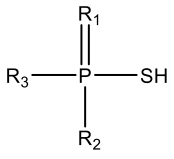
CLAIMS

WHAT IS CLAIMED IS

1. A thiophosphoric acid product comprising at least a compound having the structure of Formula I



(Formula I)

wherein

R_1 is sulfur or oxygen;

R_2 and R_3 are, independently, one of -OR_4 or -OH, and each R_4 if included is, independently, a C3 to C18 linear or branched alkyl group, a C5 to C6 cycloalkyl group, a phenyl group, or a C6 to C18 alkylphenol group; and

wherein the thiophosphoric acid product has about 0.1 mmoles/gram or less of active sulfur as measured via titration with triphenyl phosphine.

2. The thiophosphoric acid product of claim 1, wherein R_1 is sulfur, R_2 and R_3 are, independently, the -OR_4 group with each R_4, independently, a C3 to C18 linear or branched alkyl group.

3. The thiophosphoric acid product of claim 1, wherein the thiophosphoric acid product is substantially free of phosphorus polysulfide compounds.

4. The thiophosphoric acid product of claim 3, wherein the thiophosphoric acid product includes phosphorus polysulfide compounds, but no more than about 1 weight percent of the phosphorus polysulfide compounds.

5. The thiophosphoric acid product of claim 1, wherein the compound of Formula I includes the reaction product of an organic hydroxy compound and phosphorus pentasulfide.

6. The thiophosphoric acid product of claim 5, wherein the organic hydroxy compound is provided in a molar ratio relative to the phosphorus pentasulfide of about 4:1 to about 10:1.

7. The thiophosphoric acid product of claim 5, wherein the organic hydroxy compound is one or more of methyl alcohol, ethyl alcohol, propyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, tert-butyl alcohol, sec-butyl alcohol, phenol, naphthol, an amyl alcohol, hexyl alcohol, iso-hexyl alcohol, octyl alcohol, decyl alcohol, dodecyl alcohol, octadecyl alcohol, 2-ethylhexyl alcohol, 4-methyl-2-pentyl alcohol, phenyl alcohol, butylphenyl alcohol, cyclohexyl alcohol, methylcyclopentyl alcohol, propenyl alcohol, butenyl alcohol, or combinations thereof.

8. The thiophosphoric acid product of claim 1, wherein the thiophosphoric acid product is distilled and recovered as a condensate of the distillation.

9. The thiophosphoric acid product of claim 8, wherein the distillation occurs at a temperature of at least about 80° C. and/or a pressure of at least about 0.4 torr.

10. The thiophosphoric acid product of claim 9, wherein the condensate is recovered at a temperature of about 10° C. or less.

11. The thiophosphoric acid product of claim 8, wherein the distillation occurs in a falling-film evaporator, a wiped-film evaporator, a thin-film evaporator, a short-path evaporator, or combinations thereof.

12. The thiophosphoric acid product of claim 1, wherein the compound of Formula I is selected from a dipropyl dithiophosphoric acid, a diisopropyl dithiophosphoric acid, a dibutyl dithiophosphoric acid, a diisobutyl dithiophosphoric acid, a di-ethylhexyl dithiophosphoric acid, or combinations thereof.

13. An antiwear additive for lubricating compositions comprising the reaction product of the thiophosphoric acid product of claim 1 and a reactant selected from (i) an unsaturated carboxylic acid, (ii) a basic or neutral metal compound including one or more of a metal oxide, a metal hydroxide, or a metal carbonate; or (iii) an unsaturated ester of a carboxylic acid.

14. The antiwear additive of claim 13, wherein the reactant is (i) the unsaturated ester of a carboxylic acid and wherein the unsaturated ester of a carboxylic acid is an C1 to C20 alkyl (meth)acrylate.

15. The antiwear additive of claim 14, wherein the unsaturated ester of a carboxylic acid is methyl acrylate, methyl methacrylate, ethyl acrylate, ethyl methacrylate, or combinations thereof.

16. The antiwear additive of claim 13, wherein the reactant is (ii) the basic or neutral metal compound and includes a metal oxide, a metal hydroxide, or a metal carbonate of aluminum, lead, tin, molybdenum, manganese, nickel, copper, titanium, zirconium, zinc, or combinations thereof.

17. The antiwear additive of claim 16, wherein the basic or neutral metal compound is a molar excess of zinc oxide.

18. The antiwear additive of claim 13, wherein the reactant is (iii) the unsaturated carboxylic acid and wherein the unsaturated carboxylic acid is a C3 to C20 unsaturated fatty acid.

19. The antiwear additive of claim 18, wherein the unsaturated carboxylic acid is acrylic acid, methacrylic acid, 2-ethyl acrylic acid, or combinations thereof.

20. A lubricating composition including the antiwear additive of claim 13.