

5 **IMPROVED PROCESS FOR PREPARATION OF LOW MOLECULAR WEIGHT
 MOLYBDENUM SUCCINIMIDE COMPLEXES**

FIELD OF THE INVENTION

 The present invention generally relates to an improved process for preparing low molecular weight molybdenum succinimide complexes.

10 **BACKGROUND OF THE INVENTION**

 In general, organic molybdenum compounds are known to improve the lubricating properties of engine oils. For example, molybdenum dithiocarbamates are typically employed for the reduction of friction. The molybdenum dithiocarbamates, however, contain sulfur and slowly lose the ability to reduce friction unless an alternate sulfur source is present
15 in the lubricating oil. Another example of organic molybdenum compounds are sulfurized molybdenum polyisobutenyl succinimide complexes which are used to mediate wear, reduce friction, and/or control oxidation. See, e.g., U.S. Patent Nos. 4,259,194; 4,265,773; 4,283,295; 4,285,822; and 6,962,896 and U.S. Patent Application Publication No. 2005/0209111. Problems associated with the use of sulfur in lubricating oils are that sulfur
20 can be incompatible with emission control devices and can result in corrosion problems.

 U.S. Patent Nos. 4,357,149 and 4,500,439 disclose molybdated C₁₅-C₂₀ alkenyl succinimides. In Example XI of both of these patents, a molybdated succinimide is prepared by reacting a C₁₅-C₂₀ alkenyl succinic anhydride with triethylene tetramine followed by treatment with a molybdic acid solution.

25 Russian Patent No. 2201433 discloses a molybdated succinimide post-treated with maleic anhydride as an additive for motor oils used in internal combustion engines. Russian Patent No. 2201433 further discloses that the additives are prepared by reacting an alkenyl succinimide of polyethylene polyamine with ammonium molybdate in the presence of water as a promoter and then reacting the resulting product with maleic anhydride taken in amounts
30 of 0.2 to 1.0 mole per 1 mole of alkenyl succinimide of polyethylene polyamine. All of the examples disclosed in Russian Patent No. 2201433 employ a high molecular weight polyisobutenyl (950 M.W.) succinic anhydride (PIBSA) in preparing the alkenyl succinimide of polyethylene polyamine.

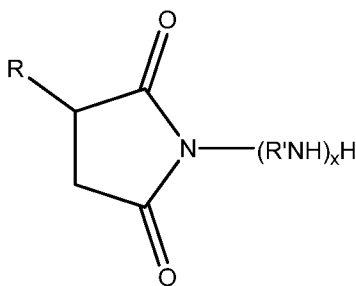
5 Molybdenum succinimide complexes are also described in U.S. Patent Application Publication No. 2009/0325832. These complexes are prepared by a process comprising (a) reacting an alkyl or alkenyl succinimide of a polyamine, with an ethylenically unsaturated carboxylic acid or anhydride thereof; and (b) reacting the product of step (a) with an acidic molybdenum compound. Also disclosed is a lubricating oil composition containing at least
10 (a) a major amount of a base oil of lubricating viscosity and (b) a minor amount of the molybdated succinimide complex.

It is desirable in certain applications (e.g. wear inhibition, oxidation control, and friction performance) for additives to contain a high concentration of molybdenum and basic nitrogen, in addition to other physical and handling properties such as being lower in color
15 intensity. Also desirable is a process which does not result in particulate matter in the final product.

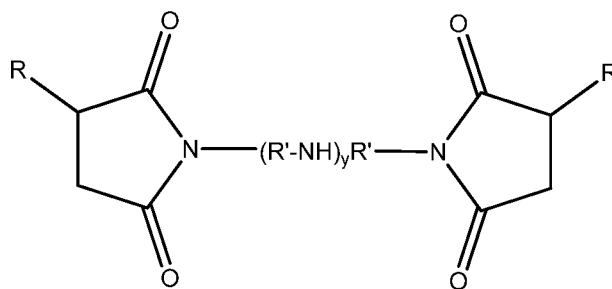
SUMMARY OF THE INVENTION

In accordance with one embodiment of the present invention, there is provided a process for
20 preparing a molybdated succinimide complex, the process comprising:

(a) reacting an alkyl or alkenyl succinimide of a polyamine of formula I, or formula II or mixtures thereof:



Formula (I)



Formula (II)

wherein R is an about C₁₂ to C₃₀ alkyl or alkenyl group, R' is a straight or branched-chain alkylene group having 2 to 3 carbon atoms, x is 1 to 11, and y is 1 to 10, with an α,β -unsaturated mono-carboxylic acid or carboxylic acid ester, in a charge mole ratio of the α,β -unsaturated mono-carboxylic acid or carboxylic acid ester to the succinimide of formula I or formula II or mixtures thereof of about 0.1:1 to about 6:1, and wherein the reaction temperature is no greater than about 135°C; and

(b) reacting the succinimide product of step (a) with an acidic molybdenum compound,

wherein the molybdated succinimide complex prepared is a liquid at room temperature.

Among other factors, the present invention is based on the surprising discovery of an improved process for the preparation of molybdated succinimide complexes. It has been found that molybdenum succinimide complexes derived from low molecular weight alkyl or alkenyl succinimides where the amine portion of the molecule has been post-treated with an α,β -unsaturated mono-carboxylic acid or carboxylic acid ester results in a product that is a liquid at room temperature, and results in a product with no visible particulate matter.

Another advantage of the present process is that the reaction of an alkyl or alkenyl succinimide of a polyamine with an α,β -unsaturated mono-carboxylic acid or carboxylic acid ester is carried out at a temperature no greater than about 135°C.

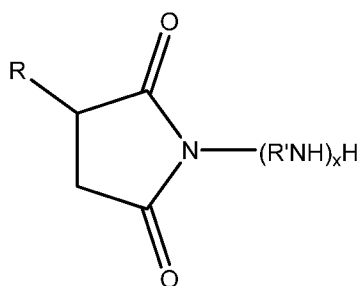
The post-treatment with an α,β -unsaturated mono-carboxylic acid or carboxylic acid ester at no greater than about 135°C, compared to the use of maleic anhydride at temperatures as high as 160°C, advantageously allows for a product which has an increased amount of molybdenum, improved Total Basic Nitrogen (TBN), improved wear performance, and more desirable physical and handling properties (such as a lower pour point). The resulting product

5 also advantageously provides high friction reduction, and inhibits wear when incorporated into a lubricating oil composition for use in internal combustion engines.

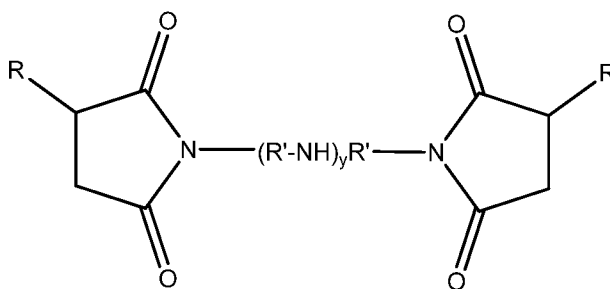
DETAILED DESCRIPTION OF THE INVENTION

In general, provided herein is a process for preparing a molybdated succinimide complex, the process comprising:

10 (a) reacting an alkyl or alkenyl succinimide of a polyamine of formula I or formula II or mixtures thereof:



Formula (I)



Formula (II)

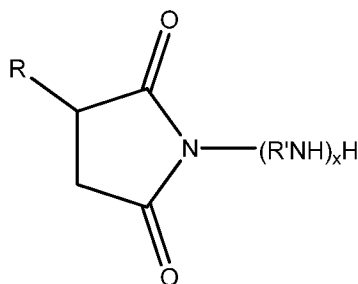
15 wherein R is an about C₁₂ to C₃₀ alkyl or alkenyl group, R' is a straight or branched-chain alkylene group having 2 to 3 carbon atoms, x is 1 to 11, and y is 1 to 10, with an α,β-unsaturated mono-carboxylic acid or carboxylic acid ester, in a charge mole ratio of the α,β-unsaturated mono-carboxylic acid or carboxylic acid ester to the succinimide of formula I or
 20 formula II or mixtures thereof of about 0.1:1 to about 6:1, and wherein the reaction temperature is no greater than about 135°C; and

- 5 (b) reacting the succinimide product of step (a) with an acidic molybdenum compound, wherein the molybdated succinimide complex prepared is a liquid at room temperature.

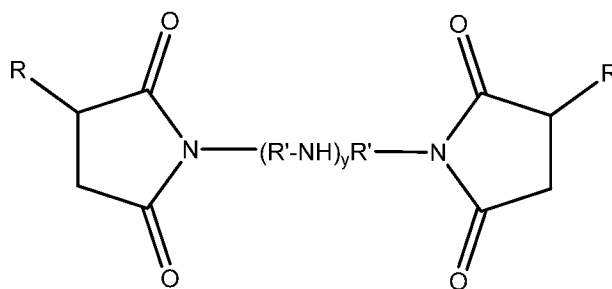
In one embodiment, the reaction temperature of step (a) in the process is no greater than 135°C. In another embodiment, the reaction temperature of step (a) in the process is no greater than 100°C. In another embodiment, the reaction temperature of step (a) in the process is no greater than 80°C.

In one embodiment, the R substituent has a number average molecular weight ranging from about 167 to about 419 and preferably from about 223 to about 279. In another embodiment, R is an about C₁₂ to about C₂₄ alkyl or alkenyl group; R' is 2; and x is 2 to 5.

- 15 In step (a), a succinimide of formula I or formula II or mixtures thereof:



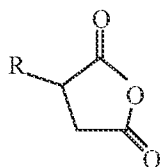
Formula (I)



Formula (II)

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wherein R, R', x and y have the aforesaid meanings, is reacted with an α,β -unsaturated mono-carboxylic acid or carboxylic acid ester, such as acrylic acid. The starting succinimide of formula I or formula II or mixtures thereof can be obtained by reacting an anhydride of formula III:



Formula (III)

5

wherein R has the aforesated meaning, with a polyamine. The anhydride of formula III is either commercially available from such sources as, for example, Sigma Aldrich Corporation (St. Louis, Mo., U.S.A.), or can be prepared by any method well known in the art. . In one
 10 embodiment, the charge mole ratio of polyamine to the anhydride of formula III is 0.5:1 to 1:1. In another embodiment, the charge mole ratio of polyamine to the anhydride of formula III is 0.8:1 to 1:1. In another embodiment, the charge mole ratio of polyamine to the anhydride of formula III is 0.9:1.

In one embodiment, the alkyl or alkenyl mono- or bis-succinimide of step (a) is a
 15 mixture of the succinimides of formula I and formula II. In another embodiment, the ratio of the mono-succinimide of formula I to the bis-succinimide of formula II in the succinimide mixture is from about 1:1 to 10:1. In another embodiment, the ratio of the mono-succinimide of formula I to the bis-succinimide of formula II in the succinimide mixture is at least about 4:1. In another embodiment, the ratio of the mono-succinimide of formula I to the bis-succinimide of formula II in the succinimide mixture is 9:1. In another embodiment, the ratio of the mono-succinimide of formula I to the bis-succinimide of formula II in the succinimide mixture is 1:1.
 20

Suitable polyamines for use in preparing the succinimide of formula I or formula II or mixtures thereof are polyalkylene polyamines or mixtures of polyalkylene polyamines,
 25 including polyalkylene diamines. Such polyalkylene polyamines will typically contain about 2 to about 12 nitrogen atoms and about 2 to 24 carbon atoms. Particularly suitable polyalkylene polyamines are those having the formula: $H_2N-(R^1NH)_x-H$ wherein R^1 is a straight- or branched-chain alkylene group having 2 or 3 carbon atoms, preferably 2 carbon atoms, and x is 1 to 11. Representative examples of suitable polyalkylene polyamines
 30 include polyethylene polyamines such as ethylenediamine, diethylenetriamine, triethylenetetraamine, tetraethylenepentamine and mixtures thereof. In one embodiment, the polyalkylene polyamine is tetraethylenepentamine.

5 Many of the polyamines suitable for use in the present invention are commercially available and others may be prepared by methods which are well known in the art. For example, methods for preparing amines and their reactions are detailed in Sidgwick's "The Organic Chemistry of Nitrogen", Clarendon Press, Oxford, 1966; Noller's "Chemistry of Organic Compounds", Saunders, Philadelphia, 2nd Ed., 1957; and Kirk-Othmer's
10 "Encyclopedia of Chemical Technology", 2nd Ed., especially Volume 2, pp. 99-116.

In one embodiment, the anhydride of formula III is reacted with the polyamine at a temperature of about 130°C to about 220°C. In another embodiment, the anhydride of formula III is reacted with the polyamine at a temperature from about 145°C to about 175°C. The reaction can be carried out under an inert atmosphere, such as nitrogen or argon. In one
15 embodiment, the amount of anhydride of formula III employed in the reaction can range from about 30 to about 95 wt. %. In another embodiment, the amount of anhydride of formula III employed in the reaction can range from about 40 to about 60 wt. %, based on the total weight of the reaction mixture. The reaction mixture may be mixed with or without diluent oil. The charge mole ratio (CMR) of polyamine:anhydride of formula III will vary, for
20 example from 0.5:1 to 1:1. In another embodiment, the ratio is 0.8:1 to 1:1. In another embodiment, the ratio is 0.9:1.

Suitable α,β -unsaturated mono-carboxylic acids or carboxylic acids esters include, but are not limited to, acrylic acid, methacrylic acid, methyl, ethyl, isopropyl, n-butyl and isobutyl esters of both acrylic and methacrylic acids, and the like, and mixtures thereof. A
25 preferred α,β -unsaturated mono-carboxylic acid is acrylic acid. The α,β -unsaturated mono-carboxylic acid or carboxylic acid ester bonds onto an amine portion of the succinimide starting compound to provide a carboxylic acid or ester functionality. The treatment of the succinimide of formula I with the α,β -unsaturated mono-carboxylic acid advantageously allows for a sufficient amount of the molybdenum compound to be incorporated into the
30 molybdated succinic complex and a product with a higher total base number (TBN).

Generally, the α,β -unsaturated mono-carboxylic acid is a liquid at room temperature and does not require heating prior to mixing with the succinimide of formula I or formula II or mixtures thereof. The mole ratio of the α,β -unsaturated mono-carboxylic acid or carboxylic acids ester, such as acrylic acid, to the succinimide of formula I or formula II or
35 mixtures thereof will vary widely, for example, from about 0.1:1 to about 6:1. In another

5 embodiment, the molar ratio is from 1:1 to 6:1. In another embodiment, the molar ratio is from 1:1 to 2:1. In another embodiment the molar ratio is 1:1.

The molybdenum compounds used to prepare the molybdated succinimide complex of the present invention are acidic molybdenum compounds or salts of acidic molybdenum compounds. Generally, these molybdenum compounds are hexavalent. Representative
10 examples of suitable molybdenum compounds include, but are not limited to, molybdenum trioxide, molybdic acid, ammonium molybdate, sodium molybdate, potassium molybdate and other alkaline metal molybdates and other molybdenum salts such as hydrogen salts, e.g., hydrogen sodium molybdate, MoOCl_4 , MoO_2Br_2 , $\text{Mo}_2\text{O}_3\text{Cl}_6$, or similar acidic molybdenum compounds. In one embodiment, the acidic molybdenum compound is molybdenum trioxide,
15 molybdic acid, ammonium molybdate, and alkali metal molybdates. In another embodiment, the acidic molybdenum compound is molybdenum trioxide

In step (b), a mixture of the succinimide product of step (a) and acidic molybdenum compound is prepared with or without a diluent. A diluent is used, if necessary, to provide a suitable viscosity for easy stirring. Suitable diluents are lubricating oils and liquid
20 compounds containing only carbon and hydrogen. If desired, ammonium hydroxide may also be added to the reaction mixture to provide a solution of ammonium molybdate.

Generally, the reaction mixture is heated at a temperature less than or equal to about 100°C and preferably from about 80°C to about 100°C until the molybdenum is sufficiently reacted. The reaction time for this step is typically in the range of from about 15 minutes to
25 about 5 hours and preferably from about 1 to about 2 hours. The molar ratio of the molybdenum compound to the succinimide product of step (a) is about 0.1:1 to about 2:1. In another embodiment, the molar ratio of the molybdenum compound to the succinimide product of step (a) is from about 0.5:1 to about 1.5:1. In another embodiment, the molar ratio of the molybdenum compound to the succinimide product of step (a) is about 1:1. Any water
30 present following the reaction of the molybdenum compound and succinimide product of step (a) is removed by heating the reaction mixture to a temperature greater than about 100°C . In another embodiment, any water present following the reaction of the molybdenum compound and succinimide product of step (a) is removed by heating the reaction mixture to a temperature from about 120°C to about 160°C , or by heating the reaction mixture to a
35 suitable temperature under vacuum.

5 The molybdated succinimide complex of the present invention is generally a liquid at room temperature. The pour point of the molybdated succinimide complex of the present invention is typically less than 120°C. In another embodiment, the pour point of the molybdated succinimide complex of the present invention is no greater than 115°C.

THE OIL OF LUBRICATING VISCOSITY

10 The base oil of lubricating viscosity for use in the lubricating oil compositions of this invention is typically present in a major amount, e.g., an amount of greater than 50 wt. %, preferably greater than about 70 wt. %, more preferably from about 80 to about 99.5 wt. % and most preferably from about 85 to about 98 wt. %, based on the total weight of the composition. The expression "base oil" as used herein shall be understood to mean a base
15 stock or blend of base stocks which is a lubricant component that is produced by a single manufacturer to the same specifications (independent of feed source or manufacturer's location); that meets the same manufacturer's specification; and that is identified by a unique formula, product identification number, or both. The base oil for use herein can be any presently known or later-discovered base oil of lubricating viscosity used in formulating
20 lubricating oil compositions for any and all such applications, e.g., engine oils, marine cylinder oils, functional fluids such as hydraulic oils, gear oils, transmission fluids, etc. Additionally, the base oils for use herein can optionally contain viscosity index improvers, e.g., polymeric alkylmethacrylates; olefinic copolymers, e.g., an ethylene-propylene copolymer or a styrene-butadiene copolymer; and the like and mixtures thereof.

25 As one skilled in the art would readily appreciate, the viscosity of the base oil is dependent upon the application. Accordingly, the viscosity of a base oil for use herein will ordinarily range from about 2 to about 2000 centistokes (cSt) at 100° Centigrade (C). Generally, individually the base oils used as engine oils will have a kinematic viscosity range at 100°C of about 2 cSt to about 30 cSt, preferably about 3 cSt to about 16 cSt, and most
30 preferably about 4 cSt to about 12 cSt and will be selected or blended depending on the desired end use and the additives in the finished oil to give the desired grade of engine oil, e.g., a lubricating oil composition having an SAE Viscosity Grade of 0W, 0W-20, 0W-30, 0W-40, 0W-50, 0W-60, 5W, 5W-20, 5W-30, 5W-40, 5W-50, 5W-60, 10W, 10W-20, 10W-30, 10W-40, 10W-50, 15W, 15W-20, 15W-30 or 15W-40. Oils used as gear oils can have
35 viscosities ranging from about 2 cSt to about 2000 cSt at 100°C.

5 Base stocks may be manufactured using a variety of different processes including, but not limited to, distillation, solvent refining, hydrogen processing, oligomerization, esterification, and rerefining. Rerefined stock shall be substantially free from materials introduced through manufacturing, contamination, or previous use. The base oil of the lubricating oil compositions of this invention may be any natural or synthetic lubricating base
10 oil. Suitable hydrocarbon synthetic oils include, but are not limited to, oils prepared from the polymerization of ethylene or from the polymerization of 1-olefins to provide polymers such as polyalphaolefin or PAO oils, or from hydrocarbon synthesis procedures using carbon monoxide and hydrogen gases such as in a Fischer-Tropsch process. For example, a suitable base oil is one that comprises little, if any, heavy fraction; e.g., little, if any, lube oil fraction
15 of viscosity 20 cSt or higher at 100°C.

 The base oil may be derived from natural lubricating oils, synthetic lubricating oils or mixtures thereof. Suitable base oil includes base stocks obtained by isomerization of synthetic wax and slack wax, as well as hydrocracked base stocks produced by hydrocracking (rather than solvent extracting) the aromatic and polar components of the crude. Suitable
20 base oils include those in all API categories I, II, III, IV and V as defined in API Publication 1509, 14th Edition, Addendum I, Dec. 1998. Group IV base oils are polyalphaolefins (PAO). Group V base oils include all other base oils not included in Group I, II, III, or IV. Although Group II, III and IV base oils are preferred for use in this invention, these base oils may be prepared by combining one or more of Group I, II, III, IV and V base stocks or base oils.

25 Useful natural oils include mineral lubricating oils such as, for example, liquid petroleum oils, solvent-treated or acid-treated mineral lubricating oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types, oils derived from coal or shale, animal oils, vegetable oils (e.g., rapeseed oils, castor oils and lard oil), and the like.

 Useful synthetic lubricating oils include, but are not limited to, hydrocarbon oils and
30 halo-substituted hydrocarbon oils such as polymerized and interpolymerized olefins, e.g., polybutylenes, polypropylenes, propylene-isobutylene copolymers, chlorinated polybutylenes, poly(1-hexenes), poly(1-octenes), poly(1-decenes), and the like and mixtures thereof; alkylbenzenes such as dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di(2-ethylhexyl)-benzenes, and the like; polyphenyls such as biphenyls, terphenyls, alkylated
35 polyphenyls, and the like; alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivative, analogs and homologs thereof and the like.

5 Other useful synthetic lubricating oils include, but are not limited to, oils made by polymerizing olefins of less than 5 carbon atoms such as ethylene, propylene, butylenes, isobutene, pentene, and mixtures thereof. Methods of preparing such polymer oils are well known to those skilled in the art.

 Additional useful synthetic hydrocarbon oils include liquid polymers of alpha olefins
10 having the proper viscosity. Especially useful synthetic hydrocarbon oils are the hydrogenated liquid oligomers of C₆ to C₁₂ alpha olefins such as, for example, 1-decene trimer.

 Another class of useful synthetic lubricating oils include, but are not limited to, alkylene oxide polymers, i.e., homopolymers, interpolymers, and derivatives thereof where
15 the terminal hydroxyl groups have been modified by, for example, esterification or etherification. These oils are exemplified by the oils prepared through polymerization of ethylene oxide or propylene oxide, the alkyl and phenyl ethers of these polyoxyalkylene polymers (e.g., methyl poly propylene glycol ether having an average molecular weight of 1,000, diphenyl ether of polyethylene glycol having a molecular weight of 500-1000, diethyl
20 ether of polypropylene glycol having a molecular weight of 1,000-1,500, etc.) or mono- and polycarboxylic esters thereof such as, for example, the acetic esters, mixed C₃-C₈ fatty acid esters, or the C₁₃ oxo acid diester of tetraethylene glycol.

 Yet another class of useful synthetic lubricating oils include, but are not limited to, the esters of dicarboxylic acids e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl
25 succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acids, alkyl malonic acids, alkenyl malonic acids, etc., with a variety of alcohols, e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, etc. Specific examples of these esters include dibutyl adipate, di(2-ethylhexyl)sebacate, di-n-hexyl fumarate, dioctyl
30 sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, the complex ester formed by reacting one mole of sebacic acid with two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid and the like.

 Esters useful as synthetic oils also include, but are not limited to, those made from
35 carboxylic acids having from about 5 to about 12 carbon atoms with alcohols, e.g., methanol,

5 ethanol, etc., polyols and polyol ethers such as neopentyl glycol, trimethylol propane, pentaerythritol, dipentaerythritol, tripentaerythritol, and the like.

Silicon-based oils such as, for example, polyalkyl-, polyaryl-, polyalkoxy- or polyaryloxy-siloxane oils and silicate oils, comprise another useful class of synthetic lubricating oils. Specific examples of these include, but are not limited to, tetraethyl silicate, tetra-isopropyl silicate, tetra-(2-ethylhexyl) silicate, tetra-(4-methyl-hexyl)silicate, tetra-(p-tert-butylphenyl)silicate, hexyl-(4-methyl-2-pentoxy)disiloxane, poly(methyl)siloxanes, poly(methylphenyl)siloxanes, and the like. Still yet other useful synthetic lubricating oils include, but are not limited to, liquid esters of phosphorous containing acids, e.g., tricresyl phosphate, trioctyl phosphate, diethyl ester of decane phosphonic acid, etc., polymeric tetrahydrofurans and the like.

The lubricating oil may be derived from unrefined, refined and rerefined oils, either natural, synthetic or mixtures of two or more of any of these of the type disclosed hereinabove. Unrefined oils are those obtained directly from a natural or synthetic source (e.g., coal, shale, or tar sands bitumen) without further purification or treatment. Examples of unrefined oils include, but are not limited to, a shale oil obtained directly from retorting operations, a petroleum oil obtained directly from distillation or an ester oil obtained directly from an esterification process, each of which is then used without further treatment. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. These purification techniques are known to those of skill in the art and include, for example, solvent extractions, secondary distillation, acid or base extraction, filtration, percolation, hydrotreating, dewaxing, etc. Rerefined oils are obtained by treating used oils in processes similar to those used to obtain refined oils. Such rerefined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques directed to removal of spent additives and oil breakdown products.

Lubricating oil base stocks derived from the hydroisomerization of wax may also be used, either alone or in combination with the aforesaid natural and/or synthetic base stocks. Such wax isomerate oil is produced by the hydroisomerization of natural or synthetic waxes or mixtures thereof over a hydroisomerization catalyst.

5 Natural waxes are typically the slack waxes recovered by the solvent dewaxing of mineral oils; synthetic waxes are typically the wax produced by the Fischer-Tropsch process.

ADDITIONAL LUBRICATING OIL ADDITIVES

Lubricating oil compositions containing the molybdated succinimide complex prepared by the process of the present invention may also contain other conventional
10 additives for imparting auxiliary functions to give a finished lubricating oil composition in which these additives are dispersed or dissolved. For example, the lubricating oil compositions can be blended with antioxidants, anti-wear agents, ashless dispersants, detergents, rust inhibitors, dehazing agents, demulsifying agents, metal deactivating agents, friction modifiers, antifoaming agents, pour point depressants, co-solvents, package
15 compatibilisers, corrosion-inhibitors, dyes, extreme pressure agents and the like and mixtures thereof. A variety of the additives are known and commercially available. These additives, or their analogous compounds, may be employed for the preparation of the lubricating oil compositions of the invention by the usual blending procedures.

Examples of antioxidants include, but are not limited to, aminic types, e.g.,
20 diphenylamine, phenyl-alpha-naphthyl-amine, N,N-di(alkylphenyl) amines; and alkylated phenylene-diamines; phenolics such as, for example, BHT, sterically hindered alkyl phenols such as 2,6-di-tert-butylphenol, 2,6-di-tert-butyl-p-cresol and 2,6-di-tert-butyl-4-(2-octyl-3-propanoic) phenol; and mixtures thereof.

Examples of antiwear agents include, but are not limited to, zinc
25 dialkyldithiophosphates and zinc diaryldithiophosphates, e.g., those described in an article by Born et al. entitled "Relationship between Chemical Structure and Effectiveness of some Metallic Dialkyl- and Diaryl-dithiophosphates in Different Lubricated Mechanisms", appearing in Lubrication Science 4-2 January 1992, see for example pages 97-100; aryl phosphates and phosphites, sulfur-containing esters, phosphosulfur compounds, metal or ash-free dithiocarbamates, xanthates, alkyl sulfides and the like and mixtures thereof.
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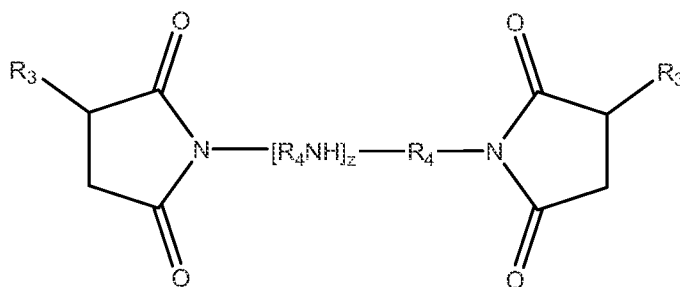
Representative examples of ashless dispersants include, but are not limited to, amines, alcohols, amides, or ester polar moieties attached to a polymer backbone via bridging groups. An ashless dispersant of the present invention may be, for example, selected from oil soluble salts, esters, amino-esters, amides, imides, and oxazolines of long chain hydrocarbon
35 substituted mono and dicarboxylic acids or their anhydrides; thiocarboxylate derivatives of

5 long chain hydrocarbons, long chain aliphatic hydrocarbons having a polyamine attached directly thereto; and Mannich condensation products formed by condensing a long chain substituted phenol with formaldehyde and polyalkylene polyamine.

Carboxylic dispersants are reaction products of carboxylic acylating agents (acids, anhydrides, esters, etc.) comprising at least about 34 and preferably at least about 54 carbon
 10 atoms with nitrogen containing compounds (such as amines), organic hydroxy compounds (such as aliphatic compounds including monohydric and polyhydric alcohols, or aromatic compounds including phenols and naphthols), and/or basic inorganic materials. These reaction products include imides, amides, esters, and salts.

Succinimide dispersants are a type of carboxylic dispersant. They are produced by
 15 reacting hydrocarbyl-substituted succinic acylating agent with organic hydroxy compounds, or with amines comprising at least one hydrogen atom attached to a nitrogen atom, or with a mixture of the hydroxy compounds and amines. The term "succinic acylating agent" refers to a hydrocarbon-substituted succinic acid or a succinic acid-producing compound, the latter encompasses the acid itself. Such materials typically include hydrocarbyl-substituted
 20 succinic acids, anhydrides, esters (including half esters) and halides.

Succinic-based dispersants have a wide variety of chemical structures. One class of succinic-based dispersants may be represented by formula IV:



Formula (IV)

25 wherein each R₃ is independently a hydrocarbyl group, such as a polyolefin-derived group. Typically the hydrocarbyl group is an alkenyl group, such as a polyisobutenyl group. Alternatively expressed, the R₃ groups can contain about 40 to about 500 carbon atoms, and these atoms may be present in aliphatic forms. R₄ is an alkylene group, commonly an ethylene (C₂H₄) group; and z is 1 to 11. Examples of succinimide dispersants include those
 30 described in, for example, U.S. Patent Nos. 3,172,892, 4,234,435 and 6,165,235.

5 The polyalkenes from which the substituent groups are derived are typically homopolymers and interpolymers of polymerizable olefin monomers of 2 to about 16 carbon atoms, and usually 2 to 6 carbon atoms. The amines which are reacted with the succinic acylating agents to form the carboxylic dispersant composition can be monoamines or polyamines.

10 Succinimide dispersants are referred to as such since they normally contain nitrogen largely in the form of imide functionality, although the nitrogen functionality may be in the form of amines, amine salts, amides, imidazolines as well as mixtures thereof. To prepare a succinimide dispersant, one or more succinic acid-producing compounds and one or more amines are heated and typically water is removed, optionally in the presence of a
15 substantially inert organic liquid solvent/diluent. The reaction temperature can range from about 80°C up to the decomposition temperature of the mixture or the product, which typically falls between about 100°C to about 300°C. Additional details and examples of procedures for preparing the succinimide dispersants of the present invention include those described in, for example, U.S. Patent Nos. 3,172,892, 3,219,666, 3,272,746, 4,234,435,
20 6,165,235 and 6,440,905.

 Suitable ashless dispersants may also include amine dispersants, which are reaction products of relatively high molecular weight aliphatic halides and amines, preferably polyalkylene polyamines. Examples of such amine dispersants include those described in, for example, U.S. Patent Nos. 3,275,554, 3,438,757, 3,454,555 and 3,565,804.

25 Suitable ashless dispersants may further include "Mannich dispersants," which are reaction products of alkyl phenols in which the alkyl group contains at least about 30 carbon atoms with aldehydes (especially formaldehyde) and amines (especially polyalkylene polyamines). Examples of such dispersants include those described in, for example, U.S. Patent Nos. 3,036,003, 3,586,629, 3,591,598 and 3,980,569.

30 Suitable ashless dispersants may also be post-treated ashless dispersants such as post-treated succinimides, e.g., post-treatment processes involving borate or ethylene carbonate as disclosed in, for example, U.S. Patent Nos. 4,612,132 and 4,746,446; and the like as well as other post-treatment processes. The carbonate-treated alkenyl succinimide is a polybutene succinimide derived from polybutenes having a molecular weight of about 450 to about 3000,
35 preferably from about 900 to about 2500, more preferably from about 1300 to about 2400,

5 and most preferably from about 2000 to about 2400, as well as mixtures of these molecular weights.

A preferred ashless dispersant is prepared by reacting, under reactive conditions, a mixture of a polybutene succinic acid derivative, an unsaturated acidic reagent copolymer of an unsaturated acidic reagent and an olefin, and a polyamine, such as disclosed in U.S. Patent
10 No. 5,716,912, the contents of which are incorporated herein by reference.

Suitable ashless dispersants may also be polymeric, which are interpolymers of oil-solubilizing monomers such as decyl methacrylate, vinyl decyl ether and high molecular weight olefins with monomers containing polar substitutes. Examples of polymeric dispersants include those described in, for example, U.S. Patent Nos. 3,329,658; 3,449,250
15 and 3,666,730.

In one preferred embodiment of the present invention, an ashless dispersant for use in the lubricating oil composition is a bis-succinimide derived from a polyisobutenyl group having a number average molecular weight of about 700 to about 2300. The dispersant(s) for use in the lubricating oil compositions of the present invention are preferably non-polymeric
20 (e.g., are mono- or bis-succinimides).

Generally, the one or more ashless dispersants are present in the lubricating oil composition in an amount ranging from about 0.01 wt. % to about 10 wt. %, based on the total weight of the lubricating oil composition.

Representative examples of metal detergents include sulfonates, alkylphenates, sulfurized alkyl phenates, carboxylates, salicylates, phosphonates, and phosphinates.
25 Commercial products are generally referred to as neutral or overbased. Overbased metal detergents are generally produced by carbonating a mixture of hydrocarbons, detergent acid, for example: sulfonic acid, alkylphenol, carboxylate etc., metal oxide or hydroxides (for example calcium oxide or calcium hydroxide) and promoters such as xylene, methanol and water. For example, for preparing an overbased calcium sulfonate, in carbonation, the calcium oxide or hydroxide reacts with the gaseous carbon dioxide to form calcium carbonate. The sulfonic acid is neutralized with an excess of CaO or Ca(OH)₂, to form the sulfonate.
30

Other examples of suitable detergents include borated sulfonates. In general, a borated sulfonate for use herein can be any borated sulfonate known in the art. A borated sulfonate
35

5 for use herein can have a total base number (TBN) of from about 10 to about 500. In one embodiment, a borated sulfonate has a TBN is from about 10 to about 100. In one embodiment, a borated sulfonate has a TBN is from about 100 to about 250. In one embodiment, a borated sulfonate has a TBN of from about 250 to about 500.

The borated alkaline earth metal sulfonates can be prepared by methods known in the art, e.g., as disclosed in U.S. Patent Application Publication No. 20070123437, the contents
10 of which are incorporated by reference herein. For example, the borated alkaline earth metal sulfonate is prepared in the following manner: (a) reacting (i) at least one of an oil soluble sulfonic acid or alkaline earth sulfonate salt or mixtures thereof; (ii) at least one source of an alkaline earth metal; and (iii) at least one source of boron, in the presence of (iv) at least one
15 hydrocarbon solvent; and (v) from 0 to less than 10 mole percent, relative to the source of boron, of an overbasing acid, other than the source of boron; and (b) heating the reaction product of (a) to a temperature above the distillation temperature of (iv) to distill (iv) and water of reaction.

Metal-containing or ash-forming detergents function as both detergents to reduce or
20 remove deposits and as acid neutralizers or rust inhibitors, thereby reducing wear and corrosion and extending engine life. Detergents generally comprise a polar head with a long hydrophobic tail. The polar head comprises a metal salt of an acidic organic compound. The salts may contain a substantially stoichiometric amount of the metal in which case they are usually described as normal or neutral salts, and would typically have a total base number or
25 TBN (as can be measured by ASTM D2896) of from 0 to about 80. A large amount of a metal base may be incorporated by reacting excess metal compound (e.g., an oxide or hydroxide) with an acidic gas (e.g., carbon dioxide). The resulting overbased detergent comprises neutralized detergent as the outer layer of a metal base (e.g., carbonate) micelle. Such overbased detergents may have a TBN of about 150 or greater, and typically will have a
30 TBN of from about 250 to about 450 or more.

Detergents that may be used include oil-soluble neutral and overbased sulfonates, phenates, sulfurized phenates, thiophosphonates, salicylates, and naphthenates and other oil-soluble carboxylates of a metal, particularly the alkali or alkaline earth metals, e.g., barium, sodium, potassium, lithium, calcium, and magnesium. The most commonly used metals are
35 calcium and magnesium, which may both be present in detergents used in a lubricant, and mixtures of calcium and/or magnesium with sodium. Particularly convenient metal

5 detergents are neutral and overbased calcium sulfonates having TBN of from about 20 to about 450, neutral and overbased calcium phenates and sulfurized phenates having TBN of from about 50 to about 450 and neutral and overbased magnesium or calcium salicylates having a TBN of from about 20 to about 450. Combinations of detergents, whether overbased or neutral or both, may be used.

10 In one embodiment, the detergent can be one or more alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid. Suitable hydroxyaromatic compounds include mononuclear monohydroxy and polyhydroxy aromatic hydrocarbons having 1 to 4, and preferably 1 to 3, hydroxyl groups. Suitable hydroxyaromatic compounds include phenol, catechol, resorcinol, hydroquinone, pyrogallol, cresol, and the like. The
15 preferred hydroxyaromatic compound is phenol.

The alkyl substituted moiety of the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid is derived from an alpha olefin having from about 10 to about 80 carbon atoms. The olefins employed may be linear or branched. The olefin may be a mixture of linear olefins, a mixture of isomerized linear olefins, a mixture of
20 branched olefins, a mixture of partially branched linear or a mixture of any of the foregoing.

In one embodiment, the mixture of linear olefins that may be used is a mixture of normal alpha olefins selected from olefins having from about 12 to about 30 carbon atoms per molecule. In one embodiment, the normal alpha olefins are isomerized using at least one of a solid or liquid catalyst.

25 In another embodiment, the olefins are a branched olefinic propylene oligomer or mixture thereof having from about 20 to about 80 carbon atoms, i.e., branched chain olefins derived from the polymerization of propylene. The olefins may also be substituted with other functional groups, such as hydroxy groups, carboxylic acid groups, heteroatoms, and the like. In one embodiment, the branched olefinic propylene oligomer or mixtures thereof have from
30 about 20 to about 60 carbon atoms. In one embodiment, the branched olefinic propylene oligomer or mixtures thereof have from about 20 to about 40 carbon atoms.

In one embodiment, at least about 75 mole% (e.g., at least about 80 mole%, at least about 85 mole%, at least about 90 mole%, at least about 95 mole%, or at least about 99 mole%) of the alkyl groups contained within the alkali or alkaline earth metal salt of an alkyl-
35 substituted hydroxyaromatic carboxylic acid such as the alkyl groups of an alkaline earth

5 metal salt of an alkyl-substituted hydroxybenzoic acid detergent are a C₂₀ or higher. In another embodiment, the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid is an alkali or alkaline earth metal salt of an alkyl-substituted hydroxybenzoic acid that is derived from an alkyl-substituted hydroxybenzoic acid in which the alkyl groups are the residue of normal alpha-olefins containing at least 75
10 mole% C₂₀ or higher normal alpha-olefins.

In another embodiment, at least about 50 mole % (e.g., at least about 60 mole %, at least about 70 mole %, at least about 80 mole %, at least about 85 mole %, at least about 90 mole %, at least about 95 mole %, or at least about 99 mole %) of the alkyl groups contained within the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic
15 carboxylic acid such as the alkyl groups of an alkali or alkaline earth metal salt of an alkyl-substituted hydroxybenzoic acid are about C₁₄ to about C₁₈.

The resulting alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid will be a mixture of ortho and para isomers. In one embodiment, the product will contain about 1 to 99% ortho isomer and 99 to 1% para isomer.
20 In another embodiment, the product will contain about 5 to 70% ortho and 95 to 30% para isomer.

The alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid can be neutral or overbased. Generally, an overbased alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid is one in which the TBN
25 of the alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid has been increased by a process such as the addition of a base source (e.g., lime) and an acidic overbasing compound (e.g., carbon dioxide).

Overbased salts may be low overbased, e.g., an overbased salt having a TBN below about 100. In one embodiment, the TBN of a low overbased salt may be from about 5 to about 50. In another embodiment, the TBN of a low overbased salt may be from about 10 to about 30. In yet another embodiment, the TBN of a low overbased salt may be from about 15 to about 20.
30

Overbased detergents may be medium overbased, e.g., an overbased salt having a TBN from about 100 to about 250. In one embodiment, the TBN of a medium overbased salt

5 may be from about 100 to about 200. In another embodiment, the TBN of a medium overbased salt may be from about 125 to about 175.

Overbased detergents may be high overbased, e.g., an overbased salt having a TBN above about 250. In one embodiment, the TBN of a high overbased salt may be from about 250 to about 450.

10 Sulfonates may be prepared from sulfonic acids which are typically obtained by the sulfonation of alkyl substituted aromatic hydrocarbons such as those obtained from the fractionation of petroleum or by the alkylation of aromatic hydrocarbons. Examples included those obtained by alkylating benzene, toluene, xylene, naphthalene, diphenyl or their halogen derivatives. The alkylation may be carried out in the presence of a catalyst with alkylating
15 agents having from about 3 to more than 70 carbon atoms. The alkaryl sulfonates usually contain from about 9 to about 80 or more carbon atoms, preferably from about 16 to about 60 carbon atoms per alkyl substituted aromatic moiety.

The oil soluble sulfonates or alkaryl sulfonic acids may be neutralized with oxides, hydroxides, alkoxides, carbonates, carboxylate, sulfides, hydrosulfides, nitrates and borates.
20 The amount of metal compound is chosen having regard to the desired TBN of the final product but typically ranges from about 100 to about 220 wt. % (preferably at least about 125 wt. %) of that stoichiometrically required.

Metal salts of phenols and sulfurized phenols are prepared by reaction with an appropriate metal compound such as an oxide or hydroxide and neutral or overbased products
25 may be obtained by methods well known in the art. Sulfurized phenols may be prepared by reacting a phenol with sulfur or a sulfur containing compound such as hydrogen sulfide, sulfur monohalide or sulfur dihalide, to form products which are generally mixtures of compounds in which 2 or more phenols are bridged by sulfur containing bridges.

Generally, the one or more detergents are present in the lubricating oil composition in
30 an amount ranging from about 0.01 wt. % to about 10 wt. %, based on the total weight of the lubricating oil composition.

Examples of rust inhibitors include, but are not limited to, nonionic polyoxyalkylene agents, e.g., polyoxyethylene lauryl ether, polyoxyethylene higher alcohol ether, polyoxyethylene nonylphenyl ether, polyoxyethylene octylphenyl ether, polyoxyethylene
35 octyl stearyl ether, polyoxyethylene oleyl ether, polyoxyethylene sorbitol monostearate,

5 polyoxyethylene sorbitol monooleate, and polyethylene glycol monooleate; stearic acid and other fatty acids; dicarboxylic acids; metal soaps; fatty acid amine salts; metal salts of heavy sulfonic acid; partial carboxylic acid ester of polyhydric alcohol; phosphoric esters; (short-chain) alkenyl succinic acids; partial esters thereof and nitrogen-containing derivatives thereof; synthetic alkarylsulfonates, e.g., metal dinonylnaphthalene sulfonates; and the like
10 and mixtures thereof.

Examples of friction modifiers include, but are not limited to, alkoxyated fatty amines; borated fatty epoxides; fatty phosphites, fatty epoxides, fatty amines, borated alkoxyated fatty amines, metal salts of fatty acids, fatty acid amides, glycerol esters, borated glycerol esters; and fatty imidazolines as disclosed in U.S. Patent No. 6,372,696, the contents
15 of which are herein incorporated by reference; friction modifiers obtained from a reaction product of a C_4 to C_{75} , preferably a C_6 to C_{24} , and most preferably a C_6 to C_{20} , fatty acid ester and a nitrogen-containing compound selected from the group consisting of ammonia, and an alkanolamine and the like and mixtures thereof.

Examples of antifoaming agents include, but are not limited to, polymers of alkyl
20 methacrylate; polymers of dimethylsilicone and the like and mixtures thereof.

Examples of a pour point depressant include, but are not limited to, polymethacrylates, alkyl acrylate polymers, alkyl methacrylate polymers, di(tetra-paraffin phenol)phthalate, condensates of tetra-paraffin phenol, condensates of a chlorinated paraffin with naphthalene and combinations thereof. In one embodiment, a pour point depressant
25 comprises an ethylene-vinyl acetate copolymer, a condensate of chlorinated paraffin and phenol, polyalkyl styrene and the like and combinations thereof. The amount of the pour point depressant may vary from about 0.01 wt. % to about 10 wt. %.

Examples of a demulsifier include, but are not limited to, anionic surfactants (e.g., alkyl-naphthalene sulfonates, alkyl benzene sulfonates and the like), nonionic alkoxyated
30 alkylphenol resins, polymers of alkylene oxides (e.g., polyethylene oxide, polypropylene oxide, block copolymers of ethylene oxide, propylene oxide and the like), esters of oil soluble acids, polyoxyethylene sorbitan ester and the like and combinations thereof. The amount of the demulsifier may vary from about 0.01 wt. % to about 10 wt. %.

Examples of a corrosion inhibitor include, but are not limited to, half esters or amides
35 of dodecylsuccinic acid, phosphate esters, thiophosphates, alkyl imidazolines, sarcosines and

5 the like and combinations thereof. The amount of the corrosion inhibitor may vary from about 0.01 wt. % to about 5 wt. %.

Examples of an extreme pressure agent include, but are not limited to, sulfurized animal or vegetable fats or oils, sulfurized animal or vegetable fatty acid esters, fully or partially esterified esters of trivalent or pentavalent acids of phosphorus, sulfurized olefins, dihydrocarbyl polysulfides, sulfurized Diels-Alder adducts, sulfurized dicyclopentadiene, sulfurized or co-sulfurized mixtures of fatty acid esters and monounsaturated olefins, co-sulfurized blends of fatty acid, fatty acid ester and alpha-olefin, functionally-substituted dihydrocarbyl polysulfides, thia-aldehydes, thia-ketones, epithio compounds, sulfur-containing acetal derivatives, co-sulfurized blends of terpene and acyclic olefins, and polysulfide olefin products, amine salts of phosphoric acid esters or thiophosphoric acid esters and the like and combinations thereof. The amount of the extreme pressure agent may vary from about 0.01 wt. % to about 5 wt. %.

Each of the foregoing additives, when used, is used at a functionally effective amount to impart the desired properties to the lubricant. Thus, for example, if an additive is a friction modifier, a functionally effective amount of this friction modifier would be an amount sufficient to impart the desired friction modifying characteristics to the lubricant. Generally, the concentration of each of these additives, when used, may range, unless otherwise specified, from about 0.001% to about 20% by weight, and in one embodiment about 0.01% to about 10% by weight based on the total weight of the lubricating oil composition.

25 The final application of the lubricating oil compositions containing the molybdated succinimide complexes prepared by the process of this invention may be, for example, in marine cylinder lubricants in crosshead diesel engines, crankcase lubricants in automobiles and railroads and the like, lubricants for heavy machinery such as steel mills and the like, or as greases for bearings and the like. Whether the lubricating oil composition is fluid or solid will ordinarily depend on whether a thickening agent is present. Typical thickening agents include polyurea acetates, lithium stearate and the like.

In another embodiment of the invention, the molybdated succinimide complex prepared by the process of the present invention may be provided as an additive package or concentrate in which the additive is incorporated into a substantially inert, normally liquid organic diluent such as, for example, mineral oil, naphtha, benzene, toluene or xylene to form

5 an additive concentrate. These concentrates usually contain from about 20% to about 80% by weight of such diluent. Typically, a neutral oil having a viscosity of about 4 to about 8.5 cSt at 100°C and preferably about 4 to about 6 cSt at 100°C will be used as the diluent, though synthetic oils, as well as other organic liquids which are compatible with the additives and finished lubricating oil can also be used. The additive package will also typically contain one
10 or more of the various other additives, referred to above, in the desired amounts and ratios to facilitate direct combination with the requisite amount of base oil.

EXAMPLES

The following non-limiting examples are illustrative of the present invention.

EXAMPLE 1

15 Molybdenum Post-Treated Low Molecular Weight Succinimide Complex

Made from Acrylic Acid

Into a round bottom flask equipped with an overhead mechanical stirrer, water condenser with nitrogen line and Dean-Stark trap, addition funnel, temperature controller, heating mantle, and thermocouple was added 70.00 g of octadecenyl succinic anhydride
20 (ODSA) (available from Sigma Aldrich Corporation, St. Louis, Mo., U.S.A.) and 39.57g of Chevron 100 neutral oil. The mixture was heated to 127°C and 33.63g of tetraethylenepentamine (TEPA; 0.9 mole equivalent to ODSA) was charged drop wise into the mixture via the addition funnel. Slight foaming occurred during the initial charge stage. After the TEPA was charged, the temperature was increased to 165°C and then held at 165°C
25 until the reaction was complete as indicated by the IR spectrum.

The material was cooled to room temperature and 41.03g was transferred to a round bottom flask. The flask was heated to 110°C for acrylic acid addition. Next, 3.10g of acrylic acid (1 mole equivalent to TEPA) was added drop-wise to maintain the temperature at 110°C. After addition of acrylic acid, the reactor temperature was increased to 135°C and then held
30 at this temperature until completion of the reaction (about 3 to 5 hours).

Next, 9.501g of the acrylic acid treated succinimide was added to a 250 mL 3-neck round bottom flask equipped with a magnetic stir plate, Dean-Stark trap with condenser and nitrogen line. 40g of toluene was added and the mixture was stirred to dissolve. Next, 1.628g of molybdenum trioxide (1 mole equivalent to TEPA), 8.7 g of distilled water, and 2 drops of

5 foam inhibitor were added. The mixture was stirred and heated at 89°C overnight. Water and toluene were then removed at 114°C. The resulting product did not contain visible particulate matter.

The product was cooled and then filtered through Celite 512 and anhydrous magnesium sulfate with a Buchner funnel. The filtrate was collected and concentrated using
10 a rotary evaporator (full pump vacuum at a maximum temperature of 77°C) to remove toluene and any residual water. The product was a clear brown liquid at room temperature, and had the following properties:

Mo = 9.189 wt. %

Total Base Number = 114 mg KOH/g

15 COMPARATIVE EXAMPLE A

Molybdenum Post-Treated Low Molecular Weight Succinimide Complex

Made from Maleic Anhydride

Into a 1 L, 3-neck round bottom flask equipped with an overhead mechanical stirrer, water condenser with nitrogen line and Dean-Stark trap, temperature controller, heating
20 mantle, and thermocouple was added 245 g of octadecenyl succinic anhydride (ODSA) (available from Sigma Aldrich Corporation, St. Louis, Mo., U.S.A.), 242 g of Exxon 150 neutral oil and two drops of foam inhibitor (200 to 350 cSt; available from Dow Corning). The mixture was heated to 100°C and 132.64 g of tetraethylenepentamine (TEPA; 1.0 mole equivalent to ODSA) was charged drop wise into the mixture via an addition funnel. Slight
25 foaming occurred during the initial charge stage. After the TEPA was charged, the temperature was increased to 160°C over about 60 minutes and then held at 160°C overnight.

The material was cooled to 100°C and transferred to a 3 L round bottom flask. The flask was heated at 80°C for maleic anhydride addition. Next, 67 g of maleic anhydride (1
30 mole equivalent to TEPA) was heated in a beaker to melt the solids. The liquefied maleic anhydride was transferred to a pre-warmed addition funnel with a glass stopcock. Maleic anhydride was then added drop-wise to control excessive foaming and to maintain the temperature between 80 to 110°C. A hot air gun was used on the addition funnel to prevent maleic anhydride from solidifying during addition. After the maleic anhydride was added, a

5 Dean-Stark trap was attached to the round bottom flask. The reactor temperature was increased to 160°C over an hour and then held at this temperature overnight.

The mixture was cooled to 80°C and then 100 g was transferred to a 250 mL 3-neck round bottom flask equipped with a magnetic stir plate, Dean-Stark trap with condenser and nitrogen line. Next, 17.34 g of molybdenum trioxide (1 mole equivalent to TEPA), 50 g of
10 toluene, 17 g of distilled water, and 2 drops of foam inhibitor were added. The mixture was stirred and heated at 100°C overnight. The resulting product contained visible particulate matter. The product was then filtered through Celite 512 with a Buchner funnel under vacuum at 80°C to 140°C. The filtrate was collected and concentrated using a rotary evaporator (full pump vacuum at a maximum temperature of 140°C) to remove toluene and
15 residual water. The product obtained was a very viscous, nearly solid, brown oil at room temperature, and had the following properties:

Mo = 8.16 wt. %

Total Base Number = 74.5 mg KOH/g

EXAMPLE 2

20 Molybdenum Post-Treated Low Molecular Weight Succinimide Complex

Made from Acrylic Acid

A molybdated succinimide complex was prepared using the same general procedure and components outlined in Example 1 except that the temperature for the acrylic acid treatment step was kept below 100°C for the addition of acrylic acid and then a reaction
25 temperature of 75°C was maintained for 3 hours. The molybdated succinimide complex was a liquid at room temperature, did not contain visible particulate matter, and had the following properties:

Mo = 9.342 wt. %

Total Base Number = 123.4 mg KOH/g

30

5

COMPARATIVE EXAMPLE B**Molybdenum Post-Treated Low Molecular Weight Succinimide Complex****Made from Maleic Anhydride**

A molybdated succinimide complex was prepared using the same general procedure and components outlined in Comparative Example A except that the temperature for the maleic anhydride treatment step was 75°C for addition of maleic anhydride and then about 100°C overnight. Also, toluene was necessary to facilitate stirring the maleic anhydride and succinimide mixture. The product contained visible particulate matter prior to filtration. Once solvent was removed, the molybdated succinimide complex was a solid at room temperature and had the following property:

15 Total Base Number = 64.1 mg KOH/g

EXAMPLE 3**Molybdenum Post-Treated Low Molecular Weight Bis-Succinimide Complex****Made from Acrylic Acid**

A molybdated succinimide complex was prepared using the same general procedure and components outlined in Example 1 except that 0.5 mole equivalent TEPA to ODSA was used. The molybdated succinimide complex was a liquid at room temperature, did not contain visible particulate matter, and had the following properties:

Mo = 5.7 wt. %

Total Base Number = 57.8 mg KOH/g

25

EXAMPLE 4

A lubricating oil composition was formed by adding 1 wt. % of the lubricating oil additive of Example 1 to a CHEVRON 100 neutral oil.

EXAMPLE 5

A lubricating oil composition was formed by adding 1 wt. % of the lubricating oil additive of Example 2 to a CHEVRON 100 neutral oil.

30

5

EXAMPLE 6

A lubricating oil composition was formed by adding 1 wt. % of the lubricating oil additive of Example 3 to a CHEVRON 100 neutral oil.

COMPARATIVE EXAMPLE C

10 A lubricating oil composition was formed by adding 1 wt. % of the lubricating oil additive of Comparative Example A to a CHEVRON 100 neutral oil.

EXAMPLE 7**Wear Performance****Mini-Traction Machine (MTM) Evaluation**

15 The lubricating oil additives of Example 3, Example 4, and Comparative Example C were evaluated using a Mini-Traction Machine (MTM) tribometer (PCS Instruments Ltd., London UK). The MTM tribometer was set up to run in pin on disk mode using polished disks of 52100 steel from PCS Instruments, and a 0.25 inch stationary ball bearing, also of 52100 steel from Falex Corporation, in place of a pin. The test was conducted at 100°C for 40 minutes at 7 Newtons load at a sliding speed of 200 mm/s following a break-in period of 5 minutes at 0.1 Newtons and a sliding speed of 2000 mm/s. The wear scars on the balls were measured manually on an optical microscope and recorded. The MTM wear performance data are presented in Table 1.

TABLE 1**MTM Wear Performance Results**

Test Oil	Wear scar (µm)
Comparative Example C	170
Example 4	121
Example 5	111
Example 6	121

25

5 As the results illustrated in Table 1 show, the molybdenum succinimide compounds made from acrylic acid (Examples 4, 5 and 6) demonstrate superior anti-wear performance over the molybdenum succinimide compound made from maleic anhydride (Comparative Example C).

10 Wear performance is further improved by the molybdenum compound made by the process of this invention when the temperature employed to react the acrylic acid with the reactive amino groups of the polyalkylene polyamine is maintained at no greater than 100°C (Example 5).

EXAMPLE 8

15 A baseline lubricating oil formulation was formed containing 5 wt. % succinimide dispersant, 3 wt. % borated succinimide dispersant, (4 mM/kg) low overbased calcium sulfonate, (58 mM/kg) carboxylate detergent, (8 mM/kg) zinc dithiophosphate, 0.5 wt. % diphenylamine antioxidant, 0.5 wt. % hindered phenol anti-oxidant, 0.3 wt. % pour point depressant, 9.85 wt. % olefin copolymer viscosity index improver and 5 ppm foam inhibitor in a Group II base oil.

EXAMPLE 9

20 A baseline lubricating oil formulation was formed containing the same additives, base oil and treat rate as in EXAMPLE 8. The lubricating oil additive of Example 1 was formulated into this baseline lubricating oil such that the total Mo content in the formulation was 500ppm.

COMPARATIVE EXAMPLE D

25 A baseline lubricating oil formulation was formed containing the same additives, base oil and treat rate as in EXAMPLE 8. The lubricating oil additive of Comparative Example A was formulated into this baseline lubricating oil such that the total Mo content in the formulation was 500ppm.

5

EXAMPLE 10**Friction Performance****High Frequency Reciprocating Rig (HFRR) Evaluation**

The friction performance of the lubricating oil composition of Example 7 containing the lubricating oil composition of Example 6 and the lubricating oil additive of Example 1 was evaluated using a High Frequency Reciprocating Rig (HFRR), and compared to the friction performance of the lubricating oil composition of Comparative Example D containing the lubricating oil composition of Example 6 and the lubricating oil additive of Comparative Example A.

The HFRR test rig is an industry recognized tribometer for determining lubricant performance. The PCS instrument uses an electromagnetic vibrator to oscillate a specimen (the ball) over a small amplitude while pressing it against a fixed specimen (a flat disk). The amplitude and frequency of the oscillation and the load are variable. The frictional force between the ball and flat and the electrical contact resistance (ECR) are measured. The flat, stationary specimen is held in a bath to which the lubricating oil is added, and can be heated. For this test, the tribometer was set up to run at 20 Hz for 20 minutes, using 6mm ball on flat specimens of 52100 steel. The load was 1kg and temperature was 116°C. The lubricating oils were pretreated with about 6% by weight, based on the total weight of lubricating oil, of diesel engine soot collected from diesel engine exhaust. The soot was stirred into the oil to wet it and then homogenized for 15 minutes prior to testing. In this test, a smaller coefficient of friction corresponds to a more effective lubricating friction modifier additive. The HFRR friction performance data are represented in Table 2.

TABLE 2**HFRR Wear and Friction Performance Results**

Description	Coefficient of Friction
Example 8 (Baseline)	0.123
Comparative Example D	0.092
Example 9	0.077

5 As the data in Table 2 show, the molybdenum succinimide complex of the present invention, derived from acrylic acid, demonstrates significantly better anti-friction properties than the molybdenum succinimide complex derived from maleic anhydride.

EXAMPLE 11

Physical and Chemical Properties

10 Total Basic Nitrogen (TBN) using ASTM D2896, molybdenum content (Mo wt%) using Inductively Coupled Plasma (ICP) Atomic Emission Spectroscopy, and Color using ASTM D1500 (using a Gardner Colorimeter) were determined for the molybdenum succinimide complexes of Comparative Example A, Example 1 and Example 2. Pour points were measured by gradually heating the sample in 5°C increments until the sample would
15 flow readily. The physical appearance of each sample was compared. Physical and Chemical data are represented in Table 3.

TABLE 3

Physical and Chemical Properties

Compound	TBN mgKOH/g	Mo wt. %	Pour Point, °C	D1500 Color	Physical Description
Comparative Example A	74.5	8.16	>120	4.1DD	Very viscous, nearly solid, at room temperature. Visible particulates in the product
Comparative Example B	64.1	NA	>200	NA	Solid at room temperature
Example 1	114	9.19	115	2.3DD	Brown liquid at room temperature. No visible particulates in the product
Example 2	123	9.34	85	4.1DD	Brown liquid at room temperature. No visible particulates in the product

20 As the data in Table 3 show, the molybdenum succinimide complexes made from acrylic acid (Examples 1 and 2) contain higher basic nitrogen, and possess more desirable physical and handling properties than the molybdenum succinimide complexes derived from maleic anhydride (Comparative Examples A and B).

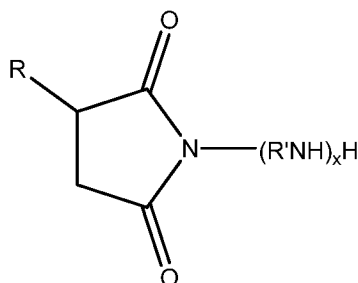
5 Physical and chemical properties are further improved for the complexes made by the process of this invention when the temperature to react the α,β -unsaturated monocarboxylic acid or carboxylate compound with the reactive amino groups of the low molecular weight alkylamine is maintained at or below about 100°C.

 It will be understood that various modifications may be made to the embodiments
10 disclosed herein. Therefore the above description should not be construed as limiting, but merely as exemplifications of preferred embodiments. For example, the functions described above and implemented as the best mode for operating the present invention are for illustration purposes only. Other arrangements and methods may be implemented by those skilled in the art without departing from the scope and spirit of this invention. Moreover,
15 those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

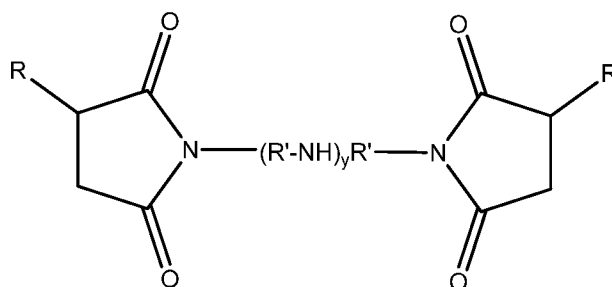
5 WHAT IS CLAIMED IS:

1. A process for preparing a molybdated succinimide complex, the process comprising:

(a) reacting an alkyl or alkenyl succinimide of a polyamine of formula I or formula II or mixtures thereof:



Formula (I)



Formula (II)

15 wherein R is an about C₁₂ to C₃₀ alkyl or alkenyl group, R' is a straight or branched-chain alkylene group having 2 to 3 carbon atoms, x is 1 to 11, and y is 1 to 10, with an α,β-unsaturated mono-carboxylic acid or carboxylic acid ester, in a charge mole ratio of the α,β-unsaturated mono-carboxylic acid or carboxylic acid ester to the succinimide of formula I or formula II or mixtures thereof of about 0.1:1 to about 6:1, and wherein the reaction
20 temperature is no greater than about 135°C; and

(b) reacting the succinimide product of step (a) with an acidic molybdenum compound to provide the molybdated succinimide complex, wherein the molybdated succinimide complex prepared is a liquid at room temperature.

- 5 2. The process of Claim 1, wherein R is about C₁₂ to about C₂₄ alkyl or alkenyl group, R¹ is 2, and x is 2 to 5 and y is 1 to 4.
3. The process of Claim 1, wherein the α,β -unsaturated mono-carboxylic acid or carboxylic acid ester is selected from the group consisting of acrylic acid, methacrylic acid and mixtures thereof.
- 10 4. The process of Claim 1, wherein the acidic molybdenum compound is selected from the group consisting of molybdic acid, ammonium molybdate, sodium molybdate, potassium molybdates, hydrogen sodium molybdate, MoOCl₄, MoO₂Br₂, Mo₂O₃Cl₆, molybdenum trioxide and mixtures thereof.
5. The process of Claim 1, wherein the α,β -unsaturated mono-carboxylic acid or
15 carboxylic acid ester is acrylic acid and the acidic molybdenum compound is molybdenum trioxide.
6. The process of Claim 2, wherein the α,β -unsaturated mono-carboxylic acid or carboxylic acid ester is acrylic acid and the acidic molybdenum compound is molybdenum trioxide.
- 20 7. The process of Claim 1, wherein the molar ratio of the α,β -unsaturated mono-carboxylic acid or carboxylic acid ester thereof to the succinimide of formula I is about 1:1 to about 6:1.
8. The process of Claim 1, wherein the molar ratio of the α,β -unsaturated mono-carboxylic acid or carboxylic acid ester thereof to the succinimide of formula I is about 1:1 to
25 about 2:1.
9. The process of Claim 1, wherein the molar ratio of the molybdenum compound to the succinimide product of step (a) is about 0.1:1 to about 2:1.
10. The process of Claim 1, wherein the alkyl or alkenyl succinimide of step (a) is a mixture of the succinimides of Formula I and Formula II.
- 30 11. The process of Claim 13, wherein the ratio of the succinimide of Formula I to the succinimide of Formula II in the succinimide mixture is from about 1:1 to 10:1.
12. The process of Claim 1, wherein there is no visible particulate matter in the molybdated succinimide complex product.

- 5 13. The process of Claim 1, wherein the reaction temperature of step (a) is no greater than 100°C.
14. The process of Claim 1, wherein the reaction temperature of step (a) is no greater than 80°C.
15. The process of Claim 1, wherein the molybdated succinimide complex product
- 10 has a
- pour point less than 120°C.