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FATTY-ACID MODIFIED PHENOL-FORMALDEHYDE RESINS

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This invention relates to new compositions of matter, and, more specifically, it is concerned with compositions containing metallo salts of phenol condensation products.

It is an object of this invention to provide new compositions of matter having advantageous physical and chemical properties and many valuable applications. Other objects will appear from the following detailed description.

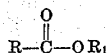
The objects of this invention are achieved by the provision of a new composition of matter comprising a higher fatty alcohol having at least 8 carbon atoms and a metal salt of a condensation product of from 1 to 4 mols of a mono-alkyl monohydric phenol having from 4 to 12 carbon atoms in the alkyl group, an equimolar amount of formaldehyde, and 1 mol of a higher fatty acid having at least 8 carbon atoms.

These compositions are moderately hard thermoplastic materials of straw-yellow to dark brown color. In general, most of the compositions have an indefinite melting point above about 170° F.; the melting point being dependent on the particular metal of the metal salt and the amount of the higher fatty alcohol present. As stated, the compositions are thermoplastic and can be prepared in any suitable hardness ranging from a pliable mass at room temperature to a hardness comparable to that of carnauba wax. They are soluble in gasoline, kerosene, and various petroleum naphthas. We have found these compositions to be particularly useful in coating compositions, waxes, insecticidal compositions, etc., as will be more fully described hereinafter.

The compositions of our invention may be prepared in several ways. According to one method of their preparation, the mono-alkyl phenol is condensed with formaldehyde and a higher fatty acid having at least 8 carbon atoms, and the condensation product is converted to a metal salt. To the resulting metal salt, a higher fatty alcohol of at least 8 carbon atoms is then added, yielding the composition of our invention. Alternatively, the higher fatty alcohol need not be added last, but may be mixed with the ingredients used to form the condensation product, i. e., the phenol, formaldehyde and higher fatty acid. In other words, the higher fatty alcohol can be added during any stage of this method of preparation of our new compositions.

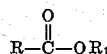
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It will be noted that the higher fatty alcohols of at least 8 carbon atoms and the higher fatty acids of at least 8 carbon atoms are, in effect, hydrolysis products of fatty mono-esters having a total of at least 16 carbon atoms. Also, it is known that the hydrolysis of esters with a metal base, more commonly called saponification, results in the formation of a metal salt of the liberated fatty acids and free fatty alcohols. Accordingly, a preferred method of obtaining the compositions of our invention comprises saponifying an ester having the formula



wherein R is an aliphatic radical of at least 7 carbon atoms and R₁ is an aliphatic radical of at least 8 carbon atoms, with a metal base and condensing the saponification product with a mono-alkyl phenol and formaldehyde. This method avoids a separate neutralization step and the separate addition of free fatty alcohols, two of the ingredients of our composition being present originally in the form of an ester. In the cases where the metal of the salt to be prepared does not form a strong base, e. g., the heavy metals, such as iron, copper, lead, etc., the saponification is conducted with an alkali metal base, and after the condensation product has been made, the alkali metal salt thereof is subjected to metathesis or double decomposition with a water soluble salt of such heavy metal, thereby obtaining the heavy metal salt of the condensation product.

Another alternative method of preparing our compositions involving the use of an ester having the formula



as defined hereinabove, is first to form a condensation product of the mono-alkyl phenol, formaldehyde and the ester and then to saponify the condensation product with a metal base, thereby liberating the higher fatty alcohols from the condensed ester and forming the metal salt of the condensation product. In this instance also, metal salts of the condensation product other than the alkali metal salts may be formed by metathesis.

While we do not know the exact chemical constitution of the condensation product, it is our present belief, without being limited thereto, that one mol of the phenol is linked through a methylene group to the higher fatty acid or acid residue in the salt or ester, most probably at the alpha carbon atom of the fatty acid or acid residue. Any excess phenol and formaldehyde then condense onto the phenolic nucleus of the above product. In any event, we are certain that a unitary condensation product is obtained from the phenol, formaldehyde and fatty acid, i. e., all of these ingredients are chemically combined. We are also certain that the higher fatty acid reacts with the phenol and formaldehyde in such manner as not to involve the carboxy group of the fatty acid, since the same type of product is finally obtained whether the phenol and formaldehyde are condensed with the free higher fatty acid, the fatty acid salts or the fatty acid esters.

Regardless of the specific method by which our compositions are prepared, the condensation and saponification reactions which are common to all of the methods of preparation disclosed herein are conducted under substantially identical conditions in each of the methods. The condensation reaction, which proceeds slowly at room temperature, is generally conducted at a mildly elevated temperature, say 150° to 175° F., but not in excess of 250° F. The condensation reaction is conducted in a closed vessel under reflux until all of the formaldehyde is consumed. Either acid or alkaline condensing agents may be employed as is known in the art of phenol-formaldehyde condensations. After completion of the condensation, the product is dehydrated by raising the temperature, say to 280° F., to distill off all water. The same temperature conditions are employed for the saponification and double decomposition reactions as are employed for the condensation; i. e., although these reactions proceed at room temperature, it is preferred to speed up the reactions by employing temperatures in the neighborhood of 150° to 175° F., but not in excess of 250° F.

As has been stated hereinabove, the proportions employed to prepare the condensation product are 1 mol of the higher fatty acid or its equivalent, 1 to 4 mols of the mono-alkyl phenol and 1 to 4 mols of formaldehyde. The phenol and formaldehyde are used in substantially equal amounts within the range of proportions stated. When amounts of the phenol and formaldehyde in excess of 1 mol are employed, the excess condenses on to the phenolic nucleus of the condensation product of 1 mol each of the higher fatty acid, the phenol and formaldehyde and forms condensation products of a greater consistency.

The free higher fatty alcohol in our composition functions as a plasticizer for the metal salt of the condensation product and facilitates the formation of solutions of our composition in various petroleum solvents and mineral lubricating oils. Generally, in order to obtain the plasticizing and solubilizing functions of the free higher fatty alcohol, it is necessary to use it in amount not less than 1/2 mol per mol of the fatty acid employed in preparing the condensation product. As much as 2 mols of the free higher fatty alcohol can be used per mol of fatty acid, but amounts in excess thereof are undesirable since such excess amounts tend to form masses of too soft a character. Of course, when an ester is used in the preparation of our compositions, the free fatty alcohol will be present in sub-

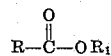
stantially equimolar (1 mol) amounts with the fatty acid.

The alkyl substituent of the mono-alkyl phenol employed in our invention has from 4 to 12 carbon atoms. The use of alkyl phenols having more or less carbon atoms in the alkyl group than the range stated is not satisfactory because the resulting salts of the condensation products prepared therefrom tend to be difficultly soluble in mineral lubricating oils. A preferred group of the mono-alkyl phenols are those prepared by alkylating phenol with an olefin having from 4 to 12 carbon atoms in the presence of a concentrated sulfuric acid catalyst at a temperature not exceeding 220° F. The resulting alkylated phenols may be washed with water and dilute caustic soda to remove the sulfuric acid catalyst, but this is not necessary. Other mono-alkyl phenols than the secondary and tertiary mono-alkyl phenols obtained by alkylating phenol with an olefin having from 4 to 12 carbon atoms are also successfully employed. Thus, n-alkyl phenols having from 4 to 12 carbon atoms in the alkyl substituent, prepared by alkylating phenol with an n-alkyl halide in the presence of a Friedel-Crafts catalyst can also be employed. Representative mono-alkyl phenols include n-butyl phenol, sec-butyl phenol, tert-butyl phenol, n-amyl phenol, sec-amyl phenol, tert-amyl phenol, n-hexyl phenol, n-octyl phenol, (alpha, alpha, gamma, gamma) tetramethylbutyl phenol, triisobutyl phenol and the like.

The higher fatty acids of at least 8 carbon atoms which are employed in preparing the condensation products of our compositions are the saturated and mono-olefinic aliphatic monocarboxylic acids. These include caprylic, pelargonic, nonylenic, capric, decylenic, undecylenic, lauric, myristic, palmitic, stearic, oleic, ricinoleic, arachidic, behenic, erucic, brassidic, carnauba, cerotic, melissic and psyllaic acids. Fatty acids of greater than mono-olefinic unsaturation, such as linoleic and linolenic acids, are undesirable since they tend to confer undesirable hardening and drying properties on the condensation products made therefrom. Fatty acids having less than 8 carbon atoms are not suitable since as the chain length decreases, the condensation products formed tend to become too hard and brittle and of decreasing solubility in petroleum solvents.

The higher fatty alcohols of at least 8 carbon atoms which are employed as the solubilizing and plasticizing agent in our compositions are the saturated and mono-olefinic aliphatic monohydric alcohols. These include n-octyl, 2-ethylhexyl, octenyl, nonyl, decyl, decenyl, undecyl, undecenyl, lauryl myristyl, cetyl, stearyl, oleyl, ricinoleyl, eicosyl, eicosenyl, docosyl, erucyl, ceryl and melissyl alcohols. Other fatty alcohols having less than 8 carbon atoms and polyolefinic fatty alcohols are not satisfactory since they may evaporate too readily, have too high a flash point for safe use, or give an undesirable odor to the product. The lower alcohols are not good plasticizers, and the polyolefinic alcohols give undesirable hardening and drying effects.

As will be apparent from the foregoing, when that modification of the invention which employs an ester of the formula



(R being an aliphatic radical of at least 7 carbon atoms and R₁ being an aliphatic radical of at

least 8 carbon atoms) for the preparation of our composition is used, such ester is a combination of any of the foregoing alcohols and acids. Since many of such esters occur naturally, as in waxes, it is preferred to use such naturally occurring esters because of their relative cheapness. Examples of such materials are beeswax, carnauba wax, candelilla wax, Chinese insect wax, cottonseed wax, flax wax, ouricury wax, montan wax, sugar cane wax, sperm oil, spermaceti, sea weed wax, lanolin, and degreas (wool fat). The use of degreas is particularly preferred.

Any metal can be employed for the production of the metal salts of the condensation products disclosed herein. These include sodium, potassium, lithium, beryllium, calcium, magnesium, barium, strontium, zinc, silver, mercury, cadmium, aluminum, bismuth, tin, lead, copper, vanadium, antimony, chromium, manganese, iron, cobalt and nickel. In preparing our compositions by direct neutralization or by saponification of an ester, it is preferred to employ the alkali metal or alkaline earth metal hydroxides, because these are strong bases. Where salts of other metals than the alkali and alkaline earth metals are to be prepared, it is preferred to first make the alkali metal salt and then to make the salt of the other metal by metathesis with a water-soluble salt, such as the nitrate, chloride or sulfate, as appropriate, of such other metal.

The preparation of our new compositions is illustrated by the following examples:

Example I

Three thousand five hundred and twenty (3520) pounds of para - (alpha,alpha,gamma,gamma) tetramethylbutyl phenol prepared by alkylating phenol with diisobutylene in the presence of a concentrated sulfuric acid catalyst were added to a reaction vessel equipped with a reflux condenser and means for heating, cooling and agitating the charge. The phenol added was the crude reaction product, still containing the sulfuric acid catalyst. There was then added 3520 pounds of degreas having a neutralization number between 40 and 60. The mixture was agitated and heated to 160° F. Then 592 pounds of calcium hydroxide in a 33 per cent by weight water slurry were slowly added to the reaction vessel while maintaining the temperature at 160° F. The temperature was held at this point while continuously agitating the reaction mass until the saponification of the degreas was complete. Thereafter, 1360 lbs. of a 37 per cent by weight aqueous solution of formaldehyde was slowly added to the reaction vessel while maintaining the temperature not in excess of 170° F. After the formaldehyde was added, the mixture was refluxed at 170° F. until all the formaldehyde was consumed. Thereupon, the reflux condenser was replaced by an ordinary condenser and the reaction mass was heated to 280° F. to distill off all water and to dehydrate the product in the reaction vessel. The product in the reaction vessel was then filtered hot to remove excess calcium hydroxide and any other insolubles. The solidified product was a fairly hard light brown mass having a melting point of about 238° F. It was permanently thermoplastic and soluble in petroleum naphtha. The relative molar proportions of the phenol, degreas and formaldehyde in this example were in the ratio 2.7:1:2.7.

Example II

Two hundred and six (206) pounds of para-

(alpha,alpha,gamma,gamma) tetramethylbutyl phenol were mixed with 250 pounds of degreas and heated to 160° F. Then, while maintaining this temperature, 50 pounds of sodium hydroxide dissolved in 128 pounds of water were slowly added with stirring. The mixture was held at this temperature until saponification of the degreas was complete. Thereafter, 82 pounds of a 37 per cent by weight aqueous solution of formaldehyde were slowly added to the reaction mass and the temperature was not permitted to exceed 170° F. The mixture was then refluxed until all of the formaldehyde was consumed. Thereafter, the mixture was heated to 380° F. to distill off all water and the product in the reaction vessel was filtered hot to remove all insolubles. The solidified product was a fairly hard light brown thermoplastic mass having a melting point of about 310° F. The relative molar proportions of the phenol, degreas and formaldehyde in this example were in the ratio 2.2:1:2.2.

Typical properties of the degreas used in the above examples are:

Specific gravity 60°/60° F. -----	0.9322-0.9449
Solidification point, °F. -----	100-104
Saponification No. -----	84-127
Iodine No. -----	15-21.5

Example III

Ninety (90) pounds of the product of Example II was subjected to a double decomposition reaction with 63 pounds of ferrous chloride dissolved in water by agitating the reactants at temperatures of 150°-170° F. The reaction product was washed with water to remove water soluble salts and then dried at 250° F. The resulting iron salt composition was a thermoplastic solid having an indefinite melting point in excess of 180° F.

Example IV

The barium salt composition was prepared in the same manner as the iron salt of Example III by reacting 90 pounds of the product of Example II with 35 pounds of barium chloride dissolved in water. The resulting barium salt composition was a thermoplastic solid having an indefinite melting point in excess of 240° F.

Example V

In a similar manner, the stannous salt, the aluminum salt and the cupric salt were prepared by reacting in each instance 90 pounds of the product of Example II with 39 pounds of stannous chloride dissolved in water for the stannous salt, 23 pounds of aluminum sulfate dissolved in water for the aluminum salt and 14 pounds of cupric chloride dissolved in water for the copper salt. Each of the resulting salts had an indefinite melting point in excess of about 212° F. but they were thermoplastic solids at room temperature.

It should be noted that although the product of Example II had a melting point of 310° F., it was slightly soluble and/or sufficiently dispersible in water to permit the double decomposition reactions of Example III, IV or V. In lieu of replacing all of the sodium ion in the double decomposition reactions, if desired, any portion thereof may be replaced by controlling the amount of the water-soluble salt added, thereby forming mixed salts.

Example VI

One mol of p-tertiarybutyl phenol was mixed with 1 mol of oleic acid and heated to 160° F. Then 1 mol of formaldehyde was slowly added

at a temperature not in excess of 165° F. The mixture was then refluxed until all of the formaldehyde was consumed. Thereafter, 1 mol of sodium hydroxide in 3 parts of water was added to neutralize the mixture. To the neutralized mixture there was then added 0.5 mol of cetyl alcohol. The mixture was agitated while heating to 385° F. to distill off all water. The product was then filtered hot to remove any insolubles. The solidified product was a fairly hard light brown mass having a melting point of about 255° F.

Our new compositions have many advantageous uses. Since the compositions have positive anti-corrosive properties, they are eminently useful in preparing slushing compounds, as undercoatings in the lagging of metallic vessels and as anti-corrosive additives in mineral oil lubricant compositions. When used as protective coatings for metals, the compositions of our invention form tough, adherent, water-repellent films; yet when it is desired to remove the coatings, they may be easily removed merely by wiping with a cloth dipped in kerosene, gasoline, Stoddard solvent or other petroleum naphtha. The compositions form excellent textile impregnants when dissolved in a volatile petroleum naphtha, since they make the textiles water-repellent and prevent rotting of the textile base. When added to paints, our compositions promote adhesion and prevent scaling, rusting and other corrosion of metal parts covered by the paint film. In coating compositions having an asphalt base, small amounts of our compositions act as an anti-oxidant and modifier which eliminates or materially reduces cracking, checking, alligatoring and slipping. Our compositions act as effective adhesives in insecticidal compositions employing residual toxicants, such as p-p', bis(chlorophenyl) 1,1,1-trichloroethane, tetraethylpyrophosphate, benzene hexachloride, 1,2,4,5,6,7,8,8-octachlor-4,7-methano-3a,4,7,7a-tetrahydroindane, etc. Our new compositions also modify the structure of both amorphous and crystalline paraffin waxes. Our new compositions are also useful in modifying vegetable, animal or mineral wax compositions to give improved characteristics to floor coverings, metal coverings, furniture polishes and automobile polishes. In wax polishes, the compositions of our invention can replace the usual beeswax plasticizer and modifier, or even hard waxes like carnauba wax. When the petroleum solvent has evaporated from the modified wax polish, there remains a clear, hard, plastic film.

The following examples are illustrative of some of the uses of our compositions.

Example VII

A residual insecticide spray was prepared to contain 6 per cent by weight of p-p',bis (chlorophenyl)-1,1,1-trichlorethane in an insecticide naphtha base. A comparison was made between this spray and an identical spray containing additionally 1 per cent by weight of the product of Example I, as follows: The two insecticide compositions were sprayed on a panel in an amount of 1 ounce of liquid per 100 sq. ft. and allowed to dry. The panel was then placed in such manner as to be contacted with flies (*Musca domestica*). The apparent effective time of killing of the spray not containing our composition was 94 days; whereas the apparent effective time of killing of the spray containing our composition was more than 165 days.

Example VIII

A polishing wax was prepared by substituting

the product of Example I for either carnauba wax or beeswax in a standard wax. A comparison of the waxes follows:

	A	B	C	D
Make-up, Percent by Wt.:				
Carnauba Wax.....	17.0	17.0	8.5	
122° F. E. M. P. Paraffin Wax.....	14.0	14.0	14.0	14.0
Beeswax.....	1.5		1.5	1.5
200°-300° F. Naphtha.....	67.5	67.5	67.5	67.5
Product of Example I.....		1.5	8.5	17.0
Inspection: Melting Point, °F., Saybolt, Paraffin.....	122.8	95	65	(1)
Penetration, ASTM 217-44T, 77° F., 150 G., 5 Sec., Unworked.....	50	Too soft	Too soft	(1)
Naphtha by Dist'n., Percent.....	65.6	65.8	65.7	65.5

(1) Liquid at room temperature.

Polish A, which was the standard, presented the conventional car wax appearance and polished to a film having a smooth hard finish. Polish B, in which the beeswax was replaced by the composition of our invention, was softer than the standard and also polished to a film having a smooth hard finish. Polish B, in which half of the carnauba wax was replaced by the composition of our invention, was a mush-like material easily applied to leave a smooth hard finish. Polish C in which all the carnauba wax was replaced by the composition of our invention, was liquid at room temperature and left a smooth hard film. The compositions of our invention may thus be used to vary the characteristics of wax polishes, making them easier to apply and easier to rub into a smooth hard coat which is more plastic and more impervious to water than conventional wax coats. The films prepared from waxes containing the compositions of our invention have better non-slip properties than a film of a standard carnauba base wax. The waxes containing the compositions of our invention are also cheaper than standard carnauba base waxes, since the expensive carnauba wax can be replaced wholly or in part with out inexpensive compositions.

Example IX

A canvas cover was treated with a 10 per cent by weight solution in V. M. & P. naphtha of the copper salt composition of Example V. The canvas was then exposed to weather. After six months, the canvas was still resistant to water and showed no evidence of rotting where it came in contact with brackish water.

Example X

A canvas boat cover was treated with a 10 per cent solution in V. M. & P. naphtha of the aluminum salt composition of Example V. A brush was used to apply the solution to the cover. After six months weathering, the canvas was impervious to water and showed no deterioration.

Resort may be had to such modifications and variations as fall within the spirit of the invention and the scope of the appended claims.

We claim:

1. A composition of matter comprising a higher fatty alcohol selected from the class consisting of the saturated and mono-olefinic aliphatic monohydric alcohols having at least 8 carbon atoms and a metal salt of a condensation product of from 1 to 4 mols of a mono-alkyl monohydric phenol having from 4 to 12 carbon atoms in the alkyl group, an equimolar amount of formaldehyde, and 1 mol of a higher

fatty acid selected from the class consisting of the saturated and mono-olefinic aliphatic monocarboxylic acids having at least 8 carbon atoms, the amount of said higher fatty alcohol ranging from $\frac{1}{8}$ to 2 mols per mol of said higher fatty acid.

2. The composition of claim 1, wherein the higher fatty alcohol is degreas fatty alcohols, and the higher fatty acid is degreas fatty acids.

3. The composition of claim 1, wherein the higher fatty alcohol is sperm oil fatty alcohols, and the higher fatty acid is sperm oil fatty acids.

4. The composition of claim 1, wherein the higher fatty alcohol is beeswax fatty alcohols and the higher fatty acid is beeswax fatty acids.

5. The composition of claim 1, wherein the metal salt is an alkali metal salt.

6. The composition of claim 1, wherein the metal salt is an alkaline earth metal salt.

7. The composition of claim 1, wherein the metal salt is a calcium salt.

8. The composition of claim 1, wherein the metal salt is a sodium salt.

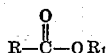
9. The composition of claim 1, wherein the metal salt is a copper salt.

10. A composition of matter comprising degreas fatty alcohols and a calcium salt of a condensation product of from 1 to 4 mols of (alpha, alpha, gamma, gamma) tetramethylbutyl phenol, an equimolar amount of formaldehyde and 1 mol of degreas fatty acids, the amount of said degreas fatty alcohols ranging from $\frac{1}{8}$ to 2 mols per mol of said degreas fatty acids.

11. A composition of matter comprising cetyl alcohol and a sodium salt of a condensation product of from 1 to 4 mols of tertiarybutyl phenol, an equimolar amount of formaldehyde and 1 mol of oleic acid, the amount of cetyl alcohol ranging from $\frac{1}{8}$ to 2 mols per mol of oleic acid.

12. The process which comprises condensing from 1 to 4 mols of a mono-alkyl monohydric phenol having from 4 to 12 carbon atoms in the alkyl group, an equimolar amount of formaldehyde and 1 mol of a higher fatty acid selected from the class consisting of the saturated and mono-olefinic aliphatic monocarboxylic acids having at least 8 carbon atoms, then forming a metal salt of the condensation product, and adding in an amount of from $\frac{1}{8}$ to 2 mols per mol of said higher fatty acid a higher fatty alcohol selected from the class consisting of the saturated and mono-olefinic aliphatic monohydric alcohols having at least 8 carbon atoms.

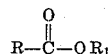
13. The process which comprises condensing from 1 to 4 mols of a mono-alkyl monohydric phenol having from 4 to 12 carbon atoms in the alkyl group, an equimolar amount of formaldehyde and 1 mol of an ester having the formula



wherein R is an aliphatic radical of at least 7 carbon atoms and R₁ is an aliphatic radical of at least 8 carbon atoms, both R and R₁ being selected from the class consisting of saturated and monoolefinic aliphatic radicals, and saponifying the condensation product with a

strong base selected from the class consisting of alkali metal and alkaline earth metal hydroxides.

14. The process which comprises saponifying 1 mol of an ester having the formula



wherein R is an aliphatic radical of at least 7 carbon atoms and R₁ is an aliphatic radical of at least 8 carbon atoms, both R and R₁ being selected from the class consisting of saturated and mono-olefinic aliphatic radicals, with a strong base selected from the class consisting of alkali metal and alkaline earth metal hydroxides, and reacting the saponified mixture with 1 to 4 mols of a mono-alkyl monohydric phenol having from 4 to 12 carbon atoms in the alkyl group and an equimolar amount of formaldehyde to condense together the metal salt of the fatty acid derived from the saponification, the phenol and the formaldehyde.

15. The process of claim 14, wherein the base is an alkali metal hydroxide, and salts of other metals are prepared by metathesis of the alkali metal salt of the condensation product with a water-soluble salt of such other metal.

16. The process which comprises saponifying 1 mol of degreas with calcium hydroxide, and reacting the saponified mixture with 1 to 4 mols of (alpha, alpha, gamma, gamma) tetramethylbutyl phenol and an equimolar amount of formaldehyde to condense together the calcium salt of the degreas fatty acids, the phenol and the formaldehyde.

17. The process which comprises saponifying 1 mol of degreas with sodium hydroxide, and reacting the saponified mixture with 1 to 4 mols of (alpha, alpha, gamma, gamma) tetramethylbutyl phenol and an equimolar amount of formaldehyde to condense together the sodium salt of the degreas fatty acids, the phenol and the formaldehyde.

18. The process of claim 17, wherein other metal salts of the condensation product are prepared by metathesis of the sodium salt of the condensation product with a water-soluble salt of such other metal.

19. The process of claim 18 wherein the water-soluble salt is a water-soluble copper salt.

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