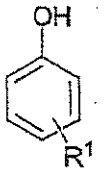
metal alkyl phenates. Furthermore, there is a need for new lubricating oil detergents with a low free alkyl phenol content. Furthermore there is a need for new lubricating oil detergents having a low sulfur content.

SUMMARY OF THE ~~INVENTION~~DISCLOSURE

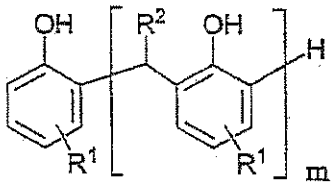
[6] Provided herein are methods of making sulfurized metal alkyl phenate compositions having a low alkyl phenol content. In one aspect, provided herein is a method of making a sulfurized metal alkyl phenate composition comprising the steps of:

(a) reacting a phenol compound of Formula (I):



(I)

wherein R^1 is alkyl, alkylaryl, or arylalkyl, in the presence of a catalyst with an aldehyde having formula R^2-CHO to form a phenolic resin of Formula (II):



(II); and

(b) reacting the phenolic resin wherein m is an integer from 1 to 50; R^1 is as defined above, and R^2 is H, alkyl, alkenyl, alkynyl, cycloalkyl, aryl, alkylaryl or arylalkyl simultaneously with at least one metal base and a first sulfurizing agent to form a sulfurized metal alkyl phenate.

[7] In some embodiments, the method disclosed herein further comprises reacting the product of step b with carbon dioxide. In further embodiments, the reaction with carbon dioxide takes place in the presence of ethylene glycol.

[8] In some embodiments, R^1 is alkyl. In certain embodiments, R^1 is alkyl of 8 to 100 carbon atoms or 8 to 50 carbon atoms or 10 to 30 carbon atoms. In further embodiments, R^1 is a $C_{12}H_{25}$ or dodecyl at the 4-position of the phenolic ring. In other embodiments, R^2 is H.

Formula (III), (IV), (V) or (VI) is 1. In still further embodiments, x of Formula (III), (IV), (V) or (VI) is 1 and n is 0.

[12] In some embodiments, R^1 is a $C_{12}H_{25}$ alkyl group at the 4-position of the phenolic ring; and R^2 is H. In further embodiments, each of r, s and t is 1. In some embodiments, each of m, p and q is 1.

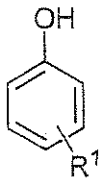
[13] In certain embodiments, the sulfurized metal alkyl phenate composition comprises the unreacted phenol compound of Formula (I), a metal salt thereof or a combination thereof and wherein the total amount of the unreacted phenol compound and the metal salt thereof is less than about 5 wt.%, based on the total weight of the sulfurized metal alkyl phenate composition.

[14] In some embodiments, the method disclosed herein further comprises reacting the sulfurized metal alkyl phenate composition with a second sulfurizing agent to lower the total amount of the unreacted phenol compound of Formula (I) and a metal salt thereof to less than about 2.0 wt.%, based on the total weight of the sulfurized metal alkyl phenate composition. In further embodiments, the second sulfurizing agent is sulfur.

[15] In certain embodiments, the method disclosed herein further comprises an overbasing step of contacting the sulfurized metal alkyl phenate composition with carbon dioxide.

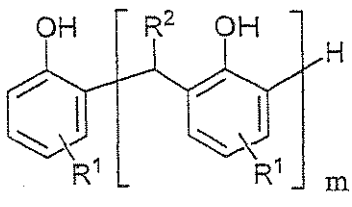
[15a] In one aspect, there is provided a method of making a sulfurized metal phenate composition comprising the steps of:

(a) reacting a phenol compound of Formula (I):



(I)

wherein R^1 is alkyl, alkylaryl, or arylalkyl, in the presence of a catalyst with an aldehyde having formula R^2-CHO to form a phenolic resin of Formula (II):



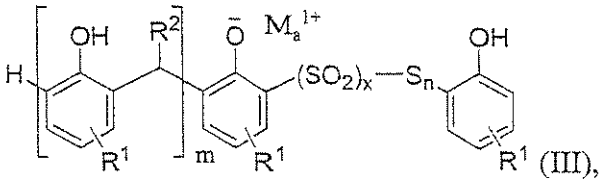
(II);

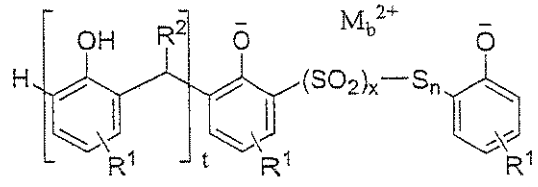
(b) reacting the phenolic resin wherein m is an integer from 1 to 50; R^1 is as defined above; and R^2 is H, alkyl, alkenyl, alkynyl, cycloalkyl, aryl, alkylaryl or arylalkyl simultaneously with at least one metal base and a first sulfurizing agent to form a sulfurized metal alkyl phenate; and

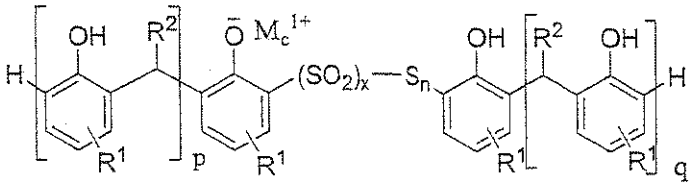
(c) reacting the sulfurized metal alkyl phenate composition with a second sulfurizing agent to lower the total amount of the unreacted phenol compound of Formula (I) and a metal salt thereof to less than 2.0 wt.%, based on the total weight of the sulfurized metal alkyl phenate composition.

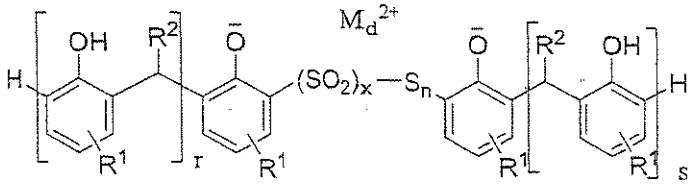
[16] In another aspect, provided herein is a sulfurized metal alkyl phenate composition or an overbased sulfurized metal alkyl phenate composition prepared by the methods disclosed herein.

[16a] In another aspect, there is provided a sulfurized metal phenate composition comprising at least one of the Formulae (III) – (IV):

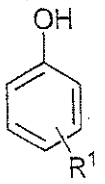

(III),


(IV),


(V), and


(VI),

wherein the total amount of a phenol compound of Formula (I):

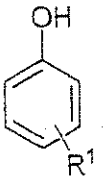


(I)

and a metal salt thereof in the sulfurized metal alkyl phenate composition is less than 2.0 wt.%, based on the total weight of the sulfurized metal alkyl phenate composition, and wherein each of M_a^{1+} and M_c^{1+} is independently a monovalent metal ion; each of M_b^{2+} and M_d^{2+} is independently a divalent metal ion; each of m, n, p, q, r, s and t is independently an integer from 1 to 50; x is an integer from 0 to 2; R^1 is alkyl, alkylaryl, or arylalkyl; and R^2 is H, alkyl, alkenyl, alkynyl, cycloalkyl, aryl, alkylaryl or arylalkyl.

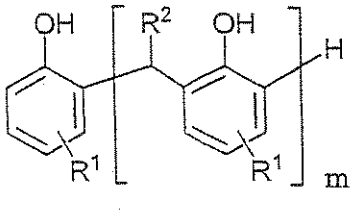
[16b] In another aspect, there is provided a sulfurized metal phenate composition prepared by a method comprising the steps of:

(a) reacting a phenol compound of Formula (I):



(I)

wherein R^1 is alkyl, alkylaryl, or arylalkyl, in the presence of a catalyst with an aldehyde having formula R^2-CHO to form a phenolic resin of Formula (II):



(II);

(b) reacting the phenolic resin wherein m is an integer from 1 to 50; R^1 is as defined above, and R^2 is H, alkyl, alkenyl, alkynyl, cycloalkyl, aryl, alkylaryl or arylalkyl simultaneously with at least one metal base and a first sulfurizing agent to form a sulfurized metal alkyl phenate; and

(c) reacting the sulfurized metal alkyl phenate composition with a second sulfurizing agent to lower the total amount of the unreacted phenol compound and a metal salt thereof in the sulfurized metal alkyl phenate composition to less than 2.0 wt.%, based on the total weight of the sulfurized metal alkyl phenate composition.

[17] In another aspect, provided herein is a lubricating oil composition comprising a base oil and a sulfurized metal alkyl phenate composition disclosed herein. In some embodiments, the lubricating oil composition further comprises at least an additive selected from the group consisting of antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, friction modifiers, multi-functional additives, viscosity index improvers, pour point depressants, foam inhibitors, metal deactivators, dispersants, corrosion inhibitors, lubricity improvers, thermal stability improvers, anti-haze additives, icing inhibitors, dyes, markers, static dissipaters, biocides and combinations thereof. In further embodiments, the base oil is present in a major amount.