

HYDROPROCESSING FOR LUBRICANT BASESTOCK PRODUCTION

FIELD

[0001] Systems and methods are provided for production of lubricant oil basestocks.

BACKGROUND

[0002] As the supply of low sulfur, low nitrogen crudes decrease, refineries are processing crudes with greater sulfur and nitrogen contents at the same time that environmental regulations are mandating lower levels of these heteroatoms in products. Consequently, a need exists for increasingly efficient desulfurization and denitrogenation catalysts.

[0003] U.S. Patent Nos. 8,722,563 and 8,722,564 describe multimetallic hydroprocessing catalysts prepared by forming a catalyst precursor and then heating the catalyst precursor to form the catalyst. The multimetallic catalysts are described as having improved activity for hydrodenitrogenation of various types of feeds.

[0004] U.S. Patent 6,620,313, U.S. Patent 7,232,515, and U.S. Patent 7,513,989 describe various types of processing sequences that include hydroprocessing in the presence of a bulk multimetallic catalyst. The processes are described as being suitable for production of lubricant basestocks.

SUMMARY

[0005] In an aspect, a process for selectively hydroconverting a raffinate produced from solvent refining a lubricating oil feedstock is provided, including

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conducting the lubricating oil feedstock to a solvent extraction zone and separating therefrom an aromatics rich extract and a paraffins rich raffinate; stripping the raffinate of solvent to produce a raffinate feed having a dewaxed oil viscosity index from about 80 to about 105 and a final boiling point of no greater than about 650°C; passing the raffinate feed to a first hydroconversion zone and processing the raffinate feed in the presence of a mixed metal catalyst under hydroconversion conditions; and passing the first hydroconverted raffinate to a second reaction zone and conducting cold hydrofinishing of the first hydroconverted raffinate in the presence of a hydrofinishing catalyst under cold hydrofinishing conditions, wherein the mixed metal catalyst comprises a sulfided mixed metal catalyst formed by sulfiding a mixed metal catalyst precursor composition, the mixed metal catalyst precursor composition being produced by a) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (i) a first organic compound containing at least one amine group, and (ii) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group to a temperature from about 195°C to about 260°C for a time sufficient for the first and second organic compounds to form a reaction product in situ that contains an amide moiety, unsaturated carbon atoms not present in the first or second organic compounds, or both; b) heating a composition comprising one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (iii) a first organic compound containing at least one amine group and at least 10 carbon atoms or (iv) a second organic compound containing at least one carboxylic acid group and at least 10 carbon atoms, but not both (iii) and (iv), wherein the reaction product contains additional unsaturated carbon atoms, relative to (iii) the first organic compound or

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(iv) the second organic compound, wherein the metals of the catalyst precursor composition are arranged in a crystal lattice, and wherein the reaction product is not located within the crystal lattice, to a temperature from about 195°C to about 260°C for a time sufficient for the first or second organic compounds to form a reaction product in situ that contains unsaturated carbon atoms not present in the first or second organic compounds; or c) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a pre-formed amide formed from (v) a first organic compound containing at least one amine group, and (vi) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group, to form additional in situ unsaturated carbon atoms not present in the first organic compound, the second organic compound, or both, but not for so long that the pre-formed amide substantially decomposes, thereby forming a catalyst precursor containing in situ formed unsaturated carbon atoms.

[0006] In another aspect, a process for producing a lubricating oil feedstock is provided, including exposing a feedstock to a mixed metal catalyst under effective hydroprocessing conditions to form a hydroprocessed effluent; separating the hydroprocessed effluent to form at least a gas phase effluent and a liquid hydroprocessed effluent; optionally exposing at least a portion of the liquid hydroprocessed effluent to a hydrocracking catalyst under effective hydrocracking conditions to form a hydrocracked effluent; exposing at least a portion of the optionally hydrocracked effluent to a dewaxing catalyst under effective catalytic dewaxing conditions to form an optionally hydrocracked, dewaxed effluent, wherein the mixed metal catalyst comprises a sulfided mixed metal catalyst formed by sulfiding a mixed metal catalyst precursor composition, the mixed metal catalyst

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precursor composition being produced by a) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (i) a first organic compound containing at least one amine group, and (ii) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group to a temperature from about 195°C to about 250°C for a time sufficient for the first and second organic compounds to form a reaction product in situ that contains an amide moiety, unsaturated carbon atoms not present in the first or second organic compounds, or both; b) heating a composition comprising one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (iii) a first organic compound containing at least one amine group and at least 10 carbon atoms or (iv) a second organic compound containing at least one carboxylic acid group and at least 10 carbon atoms, but not both (iii) and (iv), wherein the reaction product contains additional unsaturated carbon atoms, relative to (iii) the first organic compound or (iv) the second organic compound, wherein the metals of the catalyst precursor composition are arranged in a crystal lattice, and wherein the reaction product is not located within the crystal lattice, to a temperature from about 195°C to about 250°C for a time sufficient for the first or second organic compounds to form a reaction product in situ that contains unsaturated carbon atoms not present in the first or second organic compounds; or c) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a pre-formed amide formed from (v) a first organic compound containing at least one amine group, and (vi) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group, to form additional in situ unsaturated

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carbon atoms not present in the first organic compound, the second organic compound, or both, but not for so long that the pre-formed amide substantially decomposes, thereby forming a catalyst precursor containing in situ formed unsaturated carbon atoms.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 schematically shows an example of a configuration suitable for processing a feed to produce lubricant basestock products.

[0008] FIG. 2 shows processing conditions and results for hydrodenitrogenation of a feed in the presence of various catalysts.

DETAILED DESCRIPTION

[0009] All numerical values within the detailed description and the claims herein are modified by “about” or “approximately” the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

Overview

[0010] In various aspects, methods are provided for hydroprocessing a feed (such as hydrotreating, hydrocracking, or hydrofining a feed) to generate a product with a reduced or minimized aromatics content relative to the severity of the hydroprocessing conditions. In some types of hydroprocessing applications, it can be desirable to select the severity of hydroprocessing conditions to achieve a desired level of removal for sulfur, a desired level for removal of nitrogen, and/or a desired level for increasing the viscosity index of a feed. The severity for heteroatom

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removal and/or viscosity index uplift can also correspond to an amount of conversion of a feed to lower boiling point products, so the lowest severity conditions suitable for achieving a product quality can be desirable. Some aromatics saturation is performed during this hydroprocessing, but typically one or more additional aromatics saturation steps are required in order to achieve a target level of aromatics in a resulting product. By improving the aromatics saturation during hydroprocessing, the severity of subsequent aromatics saturation processes can be reduced.

[0011] In some aspects, the methods can include use of a catalyst formed from a catalyst precursor composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (i) a first organic compound containing at least one amine group and at least 10 carbons or (ii) a second organic compound containing at least one carboxylic acid group and at least 10 carbons, but not both (i) and (ii).

[0012] In other aspects, the process can use a catalyst formed from a catalyst precursor composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (i) a first organic compound containing at least one amine group, and (ii) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group. More broadly, this aspect of the present disclosure relates to use of a catalyst formed from a catalyst precursor composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a condensation reaction product formed

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from (i) a first organic compound containing at least one first functional group, and (ii) a second organic compound separate from said first organic compound and containing at least one second functional group, wherein said first functional group and said second functional group are capable of undergoing a condensation reaction and/or a (decomposition) reaction causing an additional unsaturation to form an associated product.

[0013] In still other aspects, the process can use a catalyst formed from a catalyst precursor composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product comprising an amide group. In this type of aspect, the reaction product is formed prior to incorporation into the catalyst precursor. The reaction product is an amide-containing reaction product formed from an ex-situ reaction of (i) a first organic compound containing at least one amine group, and (ii) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group.

Use of a Mixed Metal Catalyst Formed from a Suitable Precursor as a Hydrotreating Catalyst for Lubricant Basestock Production

[0014] In various aspects, methods are provided for improving the yield of distillate products from hydroprocessing (including hydrotreatment, hydrocracking, and/or catalytic dewaxing) of gas oil feedstocks, such as vacuum gas oil feeds or other feeds having a similar type of boiling range, during the production of lubricant base oils. In addition to using a mixed metal catalyst formed from a suitable precursor, the methods can involve stripping of gases and/or fractionation to separate out a distillate fraction during initial hydrotreatment of a feed. This can allow for an improved yield of distillate products at a desired level of conversion,

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such as a level of conversion selected for processing a feedstock to generate lubricating oil basestocks. The improved yield of distillate can be achieved while reducing or minimizing production of lower boiling compounds, such as light ends or naphtha boiling range products. Additionally or alternately, use of a catalyst derived from a suitable precursor composition while hydroprocessing a gas oil feedstock can result in reduced or minimized levels of aromatics in the resulting lubricant basestocks at a desired level of feed conversion.

[0015] As an example, some improvements in distillate product yield can be achieved based on separation or removal of contaminant gases during hydrotreatment of a feedstock. This can reduce the required severity of subsequent processing stages, allowing for less conversion of desired distillate boiling range products to naphtha or lower boiling range products. Removal of contaminant gases can also reduce the temperature required to achieve a desired level of conversion to distillates, or alternatively, increase the amount of conversion at a specified temperature. Other improvements in distillate yield can be achieved by fractionating the feedstock during hydrotreatment, so that distillate boiling range components are exposed to fewer hydroprocessing stages. Avoiding exposure of distillate boiling range products to additional hydroprocessing, such as a second hydrotreatment stage, can prevent further conversion of such products to naphtha or lower boiling range products. Still other improvements in distillate yield can be achieved by stripping contaminant gases and/or fractionating the hydrotreated feedstock after hydrotreatment and before hydrocracking. Once again, this can reduce additional conversion of products by avoiding exposure to a downstream hydrocracking stage or reducing the severity of such a stage.

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[0016] The yield improvements from performing a separation between hydrotreatment and hydrocracking can be further enhanced by using a mixed metal catalyst formed from a suitable catalyst precursor as the hydrotreating catalyst. It has been discovered that a catalyst formed from a suitable catalyst precursor can provide an unexpectedly improved activity for aromatic saturation at a given level of process severity for hydrodenitrogenation and/or hydrodesulfurization. Thus, use of a catalyst formed from a suitable catalyst precursor in an initial hydrotreatment stage can reduce or minimize the need to increase process severity to achieve a target level of aromatics.

[0017] As an example, a typical reaction system for producing a lubricant basestock can include a hydrotreating stage for removal of heteroatoms; a hydrocracking stage for increasing the viscosity index of the resulting lubricant basestock product; a dewaxing stage for improving cold flow properties of the product(s), such as pour point; and an aromatic saturation stage for achieving a final aromatics target level in the product(s). Using a catalyst formed from a suitable catalyst precursor can allow the hydrotreating stage to be operated at a severity sufficient for heteroatom removal in order to convert the initial feed into a hydrotreated effluent with a reduced content of sulfur and nitrogen. The unexpected aromatics saturation benefit of the catalyst formed from a suitable precursor can reduce or minimize the need to perform additional conversion of the feed in order to achieve a desired level of aromatics saturation in the final product. In addition to improving yield by avoiding excess conversion during hydrotreatment, additional yield improvement can be achieved by performing a separation on the hydrotreated effluent, such as to remove distillate and lower boiling range components. This type of separation can remove distillate fuel components in the hydrotreated effluent before such components are cracked to less

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valuable naphtha or light ends boiling range compounds. This can also allow subsequent stages to operate under “sweet” conditions. Operating under sweet conditions can allow the subsequent hydrocracking and dewaxing reactions to have higher selectivity for improving product properties at a given level of conversion.

[0018] FIG. 1 shows an example of a reaction system suitable for production of lubricant basestocks. It is noted that FIG. 1 includes a variety of reaction system elements, but not all elements are required in each possible configuration. For example, in FIG. 1, reactors and/or stages and/or catalyst beds 110, 120, and 130 are shown, but in various aspects either one or two of reactors 110, 120, and/or 130 may be omitted.

[0019] In FIG. 1, reactors 110, 120, and/or 130 schematically represent hydroprocessing of a feed prior to separation. The hydroprocessing in reactors 110, 120, and/or 130 can typically correspond to hydroprocessing of a feed in the presence of 500 wppm or more of sulfur. In the example shown in FIG. 1, a feed 105 is introduced into a first reactor 110 containing a hydrotreating catalyst. The effluent from reactor 110 is passed into reactor 120 containing a first hydrocracking catalyst. The effluent from reactor 120 is passed into reactor 130 containing a second hydrotreating catalyst. The sequence of reactors 110, 120, and 130 in FIG. 1 is provided for convenience of illustrating processing of a feed. It is understood that any convenient ordering of reactors 110, 120, and 130 may be used and/or any one or any two of reactors 110, 120, and 130 may be omitted. For example, other suitable configurations could include having a hydrocracking reactor or bed 120 followed by a hydrotreating reactor or bed 110 without second hydrocracking reactor 130; having only one or more hydrocracking reactors 120 and/or 130; having only hydrotreating reactor 110; or any other convenient combination.

[0020] The effluent from the final reactor or bed of reactors 110, 120, and 130 can then be passed into a separation stage 140. In FIG. 1, separation stage 140 is schematically shown as a fractionation stage. Such a fractionation stage can be suitable for separating the hydroprocessed effluent from the hydroprocessing reactors or beds 110, 120 and/or 130 into a plurality of fractions, such as light ends fraction, one or more naphtha boiling range fractions, one or more distillate boiling range fractions, optionally one or more lubricant boiling range fractions, and a bottoms fraction. Alternatively, separation stage 140 can correspond to a separator for separating light ends and contaminant gases generated during hydroprocessing (such as H_2S and NH_3) from the liquid product portions of the hydroprocessed effluent. More generally, any other convenient type of separation stage can be used as separation stage 140, including combinations of separators and fractionators.

[0021] Depending on the nature of the separation in separation stage 140, at least a portion of the liquid hydroprocessed effluent is passed into a hydrocracking and/or aromatic saturation reactor 150. Due to the initial hydroprocessing reactor(s) and the separation stage 140, the sulfur content of the hydroprocessed effluent can generally be sufficiently low (such as 500 wppm or less) for operating aromatic saturation and/or hydrocracking reactor or bed(s) 150 under sweet processing conditions. In some optional aspects, the hydrocracking catalyst may be omitted. In some optional aspects, the aromatic saturation catalyst may be omitted. In some optional aspects, the aromatic saturation and/or hydrocracking reactor 150 may be omitted. The effluent from reactor 150 can then be passed into a dewaxing reactor or bed 160 for catalytic dewaxing. The dewaxed effluent can then optionally be passed into hydrofinishing reactor or bed 170. The effluent from dewaxing reactor 160 or hydrofinishing reactor 170 can correspond to the final effluent, which can

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then be fractionated to form one or more desired fuel and/or lubricant boiling range products.

[0022] Depending on the aspect, the initial reactors 110, 120, and/or 130 can be used to desulfurize and denitrogenate a feedstock, saturate some aromatics, and/or potentially provide some increase in viscosity index. For example, the hydrocracking reactor 150 can increase the viscosity index (VI) of a resulting lubricant base stock product. The dewaxing reactor 160 can reduce the pour point of a resulting lubricant base stock product. The aromatics saturation catalyst in reactor 150 and/or the hydrofinishing catalyst in reactor 170 can further reduce the aromatics content of the resulting product.

[0023] In various aspects, a mixed metal catalyst formed from a suitable precursor can be used in one or more reactors of the reaction system schematically represented in FIG. 1. A mixed metal catalyst formed from a suitable precursor can be suitable for hydroprocessing under sour conditions, such as for hydrotreating in reactor 110, hydrocracking in reactor 120, hydrocracking in second hydrocracking reactor 130, or in a combination thereof. Additionally or alternately, a mixed metal catalyst formed from a suitable precursor can be suitable for hydrocracking in a hydrocracking reactor 150, for aromatic saturation / hydrofinishing in reactors 150 and/or 170, or a combination thereof.

[0024] As one example of a suitable configuration, a feed can initially be hydroprocessed under sour conditions, such as by exposing the feed to one or more beds of hydrotreatment catalyst under effective hydrotreating conditions. The hydrotreated feed can optionally be hydrocracked under effective (sour) hydrocracking conditions. The hydroprocessed feed can then be fractionated to

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form at least a light ends fraction, a distillate fraction corresponding to a diesel fuel product, and a bottoms fraction for further processing. Optionally, a plurality of fuel products can be formed by fractionation, such as one or more naphtha boiling range fractions and one or more distillate boiling range fractions. The bottoms fraction can then be hydrocracked under effective (sweet) hydrocracking conditions, followed by catalytic dewaxing under effective dewaxing conditions. Optionally, the hydrocracked, dewaxed effluent can then be hydrofinished prior to fractionation to form desired fuel and lubricant boiling range products.

[0025] In this discussion, the severity of hydroprocessing performed on a feed can be characterized based on an amount of conversion of the feedstock. In various aspects, the reaction conditions in the reaction system can be selected to generate a desired level of conversion of a feed. Conversion of a feed is defined in terms of conversion of molecules that boil above a temperature threshold to molecules below that threshold. The conversion temperature can be any convenient temperature. Unless otherwise specified, the conversion temperature in this discussion is a conversion temperature of 700°F (371°C).

[0026] The amount of conversion can correspond to the total conversion of molecules within any stage of the reaction system that is used to hydroprocess the lower boiling portion of the feed from the vacuum distillation unit. The amount of conversion desired for a suitable feedstock can depend on a variety of factors, such as the boiling range of the feedstock, the amount of heteroatom contaminants (such as sulfur and/or nitrogen) in the feedstock, and/or the nature of the desired lubricant products. Suitable amounts of conversion across all hydroprocessing stages can correspond to at least about 25 wt% conversion of 700°F+ (371°C+) portions of the feedstock to portions boiling below 700°F, such as at least about 35 wt%, or at least

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about 45 wt%, or at least about 50 wt%. In various aspects, the amount of conversion is about 75 wt% or less, such as about 65 wt% or less, or 55 wt% or less. It is noted that the amount of conversion refers to conversion during a single pass through a reaction system. For example, a portion of the unconverted feed (boiling at above 700°F) can be recycled to the beginning of the reaction system and/or to another earlier point in the reaction system for further hydroprocessing.

[0027] In this discussion, a stage can correspond to a single reactor or a plurality of reactors. Optionally, multiple parallel reactors can be used to perform one or more of the processes, or multiple parallel reactors can be used for all processes in a stage. Each stage and/or reactor can include one or more catalyst beds containing hydroprocessing catalyst. Note that a “bed” of catalyst in the discussion below can refer to a partial physical catalyst bed. For example, a catalyst bed within a reactor could be filled partially with a hydrocracking catalyst and partially with a dewaxing catalyst. For convenience in description, even though the two catalysts may be stacked together in a single catalyst bed, the hydrocracking catalyst and dewaxing catalyst can each be referred to conceptually as separate catalyst beds.

[0028] In this discussion, a medium pore dewaxing catalyst refers to a catalyst that includes a 10-member ring molecular sieve. Examples of molecular sieves suitable for forming a medium pore dewaxing catalyst include 10-member ring 1-dimensional molecular sieves, such as EU-1, ZSM-35 (or ferrierite), ZSM-11, ZSM-57, NU-87, SAPO-11, ZSM-48, ZSM-23, and ZSM-22. In this discussion, a large pore hydrocracking catalyst refers to a catalyst that includes a 12-member ring molecular sieve. An example of a molecular sieve suitable for forming a large pore

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hydrocracking catalyst is USY zeolite with a silica to alumina ratio of about 200:1 or less and a unit cell size of about 24.5 Angstroms or less.

[0029] In this discussion, the distillate boiling range is defined as 350°F (177°C) to 700°F (371°C). Distillate boiling range products can include products suitable for use as kerosene products (including jet fuel products) and diesel products, such as premium diesel or winter diesel products. Such distillate boiling range products can be suitable for use directly, or optionally after further processing. With regard to other boiling ranges, the lubricant boiling range is defined as 700°F (371°C) to 950°F (482°C) and the naphtha boiling range is defined as 100°F (37°C) to 350°F (177°C).

[0030] A wide range of petroleum and chemical feedstocks can be hydroprocessed in accordance with the present disclosure. Some suitable feedstocks include gas oils, such as vacuum gas oils. More generally, suitable feedstocks include whole and reduced petroleum crudes, atmospheric and vacuum residua, solvent deasphalted residua, cycle oils, FCC tower bottoms, gas oils, including atmospheric and vacuum gas oils and coker gas oils, light to heavy distillates including raw virgin distillates, hydrocrackates, hydrotreated oils, dewaxed oils, slack waxes, Fischer-Tropsch waxes, raffinates, and mixtures of these materials.

[0031] One way of defining a feedstock is based on the boiling range of the feed. One option for defining a boiling range is to use an initial boiling point for a feed and/or a final boiling point for a feed. Another option, which in some instances may provide a more representative description of a feed, is to characterize a feed based on the amount of the feed that boils at one or more temperatures. For

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example, a “T5” boiling point for a feed is defined as the temperature at which 5 wt% of the feed will boil off. Similarly, a “T95” boiling point is a temperature at which 95 wt% of the feed will boil, while a “T99.5” boiling point is a temperature at which 99.5 wt% of the feed will boil.

[0032] Typical feeds include, for example, feeds with an initial boiling point of at least about 650°F (343°C), or at least about 700°F (371°C), or at least about 750°F (399°C). The amount of lower boiling point material in the feed may impact the total amount of diesel generated as a side product. Alternatively, a feed may be characterized using a T5 boiling point, such as a feed with a T5 boiling point of at least about 650°F (343°C), or at least about 700°F (371°C), or at least about 750°F (399°C). Typical feeds include, for example, feeds with a final boiling point of about 1150°F (621°C), or about 1100°F (593°C) or less, or about 1050°F (566°C) or less. Alternatively, a feed may be characterized using a T95 boiling point, such as a feed with a T95 boiling point of about 1150°F (621°C), or about 1100°F (593°C) or less, or about 1050°F (566°C) or less. It is noted that feeds with still lower initial boiling points and/or T5 boiling points may also be suitable for increasing the yield of premium diesel, so long as sufficient higher boiling material is available so that the overall nature of the process is a lubricant base oil production process. Feedstocks such as deasphalted oil with a final boiling point or a T95 boiling point of about 1150°F (621°C) or less may also be suitable.

[0033] In some aspects, feeds with an increased amount of distillate boiling range components can be used as feedstocks. Traditionally such distillate boiling range components would be excluded from a process for hydrocracking of a gas oil feed, in order to avoid conversion of the distillate components to less valuable naphtha or light ends products. In such aspects, the T5 boiling point of a feedstock

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can be at least about 473°F (245°C), such as at least about 527°F (275°C), or at least about 572°F (300°C), or at least about 600°F (316°C).

[0034] In aspects involving an initial sulfur removal stage prior to hydrocracking, the sulfur content of the feed can be at least about 100 ppm by weight of sulfur, or at least about 1000 wppm, or at least about 2000 wppm, or at least about 4000 wppm, or at least about 20,000 wppm, such as up to about 40,000 wppm or more. In other embodiments, including some embodiments where a previously hydrotreated and/or hydrocracked feed is used, the sulfur content can be about 2000 wppm or less, or about 1000 wppm or less, or about 500 wppm or less, or about 100 wppm or less.

[0035] In aspects involving an initial hydroprocessing stage prior to hydrocracking, the nitrogen content of the feed can be at least about 50 ppm by weight of nitrogen, or at least about 100 wppm, or at least about 500 wppm, or at least about 1000 wppm, or at least about 2500 wppm, such as up to about 5,000 wppm or more. In other embodiments, including some embodiments where a previously hydrotreated and/or hydrocracked feed is used, the nitrogen content can be about 500 wppm or less, or about 100 wppm or less, or about 50 wppm or less, or about 10 wppm or less.

[0036] In aspects involving an initial hydroprocessing stage prior to hydrocracking, the aromatics content of the feed can be at least about 5 wt% aromatics, or at least about 10 wt%, or at least about 15 wt%, or at least about 20 wt%, or at least about 25 wt%, such as up to about 30 wt% or more. In other embodiments, including some embodiments where a previously hydrotreated and/or

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hydrocracked feed is used, the aromatics content can be about 15 wt% or less, or about 10 wt% or less, or about 5 wt% or less, or about 1 wt% or less.

[0037] In some aspects, at least a portion of the feed can correspond to a feed derived from a biocomponent source. In this discussion, a biocomponent feedstock refers to a hydrocarbon feedstock derived from a biological raw material component, from biocomponent sources such as vegetable, animal, fish, and/or algae. Note that, for the purposes of this document, vegetable fats/oils refer generally to any plant based material, and can include fat/oils derived from a source such as plants of the genus *Jatropha*. Generally, the biocomponent sources can include vegetable fats/oils, animal fats/oils, fish oils, pyrolysis oils, and algae lipids/oils, as well as components of such materials, and in some embodiments can specifically include one or more type of lipid compounds. Lipid compounds are typically biological compounds that are insoluble in water, but soluble in nonpolar (or fat) solvents. Non-limiting examples of such solvents include alcohols, ethers, chloroform, alkyl acetates, benzene, and combinations thereof.

Hydrotreatment Conditions

[0038] In various aspects, hydrotreating of a feed can be performed by exposing the feed to a catalyst formed from a suitable precursor, as described below, in the presence of hydrogen. A hydrogen stream is, therefore, fed or injected into a vessel or reaction zone or hydroprocessing zone in which the hydroprocessing catalyst is located. Hydrogen, which is contained in a hydrogen-containing “treat gas,” is provided to the reaction zone. Treat gas, as referred to in this disclosure, can be either pure hydrogen or a hydrogen-containing gas, which is a gas stream containing hydrogen in an amount that is sufficient for the intended reaction(s), optionally including one or more other gasses (e.g., nitrogen and light hydrocarbons

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such as methane), and which will not adversely interfere with or affect either the reactions or the products. Impurities, such as H_2S and NH_3 are undesirable and would typically be removed from the treat gas before it is conducted to the reactor. The treat gas stream introduced into a reaction stage will preferably contain at least about 50 vol. % and more preferably at least about 75 vol. % hydrogen.

[0039] Hydrotreating conditions can include temperatures of about 200°C to about 450°C , or about 315°C to about 425°C ; pressures of about 250 psig (1.8 MPag) to about 5000 psig (34.6 MPag) or about 300 psig (2.1 MPag) to about 3000 psig (20.8 MPag); liquid hourly space velocities (LHSV) of about 0.1 hr^{-1} to about 10 hr^{-1} ; and hydrogen treat rates of about 200 scf/B ($35.6\text{ m}^3/\text{m}^3$) to about 10,000 scf/B ($1781\text{ m}^3/\text{m}^3$), or about 500 ($89\text{ m}^3/\text{m}^3$) to about 10,000 scf/B ($1781\text{ m}^3/\text{m}^3$).

[0040] Optionally, the hydrotreatment can be performed using a mixture of the catalyst formed from a suitable precursor and a conventional hydrotreating catalyst, such as those that comprise at least one Group VIII non-noble metal (Columns 8 – 10 of IUPAC periodic table), preferably Fe, Co, and/or Ni, such as Co and/or Ni; and at least one Group VI metal (Column 6 of IUPAC periodic table), preferably Mo and/or W. Such hydroprocessing catalysts can optionally include transition metal sulfides. These metals or mixtures of metals are typically present as oxides or sulfides on refractory metal oxide supports. Suitable metal oxide supports include low acidic oxides such as silica, alumina, titania, silica-titania, and titania-alumina. Suitable aluminas are porous aluminas such as gamma or eta having average pore sizes from 50 to $200\text{ \AA}$, or 75 to $150\text{ \AA}$; a surface area from 100 to $300\text{ m}^2/\text{g}$, or 150 to $250\text{ m}^2/\text{g}$; and a pore volume of from 0.25 to $1.0\text{ cm}^3/\text{g}$, or 0.35 to $0.8\text{ cm}^3/\text{g}$. The supports are preferably not promoted with a halogen such as fluorine as this generally increases the acidity of the support.

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[0041] The at least one Group VIII non-noble metal, in oxide form, can typically be present in an amount ranging from about 2 wt% to about 40 wt%, preferably from about 4 wt% to about 15 wt%. The at least one Group VI metal, in oxide form, can typically be present in an amount ranging from about 2 wt% to about 70 wt%, preferably for supported catalysts from about 6 wt% to about 40 wt% or from about 10 wt% to about 30 wt%. These weight percents are based on the total weight of the catalyst. Suitable metal catalysts include cobalt/molybdenum (1-10% Co as oxide, 10-40% Mo as oxide), nickel/molybdenum (1-10% Ni as oxide, 10-40% Co as oxide), or nickel/tungsten (1-10% Ni as oxide, 10-40% W as oxide) on alumina, silica, silica-alumina, or titania.

[0042] Alternatively, the hydrotreating catalyst can be a bulk metal catalyst, or a combination of stacked beds of supported and bulk metal catalyst. By bulk metal, it is meant that the catalysts are unsupported wherein the bulk catalyst particles comprise 30-100 wt. % of at least one Group VIII non-noble metal and at least one Group VIB metal, based on the total weight of the bulk catalyst particles, calculated as metal oxides and wherein the bulk catalyst particles have a surface area of at least 10 m²/g. It is furthermore preferred that the bulk metal hydrotreating catalysts used herein comprise about 50 to about 100 wt%, and even more preferably about 70 to about 100 wt%, of at least one Group VIII non-noble metal and at least one Group VIB metal, based on the total weight of the particles, calculated as metal oxides. The amount of Group VIB and Group VIII non-noble metals can easily be determined VIB TEM-EDX.

[0043] Bulk catalyst compositions comprising one Group VIII non-noble metal and two Group VIB metals are preferred. It has been found that in this case, the

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bulk catalyst particles are sintering-resistant. Thus the active surface area of the bulk catalyst particles is maintained during use. The molar ratio of Group VIB to Group VIII non-noble metals ranges generally from 10:1-1:10 and preferably from 3:1-1:3. In the case of a core-shell structured particle, these ratios of course apply to the metals contained in the shell. If more than one Group VIB metal is contained in the bulk catalyst particles, the ratio of the different Group VIB metals is generally not critical. The same holds when more than one Group VIII non-noble metal is applied. In the case where molybdenum and tungsten are present as Group VIB metals, the molybdenum:tungsten ratio preferably lies in the range of 9:1-1:9. Preferably the Group VIII non-noble metal comprises nickel and/or cobalt. It is further preferred that the Group VIB metal comprises a combination of molybdenum and tungsten. Preferably, combinations of nickel/molybdenum/tungsten and cobalt/molybdenum/tungsten and nickel/cobalt/molybdenum/tungsten are used. These types of precipitates appear to be sinter-resistant. Thus, the active surface area of the precipitate is maintained during use. The metals are preferably present as oxidic compounds of the corresponding metals, or if the catalyst composition has been sulfided, sulfidic compounds of the corresponding metals.

[0044] It is also preferred that the bulk metal hydrotreating catalysts used herein have a surface area of at least 50 m²/g and more preferably of at least 100 m²/g. It is also desired that the pore size distribution of the bulk metal hydrotreating catalysts be approximately the same as the one of conventional hydrotreating catalysts. Bulk metal hydrotreating catalysts have a pore volume of 0.05-5 ml/g, or of 0.1-4 ml/g, or of 0.1-3 ml/g, or of 0.1-2 ml/g determined by nitrogen adsorption. Preferably, pores smaller than 1 nm are not present. The bulk metal hydrotreating catalysts can have a median diameter of at least 50 nm, or at least 100 nm. The bulk

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metal hydrotreating catalysts can have a median diameter of not more than 5000 μm , or not more than 3000 μm . In an embodiment, the median particle diameter lies in the range of 0.1-50 μm and most preferably in the range of 0.5-50 μm .

Hydrocracking Conditions

[0045] Hydrocracking catalysts typically contain sulfided base metals on acidic supports, such as amorphous silica alumina, cracking zeolites or other cracking molecular sieves such as USY, or acidified alumina. In some preferred aspects, a hydrocracking catalyst can include at least one molecular sieve, such as a zeolite. Often these acidic supports are mixed or bound with other metal oxides such as alumina, titania or silica. Non-limiting examples of supported catalytic metals for hydrocracking catalysts include nickel, nickel-cobalt-molybdenum, cobalt-molybdenum, nickel-tungsten, nickel-molybdenum, and/or nickel-molybdenum-tungsten. Additionally or alternately, hydrocracking catalysts with noble metals can also be used. Non-limiting examples of noble metal catalysts include those based on platinum and/or palladium. Support materials which may be used for both the noble and non-noble metal catalysts can comprise a refractory oxide material such as alumina, silica, alumina-silica, kieselguhr, diatomaceous earth, magnesia, zirconia, or combinations thereof, with alumina, silica, alumina-silica being the most common (and preferred, in one embodiment).

[0046] In some aspects, a hydrocracking catalyst can include a large pore molecular sieve that is selective for cracking of branched hydrocarbons and/or cyclic hydrocarbons. Zeolite Y, such as ultrastable zeolite Y (USY) is an example of a zeolite molecular sieve that is selective for cracking of branched hydrocarbons and cyclic hydrocarbons. Depending on the aspect, the silica to alumina ratio in a USY zeolite can be at least about 10, such as at least about 15, or at least about 25, or at

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least about 50, or at least about 100. Depending on the aspect, the unit cell size for a USY zeolite can be about 24.50 Angstroms or less, such as about 24.45 Angstroms or less, or about 24.40 Angstroms or less, or about 24.35 Angstroms or less, such as about 24.30 Angstroms.

[0047] In various embodiments, the conditions selected for hydrocracking can depend on the desired level of conversion, the level of contaminants in the input feed to the hydrocracking stage, and potentially other factors. A hydrocracking process performed under sour conditions, such as conditions where the sulfur content of the input feed to the hydrocracking stage is at least 500 wppm, can be carried out at temperatures of about 550°F (288°C) to about 840°F (449°C), hydrogen partial pressures of from about 250 psig to about 5000 psig (1.8 MPag to 34.6 MPag), liquid hourly space velocities of from 0.05 h⁻¹ to 10 h⁻¹, and hydrogen treat gas rates of from 35.6 m³/m³ to 1781 m³/m³ (200 SCF/B to 10,000 SCF/B). In other embodiments, the conditions can include temperatures in the range of about 600°F (343°C) to about 815°F (435°C), hydrogen partial pressures of from about 500 psig to about 3000 psig (3.5 MPag-20.9 MPag), liquid hourly space velocities of from about 0.2 h⁻¹ to about 2 h⁻¹ and hydrogen treat gas rates of from about 213 m³/m³ to about 1068 m³/m³ (1200 SCF/B to 6000 SCF/B).

[0048] A hydrocracking process performed under non-sour conditions can be performed under conditions similar to those used for sour conditions, or the conditions can be different. Alternatively, a non-sour hydrocracking stage can have less severe conditions than a similar hydrocracking stage operating under sour conditions. Suitable hydrocracking conditions can include temperatures of about 550°F (288°C) to about 840°F (449°C), hydrogen partial pressures of from about 250 psig to about 5000 psig (1.8 MPag to 34.6 MPag), liquid hourly space

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velocities of from 0.05 h^{-1} to 10 h^{-1} , and hydrogen treat gas rates of from $35.6 \text{ m}^3/\text{m}^3$ to $1781 \text{ m}^3/\text{m}^3$ (200 SCF/B to 10,000 SCF/B). In other embodiments, the conditions can include temperatures in the range of about 600°F (343°C) to about 815°F (435°C), hydrogen partial pressures of from about 500 psig to about 3000 psig (3.5 MPag-20.9 MPag), liquid hourly space velocities of from about 0.2 h^{-1} to about 2 h^{-1} and hydrogen treat gas rates of from about $213 \text{ m}^3/\text{m}^3$ to about $1068 \text{ m}^3/\text{m}^3$ (1200 SCF/B to 6000 SCF/B).

Dewaxing Process

[0049] In various embodiments, a dewaxing catalyst is also included. Typically, the dewaxing catalyst is located in a bed downstream from any hydrocracking catalyst stages and/or any hydrocracking catalyst present in a stage. This can allow the dewaxing to occur on molecules that have already been hydrotreated or hydrocracked to remove a significant fraction of organic sulfur- and nitrogen-containing species. The dewaxing catalyst can be located in the same reactor as at least a portion of the hydrocracking catalyst in a stage. Alternatively, the effluent from a reactor containing hydrocracking catalyst, possibly after a gas-liquid separation, can be fed into a separate stage or reactor containing the dewaxing catalyst.

[0050] Suitable dewaxing catalysts can include molecular sieves such as crystalline aluminosilicates (zeolites). In an embodiment, the molecular sieve can comprise, consist essentially of, or be ZSM-5, ZSM-22, ZSM-23, ZSM-35, ZSM-48, zeolite Beta, ZSM-57, or a combination thereof, for example ZSM-23 and/or ZSM-48, or ZSM-48 and/or zeolite Beta. Optionally but preferably, molecular sieves that are selective for dewaxing by isomerization as opposed to cracking can be used, such as ZSM-48, zeolite Beta, ZSM-23, or a combination thereof.

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Additionally or alternately, the molecular sieve can comprise, consist essentially of, or be a 10-member ring 1-D molecular sieve. Examples include EU-1, ZSM-35 (or ferrierite), ZSM-11, ZSM-57, NU-87, SAPO-11, ZSM-48, ZSM-23, and ZSM-22. Preferred materials are EU-2, EU-11, ZBM-30, ZSM-48, or ZSM-23. ZSM-48 is most preferred. Note that a zeolite having the ZSM-23 structure with a silica to alumina ratio of from about 20:1 to about 40:1 can sometimes be referred to as SSZ-32. Other molecular sieves that are isostructural with the above materials include Theta-1, NU-10, EU-13, KZ-1, and NU-23. Optionally but preferably, the dewaxing catalyst can include a binder for the molecular sieve, such as alumina, titania, silica, silica-alumina, zirconia, or a combination thereof, for example alumina and/or titania or silica and/or zirconia and/or titania.

[0051] Preferably, the dewaxing catalysts used in processes according to the disclosure are catalysts with a low ratio of silica to alumina. For example, for ZSM-48, the ratio of silica to alumina in the zeolite can be less than 200:1, or less than 110:1, or less than 100:1, or less than 90:1, or less than 80:1. In various embodiments, the ratio of silica to alumina can be from 30:1 to 200:1, 60:1 to 110:1, or 70:1 to 100:1.

[0052] In various embodiments, the catalysts according to the disclosure further include a metal hydrogenation component. The metal hydrogenation component is typically a Group VI and/or a Group VIII metal. Preferably, the metal hydrogenation component is a Group VIII noble metal. Preferably, the metal hydrogenation component is Pt, Pd, or a mixture thereof. In an alternative preferred embodiment, the metal hydrogenation component can be a combination of a non-noble Group VIII metal with a Group VI metal. Suitable combinations can include Ni, Co, or Fe with Mo or W, preferably Ni with Mo or W.

[0053] The metal hydrogenation component may be added to the catalyst in any convenient manner. One technique for adding the metal hydrogenation component is by incipient wetness. For example, after combining a zeolite and a binder, the combined zeolite and binder can be extruded into catalyst particles. These catalyst particles can then be exposed to a solution containing a suitable metal precursor. Alternatively, metal can be added to the catalyst by ion exchange, where a metal precursor is added to a mixture of zeolite (or zeolite and binder) prior to extrusion.

[0054] The amount of metal in the catalyst can be at least 0.1 wt% based on catalyst, or at least 0.15 wt%, or at least 0.2 wt%, or at least 0.25 wt%, or at least 0.3 wt%, or at least 0.5 wt% based on catalyst. The amount of metal in the catalyst can be 20 wt% or less based on catalyst, or 10 wt% or less, or 5 wt% or less, or 2.5 wt% or less, or 1 wt% or less. For embodiments where the metal is Pt, Pd, another Group VIII noble metal, or a combination thereof, the amount of metal can be from 0.1 to 5 wt%, preferably from 0.1 to 2 wt%, or 0.25 to 1.8 wt%, or 0.4 to 1.5 wt%. For embodiments where the metal is a combination of a non-noble Group VIII metal with a Group VI metal, the combined amount of metal can be from 0.5 wt% to 20 wt%, or 1 wt% to 15 wt%, or 2.5 wt% to 10 wt%.

[0055] The dewaxing catalysts useful in processes according to the disclosure can also include a binder. In some embodiments, the dewaxing catalysts used in process according to the disclosure are formulated using a low surface area binder, a low surface area binder represents a binder with a surface area of 100 m²/g or less, or 80 m²/g or less, or 70 m²/g or less.

[0056] A zeolite can be combined with binder in any convenient manner. For example, a bound catalyst can be produced by starting with powders of both the zeolite and binder, combining and mulling the powders with added water to form a mixture, and then extruding the mixture to produce a bound catalyst of a desired size. Extrusion aids can also be used to modify the extrusion flow properties of the zeolite and binder mixture. The amount of framework alumina in the catalyst may range from 0.1 to 3.33 wt%, or 0.1 to 2.7 wt%, or 0.2 to 2 wt%, or 0.3 to 1 wt%.

[0057] In yet another embodiment, a binder composed of two or more metal oxides can also be used. In such an embodiment, the weight percentage of the low surface area binder is preferably greater than the weight percentage of the higher surface area binder. Alternatively, if both metal oxides used for forming a mixed metal oxide binder have a sufficiently low surface area, the proportions of each metal oxide in the binder are less important. When two or more metal oxides are used to form a binder, the two metal oxides can be incorporated into the catalyst by any convenient method. For example, one binder can be mixed with the zeolite during formation of the zeolite powder, such as during spray drying. The spray dried zeolite/binder powder can then be mixed with the second metal oxide binder prior to extrusion. In yet another embodiment, the dewaxing catalyst is self-bound and does not contain a binder.

[0058] A bound dewaxing catalyst can also be characterized by comparing the micropore (or zeolite) surface area of the catalyst with the total surface area of the catalyst. These surface areas can be calculated based on analysis of nitrogen porosimetry data using the BET method for surface area measurement. Previous

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work has shown that the amount of zeolite content versus binder content in catalyst can be determined from BET measurements (*see, e.g., Johnson, M.F.L., Jour. Catal., (1978) 52, 425*). The micropore surface area of a catalyst refers to the amount of catalyst surface area provided due to the molecular sieve and/or the pores in the catalyst in the BET measurements. The total surface area represents the micropore surface plus the external surface area of the bound catalyst. In one embodiment, the percentage of micropore surface area relative to the total surface area of a bound catalyst can be at least about 35%, for example at least about 38%, at least about 40%, or at least about 45%. Additionally or alternately, the percentage of micropore surface area relative to total surface area can be about 65% or less, for example about 60% or less, about 55% or less, or about 50% or less.

[0059] Additionally or alternately, the dewaxing catalyst can comprise, consist essentially of, or be a catalyst that has not been dealuminated. Further additionally or alternately, the binder for the catalyst can include a mixture of binder materials containing alumina.

[0060] Process conditions in a catalytic dewaxing zone can include a temperature of about 200°C to about 450°C, preferably about 270°C to about 400°C, a hydrogen partial pressure of about 1.8 MPag to about 34.6 MPag (250 psig to 5000 psig), preferably about 4.8 MPag to about 20.8 MPag, and a hydrogen treat gas rate of about 35.6 m³/m³ (200 SCF/B) to about 1781 m³/m³ (10,000 scf/B), preferably about 178 m³/m³ (1000 SCF/B) to about 890.6 m³/m³ (5000 SCF/B). In still other embodiments, the conditions can include temperatures in the range of about 600°F (343°C) to about 815°F (435°C), hydrogen partial pressures of from about 500 psig to about 3000 psig (3.5 MPag-20.9 MPag), and hydrogen treat gas rates of from about 213 m³/m³ to about 1068 m³/m³ (1200 SCF). The LHSV can be

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from about 0.1 h^{-1} to about 10 h^{-1} , such as from about 0.5 h^{-1} to about 5 h^{-1} and/or from about 1 h^{-1} to about 4 h^{-1} .

Hydrofinishing and/or Aromatic Saturation Process

[0061] In various embodiments, a hydrofinishing, an aromatic saturation stage, or a hydrofinishing and an aromatic saturation stage may also be provided. The hydrofinishing and/or aromatic saturation stage(s) or reaction zones can occur after the last hydrocracking or dewaxing stage. The hydrofinishing and/or aromatic saturation can occur either before or after fractionation. If hydrofinishing and/or aromatic saturation occurs after fractionation, the hydrofinishing can be performed on one or more portions of the fractionated product, such as being performed on one or more lubricant base oil portions. Alternatively, the entire effluent from the last hydrocracking or dewaxing process can be hydrofinished and/or undergo aromatic saturation.

[0062] In some situations, a hydrofinishing process and an aromatic saturation process can refer to a single process performed using the same catalyst. Alternatively, one type of catalyst or catalyst system can be provided to perform aromatic saturation, while a second catalyst or catalyst system can be used for hydrofinishing. As still another alternative, aromatic saturation sometimes refers to a higher temperature range of processing than a hydrofinishing process. In such an alternative, a hydrofinishing process may be suitable for removing (for example) color bodies from a product, but otherwise result in a lower amount of aromatic saturation than an aromatic saturation process. Typically a hydrofinishing and/or aromatic saturation process will be performed in a separate reactor from dewaxing or hydrocracking processes for practical reasons, such as facilitating use of a lower temperature for the hydrofinishing or aromatic saturation process. However, an

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additional hydrofinishing reactor following a hydrocracking or dewaxing process but prior to fractionation could still be considered part of a second stage of a reaction system conceptually.

[0063] Hydrofinishing and/or aromatic saturation catalysts can include catalysts containing Group VI metals, Group VIII metals, and mixtures thereof. In an embodiment, preferred metals include at least one metal sulfide having a strong hydrogenation function. In another embodiment, the hydrofinishing catalyst can include a Group VIII noble metal, such as Pt, Pd, or a combination thereof. The mixture of metals may also be present as bulk metal catalysts wherein the amount of metal is about 30 wt. % or greater based on catalyst. Suitable metal oxide supports include low acidic oxides such as silica, alumina, silica-aluminas or titania, preferably alumina. The preferred hydrofinishing catalysts for aromatic saturation can comprise at least one metal having relatively strong hydrogenation function on a porous support. The support materials may also be modified, such as by halogenation, or in particular fluorination. The metal content of the catalyst is often as high as about 20 weight percent for non-noble metals. In some optional aspects, hydrotreating catalysts as described above can be used as hydrofinishing catalysts. In other optional aspects, a preferred hydrofinishing catalyst can include a crystalline material belonging to the M41S class or family of catalysts. The M41S family of catalysts are mesoporous materials having high silica content. Examples include MCM-41, MCM-48 and MCM-50. A preferred member of this class is MCM-41. If separate catalysts are used for aromatic saturation and hydrofinishing, an aromatic saturation catalyst can be selected based on activity and/or selectivity for aromatic saturation, while a hydrofinishing catalyst can be selected based on activity for improving product specifications, such as product color and polynuclear aromatic reduction.

[0064] Hydrofinishing conditions can include temperatures from about 125°C to about 425°C, preferably about 180°C to about 280°C, total pressures from about 500 psig (3.4 MPa) to about 3000 psig (20.7 MPa), preferably about 1500 psig (10.3 MPa) to about 2500 psig (17.2 MPa), and liquid hourly space velocity from about 0.1 hr⁻¹ to about 5 hr⁻¹ LHSV, preferably about 0.5 hr⁻¹ to about 1.5 hr⁻¹.

[0065] In aspects where aromatic saturation is contemplated as a distinct process from hydrofinishing, aromatic saturation conditions can include temperatures from about 175°C to about 425°C, or about 200°C to about 425°C, preferably about 225°C to about 325°C, or about 225°C to about 280°C, total pressures from about 500 psig (3.4 MPa) to about 3000 psig (20.7 MPa), preferably about 1500 psig (10.3 MPa) to about 2500 psig (17.2 MPa), and liquid hourly space velocity from about 0.1 hr⁻¹ to about 5 hr⁻¹ LHSV, preferably about 0.5 hr⁻¹ to about 1.5 hr⁻¹.

Alternative Process Configurations and Uses for Catalyst Formed from a Suitable Precursor

[0066] In addition to the process configuration described above, a catalyst composition derived from a suitable precursor, as described herein, can be used in a variety of hydroprocessing processes to treat a plurality of feeds under wide-ranging reaction conditions such as temperatures of from 200 to 450°C, hydrogen pressures of from 5 to 300 bar, liquid hourly space velocities of from 0.05 to 10 h⁻¹ and hydrogen treat gas rates of from 35.6 to 1780 m³ /m³ (200 to 10000 SCF/B). The term "hydroprocessing" encompasses all processes in which a hydrocarbon feed is reacted with hydrogen at the temperatures and pressures noted above, and include hydrogenation, hydrotreating, hydrodesulfurization, hydrodenitrogenation,

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hydrodemetallation, hydrodearomatization, hydroisomerization, hydrodewaxing, and hydrocracking including selective hydrocracking. Depending on the type of hydroprocessing and the reaction conditions, the products of hydroprocessing may show improved viscosities, viscosity indices, saturates content, low temperature properties, volatilities and depolarization. Feeds for hydroprocessing include reduced crudes, hydrocrackates, raffinates, hydrotreated oils, atmospheric and vacuum gas oils, coker gas oils, atmospheric and vacuum resids, deasphalted oils, dewaxed oils, slack waxes, Fischer-Tropsch waxes and mixtures thereof. It is to be understood that hydroprocessing of the present disclosure can be practiced in one or more reaction zones and can be practiced in either countercurrent flow or cocurrent flow mode. By countercurrent flow mode we mean a process mode wherein the feedstream flows countercurrent to the flow of hydrogen-containing treat gas.

[0067] A catalyst composition derived from a suitable precursor can be particularly suitable for hydrotreating the hydrocarbon feeds suitable for hydroprocessing as noted above. Examples of hydrotreating include hydrogenation of unsaturates, hydrodesulfurization, hydrodenitrogenation, hydrodearomatization and mild hydrocracking. Conventional hydrotreating conditions include temperatures of from 250°C to 450°C, hydrogen pressures of from 5 to 250 bar, liquid hourly space velocities of from 0.1 to 10 h⁻¹, and hydrogen treat gas rates of from 90 to 1780 m³/m³ (500 to 10000 SCF/B). The hydrotreating processes using the catalyst according to the disclosure may be particularly suitable for making lubricating oil basestocks meeting Group II or Group III base oil requirements.

[0068] A wide range of petroleum and chemical feedstocks can be hydroprocessed in accordance with this type of aspect. Suitable feedstocks range from the relatively light distillate fractions up to high boiling stocks such as whole

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crude petroleum, reduced crudes, vacuum tower residua, propane deasphalted residua, e.g., brightstock, cycle oils, FCC tower bottoms, gas oils including coker gas oils and vacuum gas oils, deasphalted residua and other heavy oils. The feedstock will normally be a C.sub.10 + feedstock, since light oils will usually be free of significant quantities of waxy components. However, the process is also particularly useful with waxy distillate stocks, such as gas oils, kerosenes, jet fuels, lubricating oil stocks, heating oils, hydrotreated oil stock, furfural-extracted lubricating oil stock and other distillate fractions whose pour point and viscosity properties need to be maintained within certain specification limits. Lubricating oil stocks, for example, will generally boil above 230°C and more usually above 315°C. For purposes of this disclosure, lubricating oil or lube oil is that part of the hydrocarbon feedstock having a boiling point of at least 315°C, as determined by ASTM D-1160 test method.

[0069] In some aspects, a feed can be exposed to a catalyst derived from a suitable precursor under effective conditions for performing a hydroconversion process. The hydroconversion process can be part of a series or group of processes for producing a lubricant base stock. For example, a hydroconversion process can be used to produce a lubricating oil basestock meeting at least 90% saturates and VI of at least 105 by selectively hydroconverting a raffinate produced from solvent refining a lubricating oil feedstock. The solvent extraction process selectively dissolves the aromatic components in an extract phase while leaving the more paraffinic components in a raffinate phase. Naphthenes are distributed between the extract and raffinate phases. Typical solvents for solvent extraction include phenol, furfural and N-methyl pyrrolidone. By controlling the solvent to oil ratio, extraction temperature and method of contacting distillate to be extracted with solvent, one can control the degree of separation between the extract and raffinate phases. The

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raffinate from the solvent extraction is preferably under-extracted, i.e., the extraction is carried out under conditions such that the raffinate yield is maximized while still removing most of the lowest quality molecules from the feed. Raffinate yield may be maximized by controlling extraction conditions, for example, by lowering the solvent to oil treat ratio and/or decreasing the extraction temperature. The raffinate from the solvent extraction unit is stripped of solvent and then sent to a first hydroconversion unit containing a hydroconversion catalyst. This raffinate feed has a viscosity index of from about 80 to about 105 and a boiling range not to exceed about 650°C, preferably less than 600°C, as determined by ASTM 2887 and a viscosity of from 3 to 15 cSt at 100°C. The stripped raffinate from the solvent extraction zone may be solvent dewaxed prior to being sent to the first hydroconversion unit.

[0070] The raffinate feed is passed to a first hydroconversion zone and processed in the presence of the catalyst derived from a suitable precursor under hydroconversion conditions to produce a first hydroconverted raffinate. The hydroconverted raffinate from the first hydroconversion zone may then be passed to a hydrofinishing zone or in the alternative passed to a second hydroconversion zone and then passed to a hydrofinishing zone. In the case of two hydroconversion zones, the catalyst in both hydroconversion zones may be a catalyst derived from a suitable precursor, or the catalyst derived from a suitable precursor may be used in either the first or second hydroconversion zones. In the case of two zones where the catalyst derived from a suitable precursor is used in only one of the zones, the other catalyst may be a different type of bulk or supported hydrotreating catalyst. Hydrotreating catalysts are those containing at least one Group VIB and at least one Group VIII metal supported on a refractory metal oxide. For typical alternative hydrotreating catalysts for use in this aspect, the Group VIB metal is preferably molybdenum or

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tungsten and the Group VIII metal is preferably a non-noble metal such as cobalt or nickel.

[0071] The hydroconversion conditions in either the first or second hydroconversion zones include temperatures of from 250 to 420°C, hydrogen pressures of from 300 to 3000 psig (2170 to 20786 kPa), liquid hourly space velocities of from 0.1 to 10 and hydrogen treat gas rates of from 500 to 5000 scf/B (89 to 890 m³/m³).

[0072] The hydroconversion zone(s) are then followed by a hydrofinishing zone. The hydrofinishing zone corrects product quality properties such as color, stability and toxicity. The hydrofinishing zone is characterized as a cold hydrofinishing zone with conditions including temperatures of from 150 to 360°C, hydrogen pressures of from 300 to 3000 psig (2170 to 20786 kPa), liquid hourly space velocities of from 0.1 to 10 hr⁻¹ and hydrogen treat gas rates of from 500 to 5000 scf/B (89 to 890 m³/m³). The catalyst for the hydrofinishing zone may be either the bulk metal catalyst according to the disclosure or may be a non-bulk metal hydrotreating catalyst. Hydrotreating catalysts are those containing at least one Group VIB and at least one Group VIII metal supported on a refractory metal oxide. The Group VIB metal is preferably molybdenum or tungsten and the Group VIII metal is preferably a non-noble metal such as cobalt or nickel.

[0073] The hydrofinishing zone may be preceded by or followed by a dewaxing zone. The dewaxing may be either catalytic or solvent. Solvent dewaxing may be accomplished by using a solvent and chilling to crystallize and separate wax molecules. Typical solvents include propane and ketones. Preferred ketones include methyl ethyl ketone, methyl isobutyl ketone and mixtures thereof. Catalytic

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dewaxing may be accomplished using an 8, 10 or 12 ring molecular sieve. Preferred molecular sieves include zeolites and silicoaluminophosphates (SAPOs). 10 ring molecular sieves are preferred including at least one of ZSM-5, ZSM-22, ZSM-23, ZSM-35, ZSM-48 ZSM-57, SAPO-11, and SAPO-41.

[0074] The hydrocarbon feedstocks which are typically subjected to hydroconversion herein will typically boil at a temperature above 150°C. The feedstocks can contain a substantial amount of nitrogen, e.g. at least 10 wppm nitrogen, and even greater than 500 wppm, in the form of organic nitrogen compounds. The feeds can also have a significant sulfur content, ranging from about 0.1 wt. % to 3 wt. %, or higher. If desired, the feeds can be treated in a known or conventional manner to reduce the sulfur and/or nitrogen content thereof.

[0075] For purposes of the present disclosure where it is desirable to produce a lube basestock the feed can be a wide variety of wax-containing feedstocks including feeds derived from crude oils, shale oils and tar sands as well as synthetic feeds such as those derived from the Fischer-Tropsch process. Typical wax-containing feedstocks for the preparation of lubricating base oils have initial boiling points of about 315°C or higher, and include feeds such as reduced crudes, hydrocrackates, raffinates, hydrotreated oils, atmospheric gas oils, vacuum gas oils, coker gas oils, atmospheric and vacuum resids, deasphalted oils, slack waxes and Fischer-Tropsch wax. The feed is preferably a mixture of gas oil from a coker and vacuum distillation from conventional crudes with a maximum boiling point of the coker gas oil not to exceed 1050°F. Such feeds may be derived from distillation towers (atmospheric and vacuum), hydrocrackers, hydrotreaters and solvent extraction units, and may have wax contents of up to 50% or more.

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[0076] Hydroprocessing of the present disclosure also includes slurry and ebullating bed hydrotreating processes for the removal of sulfur and nitrogen compounds and the hydrogenation of aromatic molecules present in light fossil fuels such as petroleum mid-distillates. Hydrotreating processes utilizing a slurry of dispersed catalysts in admixture with a hydrocarbon oil are generally known. For example, U.S. Pat. No. 4,557,821 to Lopez et al discloses hydrotreating a heavy oil employing a circulating slurry catalyst. Other patents disclosing slurry hydrotreating include U.S. Pat. Nos. 3,297,563; 2,912,375; and 2,700,015. The slurry hydroprocessing process of this disclosure can be used to treat various feeds including mid-distillates from fossil fuels such as light catalytic cycle cracking oils (LCCO). Distillates derived from petroleum, coal, bitumen, tar sands, or shale oil are likewise suitable feeds. On the other hand, the present process is not useful for treating heavy catalytic cracking cycle oils (HCCO), coker gas oils, vacuum gas oils (VGO) and heavier resids, which contain several percent 3+ ring aromatics, particularly large asphaltenic molecules. When treating heavier resids, excess catalyst sites are not obtainable, and reactivation of the catalyst by high temperature denitrogenation is not feasible.

[0077] The present disclosure can also be used to produce white oils. White mineral oils, called white oils, are colorless, transparent, oily liquids obtained by the refining of crude petroleum feedstocks. In the production of white oils, an appropriate petroleum feedstock is refined to eliminate, as completely as possible, oxygen, nitrogen, and sulfur compounds, reactive hydrocarbons including aromatics, and any other impurity which would prevent use of the resulting white oil in the pharmaceutical or food industry.

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[0078] In still other aspects, a catalyst derived from a suitable precursor can be used for hydrofining of hydrocarbon and/or hydrocarbonaceous feedstocks to The hydrocarbon feedstocks which are typically subjected to hydrofining herein will typically boil at a temperature above 150 C. Examples of hydrocarbon feedstocks are those derived from at least one of thermal treatment, catalytic treatment, solvent extraction, dewaxing or fractionation of a petroleum crude or fraction thereof, shale oil, tar sand or synthetic crude. Preferred feeds are waxy or dewaxed vacuum gas oil distillates, waxy or dewaxed hydrotreated or hydrocracked vacuum gas oil distillates, waxy or dewaxed solvent extracted raffinates and waxes boiling above 315°C.

[0079] The hydrocarbon feedstocks are typically subjected to hydrofining to remove nitrogen- and sulfur-containing compounds as well as remove other contaminants such as those which cause unfavorable color and stability properties as well as any solvents remaining in the feedstock from prior solvent extraction steps. Hydrofining conditions include temperatures of from 200 to 400°C, hydrogen pressures of from 150 to 3500 psig (1136 to 24234 kPa), liquid hourly space velocities of from 0.5 to 5 and hydrogen treat gas rates of from 100 to 5000 scf/B (17.8 to 890 m³/m³).

[0080] The hydrofining catalyst may also contain, in addition to the catalyst derived from a suitable precursor, from 5 to 95 wt. %, based on hydrofining catalyst, of a non-bulk metal, hydrotreating catalyst containing at least one Group VIB and at least one non-noble metal Group VIII metal on a refractory oxide support. The preferred hydrotreating catalyst comprises at least one of molybdenum and tungsten and at least one of cobalt and nickel on a metal oxide support such as silica, alumina and silica-alumina. The hydrofining catalyst may contain mixtures of

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the catalyst derived from a suitable precursor and hydrotreating catalyst. Alternatively, the catalyst derived from a suitable precursor and hydrotreating catalyst may be in separate beds, either in a single reactor or in separate reactors.

[0081] For purposes of the present disclosure where it is desirable to produce a lube basestock the feed can be a wide variety of wax-containing feedstocks including feeds derived from crude oils, shale oils and tar sands as well as synthetic feeds such as those derived from the Fischer-Tropsch process. Typical wax-containing feedstocks for the preparation of lubricating base oils have initial boiling points of about 315°C or higher, and include feeds such as reduced crudes, hydrocrackates, raffinates, hydrotreated oils, atmospheric gas oils, vacuum gas oils, coker gas oils, atmospheric and vacuum residua, deasphalted oils, slack waxes and Fischer-Tropsch wax. The feed is preferably a mixture of gas oil from a coker and vacuum distillation from conventional crudes with a maximum boiling point of the coker gas oil not to exceed 1050°F. Such feeds may be derived from distillation towers (atmospheric and vacuum), hydrocrackers, hydrotreaters and solvent extraction units, and may have wax contents of up to 50% or more.

[0082] In yet other aspects, a catalyst derived from a suitable precursor can be used for hydrocracking of a feed as part of a process for producing a lubricant oil basestock. A wide range of petroleum and chemical feedstocks can be hydroprocessed in accordance with the present disclosure. Suitable feedstocks range from the relatively light distillate fractions up to high boiling stocks such as whole crude petroleum, reduced crudes, vacuum tower residua, propane deasphalted residua, e.g., brightstock, cycle oils, FCC tower bottoms, gas oils including coker gas oils and vacuum gas oils, deasphalted residua and other heavy oils. The feedstock will normally be a C.sub.10+ feedstock, since light oils will usually be

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free of significant quantities of waxy components. However, the process is also particularly useful with waxy distillate stocks, such as gas oils, kerosenes, jet fuels, lubricating oil stocks, heating oils, hydrotreated oil stock, furfural-extracted lubricating oil stock and other distillate fractions whose pour point and viscosity properties need to be maintained within certain specification limits. Lubricating oil stocks, for example, will generally boil above 230°C and more usually above 315°C. For purposes of this disclosure, lubricating oil or lube oil is that part of the hydrocarbon feedstock having a boiling point of at least 315°C, as determined by ASTM D-1160 test method.

[0083] The hydrocarbon feedstocks which are typically subjected to hydrocracking herein will typically boil at a temperature above 150°C. The feedstocks can contain a substantial amount of nitrogen, e.g. at least 10 wppm nitrogen, and even greater than 500 wppm, in the form of organic nitrogen compounds. The feeds can also have a significant sulfur content, ranging from about 0.1 wt. % to 3 wt. %, or higher. If desired, the feeds can be treated in a known or conventional manner to reduce the sulfur and/or nitrogen content thereof. Examples of hydrocarbon feedstocks are those derived from at least one of thermal treatment, catalytic treatment, extraction, dewaxing or fractionation of a petroleum crude or fraction thereof, shale oil, tar sands or synthetic crude. For purposes of the present disclosure where it is desirable to produce a lube basestock the feed can be a wide variety of wax-containing feedstocks including feeds derived from crude oils, shale oils and tar sands as well as synthetic feeds such as those derived from the Fischer-Tropsch process. Typical wax-containing feedstocks for the preparation of lubricating base oils have initial boiling points of about 315°C or higher, and include feeds such as reduced crudes, hydrocrackates, raffinates, hydrotreated oils, atmospheric gas oils, vacuum gas oils, coker gas oils, atmospheric and vacuum

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resids, deasphalted oils, slack waxes and Fischer-Tropsch wax. Such feeds may be derived from distillation towers (atmospheric and vacuum), hydrocrackers, hydrotreaters and solvent extraction units, and may have wax contents of up to 50% or more.

[0084] As an example, a feedstock can be subjected to hydrocracking in a first zone in the presence of the catalyst derived from a suitable precursor. Hydrocracking conditions include temperatures of from 300 to 480°C, hydrogen pressures of from 1000 to 3500 psig (6995 to 24234 KPa), liquid hourly space velocities of from 0.2 to 4.0 and hydrogen treat gas rates of from 1000 to 15000 scf/B (178 to 2670 m³/m³). The product from the first hydrocracking zone may be fractionated to isolate a lubricating oil fraction.

[0085] The product, i.e., hydrocrackate, from the first hydrocracking zone may be further hydrocracked in a second hydrocracking zone. The hydrocracking conditions in the second hydrocracking zone are the same as those in the first hydrocracking zone. The hydrocracking catalyst in the second hydrocracking zone may be the catalyst derived from a suitable precursor of the first hydrocracking zone, crystalline or amorphous metal oxides or mixtures thereof. Preferred crystalline metal oxides are molecular sieves including zeolites and silicoaluminophosphates. Preferred zeolites include zeolite X and Y which may be supported on a refractory metal oxide. Preferred amorphous metal oxides include silica-alumina.

[0086] The hydrocrackate from either the first or second hydrocracking zones may be further processed by fractionation to obtain a distillate lubricating oil fraction. This distillate fraction may then be solvent extracted with conventional

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solvents such as furfural, phenol or N-methyl-2-pyrrolidone (NMP) under solvent extraction conditions. Raffinate from solvent extraction may then be further processed by a combination of dewaxing and/or hydrofinishing. Dewaxing may be by solvent or catalytic dewaxing. Preferred solvent dewaxing utilizes conventional solvents including ketones such as methyl ethyl ketone, methyl isobutyl ketone or mixtures thereof. Catalytic dewaxing is by 8, 10 or 12 ring molecular sieves, preferably 10 ring molecular sieves under catalytic dewaxing conditions. Preferred 10 ring molecular sieves are zeolites or SAPOs. Preferred zeolites include ZSM-5, ZSM-22, ZSM-23, ZSM-35, ZSM-48 and ZSM-57. Preferred SAPOs include SAPO-11 and SAPO-41. In the alternative, the distillate fraction may be catalytically dewaxed without an intervening solvent extraction step.

[0087] The solvent or catalytically dewaxed product may then be hydrofinished in a hydrofinishing zone under hydrofinishing conditions. Hydrofinishing conditions include a temperature of from 200°C to 370°C, pressure of from 150 to 3000 psig (1136 to 20786 kPa), liquid hourly space velocity of from 0.2 to 5.0 hr⁻¹, and a hydrogen treat rate of from 100 to 5000 scf/B (17.8 to 890 m³/m³). Hydrofinishing catalysts may be the bulk metal catalyst used in the hydrocracking zone or may be conventional hydrofinishing catalysts such as those containing at least one Group VIII metal on a refractory metal oxide support which may be promoted. The Group VIII metal may be combined with a Group VIB metal. If the Group VIII metal is a non-noble metal, it is preferably combined with a Group VIB metal.

[0088] Products from a process according to this type of aspect can include Group II and Group III lubricating oil basestocks. Group II basestocks have a saturates content of at least 90%, a sulfur content less than 0.03 wt. % and a VI less

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than 120. Group III basestocks have a saturates content of at least 90%, a sulfur content less than 0.03 wt. % and a VI greater than 120.

Multimetallic Catalyst and Forming Multimetallic Catalyst from a Precursor

[0089] As used herein, the term "bulk", when describing a mixed metal oxide catalyst composition, indicates that the catalyst composition is self-supporting in that it does not require a carrier or support. It is well understood that bulk catalysts may have some minor amount of carrier or support material in their compositions (e.g., about 20 wt % or less, about 15 wt % or less, about 10 wt % or less, about 5 wt % or less, or substantially no carrier or support, based on the total weight of the catalyst composition); for instance, bulk hydroprocessing catalysts may contain a minor amount of a binder, e.g., to improve the physical and/or thermal properties of the catalyst. In contrast, heterogeneous or supported catalyst systems typically comprise a carrier or support onto which one or more catalytically active materials are deposited, often using an impregnation or coating technique. Nevertheless, heterogeneous catalyst systems without a carrier or support (or with a minor amount of carrier or support) are generally referred to as bulk catalysts and are frequently formed by co-precipitation or solid-solid reactions in slurries.

[0090] In some aspects, the methods described herein can include use of a catalyst formed from a catalyst precursor composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (i) a first organic compound containing at least one amine group and at least 10 carbons or (ii) a second organic compound containing at least one carboxylic acid group and at least 10 carbons, but not both (i) and (ii), wherein the reaction product contains additional unsaturated carbon atoms, relative to (i) the first organic compound or

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(ii) the second organic compound, wherein the metals of the catalyst precursor composition are arranged in a crystal lattice, and wherein the reaction product is not located within the crystal lattice. This catalyst precursor composition can be a bulk metal catalyst precursor composition or a supported metal catalyst precursor composition. When it is a bulk mixed metal catalyst precursor composition, the reaction product can be obtained by heating the composition (though specifically the amine-containing compound or the carboxylic acid-containing compound) to a temperature from about 195°C to about 260°C for a time sufficient for the first or second organic compounds to react to form additional in situ unsaturated carbon atoms and/or become more oxidized than the first or second organic compounds, but not for so long that more than 50% by weight of the first or second organic compound is volatilized, thereby forming a catalyst precursor composition that contains in situ formed unsaturated carbon atoms and/or that is further oxidized.

[0091] Other aspects can relate to using a catalyst formed from a catalyst precursor composition containing in situ formed unsaturated carbon atoms. The catalyst can be formed from the precursor by a process comprising: (a) treating a catalyst precursor composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, with a first organic compound containing at least one amine group and at least 10 carbon atoms or a second organic compound containing at least one carboxylic acid group and at least 10 carbon atoms, to form an organically treated precursor catalyst composition; and (b) heating said organically treated precursor catalyst composition at a temperature from about 195°C to about 260°C for a time sufficient for the first or second organic compounds to react to form additional in situ unsaturated carbon atoms and/or become more oxidized, but not for so long that more than 50% by weight of the first or second organic compound

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is volatilized, thereby forming a catalyst precursor composition that contains in situ formed unsaturated carbon atoms and/or that is further oxidized. This process can be used to make a bulk metal catalyst precursor composition or a supported metal catalyst precursor composition. When used to make a bulk mixed metal catalyst precursor composition, the catalyst precursor composition containing in situ formed unsaturated carbon atoms can, in one embodiment, consist essentially of the reaction product, an oxide form of the at least one metal from Group 6, an oxide form of the at least one metal from Groups 8-10, and optionally about 20 wt % or less of a binder.

[0092] As an example, when the catalyst precursor is a bulk mixed metal catalyst precursor composition, the reaction product can be obtained by heating the composition (though specifically the first or second organic compounds, or the amine-containing or carboxylic acid-containing compound) to a temperature from about 195°C to about 260°C for a time sufficient to effectuate a dehydrogenation, and/or an at least partial decomposition, of the first or second organic compound to form an additional unsaturation and/or additional oxidation in the reaction product in situ. Accordingly, a bulk mixed metal hydroprocessing catalyst composition can be produced from this bulk mixed metal catalyst precursor composition by sulfiding it under sufficient sulfiding conditions, which sulfiding should begin in the presence of the in situ additionally unsaturated reaction product (which may result from at least partial decomposition, e.g., via oxidative dehydrogenation in the presence of oxygen and/or via non-oxidative dehydrogenation in the absence of an appropriate concentration of oxygen, of typically-unfunctionalized organic portions of the first or second organic compounds, e.g., of an aliphatic portion of an organic compound and/or through conjugation/aromatization of unsaturations expanding upon an unsaturated portion of an organic compound).

[0093] In still other aspects, a feed can be processed in a reaction system that includes a catalyst formed from a catalyst precursor composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (i) a first organic compound containing at least one amine group, and (ii) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group. When this reaction product is an amide, the presence of the reaction product in any intermediate or final composition can be determined by methods well known in the art, e.g., by infrared spectroscopy (FTIR) techniques. When this reaction product contains additional unsaturation(s) not present in the first and second organic compounds, e.g., from at least partial decomposition/dehydrogenation at conditions including elevated temperatures, the presence of the additional unsaturation(s) in any intermediate or final composition can be determined by methods well known in the art, e.g., by FTIR and/or nuclear magnetic resonance (^{13}C NMR) techniques. This catalyst precursor composition can be a bulk metal catalyst precursor composition or a heterogeneous (supported) metal catalyst precursor composition.

[0094] More broadly, this type of aspect relates to use of a catalyst formed from a catalyst precursor composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a condensation reaction product formed from (i) a first organic compound containing at least one first functional group, and (ii) a second organic compound separate from said first organic compound and containing at least one second functional group, wherein said first functional group and said second functional group are capable of undergoing a condensation reaction

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and/or a (decomposition) reaction causing an additional unsaturation to form an associated product. Though the description above and herein often refers specifically to the condensation reaction product being an amide, it should be understood that any in situ condensation reaction product formed can be substituted for the amide described herein. For example, if the first functional group is a hydroxyl group and the second functional group is a carboxylic acid or an acid chloride or an organic ester capable of undergoing transesterification with the hydroxyl group, then the in situ condensation reaction product formed would be an ester.

[0095] As an example, when the catalyst precursor is a bulk mixed metal catalyst precursor composition, the reaction product can be obtained by heating the composition (such as the condensation reactants, or the amine-containing compound and/or the carboxylic acid-containing compound) to a temperature from about 195°C to about 260°C for a time sufficient for the first and second organic compounds to form a condensation product, such as an amide, and/or an additional (decomposition) unsaturation in situ. Accordingly, a bulk mixed metal hydroprocessing catalyst composition can be produced from this bulk mixed metal catalyst precursor composition by sulfiding it under sufficient sulfiding conditions, which sulfiding should begin in the presence of the in situ product, e.g., the amide (i.e., when present, the condensation product moiety, or amide, can be substantially present and/or can preferably not be significantly decomposed by the beginning of the sulfiding step), and/or containing additional unsaturations (which may result from at least partial decomposition, e.g., via oxidative dehydrogenation in the presence of oxygen and/or via non-oxidative dehydrogenation in the absence of an appropriate concentration of oxygen, of typically-unfunctionalized organic portions of the first and/or second organic compounds, e.g., of an aliphatic portion of an

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organic compound and/or through conjugation/aromatization of unsaturations expanding upon an unsaturated portion of an organic compound or stemming from an interaction of the first and second organic compounds at a site other than their respective functional groups).

[0096] In yet other aspects, a feed can be processed using a catalyst formed from a catalyst precursor composition containing an ex-situ formed reaction product. The catalyst can be formed from the precursor by a process comprising: (a) treating a catalyst precursor composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, with an amide-containing reaction product formed from a first organic compound containing at least one amine group and at least 10 carbon atoms or a second organic compound containing at least one carboxylic acid group and at least 10 carbon atoms, to form an organically treated precursor catalyst composition; and (b) heating said organically treated precursor catalyst composition at a temperature from about 195°C to about 260°C for a time sufficient for the amide-containing reaction product to form additional in situ unsaturated carbon atoms and/or become more oxidized, but not for so long that more than 50% by weight of the first or second organic compound is volatilized, thereby forming a catalyst precursor composition that contains in situ formed unsaturated carbon atoms and/or that is further oxidized. This process can be used to make a bulk metal catalyst precursor composition or a supported metal catalyst precursor composition. When used to make a bulk mixed metal catalyst precursor composition, the catalyst precursor composition can, in one embodiment, consist essentially of the reaction product containing further unsaturated carbon atoms and/or further oxidation, an oxide form of the at least one metal from Group 6, an

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oxide form of the at least one metal from Groups 8-10, and optionally about 20 wt % or less of a binder.

[0097] When the catalyst precursor is a bulk mixed metal catalyst precursor composition, the thermal treatment of the amide-impregnated metal oxide component is carried out by heating the impregnated composition to a temperature and for a time which does not result in gross decomposition of the amide, although additional unsaturation may arise from partial *in situ* decomposition; the temperature is typically from about 195°C to about 250°C (or optionally about 195°C to about 260°C), but higher temperatures, e.g. in the range of 250 to 280°C, can be used in order to abbreviate the duration of the heating although due care is required to avoid the gross decomposition of the pre-formed amide, as discussed further below. The bulk mixed metal hydroprocessing catalyst can be produced from this precursor by sulfiding it with the sulfiding taking place with the amide present on the metal oxide component (*i.e.*, when the thermally treated amide, is substantially present and/or preferably not significantly decomposed by the beginning of the sulfiding step). Additional unsaturation may be present in the organic component of the catalyst precursor resulting from a variety of mechanisms including partial decomposition, (*e.g.*, via oxidative dehydrogenation in the presence of oxygen and/or via non-oxidative dehydrogenation in the absence of an appropriate concentration of oxygen), of typically-unfunctionalized organic portions of the amide and/or through conjugation/aromatization of unsaturations expanding upon an unsaturated portion the amide. The treated organic component may also contain additional oxygen in addition to the unsaturation when the treatment is carried out in an oxidizing atmosphere.

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[0098] Catalyst precursor compositions and hydroprocessing catalyst compositions useful in various aspects of the present disclosure can advantageously comprise (or can have metal components that consist essentially of) at least one metal from Group 6 of the Periodic Table of Elements and at least one metal from Groups 8-10 of the Periodic Table of Elements, and optionally at least one metal from Group 5 of the Periodic Table of Elements. Generally, these metals are present in their substantially fully oxidized form, which can typically take the form of simple metal oxides, but which may be present in a variety of other oxide forms, e.g., such as hydroxides, oxyhydroxides, oxycarbonates, carbonates, oxynitrates, oxysulfates, or the like, or some combination thereof. In one preferred embodiment, the Group 6 metal(s) can be Mo and/or W, and the Group 8-10 metal(s) can be Co and/or Ni. Generally, the atomic ratio of the Group 6 metal(s) to the metal(s) of Groups 8-10 can be from about 2:1 to about 1:3, for example from about 5:4 to about 1:2, from about 5:4 to about 2:3, from about 5:4 to about 3:4, from about 10:9 to about 1:2, from about 10:9 to about 2:3, from about 10:9 to about 3:4, from about 20:19 to about 2:3, or from about 20:19 to about 3:4. When the composition further comprises at least one metal from Group 5, that at least one metal can be V and/or Nb. When present, the amount of Group 5 metal(s) can be such that the atomic ratio of the Group 6 metal(s) to the Group 5 metal(s) can be from about 99:1 to about 1:1, for example from about 99:1 to about 5:1, from about 99:1 to about 10:1, or from about 99:1 to about 20:1. Additionally or alternately, when Group 5 metal(s) is(are) present, the atomic ratio of the sum of the Group 5 metal(s) plus the Group (6) metal(s) compared to the metal(s) of Groups 8-10 can be from about 2:1 to about 1:3, for example from about 5:4 to about 1:2, from about 5:4 to about 2:3, from about 5:4 to about 3:4, from about 10:9 to about 1:2, from about 10:9 to about 2:3, from about 10:9 to about 3:4, from about 20:19 to about 2:3, or from about 20:19 to about 3:4.

[0099] The metals in the catalyst precursor compositions and in the hydroprocessing catalyst compositions according to the disclosure can be present in any suitable form prior to sulfiding, but can often be provided as metal oxides. When provided as bulk mixed metal oxides, such bulk oxide components of the catalyst precursor compositions and of the hydroprocessing catalyst compositions according to the disclosure can be prepared by any suitable method known in the art, but can generally be produced by forming a slurry, typically an aqueous slurry, comprising (1) (a) an oxyanion of the Group 6 metal(s), such as a tungstate and/or a molybdate, or (b) an insoluble (oxide, acid) form of the Group 6 metal(s), such as tungstic acid and/or molybdenum trioxide, (2) a salt of the Group 8-10 metal(s), such as nickel carbonate, and optionally, when present, (3) (a) a salt or oxyanion of a Group 5 metal, such as a vanadate and/or a niobate, or (b) insoluble (oxide, acid) form of a Group 5 metal, such as niobic acid and/or diniobium pentoxide. The slurry can be heated to a suitable temperature, such as from about 60°C to about 150°C, at a suitable pressure, e.g., at atmospheric or autogenous pressure, for an appropriate time, e.g., about 4 hours to about 24 hours.

[00100] Non-limiting examples of suitable mixed metal oxide compositions can include, but are not limited to, nickel-tungsten oxides, cobalt-tungsten oxides, nickel-molybdenum oxides, cobalt-molybdenum oxides, nickel-molybdenum-tungsten oxides, cobalt-molybdenum-tungsten oxides, cobalt-nickel-tungsten oxides, cobalt-nickel-molybdenum oxides, cobalt-nickel-tungsten-molybdenum oxides, nickel-tungsten-niobium oxides, nickel-tungsten-vanadium oxides, cobalt-tungsten-vanadium oxides, cobalt-tungsten-niobium oxides, nickel-molybdenum-niobium oxides, nickel-molybdenum-vanadium oxides, nickel-molybdenum-

tungsten-niobium oxides, nickel-molybdenum-tungsten-vanadium oxides, and the like, and combinations thereof.

[00101] Suitable mixed metal oxide compositions can advantageously exhibit a specific surface area (as measured via the nitrogen BET method using a Quantachrome Autosorb.TM. apparatus) of at least about 20 m²/g, for example at least about 30 m²/g, at least about 40 m²/g, at least about 50 m²/g, at least about 60 m²/g, at least about 70 m²/g, or at least about 80 m²/g. Additionally or alternately, the mixed metal oxide compositions can exhibit a specific surface area of not more than about 500 m²/g, for example not more than about 400 m²/g, not more than about 300 m²/g, not more than about 250 m²/g, not more than about 200 m²/g, not more than about 175 m²/g, not more than about 150 m²/g, not more than about 125 m²/g, or not more than about 100 m²/g.

[00102] In some aspects, after separating and drying the mixed metal oxide (slurry) composition, it can be treated, generally by impregnation, with (i) an effective amount of a first organic compound containing at least one amine group or (ii) an effective amount of a second organic compound separate from the first organic compound and containing at least one carboxylic acid group, but not both (i) and (ii).

[00103] In other aspects, after separating and drying the mixed metal oxide (slurry) composition, it can be treated, generally by impregnation, with (i) an effective amount of a first organic compound containing at least one amine group, and (ii) an effective amount of a second organic compound separate from the first organic compound and containing at least one carboxylic acid group.

[00104] In still other aspects, after separating and drying the mixed metal oxide (slurry) composition, it can be treated, generally by impregnation, with the pre-formed amide derived from (i) an effective amount of a first organic compound containing at least one amine group, and (ii) an effective amount of a second organic compound separate from the first organic compound and containing at least one carboxylic acid group. The amide is formed by a condensation reaction between the amine reactant and the carboxylic acid reactant; this reaction, carried out ex situ, is usually accomplished at mildly elevated temperatures.

[00105] In aspects where either a first or second organic compound is used, the first organic compound can comprise at least 10 carbon atoms, for example can comprise from 10 to 20 carbon atoms or can comprise a primary monoamine having from 10 to 30 carbon atoms. Additionally or alternately, the second organic compound can comprise at least 10 carbon atoms, for example can comprise from 10 to 20 carbon atoms or can comprise only one carboxylic acid group and can have from 10 to 30 carbon atoms.

[00106] In other aspects where both a first and second organic compound are used (including aspects where a first and second organic compound are reacted ex situ to form an amide), the first organic compound can comprise at least 10 carbon atoms, for example can comprise from 10 to 20 carbon atoms or can comprise a primary monoamine having from 10 to 30 carbon atoms. Additionally or alternately, the second organic compound can comprise at least 10 carbon atoms, for example can comprise from 10 to 20 carbon atoms or can comprise only one carboxylic acid group and can have from 10 to 30 carbon atoms. Further additionally or alternately, the total number of carbon atoms comprised among both the first and second organic compounds can be at least 15 carbon atoms, for

example at least 20 carbon atoms, at least 25 carbon atoms, at least 30 carbon atoms, or at least 35 carbon atoms. Although in such embodiments there may be no practical upper limit on total carbon atoms from both organic compounds, in some embodiments, the total number of carbon atoms comprised among both the first and second organic compounds can be 100 carbon atoms or less, for example 80 carbon atoms or less, 70 carbon atoms or less, 60 carbon atoms or less, or 50 carbon atoms or less.

[00107] Representative examples of organic compounds containing amine groups can include, but are not limited to, primary and/or secondary, linear, branched, and/or cyclic amines, such as triacontaniline, octacosaniline, hexacosaniline, tetracosaniline, docosaniline, erucaniline, eicosaniline, octadecaniline, oleylaniline, linoleylaniline, hexadecaniline, sapienylaniline, palmitoleylaniline, tetradecaniline, myristoleylaniline, dodecaniline, decylaniline, nonylaniline, cyclooctaniline, octylaniline, cycloheptaniline, heptylaniline, cyclohexylaniline, n-hexylaniline, isopentylaniline, n-pentylaniline, t-butylaniline, n-butaniline, isopropylaniline, n-propylaniline, adamantaniline, adamantanemethylaniline, pyrrolidine, piperidine, piperazine, imidazole, pyrazole, pyrrole, pyrrolidine, pyrroline, indazole, indole, carbazole, norbornylaniline, aniline, pyridylaniline, benzylaniline, aminotoluene, alanine, arginine, aspartic acid, glutamic acid, glutamine, glycine, histidine, isoleucine, leucine, lysine, phenylalanine, serine, threonine, valine, 1-amino-2-propanol, 2-amino-1-propanol, diaminoeicosane, diaminooctadecane, diaminohexadecane, diaminotetradecane, diaminododecane, diaminodecane, 1,2-diaminocyclohexane, 1,3-diaminocyclohexane, 1,4-diaminocyclohexane, ethylenediamine, ethanolamine, p-phenylenediamine, o-phenylenediamine, m-phenylenediamine, 1,2-propylenediamine, 1,3-propylenediamine, 1,4-diaminobutane, 1,3-diamino-2-

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propanol, and the like, and combinations thereof. In an embodiment, the molar ratio of the Group 6 metal(s) in the composition to the first organic compound during treatment can be from about 1:1 to about 20:1.

[00108] Additionally or alternately, in some aspects the amine portion of the first organic compound can be a part of a larger functional group in that compound, so long as the amine portion (notably the amine nitrogen and the constituents attached thereto) retains its operability as a Lewis base. For instance, the first organic compound can comprise a urea, which functional group comprises an amine portion attached to the carbonyl portion of an amide group. In such an instance, the urea can be considered functionally as an "amine-containing" functional group for the purposes of the present disclosure herein, except in situations where such inclusion is specifically contradicted. Aside from ureas, other examples of such amine-containing functional groups that may be suitable for satisfying the at least one amine group in the first organic compound can generally include, but are not limited to, hydrazides, sulfonamides, and the like, and combinations thereof.

[00109] The amine functional group from the first organic compound can include primary or secondary amines, as mentioned above, but generally does not include quaternary amines, and in some instances does not include tertiary amines either. Furthermore, the first organic compound can optionally contain other functional groups besides amines. For instance, the first organic compound can comprise an aminoacid, which possesses an amine functional group and a carboxylic acid functional group simultaneously. Aside from carboxylic acids, other examples of such secondary functional groups in amine-containing organic compounds can generally include, but are not limited to, hydroxyls, aldehydes,

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anhydrides, ethers, esters, imines, imides, ketones, thiols (mercaptans), thioesters, and the like, and combinations thereof.

[00110] Additionally or alternately, in other aspects involving formation of a condensation product (including aspects involving ex situ formation of an amide), the amine functional group from the first organic compound can include primary or secondary amines, as mentioned above, but generally does not include tertiary or quaternary amines, as tertiary and quaternary amines tend not to be able to form amides. Furthermore, the first organic compound can contain other functional groups besides amines, whether or not they are capable of participating in forming an amide or other condensation reaction product with one or more of the functional groups from second organic compound. For instance, the first organic compound can comprise an aminoacid, which possesses an amine functional group and a carboxylic acid functional group simultaneously. In such an instance, the aminoacid would qualify as only one of the organic compounds, and not both; thus, in such an instance, either an additional amine-containing (first) organic compound would need to be present (in the circumstance where the aminoacid would be considered the second organic compound) or an additional carboxylic acid-containing (second) organic compound would need to be present (in the circumstance where the aminoacid would be considered the first organic compound). Aside from carboxylic acids, other examples of such secondary functional groups in amine-containing organic compounds can generally include, but are not limited to, hydroxyls, aldehydes, anhydrides, ethers, esters, imines, imides, ketones, thiols (mercaptans), thioesters, and the like, and combinations thereof.

[00111] Additionally or alternately, the amine portion of the first organic compound can be a part of a larger functional group in that compound, so long as

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the amine portion (notably the amine nitrogen and the constituents attached thereto) retains the capability of participating in forming an amide or other condensation reaction product with one or more of the functional groups from second organic compound. For instance, the first organic compound can comprise a urea, which functional group comprises an amine portion attached to the carbonyl portion of an amide group. In such an instance, provided the amine portion of the urea functional group of the first organic compound would still be able to undergo a condensation reaction with the carboxylic acid functional group of the second organic compound, then the urea can be considered functionally as an "amine-containing" functional group for the purposes of the present disclosure herein, except in situations where such inclusion is specifically contradicted. Aside from ureas, other examples of such amine-containing functional groups that may be suitable for satisfying the at least one amine group in the first organic compound can generally include, but are not limited to, hydrazides, sulfonamides, and the like, and combinations thereof.

[00112] Representative examples of organic compounds containing carboxylic acids can include, but are not limited to, primary and/or secondary, linear, branched, and/or cyclic amines, such as triacontanoic acid, octacosanoic acid, hexacosanoic acid, tetracosanoic acid, docosanoic acid, erucic acid, docosahexanoic acid, eicosanoic acid, eicosapentanoic acid, arachidonic acid, octadecanoic acid, oleic acid, elaidic acid, stearidonic acid, linoleic acid, alpha-linolenic acid, hexadecanoic acid, sapienic acid, palmitoleic acid, tetradecanoic acid, myristoleic acid, dodecanoic acid, decanoic acid, nonanoic acid, cyclooctanoic acid, octanoic acid, cycloheptanoic acid, heptanoic acid, cyclohexanoic acid, hexanoic acid, adamantanecarboxylic acid, norbornaneacetic acid, benzoic acid, salicylic acid, acetylsalicylic acid, citric acid, maleic acid, malonic acid, glutaric acid, lactic acid, oxalic acid, tartaric acid, cinnamic acid, vanillic acid, succinic acid, adipic acid,

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phthalic acid, isophthalic acid, terephthalic acid, ethylenediaminetetracarboxylic acids (such as EDTA), fumaric acid, alanine, arginine, aspartic acid, glutamic acid, glutamine, glycine, histidine, isoleucine, leucine, lysine, phenylalanine, serine, threonine, valine, 1,2-cyclohexanedicarboxylic acid, 1,3-cyclohexanedicarboxylic acid, 1,4-cyclohexanedicarboxylic acid, and the like, and combinations thereof. In an embodiment, the molar ratio of the Group 6 metal(s) in the composition to the second organic compound during treatment can be from about 3:1 to about 20:1.

[00113] In some aspects, the second organic compound can optionally contain other functional groups besides carboxylic acids. For instance, the second organic compound can comprise an aminoacid, which possesses a carboxylic acid functional group and an amine functional group simultaneously. Aside from amines, other examples of such secondary functional groups in carboxylic acid-containing organic compounds can generally include, but are not limited to, hydroxyls, aldehydes, anhydrides, ethers, esters, imines, imides, ketones, thiols (mercaptans), thioesters, and the like, and combinations thereof. In some embodiments, the second organic compound can contain no additional amine or alcohol functional groups in addition to the carboxylic acid functional group(s).

[00114] Additionally or alternately, the reactive portion of the second organic compound can be a part of a larger functional group in that compound and/or can be a derivative of a carboxylic acid that behaves similarly enough to a carboxylic acid, such that the reactive portion and/or derivative retains its operability as a Lewis acid. One example of a carboxylic acid derivative can include an alkyl carboxylate ester, where the alkyl group does not substantially hinder (over a reasonable time scale) the Lewis acid functionality of the carboxylate portion of the functional group.

[00115] In other aspects involving formation of a condensation product (including aspects involving ex situ formation of an amide), the second organic compound can contain other functional groups besides carboxylic acids, whether or not they are capable of participating in forming an amide or other condensation reaction product with one or more of the functional groups from first organic compound. For instance, the second organic compound can comprise an aminoacid, which possesses a carboxylic acid functional group and an amine functional group simultaneously. In such an instance, the aminoacid would qualify as only one of the organic compounds, and not both; thus, in such an instance, either an additional amine-containing (first) organic compound would need to be present (in the circumstance where the aminoacid would be considered the second organic compound) or an additional carboxylic acid-containing (second) organic compound would need to be present (in the circumstance where the aminoacid would be considered the first organic compound). Aside from amines, other examples of such secondary functional groups in carboxylic acid-containing organic compounds can generally include, but are not limited to, hydroxyls, aldehydes, anhydrides, ethers, esters, imines, imides, ketones, thiols (mercaptans), thioesters, and the like, and combinations thereof.

[00116] Additionally or alternately, the reactive portion of the second organic compound can be a part of a larger functional group in that compound and/or can be a derivative of a carboxylic acid that behaves similarly enough to a carboxylic acid in the presence of the amine functional group of the first organic compound, such that the reactive portion and/or derivative retains the capability of participating in forming an amide or other desired condensation reaction product with one or more of the functional groups from first organic compound. One example of a carboxylic

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acid derivative can include an alkyl carboxylate ester, where the alkyl group does not substantially hinder (over a reasonable time scale) the condensation reaction between the amine and the carboxylate portion of the ester to form an amide.

[00117] For aspects involving formation of a condensation product (including aspects involving ex situ formation of an amide), while there is not a strict limit on the ratio between the first organic compound and the second organic compound, because the goal of the addition of the first and second organic compounds is to attain a condensation reaction product, it may be desirable to have a ratio of the reactive functional groups within the first and second organic compounds, respectively, from about 1:4 to about 4:1, for example from about 1:3 to about 3:1 or from about 1:2 to about 2:1.

[00118] In certain aspects, the organic compound(s)/additive(s) and/or the reaction product(s) are not located/incorporated within the crystal lattice of the mixed metal oxide precursor composition, e.g., instead being located on the surface and/or within the pore volume of the precursor composition and/or being associated with (bound to) one or more metals or oxides of metals in a manner that does not significantly affect the crystalline lattice of the mixed metal oxide precursor composition, as observed through XRD and/or other crystallographic spectra. It is noted that, in these certain embodiments, a sulfided version of the mixed metal oxide precursor composition can still have its sulfided form affected by the organic compound(s)/additive(s) and/or the reaction product(s), even though the oxide lattice is not significantly affected.

[00119] In some aspects, one way to attain a catalyst precursor composition containing a decomposition/dehydrogenation reaction product, such as one

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containing additional unsaturations, includes: (a) treating a catalyst precursor composition, which comprises at least one metal from Group 6 of the Periodic Table of the Elements and at least one metal from Groups 8-10 of the Periodic Table of the Elements, with a first organic compound containing at least one amine group or a second organic compound separate from said first organic compound and containing at least one carboxylic acid group, but not both, to form an organically treated precursor catalyst composition; and (b) heating the organically treated precursor catalyst composition at a temperature sufficient and for a time sufficient for the first or second organic compounds to react to form an in situ product containing additional unsaturation (for example, depending upon the nature of the first or second organic compound, the temperature can be from about 195°C to about 260°C, such as from about 200°C to about 250°C), thereby forming the additionally-unsaturated and/or additionally oxidized catalyst precursor composition.

[00120] In certain advantageous embodiments, the heating step (b) above can be conducted for a sufficiently long time so as to form additional unsaturation(s), which may result from at least partial decomposition (e.g., oxidative and/or non-oxidative dehydrogenation and/or aromatization) of some (typically-unfunctionalized organic) portions of the first or second organic compounds, but generally not for so long that the at least partial decomposition volatilizes more than 50% by weight of the first or second organic compounds. Without being bound by theory, it is believed that additional unsaturation(s) formed in situ and present at the point of sulfiding the catalyst precursor composition to form a sulfided (hydroprocessing) catalyst composition can somehow assist in controlling one or more of the following: the size of sulfided crystallites; the coordination of one or more of the metals during sulfidation, such that a higher proportion of the one or

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more types of metals are in appropriate sites for promoting desired hydroprocessing reactions (such as hydrotreating, hydrodenitrogenation, hydrodesulfurization, hydrodeoxygenation, hydrodemetallation, hydrocracking including selective hydrocracking, hydroisomerization, hydrodewaxing, and the like, and combinations thereof, and/or for reducing/minimizing undesired hydroprocessing reactions, such as aromatic saturation, hydrogenation of double bonds, and the like, and combinations thereof) than for sulfided catalysts made in the absence of the in situ formed reaction product having additional unsaturation(s); and coordination/catalysis involving one or more of the metals after sulfidation, such that a higher proportion (or each) of the one or more types of metals are more efficient at promoting desired hydroprocessing reactions (e.g., because the higher proportion of metal sites can catalyze more hydrodesulfurization reactions of the same type in a given timescale and/or because the higher proportion of the metal sites can catalyze more difficult hydrodesulfurization reactions in a similar timescale) than for sulfided catalysts made in the absence of the in situ formed reaction product having additional unsaturation(s).

[00121] In other aspects, one way to attain a catalyst precursor composition containing a condensation reaction product, such as an amide, and/or a reaction product containing additional unsaturations includes: (a) treating a catalyst precursor composition, which comprises at least one metal from Group 6 of the Periodic Table of the Elements and at least one metal from Groups 8-10 of the Periodic Table of the Elements, with a first organic compound containing at least one amine group and a second organic compound separate from said first organic compound and containing at least one carboxylic acid group to form an organically treated precursor catalyst composition; and (b) heating the organically treated precursor catalyst composition at a temperature sufficient and for a time sufficient

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for the first and second organic compounds to react to form an in situ condensation product and/or an in situ product containing additional unsaturation (for amides made from amines and carboxylic acids, for example, the temperature can be from about 195°C to about 260°C, such as from about 200°C to about 250°C), thereby forming the amide-containing and/or additionally-unsaturated and/or additionally oxidized catalyst precursor composition.

[00122] Practically, the treating step (a) above can comprise one (or more) of three methods: (1) first treating the catalyst precursor composition with the first organic compound and second with the second organic compound; (2) first treating the catalyst precursor composition with the second organic compound and second with the first organic compound; and/or (3) treating the catalyst precursor composition simultaneously with the first organic compound and with the second organic compound.

[00123] In certain advantageous embodiments, the heating step (b) above can be conducted for a sufficiently long time so as to form the amide, but not for so long that the amide so formed substantially decomposes. Additionally or alternately in such advantageous embodiments, the heating step (b) above can be conducted for a sufficiently long time so as to form additional unsaturation(s), which may result from at least partial decomposition (e.g., oxidative and/or non-oxidative dehydrogenation and/or aromatization) of some (typically-unfunctionalized organic) portions of the organic compounds, but generally not for so long that the at least partial decomposition (i) substantially decomposes any condensation product, such as amide, and/or (ii) volatilizes more than 50% by weight of the combined first and second organic compounds. Without being bound by theory, it is believed that in situ formed amide and/or additional unsaturation(s) present at the point of sulfiding

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the catalyst precursor composition to form a sulfided (hydroprocessing) catalyst composition can somehow assist in controlling one or more of the following: the size of sulfided crystallites; the coordination of one or more of the metals during sulfidation, such that a higher proportion of the one or more types of metals are in appropriate sites for promoting desired hydroprocessing reactions (such as hydrotreating, hydrodenitrogenation, hydrodesulfurization, hydrodeoxygenation, hydrodemetallation, hydrocracking including selective hydrocracking, hydroisomerization, hydrodewaxing, and the like, and combinations thereof, and/or for reducing/minimizing undesired hydroprocessing reactions, such as aromatic saturation, hydrogenation of double bonds, and the like, and combinations thereof) than for sulfided catalysts made in the absence of the in situ formed reaction product having an amide (condensation reaction product of functional groups) and/or additional unsaturation(s); and coordination/catalysis involving one or more of the metals after sulfidation, such that a higher proportion (or each) of the one or more types of metals are more efficient at promoting desired hydroprocessing reactions (e.g., because the higher proportion of metal sites can catalyze more hydrodesulfurization reactions of the same type in a given timescale and/or because the higher proportion of the metal sites can catalyze more difficult hydrodesulfurization reactions in a similar timescale) than for sulfided catalysts made in the absence of the in situ formed reaction product having an amide (condensation reaction product of functional groups) and/or additional unsaturation(s).

[00124] When used to make a bulk mixed metal catalyst precursor composition, the in situ reacted catalyst precursor composition can, in one embodiment, consist essentially of the reaction product, an oxide form of the at least one metal from

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Group 6, an oxide form of the at least one metal from Groups 8-10, and optionally about 20 wt % or less of a binder (e.g., about 10 wt % or less).

[00125] After treatment of the catalyst precursor containing the at least one Group 6 metal and the at least one Group 8-10 metal with the first and/or second organic compounds, the organically treated catalyst precursor composition can be heated to a temperature high enough to form the reaction product and optionally but preferably high enough to enable any dehydrogenation/decomposition/condensation byproduct to be easily removed (e.g., in order to drive the reaction equilibrium to the at least partially dehydrogenated/decomposed product and/or condensation product). Additionally or alternately, the organically treated catalyst precursor composition can be heated to a temperature low enough so as to substantially retain the reaction product containing the additional unsaturations and/or the condensation product, so as not to significantly decompose the reaction product, and/or so as not to significantly volatilize (more than 50% by weight of) the first and/or second organic compounds (whether reacted or not).

[00126] It is contemplated that the specific lower and upper temperature limits based on the above considerations can be highly dependent upon a variety of factors that can include, but are not limited to, the atmosphere under which the heating is conducted, the chemical and/or physical properties of the first organic compound, the second organic compound, the reaction product, and/or any reaction byproduct, or a combination thereof. In one embodiment, the heating temperature can be at least about 120°C, for example at least about 150°C, at least about 165°C, at least about 175°C, at least about 185°C, at least about 195°C, at least about 200°C, at least about 210°C, at least about 220°C, at least about 230°C, at least about 240°C, or at least about 250°C. Additionally or alternately, the heating temperature can be

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not greater than about 400°C, for example not greater than about 375°C, not greater than about 350°C, not greater than about 325°C, not greater than about 300°C, not greater than about 275°C, not greater than about 250°C, not greater than about 240°C, not greater than about 230°C, not greater than about 220°C, not greater than about 210°C, or not greater than about 200°C.

[00127] In one embodiment, the heating can be conducted in a low- or non-oxidizing atmosphere (and conveniently in an inert atmosphere, such as nitrogen). In an alternate embodiment, the heating can be conducted in a moderately- or highly-oxidizing environment. In another alternate embodiment, the heating can include a multi-step process in which one or more heating steps can be conducted in the low- or non-oxidizing atmosphere, in which one or more heating steps can be conducted in the moderately- or highly-oxidizing environment, or both. Of course, the period of time for the heating in the environment can be tailored to the first or second organic compound, but can typically extend from about 5 minutes to about 168 hours, for example from about 10 minutes to about 96 hours, from about 10 minutes to about 48 hours, from about 10 minutes to about 24 hours, from about 10 minutes to about 18 hours, from about 10 minutes to about 12 hours, from about 10 minutes to about 8 hours, from about 10 minutes to about 6 hours, from about 10 minutes to about 4 hours, from about 20 minutes to about 96 hours, from about 20 minutes to about 48 hours, from about 20 minutes to about 24 hours, from about 20 minutes to about 18 hours, from about 20 minutes to about 12 hours, from about 20 minutes to about 8 hours, from about 20 minutes to about 6 hours, from about 20 minutes to about 4 hours, from about 30 minutes to about 96 hours, from about 30 minutes to about 48 hours, from about 30 minutes to about 24 hours, from about 30 minutes to about 18 hours, from about 30 minutes to about 12 hours, from about 30 minutes to about 8 hours, from about 30 minutes to about 6 hours, from about 30

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minutes to about 4 hours, from about 45 minutes to about 96 hours, from about 45 minutes to about 48 hours, from about 45 minutes to about 24 hours, from about 45 minutes to about 18 hours, from about 45 minutes to about 12 hours, from about 45 minutes to about 8 hours, from about 45 minutes to about 6 hours, from about 45 minutes to about 4 hours, from about 1 hour to about 96 hours, from about 1 hour to about 48 hours, from about 1 hour to about 24 hours, from about 1 hour to about 18 hours, from about 1 hour to about 12 hours, from about 1 hour to about 8 hours, from 1 hour minutes to about 6 hours, or from about 1 hour to about 4 hours.

[00128] Additionally or alternately, in aspects where an ex situ formed amide is used, the amide can be formed prior to impregnation into the metal oxide component of the catalyst precursor by reaction of the amine component and the carboxylic acid component. Reaction typically takes place readily at mildly elevated temperatures up to about 200°C with liberation of water as a by-product of the reaction at temperatures above 100°C and usually above 150°C. The reactants can usually be heated together to form a melt in which the reaction takes place and the melt impregnated directly into the metal oxide component which is preferably pre-heated to the same temperature as the melt in order to assist penetration into the structure of the metal oxide component. The reaction can also be carried out in the presence of a solvent if desired and the resulting solution used for the impregnation step. In certain embodiments, the amide and its heat treated derivative may not be located/incorporated within the crystal lattice of the mixed metal oxide precursor, *e.g.*, may instead be located on the surface and/or within the pore volume of the precursor and/or be associated with (bound to) one or more metals or oxides of metals in a manner that does not significantly affect the crystalline lattice of the mixed metal oxide precursor composition, as observed through XRD and/or other crystallographic spectra. A sulfided version of the mixed metal oxide precursor

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composition can still have its sulfided form affected by the organic compound(s)/additive(s) and/or the reaction product(s), even though the oxide lattice is not significantly affected.

[00129] There is not a strict limit on the ratio between the amine reactant and the carboxylic reactant, and accordingly, the ratio of the reactive amine and carboxylic acid groups in the two reactants may vary, respectively, from about 1:4 to about 4:1, for example from about 1:3 to about 3:1 or from about 1:2 to about 2:1. It has been observed that catalysts made with amides from equimolar quantities of the amine and carboxylic acid reactants compounds show performance improvements in hydroprocessing certain feeds and for this reason, amides made with an equimolar ratio are preferred.

[00130] The pre-formed amide is suitably impregnated into the metal oxide precursor by incipient wetness impregnation with the amount determined according to the pore volume of the metal oxide component. Following impregnation, a heat treatment is carried out which first removes any residual water and/or solvent but also creates a reaction product containing additional unsaturation sites and possibly additional oxygen. The amide-impregnated metal oxide component is then heated at a temperature sufficient and for a time sufficient to form a product containing the additional unsaturation which is characteristic of the desired organic component; this treatment with the pre-formed amide is typically from about 195°C to about 280°C, for example from about 200°C to about 250°C).

[00131] The heating step should not be conducted for so long that the amide becomes substantially decomposed but is continued for a sufficiently long time to form additional unsaturation(s), which may result from at least partial

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decomposition (*e.g.*, oxidative and/or non-oxidative dehydrogenation and/or aromatization) of some (typically-unfunctionalized organic) portions of the organic compounds. On the other hand, the heating should not be conducted for so long that the decomposition substantially results in gross decomposition of the amide or any condensation product. The impregnated catalyst precursor composition can be heated to a temperature high enough to form the unsaturated reaction product and typically high enough to enable any byproducts such as water to be removed. The temperature to which the impregnated precursor composition is heated should, however, be maintained low enough so as to substantially retain the amide reaction product with the additional unsaturations and any oxygen, and so as not to significantly decompose the functionalized reaction product, and/or so as not to significantly volatilize (more than 50% by weight of) the amide.

[00132] The specific lower and upper temperature limits based on the above considerations can be dependent upon a variety of factors that can include, but are not limited to, the atmosphere under which the heating is conducted, the chemical and/or physical properties of the amide, the amide reaction product, and/or any functionalized reaction byproduct as well as the desired duration of the heating with higher temperatures, *e.g.* over the optimal temperature range up to 250°C, enabling shorter heating durations to be utilized.. The minimum heating temperature can, for example, suitably be at least about 120°C, for example at least about 150°C, at least about 165°C, at least about 175°C, at least about 185°C, at least about 195°C, at least about 200°C, at least about 210°C, at least about 220°C, at least about 230°C, at least about 240°C, or at least about 250°C. The maximum heating temperature should not be greater than about 400°C, for example, not greater than about 375°C, not greater than about 350°C, not greater than about 325°C, not greater than about 300°C, not greater than about 275°C, not greater than about 250°C, not greater than

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about 240°C, not greater than about 230°C, not greater than about 220°C, not greater than about 210°C, or not greater than about 200°C. Resort to temperatures above the preferred maximum of 250°C should be made with due care to avoid the gross decomposition of the amide as noted above but a slightly higher range, for example, 250-280°C, e.g. 260 or 275°C may permit usefully shorter heating steps in commercial scale operation. The temperature to be used should therefore be selected on an empirical basis depending on the nature of the amide used in the impregnation. The progress of the heating can be monitored according to the properties of the treated product, including analysis by GC-MS and by its infrared spectrum as described below.

[00133] In an embodiment, the organically treated catalyst precursor composition and/or the catalyst precursor composition containing the reaction product can contain from about 4 wt % to about 20 wt %, for example from about 5 wt % to about 15 wt %, carbon resulting from the first and second organic compounds and/or from the condensation product, as applicable, based on the total weight of the relevant composition.

[00134] Additionally or alternately, as a result of the heating step, the reaction product from the organically treated catalyst precursor can exhibit a content of unsaturated carbon atoms (which includes aromatic carbon atoms), as measured according to peak area comparisons using ^{13}C NMR techniques, of at least 29%, for example at least about 30%, at least about 31%, at least about 32%, or at least about 33%. Further additionally or alternately, the reaction product from the organically treated catalyst precursor can optionally exhibit a content of unsaturated carbon atoms (which includes aromatic carbon atoms), as measured according to peak area comparisons using ^{13}C NMR techniques, of up to about 70%, for example up to

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about 65%, up to about 60%, up to about 55%, up to about 50%, up to about 45%, up to about 40%, or up to about 35%. Still further additionally or alternately, as a result of the heating step, the reaction product from the organically treated catalyst precursor can exhibit an increase in content of unsaturated carbon atoms (which includes aromatic carbon atoms), as measured according to peak area comparisons using ^{13}C NMR techniques, of at least about 17%, for example at least about 18%, at least about 19%, at least about 20%, or at least about 21% (e.g., in an embodiment where the first organic compound is oleylamine and the second organic compound is oleic acid, such that the combined unsaturation level of the unreacted compounds is about 11.1% of carbon atoms, a .about.17% increase in unsaturated carbons upon heating corresponds to about 28.1% content of unsaturated carbon atoms in the reaction product). Yet further additionally or alternately, the reaction product from the organically treated catalyst precursor can optionally exhibit an increase in content of unsaturated carbon atoms (which includes aromatic carbon atoms), as measured according to peak area comparisons using ^{13}C NMR techniques, of up to about 60%, for example up to about 55%, up to about 50%, up to about 45%, up to about 40%, up to about 35%, up to about 30%, or up to about 25%.

[00135] Again further additionally or alternately, as a result of the heating step, the reaction product from the organically treated catalyst precursor can exhibit a ratio of unsaturated carbon atoms to aromatic carbon atoms, as measured according to peak area ratios using infrared spectroscopic techniques of a deconvoluted peak centered from about 1700 cm^{-1} to about 1730 cm^{-1} (e.g., at about 1715 cm^{-1}), compared to a deconvoluted peak centered from about 1380 cm^{-1} to about 1450 cm^{-1} (e.g., from about 1395 cm^{-1} to about 1415 cm^{-1}), of at least 0.9, for example at least 1.0, at least 1.1, at least 1.2, at least 1.3, at least 1.4, at least 1.5, at least 1.7, at least

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2.0, at least 2.2, at least 2.5, at least 2.7, or at least 3.0. Again still further additionally or alternately, the reaction product from the organically treated catalyst precursor can exhibit a ratio of unsaturated carbon atoms to aromatic carbon atoms, as measured according to peak area ratios using infrared spectroscopic techniques of a deconvoluted peak centered from about 1700 cm^{-1} to about 1730 cm^{-1} (e.g., at about 1715 cm^{-1}), compared to a deconvoluted peak centered from about 1380 cm^{-1} to about 1450 cm^{-1} (e.g., from about 1395 cm^{-1} to about 1415 cm^{-1}), of up to 15, for example up to 10, up to 8.0, up to 7.0, up to 6.0, up to 5.0, up to 4.5, up to 4.0, up to 3.5, or up to 3.0.

[00136] A (sulfided) hydroprocessing catalyst composition can then be produced by sulfiding the catalyst precursor composition containing the reaction product. Sulfiding is generally carried out by contacting the catalyst precursor composition containing the reaction product with a sulfur-containing compound (e.g., elemental sulfur, hydrogen sulfide, polysulfides, or the like, or a combination thereof, which may originate from a fossil/mineral oil stream, from a biocomponent-based oil stream, from a combination thereof, or from a sulfur-containing stream separate from the aforementioned oil stream(s)) at a temperature and for a time sufficient to substantially sulfide the composition and/or sufficient to render the sulfided composition active as a hydroprocessing catalyst. For instance, the sulfidation can be carried out at a temperature from about 300°C to about 400°C , e.g., from about 310°C to about 350°C , for a period of time from about 30 minutes to about 96 hours, e.g., from about 1 hour to about 48 hours or from about 4 hours to about 24 hours. The sulfiding can generally be conducted before or after combining the metal (oxide) containing composition with a binder, if desired, and before or after forming the composition into a shaped catalyst. The sulfiding can additionally or alternately be conducted in situ in a hydroprocessing reactor.

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Obviously, to the extent that a reaction product of the first or second organic compounds contains additional unsaturations formed in situ, it would generally be desirable for the sulfidation (and/or any catalyst treatment after the organic treatment) to significantly maintain the in situ formed additional unsaturations of said reaction product.

[00137] The sulfided catalyst composition can exhibit a layered structure comprising a plurality of stacked YS_2 layers, where Y is the Group 6 metal(s), such that the average number of stacks (typically for bulk organically treated catalysts) can be from about 1.5 to about 3.5, for example from about 1.5 to about 3.0, from about 2.0 to about 3.3, from about 2.0 to about 3.0, or from about 2.1 to about 2.8. For instance, the treatment of the metal (oxide) containing precursor composition according to the disclosure can afford a decrease in the average number of stacks of the treated precursor of at least about 0.8, for example at least about 1.0, at least about 1.2, at least about 1.3, at least about 1.4, or at least about 1.5, as compared to an untreated metal (oxide) containing precursor composition. As such, the number of stacks can be considerably less than that obtained with an equivalent sulfided mixed metal (oxide) containing precursor composition produced without the first or second organic compound treatment. The reduction in the average number of stacks can be evidenced, e.g., via X-ray diffraction spectra of relevant sulfided compositions, in which the (002) peak appears significantly broader (as determined by the same width at the half-height of the peak) than the corresponding peak in the spectrum of the sulfided mixed metal (oxide) containing precursor composition produced without the organic treatment (and/or, in certain cases, with only a single organic compound treatment using an organic compound having less than 10 carbon atoms) according to the present disclosure. Additionally or alternately to X-ray diffraction, transmission electron microscopy (TEM) can be used to obtain

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micrographs of relevant sulfided compositions, including multiple microcrystals, within which micrograph images the multiple microcrystals can be visually analyzed for the number of stacks in each, which can then be averaged over the micrograph visual field to obtain an average number of stacks that can evidence a reduction in average number of stacks compared to a sulfided mixed metal (oxide) containing precursor composition produced without the organic treatment (and/or, in certain cases, with only a single organic compound treatment) according to the present disclosure.

[00138] The sulfided catalyst composition described above can be used as a hydroprocessing catalyst, either alone or in combination with a binder. If the sulfided catalyst composition is a bulk catalyst, then only a relatively small amount of binder may be added. However, if the sulfided catalyst composition is a heterogeneous/supported catalyst, then usually the binder is a significant portion of the catalyst composition, e.g., at least about 40 wt %, at least about 50 wt %, at least about 60 wt %, or at least about 70 wt %; additionally or alternately for heterogeneous/supported catalysts, the binder can comprise up to about 95 wt % of the catalyst composition, e.g., up to about 90 wt %, up to about 85 wt %, up to about 80 wt %, up to about 75 wt %, or up to about 70 wt %. Non-limiting examples of suitable binder materials can include, but are not limited to, silica, silica-alumina (e.g., conventional silica-alumina, silica-coated alumina, alumina-coated silica, or the like, or a combination thereof), alumina (e.g., boehmite, pseudo-boehmite, gibbsite, or the like, or a combination thereof), titania, zirconia, cationic clays or anionic clays (e.g., saponite, bentonite, kaoline, sepiolite, hydrotalcite, or the like, or a combination thereof), and mixtures thereof. In some preferred embodiments, the binder can include silica, silica-alumina, alumina, titania, zirconia, and mixtures thereof. These binders may be applied as such or after

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peptization. It may also be possible to apply precursors of these binders that, during precursor synthesis, can be converted into any of the above-described binders. Suitable precursors can include, e.g., alkali metal aluminates (alumina binder), water glass (silica binder), a mixture of alkali metal aluminates and water glass (silica-alumina binder), a mixture of sources of a di-, tri-, and/or tetravalent metal, such as a mixture of water-soluble salts of magnesium, aluminum, and/or silicon (cationic clay and/or anionic clay), chlorohydrol, aluminum sulfate, or mixtures thereof.

[00139] Generally, the binder material to be used can have lower catalytic activity than the remainder of the catalyst composition, or can have substantially no catalytic activity at all (less than about 5%, based on the catalytic activity of the bulk catalyst composition being about 100%). Consequently, by using a binder material, the activity of the catalyst composition may be reduced. Therefore, the amount of binder material to be used, at least in bulk catalysts, can generally depend on the desired activity of the final catalyst composition. Binder amounts up to about 25 wt % of the total composition can be suitable (when present, from above 0 wt % to about 25 wt %), depending on the envisaged catalytic application. However, to take advantage of the resulting unusual high activity of bulk catalyst compositions according to the disclosure, binder amounts, when added, can generally be from about 0.5 wt % to about 20 wt % of the total catalyst composition.

[00140] If desired in bulk catalyst cases, the binder material can be composited with a source of a Group 6 metal and/or a source of a non-noble Group 8-10 metal, prior to being composited with the bulk catalyst composition and/or prior to being added during the preparation thereof. Compositing the binder material with any of

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these metals may be carried out by any known means, e.g., impregnation of the (solid) binder material with these metal(s) sources.

[00141] A cracking component may also be added during catalyst preparation. When used, the cracking component can represent from about 0.5 wt % to about 30 wt %, based on the total weight of the catalyst composition. The cracking component may serve, for example, as an isomerization enhancer. Conventional cracking components can be used, e.g., a cationic clay, an anionic clay, a zeolite (such as ZSM-5, zeolite Y, ultra-stable zeolite Y, zeolite X, an AlPO, a SAPO, or the like, or a combination thereof), amorphous cracking components (such as silica-alumina or the like), or a combination thereof. It is to be understood that some materials may act as a binder and a cracking component at the same time. For instance, silica-alumina may simultaneously have both a cracking and a binding function.

[00142] If desired, the cracking component may be composited with a Group 6 metal and/or a Group 8-10 non-noble metal, prior to being composited with the catalyst composition and/or prior to being added during the preparation thereof. Compositing the cracking component with any of these metals may be carried out by any known means, e.g., impregnation of the cracking component with these metal(s) sources. When both a cracking component and a binder material are used and when compositing of additional metal components is desired on both, the compositing may be done on each component separately or may be accomplished by combining the components and doing a single compositing step.

[00143] The selection of particular cracking components, if any, can depend on the intended catalytic application of the final catalyst composition. For instance, a

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zeolite can be added if the resulting composition is to be applied in hydrocracking or fluid catalytic cracking. Other cracking components, such as silica-alumina or cationic clays, can be added if the final catalyst composition is to be used in hydrotreating applications. The amount of added cracking material can depend on the desired activity of the final composition and the intended application, and thus, when present, may vary from above 0 wt % to about 80 wt %, based on the total weight of the catalyst composition. In a preferred embodiment, the combination of cracking component and binder material can comprise less than 50 wt % of the catalyst composition, for example, less than about 40 wt %, less than about 30 wt %, less than about 20 wt %, less than about 15 wt %, or less than about 10 wt %.

[00144] If desired, further materials can be added, in addition to the metal components already added, such as any material that would be added during conventional hydroprocessing catalyst preparation. Suitable examples of such further materials can include, but are not limited to, phosphorus compounds, boron compounds, fluorine-containing compounds, sources of additional transition metals, sources of rare earth metals, fillers, or mixtures thereof.

Additional Embodiments

[00145] Embodiment 1. A process for selectively hydroconverting a raffinate produced from solvent refining a lubricating oil feedstock, comprising: conducting the lubricating oil feedstock to a solvent extraction zone and separating therefrom an aromatics rich extract and a paraffins rich raffinate; stripping the raffinate of solvent to produce a raffinate feed having a dewaxed oil viscosity index from about 80 to about 105 and a final boiling point of no greater than about 650°C; passing the raffinate feed to a first hydroconversion zone and processing the raffinate feed in the presence of a mixed metal catalyst under hydroconversion conditions; and

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passing the first hydroconverted raffinate to a second reaction zone and conducting cold hydrofinishing of the first hydroconverted raffinate in the presence of a hydrofinishing catalyst under cold hydrofinishing conditions, wherein the mixed metal catalyst comprises a sulfided mixed metal catalyst formed by sulfiding a mixed metal catalyst precursor composition, the mixed metal catalyst precursor composition being produced by a) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (i) a first organic compound containing at least one amine group, and (ii) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group to a temperature from about 195°C to about 260°C for a time sufficient for the first and second organic compounds to form a reaction product in situ that contains an amide moiety, unsaturated carbon atoms not present in the first or second organic compounds, or both; b) heating a composition comprising one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (iii) a first organic compound containing at least one amine group and at least 10 carbon atoms or (iv) a second organic compound containing at least one carboxylic acid group and at least 10 carbon atoms, but not both (iii) and (iv), wherein the reaction product contains additional unsaturated carbon atoms, relative to (iii) the first organic compound or (iv) the second organic compound, wherein the metals of the catalyst precursor composition are arranged in a crystal lattice, and wherein the reaction product is not located within the crystal lattice, to a temperature from about 195°C to about 260°C for a time sufficient for the first or second organic compounds to form a reaction product in situ that contains unsaturated carbon atoms not present in the first or second organic compounds; or c) heating a composition comprising at least one

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metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a pre-formed amide formed from (v) a first organic compound containing at least one amine group, and (vi) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group, to form additional in situ unsaturated carbon atoms not present in the first organic compound, the second organic compound, or both, but not for so long that the pre-formed amide substantially decomposes, thereby forming a catalyst precursor containing in situ formed unsaturated carbon atoms.

[00146] Embodiment 2. The process of Embodiment 1, further comprising passing the raffinate feed into a second hydroconversion zone and processing the raffinate feed in the presence of a hydroconversion catalyst under second effective hydroconversion conditions, the raffinate feed being passed into the second hydroconversion zone prior to being passed into the first hydroconversion zone or after being passed into the first hydroconversion zone.

[00147] Embodiment 3. The process of any of the above embodiments, wherein the hydroconversion conditions in the first hydroconversion zone, the second hydroconversion zone, or both the first and second hydroconversion zones include temperatures of from 250°C to 420°C, hydrogen pressures of from 300 to 3000 psig (2170 to 20786 kPa), liquid hourly space velocities of from 0.1 to 10 hr⁻¹, and hydrogen treat gas rates of from 500 to 5000 scf/B (89 to 890 m³ / m³).

[00148] Embodiment 4. The process of any of the above embodiments, wherein the cold hydrofinishing conditions include temperatures of from 150°C to 360°C, hydrogen pressures of from 300 to 3000 psig (2170 to 20786 kPa), liquid hourly

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space velocities of from 0.1 to 10 and hydrogen treat gas rates of from 500 to 5000 scf/B (89 to 890 m³ / m³).

[00149] Embodiment 5. The process of any of the above embodiments, wherein solvent in the solvent extraction zone is at least one of furfural, phenol or N-methyl-2-pyrrolidone.

[00150] Embodiment 6. The process of any of the above embodiments, wherein the cold hydrofinishing step is preceded by or followed by dewaxing, the dewaxing comprising solvent dewaxing under solvent dewaxing conditions, catalytic dewaxing under catalytic dewaxing conditions, or a combination thereof.

[00151] Embodiment 7. A process for producing a lubricating oil feedstock, comprising: exposing a feedstock to a mixed metal catalyst under effective hydroprocessing conditions to form a hydroprocessed effluent; separating the hydroprocessed effluent to form at least a gas phase effluent and a liquid hydroprocessed effluent; optionally exposing at least a portion of the liquid hydroprocessed effluent to a hydrocracking catalyst under effective hydrocracking conditions to form a hydrocracked effluent; exposing at least a portion of the optionally hydrocracked effluent to a dewaxing catalyst under effective catalytic dewaxing conditions to form an optionally hydrocracked, dewaxed effluent, wherein the mixed metal catalyst comprises a sulfided mixed metal catalyst formed by sulfiding a mixed metal catalyst precursor composition, the mixed metal catalyst precursor composition being produced by a) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (i) a first organic compound containing at least one amine

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group, and (ii) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group to a temperature from about 195°C to about 250°C for a time sufficient for the first and second organic compounds to form a reaction product in situ that contains an amide moiety, unsaturated carbon atoms not present in the first or second organic compounds, or both; b) heating a composition comprising one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (iii) a first organic compound containing at least one amine group and at least 10 carbon atoms or (iv) a second organic compound containing at least one carboxylic acid group and at least 10 carbon atoms, but not both (iii) and (iv), wherein the reaction product contains additional unsaturated carbon atoms, relative to (iii) the first organic compound or (iv) the second organic compound, wherein the metals of the catalyst precursor composition are arranged in a crystal lattice, and wherein the reaction product is not located within the crystal lattice, to a temperature from about 195°C to about 250°C for a time sufficient for the first or second organic compounds to form a reaction product in situ that contains unsaturated carbon atoms not present in the first or second organic compounds; or c) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a pre-formed amide formed from (v) a first organic compound containing at least one amine group, and (vi) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group, to form additional in situ unsaturated carbon atoms not present in the first organic compound, the second organic compound, or both, but not for so long that the pre-formed amide substantially decomposes, thereby forming a catalyst precursor containing in situ formed unsaturated carbon atoms.

[00152] Embodiment 8. The process of Embodiment 7, wherein the effective hydroprocessing conditions comprise effective hydrotreating conditions, including temperatures of about 200°C to about 450°C, or about 315°C to about 425°C; pressures of about 250 psig (1.8 MPag) to about 5000 psig (34.6 MPag) or about 300 psig (2.1 MPag) to about 3000 psig (20.8 MPag); liquid hourly space velocities (LHSV) of about 0.1 hr⁻¹ to about 10 hr⁻¹; and hydrogen treat rates of about 200 scf/B (35.6 m³/m³) to about 10,000 scf/B (1781 m³/m³), or about 500 (89 m³/m³) to about 10,000 scf/B (1781 m³/m³); or wherein the effective hydroprocessing conditions comprise second effective hydrocracking conditions, including temperatures of about 550°F (288°C) to about 840°F (449°C), hydrogen partial pressures of from about 250 psig to about 5000 psig (1.8 MPag to 34.6 MPag), liquid hourly space velocities of from 0.05 h⁻¹ to 10 h⁻¹, and hydrogen treat gas rates of from 35.6 m³/m³ to 1781 m³/m³ (200 SCF/B to 10,000 SCF/B); or a combination thereof.

[00153] Embodiment 9. The process of any of Embodiments 7 or 8, further comprising exposing the feedstock to a hydrotreating catalyst different from the mixed metal catalyst under second effective hydrotreating conditions, the feedstock being exposed to the hydrotreating catalyst prior to the mixed metal catalyst, after the mixed metal catalyst but prior to the separating of the hydroprocessed effluent, or a combination thereof, the second effective hydrotreating conditions including temperatures of about 200°C to about 450°C, or about 315°C to about 425°C; pressures of about 250 psig (1.8 MPag) to about 5000 psig (34.6 MPag) or about 300 psig (2.1 MPag) to about 3000 psig (20.8 MPag); liquid hourly space velocities (LHSV) of about 0.1 hr⁻¹ to about 10 hr⁻¹; and hydrogen treat rates of about 200

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scf/B ($35.6 \text{ m}^3/\text{m}^3$) to about 10,000 scf/B ($1781 \text{ m}^3/\text{m}^3$), or about 500 ($89 \text{ m}^3/\text{m}^3$) to about 10,000 scf/B ($1781 \text{ m}^3/\text{m}^3$).

[00154] Embodiment 10. The process of any of Embodiments 7 to 9, further comprising exposing the feedstock to a hydrocracking catalyst different from the mixed metal catalyst under third effective hydrocracking conditions, the feedstock being exposed to the hydrocracking catalyst prior to the mixed metal catalyst, after the mixed metal catalyst but prior to the separating of the hydroprocessed effluent, or a combination thereof, the third effective hydrocracking conditions including temperatures of about 550°F (288°C) to about 840°F (449°C), hydrogen partial pressures of from about 250 psig to about 5000 psig (1.8 MPag to 34.6 MPag), liquid hourly space velocities of from 0.05 h^{-1} to 10 h^{-1} , and hydrogen treat gas rates of from $35.6 \text{ m}^3/\text{m}^3$ to $1781 \text{ m}^3/\text{m}^3$ (200 SCF/B to 10,000 SCF/B).

[00155] Embodiment 11. The process of any of Embodiments 7 to 10, wherein separating the hydroprocessed effluent to form at least a gas phase effluent and a liquid hydroprocessed effluent comprises separating the hydroprocessed effluent to form a hydroprocessed distillate fuel fraction and a higher boiling hydrotreated fraction, the hydroprocessed distillate fuel fraction having a T95 boiling point of about 750°F or less.

[00156] Embodiment 12. The process of any of Embodiments 7 to 11, wherein the effective hydrocracking conditions include temperatures of about 550°F (288°C) to about 840°F (449°C), hydrogen partial pressures of from about 250 psig to about 5000 psig (1.8 MPag to 34.6 MPag), liquid hourly space velocities of from 0.05 h^{-1} to 10 h^{-1} , and hydrogen treat gas rates of from $35.6 \text{ m}^3/\text{m}^3$ to $1781 \text{ m}^3/\text{m}^3$ (200 SCF/B to 10,000 SCF/B).

[00157] Embodiment 13. The process of any of Embodiments 7 to 12, wherein the effective catalytic dewaxing conditions including temperatures of about 200°C to about 450°C, preferably about 270°C to about 400°C, hydrogen partial pressures of about 1.8 MPag to about 34.6 MPag (250 psig to 5000 psig), preferably about 4.8 MPag to about 20.8 MPag, liquid hourly space velocities of from 0.05 h⁻¹ to 10 h⁻¹, and hydrogen treat gas rates of about 35.6 m³/m³ (200 SCF/B) to about 1781 m³/m³ (10,000 scf/B), preferably about 178 m³/m³ (1000 SCF/B) to about 890.6 m³/m³ (5000 SCF/B).

[00158] Embodiment 14. The process of any of Embodiments 7 to 13, the process further comprising exposing at least a portion of the optionally hydrocracked effluent to a hydrofinishing catalyst under effective hydrofinishing conditions, the effective hydrofinishing conditions including temperatures from about 125°C to about 425°C, preferably about 180°C to about 280°C, total pressures from about 500 psig (3.4 MPa) to about 3000 psig (20.7 MPa), preferably about 1500 psig (10.3 MPa) to about 2500 psig (17.2 MPa), liquid hourly space velocities from about 0.1 hr⁻¹ to about 5 hr⁻¹ LHSV, preferably about 0.5 hr⁻¹ to about 1.5 hr⁻¹, and hydrogen treat gas rates of from 500 to 5000 scf/B (89 to 890 m³ / m³), the at least a portion of the optionally hydrocracked effluent being exposed to the hydrofinishing catalyst prior to the dewaxing catalyst, after the dewaxing catalyst, or a combination thereof.

[00159] Embodiment 15. The process of any of Embodiments 7 to 14, the process further comprising exposing at least a portion of the optionally hydrocracked effluent to an aromatic saturation catalyst under effective aromatic saturation conditions, the effective aromatic saturation conditions including

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temperatures from about 200°C to about 425°C, preferably about 225°C to about 325°C, total pressures from about 500 psig (3.4 MPa) to about 3000 psig (20.7 MPa), preferably about 1500 psig (10.3 MPa) to about 2500 psig (17.2 MPa), liquid hourly space velocities from about 0.1 hr⁻¹ to about 5 hr⁻¹ LHSV, preferably about 0.5 hr⁻¹ to about 1.5 hr⁻¹, and hydrogen treat gas rates of from 500 to 5000 scf/B (89 to 890 m³ / m³), the at least a portion of the optionally hydrocracked effluent being exposed to the aromatic saturation catalyst prior to the dewaxing catalyst, after the dewaxing catalyst, or a combination thereof.

[00160] Embodiment 16. The process of any of Embodiments 7 to 15, further comprising separating the optionally hydrocracked, dewaxed effluent to form at least a lubricant boiling range fraction and a distillate boiling range fraction.

[00161] Embodiment 17. The process of any of the above embodiments, wherein the catalyst precursor composition is treated first with said first organic compound and second with said second organic compound, or wherein the catalyst precursor composition is treated first with said second organic compound and second with said first organic compound, or wherein the catalyst precursor composition is treated simultaneously with said first organic compound and with said second organic compound.

[00162] Embodiment 18. The process of any of the above embodiments, wherein said at least one metal from Group 6 is Mo, W, or a combination thereof, and wherein said at least one metal from Groups 8-10 is Co, Ni, or a combination thereof.

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[00163] Embodiment 19. The process of any of the above embodiments, wherein the mixed metal catalyst precursor composition is a bulk metal hydroprocessing catalyst precursor composition consisting essentially of the reaction product, an oxide form of the at least one metal from Group 6, an oxide form of the at least one metal from Groups 8-10, and optionally about 20 wt % or less of a binder.

EXAMPLES

Example – Hydrodenitrogenation Activity

[00164] Table 1 below shows results from processing a vacuum gas oil feedstock in the presence of various catalysts in order to determine a relative activity for hydrodenitrogenation. For the processing runs shown in Table 1, a vacuum gas oil feed was exposed to a comparative bulk catalyst and a catalyst formed from a suitable precursor as described herein. The commercially available comparative bulk catalyst corresponds to a NiMoW bulk catalyst prepared according to the methods in U.S. Patents 6,620,313; 7,232,515; or 7,513,989. Catalyst A corresponds to a NiW catalyst made from a suitable precursor as described above.

[00165] As shown in Table 1, the reaction conditions used for processing the vacuum gas oil feed in the presence of each catalysts were the same. However, based on the superior hydrodenitrogenation activity of Catalyst A, processing the feed in the presence of Catalyst A produced a hydrodenitrogenated effluent (total liquid product) with a significantly lower nitrogen content relative to processing the feed in the presence of the comparative bulk catalyst.

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Table 1 – Hydrodenitrogenation Activity

		VGO Feed	Comparative Bulk Catalyst	Catalyst A
Conditions				
LHSV	hr-1		1.1	1.1
Temp	°C		365	365
TGR	scf/bbl		5000	5000
H ₂ pressure	psig		1200	1200
Total Liquid Product				
N	wppm	1614	380	110
Relative HDN volume activity	%		100	180

Example – Improved Aromatic Saturation Activity during Lubricant Basestock Production

[00166] FIG. 2 shows results from processing a feedstock in a process train for production of a lubricant basestock product. For the processing runs in FIG. 2, a heavy neutral feed produced by solvent processing was processed under raffinate hydroconversion conditions in the presence of one of three types of catalyst systems. One catalyst corresponded to the commercially available comparative bulk catalyst described above. A second catalyst corresponded to Catalyst A. A third catalyst system corresponded to a 50 / 50 mixture by volume of the commercially available comparative bulk catalyst and a commercially available NiMo supported hydrotreating catalyst. The third catalyst system has a similar activity for hydrodesulfurization and hydrodenitrogenation compared to the activity of Catalyst A.

[00167] After exposing the heavy neutral feed to a catalyst under raffinate hydroconversion conditions, the 700°F+ fraction of the total liquid product was a)

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used in a catalytic dewaxing step to form a lubricant basestock product and b) used in a solvent dewaxing step to form a dewaxed oil product. These additional products were characterized as shown in FIG. 2.

[00168] As shown in FIG. 2, under similar processing conditions, the total liquid product produced from raffinate hydroconversion in the presence of Catalyst A had a substantially lower aromatics content and lower 3+ ring aromatics content than the total liquid product generated using the comparative bulk catalyst. Catalyst A also produced lower aromatics contents and lower 3+ ring aromatics contents relative to the mixed catalyst system which had similar hydrodesulfurization and hydrodenitrogenation activity. This demonstrates that Catalyst A can provide an unexpected benefit of improved aromatic saturation when processing a feed suitable for lubricant basestock production. As shown in FIG. 2, this additional benefit in aromatics saturation can be achieved while producing a substantially similar yield at constant product quality relative to other catalyst systems, such as the mixed catalyst system.

[00169] Although the present disclosure has been described in terms of specific embodiments, it is not so limited. Suitable alterations/modifications for operation under specific conditions should be apparent to those skilled in the art. It is therefore intended that the following claims be interpreted as covering all such alterations/modifications as fall within the true spirit/scope of the disclosure.

CLAIMS:

1. A process for selectively hydroconverting a raffinate produced from solvent refining a lubricating oil feedstock, comprising:

conducting the lubricating oil feedstock to a solvent extraction zone and separating therefrom an aromatics rich extract and a paraffins rich raffinate;

stripping the raffinate of solvent to produce a raffinate feed having a dewaxed oil viscosity index from 80 to 105 and a final boiling point of no greater than 650°C;

passing the raffinate feed to a first hydroconversion zone and processing the raffinate feed in the presence of a mixed metal catalyst under hydroconversion conditions; and

passing the first hydroconverted raffinate to a second reaction zone and conducting cold hydrofinishing of the first hydroconverted raffinate in the presence of a hydrofinishing catalyst under cold hydrofinishing conditions,

wherein the mixed metal catalyst comprises a sulfided mixed metal catalyst formed by sulfiding a mixed metal catalyst precursor composition, the mixed metal catalyst precursor composition being produced by

a) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (i) a first organic compound containing at least one amine group, and (ii) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group to a temperature from 195°C to 260°C for a time sufficient for the first and second organic compounds to form a reaction product in situ that contains an

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amide moiety, unsaturated carbon atoms not present in the first or second organic compounds, or both;

b) heating a composition comprising one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (iii) a first organic compound containing at least one amine group and at least 10 carbon atoms or (iv) a second organic compound containing at least one carboxylic acid group and at least 10 carbon atoms, but not both (iii) and (iv), wherein the reaction product contains additional unsaturated carbon atoms, relative to (iii) the first organic compound or (iv) the second organic compound, wherein the metals of the catalyst precursor composition are arranged in a crystal lattice, and wherein the reaction product is not located within the crystal lattice, to a temperature from 195°C to 260°C for a time sufficient for the first or second organic compounds to form a reaction product in situ that contains unsaturated carbon atoms not present in the first or second organic compounds; or

c) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a pre-formed amide formed from (v) a first organic compound containing at least one amine group, and (vi) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group, to form additional in situ unsaturated carbon atoms not present in the first organic compound, the second organic compound, or both, but not for so long that the pre-formed amide substantially decomposes, thereby forming a catalyst precursor containing in situ formed unsaturated carbon atoms.

2. The process of claim 1, further comprising passing the raffinate feed into a second hydroconversion zone and processing the raffinate feed in the presence of a

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hydroconversion catalyst under second effective hydroconversion conditions, the raffinate feed being passed into the second hydroconversion zone prior to being passed into the first hydroconversion zone or after being passed into the first hydroconversion zone.

3. The process of claim 1, wherein the hydroconversion conditions in the first hydroconversion zone, the second hydroconversion zone, or both the first and second hydroconversion zones include temperatures of from 250°C to 420°C, hydrogen pressures of from 300 to 3000 psig (2170 to 20786 kPa), liquid hourly space velocities of from 0.1 to 10 hr⁻¹, and hydrogen treat gas rates of from 500 to 5000 scf/B (89 to 890 m³ / m³).

4. The process of claim 1, wherein the cold hydrofinishing conditions include temperatures of from 150°C to 360°C, hydrogen pressures of from 300 to 3000 psig (2170 to 20786 kPa), liquid hourly space velocities of from 0.1 to 10 and hydrogen treat gas rates of from 500 to 5000 scf/B (89 to 890 m³ / m³).

5. The process of claim 1, wherein solvent in the solvent extraction zone is at least one of furfural, phenol or N-methyl-2-pyrrolidone.

6. The process of claim 1, wherein the cold hydrofinishing step is preceded by or followed by dewaxing, the dewaxing comprising solvent dewaxing under solvent dewaxing conditions, catalytic dewaxing under catalytic dewaxing conditions, or a combination thereof.

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7. The process of claim 1, wherein the catalyst precursor composition is treated first with said first organic compound and second with said second organic compound, or wherein the catalyst precursor composition is treated first with said second organic compound and second with said first organic compound, or wherein the catalyst precursor composition is treated simultaneously with said first organic compound and with said second organic compound.

8. The process of claim 1, wherein said at least one metal from Group 6 is Mo, W, or a combination thereof, and wherein said at least one metal from Groups 8-10 is Co, Ni, or a combination thereof.

9. The process of claim 1, wherein the mixed metal catalyst precursor composition is a bulk metal hydroprocessing catalyst precursor composition consisting essentially of the reaction product, an oxide form of the at least one metal from Group 6, an oxide form of the at least one metal from Groups 8-10, and optionally 20 wt % or less of a binder.

10. A process for producing a lubricating oil feedstock, comprising:
 exposing a feedstock to a mixed metal catalyst under effective hydroprocessing conditions to form a hydroprocessed effluent;
 separating the hydroprocessed effluent to form at least a gas phase effluent and a liquid hydroprocessed effluent;
 optionally exposing at least a portion of the liquid hydroprocessed effluent to a hydrocracking catalyst under effective hydrocracking conditions to form a hydrocracked effluent;

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exposing at least a portion of the optionally hydrocracked effluent to a dewaxing catalyst under effective catalytic dewaxing conditions to form a hydrocracked, dewaxed effluent,

wherein the mixed metal catalyst comprises a sulfided mixed metal catalyst formed by sulfiding a mixed metal catalyst precursor composition, the mixed metal catalyst precursor composition being produced by

a) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (i) a first organic compound containing at least one amine group, and (ii) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group to a temperature from 195°C to 250°C for a time sufficient for the first and second organic compounds to form a reaction product in situ that contains an amide moiety, unsaturated carbon atoms not present in the first or second organic compounds, or both;

b) heating a composition comprising one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a reaction product formed from (iii) a first organic compound containing at least one amine group and at least 10 carbon atoms or (iv) a second organic compound containing at least one carboxylic acid group and at least 10 carbon atoms, but not both (iii) and (iv), wherein the reaction product contains additional unsaturated carbon atoms, relative to (iii) the first organic compound or (iv) the second organic compound, wherein the metals of the catalyst precursor composition are arranged in a crystal lattice, and wherein the reaction product is not located within the crystal lattice, to a temperature from 195°C to 250°C for a time sufficient for the first or second organic compounds to form a reaction product in

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situ that contains unsaturated carbon atoms not present in the first or second organic compounds; or

c) heating a composition comprising at least one metal from Group 6 of the Periodic Table of the Elements, at least one metal from Groups 8-10 of the Periodic Table of the Elements, and a pre-formed amide formed from (v) a first organic compound containing at least one amine group, and (vi) a second organic compound separate from said first organic compound and containing at least one carboxylic acid group, to form additional in situ unsaturated carbon atoms not present in the first organic compound, the second organic compound, or both, but not for so long that the pre-formed amide substantially decomposes, thereby forming a catalyst precursor containing in situ formed unsaturated carbon atoms.

11. The process of claim 10, wherein the effective hydroprocessing conditions comprise effective hydrotreating conditions, including temperatures of 200°C to 450°C; pressures of 250 psig (1.8 MPag) to 5000 psig (34.6 MPag); liquid hourly space velocities (LHSV) of 0.1 hr⁻¹ to 10 hr⁻¹; and hydrogen treat rates of 200 scf/B (35.6 m³/m³) to 10,000 scf/B (1781 m³/m³).

12. The process of claim 10, wherein the effective hydroprocessing conditions comprise second effective hydrocracking conditions, including temperatures of 550°F (288°C) to 840°F (449°C), hydrogen partial pressures of from 250 psig to 5000 psig (1.8 MPag to 34.6 MPag), liquid hourly space velocities of from 0.05 h⁻¹ to 10 h⁻¹, and hydrogen treat gas rates of from 35.6 m³/m³ to 1781 m³/m³ (200 SCF/B to 10,000 SCF/B).

13. The process of claim 10, further comprising exposing the feedstock to a hydrotreating catalyst different from the mixed metal catalyst under second

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effective hydrotreating conditions, the feedstock being exposed to the hydrotreating catalyst prior to the mixed metal catalyst, after the mixed metal catalyst but prior to the separating of the hydroprocessed effluent, or a combination thereof.

14. The process of claim 10, further comprising exposing the feedstock to a hydrocracking catalyst different from the mixed metal catalyst under third effective hydrocracking conditions, the feedstock being exposed to the hydrocracking catalyst prior to the mixed metal catalyst, after the mixed metal catalyst but prior to the separating of the hydroprocessed effluent, or a combination thereof.

15. The process of claim 10, wherein separating the hydroprocessed effluent to form at least a gas phase effluent and a liquid hydroprocessed effluent comprises separating the hydroprocessed effluent to form a hydroprocessed distillate fuel fraction and a higher boiling hydrotreated fraction, the hydroprocessed distillate fuel fraction having a T95 boiling point of 750°F or less.

16. The process of claim 10, wherein the effective hydrocracking conditions including temperatures of 550°F (288°C) to 840°F (449°C), hydrogen partial pressures of from 250 psig to 5000 psig (1.8 MPag to 34.6 MPag), liquid hourly space velocities of from 0.05 h⁻¹ to 10 h⁻¹, and hydrogen treat gas rates of from 35.6 m³/m³ to 1781 m³/m³ (200 SCF/B to 10,000 SCF/B).

17. The process of claim 10, wherein the effective catalytic dewaxing conditions including temperatures of 200°C to 450°C, hydrogen partial pressures of 1.8 MPag to 34.6 MPag (250 psig to 5000 psig), liquid hourly space velocities of from 0.05 h⁻¹ to 10 h⁻¹, and hydrogen treat gas rates of 35.6 m³/m³ (200 SCF/B) to 1781 m³/m³ (10,000 scf/B).

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18. The process of claim 10, the process further comprising exposing at least a portion of the optionally hydrocracked effluent to a hydrofinishing catalyst under effective hydrofinishing conditions, the effective hydrofinishing conditions including temperatures from 125°C to 425°C, total pressures from 500 psig (3.4 MPa) to 3000 psig (20.7 MPa), liquid hourly space velocities from 0.1 hr⁻¹ to 5 hr⁻¹ LHSV, and hydrogen treat gas rates of from 500 to 5000 scf/B (89 to 890 m³ / m³), the at least a portion of the optionally hydrocracked effluent being exposed to the hydrofinishing catalyst prior to the dewaxing catalyst, after the dewaxing catalyst, or a combination thereof.

19. The process of claim 10, the process further comprising exposing at least a portion of the optionally hydrocracked effluent to an aromatic saturation catalyst under effective aromatic saturation conditions, the effective aromatic saturation conditions including temperatures from 200°C to 425°C, total pressures from 500 psig (3.4 MPa) to 3000 psig (20.7 MPa), liquid hourly space velocities from 0.1 hr⁻¹ to 5 hr⁻¹ LHSV, and hydrogen treat gas rates of from 500 to 5000 scf/B (89 to 890 m³ / m³), the at least a portion of the optionally hydrocracked effluent being exposed to the aromatic saturation catalyst prior to the dewaxing catalyst, after the dewaxing catalyst, or a combination thereof.

20. The process of claim 10, further comprising separating the optionally hydrocracked, dewaxed effluent to form at least a lubricant boiling range fraction and a distillate boiling range fraction.