filtration step is used to isolate the complex as a powder. Deep blue crystals are obtained having a melting point of about 210° C.

EXAMPLE 5

[0059] In embodiments, copper-zinc malonate formulations have the following make-up:

COMPONENT	% BY WEIGHT
Copper-zinc malonate* (Active ingredient)	0.1%
Glycerine	3.0%
Propylene Glycol	25.0%
Distilled Water	71.9%

EXAMPLE 6

[0060] A 72 year old woman is suffering from wrinkling on her face. The composition of example 5 suitable for treatment of skin containing an effective amount of copper-zinc malonate active ingredient is routinely applied to her face twice daily. Wrinkling is reduced or eliminated.

EXAMPLE 7

[0061] 3 moles of glutamic acid is thoroughly mixed with 1 mole of copper as cupric carbonate and 1 mole of zinc as zinc carbonate in a stirred tank reactor containing 100 ml of heated water (approximately 95-100° C.). After a short reaction time,

copper-zinc glutamate precipitates out of solution with a high yield. A filtration step is used to isolate the complex as a powder.

[0062] While several embodiments of the disclosure have been described, it is not intended that the disclosure be limited thereto, as it is intended that the disclosure be as broad in scope as the art will allow and that the specification be read likewise. Therefore, the above description should not be construed as limiting, but merely as exemplifications of embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

What is claimed is:

1. A method of forming a bimetal complex comprising dissolving an amino acid having at least two carboxylic acid groups in a solvent to form a solution; adding a source of a first coordination element to the solution; adding a source of a second coordination element to the solution, wherein the first coordination element is different from the second coordination element and the first and second coordination elements are individually selected from copper, silver, gold, aluminum, scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, gallium, yttrium, zirconium, niobium, molybdenum, technetium, ruthenium, rhodium, palladium, silver, cadmium, indium and tin; and recovering a bimetal complex.
2. A method as in claim 1 wherein the coordination first and second elements are copper and zinc, respectively.
3. A method as in claim 1 wherein the source of a first coordination element provides Cu^{+2} ions in the solution.
4. A method as in claim 1 wherein the source of a second coordination element provides Zn^{+2} ions in the solution.

5. A method as in claim 1 wherein the source of a first coordination element and the source of a second coordination element provides, respectively, are compounds of the formula $\text{Cu}(\text{O}_2\text{C}-\text{CH}_2\text{CO}_2)_2$ and $\text{Zn}(\text{O}_2\text{C}-\text{CH}_2\text{CO}_2)_2$.

6. A method as in claim 1 wherein the amino acid having at least two carboxylic acid groups is a glutamic acid or an aspartic acid.

7. A method of forming a bimetal complex comprising dissolving a polyamine in a solvent to form a solution; adding a source of a first coordination element to the solution; adding a source of a second coordination element to the solution,

wherein the first coordination element is different from the second coordination element and the first and second coordination elements are individually selected from copper, silver, gold, aluminum, scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, gallium, yttrium, zirconium, niobium, molybdenum, technetium, ruthenium, rhodium, palladium, silver, cadmium, indium and tin; and recovering a bimetal complex.

8. A method as in claim 7 wherein the coordination first and second elements are copper and zinc, respectively.

9. A method as in claim 7 wherein the source of a first coordination element provides Cu^{+2} ions in the solution.

10. A method as in claim 7 wherein the source of a second coordination element provides Zn^{+2} ions in the solution.

11. A method as in claim 7 wherein the source of a first coordination element and the source of a second coordination element provides, respectively, are compounds of the formula $\text{Cu}(\text{O}_2\text{C}-\text{CH}_2\text{CO}_2)_2$ and $\text{Zn}(\text{O}_2\text{C}-\text{CH}_2\text{CO}_2)_2$.

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