CLAIMS

What is claimed is:

~~1. 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 (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.

2. A process for producing a catalyst precursor composition containing *in situ* formed unsaturated carbon atoms, the 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 250°C for a time sufficient for the first or second organic compounds to react to form additional *in situ* unsaturated carbon atoms not present in 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 containing *in situ* formed unsaturated carbon atoms.

3. The catalyst precursor composition or the process of any one of the ~~previous 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.

4. The catalyst precursor composition or the process of any one of the previous embodiments, wherein said catalyst precursor composition further comprises at least one metal from Group 5 of the Periodic Table of the Elements, for example V, Nb, or a combination thereof.

5. The catalyst precursor composition or the process of any one of the previous embodiments, wherein said first organic compound comprises a primary monoamine having from 10 to 30 carbon atoms, and/or wherein said second organic compound comprises only one carboxylic acid group and has from 10 to 30 carbon atoms.

6. A bulk mixed metal catalyst precursor composition produced by heating the composition of any one of embodiments 1 and 3-5 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.

7. A bulk mixed metal hydroprocessing catalyst composition produced by sulfiding the catalyst precursor composition of embodiment 6.

8. The process of any one of embodiments 2-5, wherein the catalyst precursor composition containing *in situ* formed unsaturated carbon atoms 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.

9. A process for producing a sulfided hydroprocessing catalyst composition, comprising sulfiding the catalyst precursor composition containing *in situ* formed unsaturated carbon atoms made according to the process of any one of embodiments 2-5 and 8 under conditions sufficient to produce the sulfided ~~hydroprocessing catalyst composition.~~

10. A catalyst precursor composition containing *in situ* formed unsaturated carbon atoms made according to the process of any one of embodiments 2-5 and 8-9.

11. A sulfided hydroprocessing catalyst composition made according to the process of embodiment 10.

12. The catalyst precursor composition, the hydroprocessing catalyst, or the process of any one of the previous embodiments, wherein one or more of the following are satisfied:

the catalyst precursor composition exhibits a content of unsaturated carbon atoms, as measured according to peak area comparisons using ^{13}C NMR techniques, of at least 29%;

the catalyst precursor composition exhibits an increase in content of unsaturated carbon atoms, as measured according to peak area comparisons using ^{13}C NMR techniques, of at least about 17%, compared to a collective content of unsaturated carbon atoms present in the first or second organic compound;

the catalyst precursor composition exhibits 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}, compared to a deconvoluted peak centered from about 1380 cm^{-1} to about 1450 cm^{-1}, of at least 0.9; and

the catalyst precursor composition exhibits 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}, compared to a deconvoluted peak centered from about 1380 cm^{-1} to about 1450 cm^{-1}, of up to 15.

13. A process for producing a sulfided hydroprocessing catalyst composition, comprising sulfiding the catalyst precursor composition of any one of embodiments 1, 3-6, 10, and 12 or made according to the process of any one of embodiments 2-5, 8-9, and 12 under conditions sufficient to produce the sulfided

hydroprocessing catalyst composition, wherein one or more of the following are satisfied:

the sulfided hydroprocessing catalyst composition exhibits a layered structure comprising a plurality of stacked layers of sulfided Group 6 metal(s), such that the average number of stacked layers is from about 1.5 to about 3.5;

the sulfided hydroprocessing catalyst composition exhibits a layered structure comprising a plurality of stacked layers of sulfided Group 6 metal(s), such that the average number of stacked layers is at least about 0.8 stacked layers less than an identical sulfided hydroprocessing catalyst composition that has not been treated using first or second organic compounds;

upon exposure of the sulfided hydroprocessing catalyst composition to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided hydroprocessing catalyst composition exhibits a hydrodenitrogenation RMA of at least 57% greater than a sulfided catalyst composition that has not been treated using first or second organic compounds;

upon exposure of the sulfided hydroprocessing catalyst composition to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided hydroprocessing catalyst composition exhibits a hydrodenitrogenation RMA of up to 500% greater than a sulfided catalyst composition that has not been treated using first or second organic compounds;

upon exposure of the sulfided hydroprocessing catalyst composition to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided hydroprocessing catalyst composition exhibits a hydrodenitrogenation RMA at least 30% greater than a sulfided catalyst composition that has been treated with only a single organic compound having less than 10 carbon atoms; and

upon exposure of the sulfided hydroprocessing catalyst composition to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided hydroprocessing catalyst composition exhibits a hydrodenitrogenation RMA up to 500% greater than a sulfided catalyst composition that has been treated with only a single organic compound having less than 10 carbon atoms.

CLAIMS

What is claimed is:

1. A bulk mixed metal catalyst precursor composition produced by 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 (i) a first organic compound containing at least one amine group and at least 10 carbon atoms or (ii) a second organic compound containing at least one carboxylic acid group and at least 10 carbon atoms, but not both (i) and (ii), wherein the reaction product contains additional unsaturated carbon atoms, relative to (i) the first organic compound or (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, 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.

2. A bulk mixed metal hydroprocessing catalyst composition produced by sulfiding the catalyst precursor composition of claim 1.

3. The catalyst precursor composition of claim 1, wherein one or more of the following are satisfied:

the catalyst precursor composition exhibits a content of unsaturated carbon atoms, as measured according to peak area comparisons using ^{13}C NMR techniques, of at least 29%;

the catalyst precursor composition exhibits an increase in content of unsaturated carbon atoms, as measured according to peak area comparisons using ^{13}C NMR techniques, of at least about 17%, compared to a collective content of unsaturated carbon atoms present in the first or second organic compound;

the catalyst precursor composition exhibits 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}, compared to a deconvoluted peak centered from about 1380 cm^{-1} to about 1450 cm^{-1}, of at least 0.9; and

the catalyst precursor composition exhibits 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}, compared to a deconvoluted peak centered from about 1380 cm^{-1} to about 1450 cm^{-1}, of up to 15.

4. The bulk mixed metal catalyst precursor of claim 2, wherein one or more of the following are satisfied:

the sulfided bulk mixed metal catalyst precursor exhibits a layered structure comprising a plurality of stacked layers of sulfided Group 6 metal, such that the average number of stacked layers is from about 1.5 to about 3.5;

the sulfided bulk mixed metal catalyst precursor exhibits a layered structure comprising a plurality of stacked layers of sulfided Group 6 metal, such that the average number of stacked layers is at least about 0.8 stacked layers less than an identical sulfided bulk mixed metal catalyst precursor that has not been treated using first or second organic compounds;

upon exposure of the sulfided bulk mixed metal catalyst precursor to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided bulk mixed metal catalyst precursor exhibits a hydrodenitrogenation RMA of at least 57% greater than a sulfided catalyst composition that has not been treated using first or second organic compounds;

upon exposure of the sulfided bulk mixed metal catalyst precursor to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided bulk mixed metal catalyst precursor exhibits a hydrodenitrogenation RMA of up to 500% greater than a sulfided catalyst composition that has not been treated using first or second organic compounds;

upon exposure of the sulfided bulk mixed metal catalyst precursor to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided bulk mixed metal catalyst precursor exhibits a hydrodenitrogenation RMA at least 30% greater than a sulfided catalyst composition that has been treated with only a single organic compound having less than 10 carbon atoms; and

upon exposure of the sulfided bulk mixed metal catalyst precursor to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided bulk mixed metal catalyst precursor exhibits a hydrodenitrogenation RMA up to 500% greater than a sulfided

catalyst composition that has been treated with only a single organic compound having less than 10 carbon atoms.

5. A bulk mixed metal catalyst precursor composition according to claim 1 in which the metal from Group 6 of the Periodic Table of the Elements is tungsten.

6. A bulk mixed metal catalyst precursor composition according to claim 5 comprising one metal from Group 8 of the Periodic Table of the Elements.

7. A bulk mixed metal catalyst precursor composition according to claim 6 in which the metal from Group 8 of the Periodic Table of the Elements is nickel.

8. A bulk mixed metal catalyst precursor composition according to claim 1 in which the composition comprising the metals from Group 6 and Groups 8-10 of the Periodic Table of the Elements, and the reaction product containing additional unsaturated carbon atoms is formed from the first or second organic compounds by heating to a temperature from about 195°C to about 250°C in an oxidizing atmosphere.

9. A bulk mixed metal hydroprocessing catalyst composition produced by sulfiding the catalyst precursor composition of claim 8.

10. A process for producing a catalyst precursor composition containing *in situ*-formed unsaturated carbon atoms, the process comprising:

(a) treating a catalyst precursor 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, with a first organic compound containing at least one amine group and at least 10 carbons or a second organic compound containing at least one carboxylic acid group and at least 10 carbons, 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 250°C for a time sufficient for the first or second organic compounds to react to form additional *in situ* unsaturated carbon atoms not present in 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 containing *in situ* formed unsaturated carbon atoms.

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

12. The process of claim 10, wherein said first organic compound comprises a primary monoamine having from 10 to 30 carbon atoms or said second organic compound comprises only one carboxylic acid group and has from 10 to 30 carbon atoms.

13. The process of claim 10, wherein the catalyst precursor composition containing *in situ* formed unsaturated carbon atoms is a bulk metal hydroprocessing catalyst precursor composition consisting essentially of the reaction product of the first organic compound or the second organic compound, an oxide form of the 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.

14. A process for producing a sulfided hydroprocessing catalyst composition, comprising sulfiding the catalyst precursor composition containing *in situ* formed unsaturated carbon atoms made according to the process of claim 10 under conditions sufficient to produce the sulfided hydroprocessing catalyst composition.

15. A process for producing a sulfided hydroprocessing catalyst composition, comprising sulfiding the catalyst precursor composition containing *in situ* formed unsaturated carbon atoms made according to the process of claim 13 under conditions sufficient to produce the sulfided hydroprocessing catalyst composition.

16. A catalyst precursor composition containing *in situ* formed unsaturated carbon atoms made according to the process of claim 10.

17. A sulfided hydroprocessing catalyst composition made according to the process of claim 15.

18. The process of claim 10, wherein one or more of the following are satisfied:

the catalyst precursor composition exhibits a content of unsaturated carbon atoms, as measured according to peak area comparisons using ^{13}C NMR techniques, of at least 29%;

the catalyst precursor composition exhibits an increase in content of unsaturated carbon atoms, as measured according to peak area comparisons using ^{13}C NMR techniques, of at least about 17%, compared to a collective content of unsaturated carbon atoms present in the first or second organic compound;

the catalyst precursor composition exhibits 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}, compared to a deconvoluted peak centered from about 1380 cm^{-1} to about 1450 cm^{-1}, of at least 0.9; and

the catalyst precursor composition exhibits 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}, compared to a deconvoluted peak centered from about 1380 cm^{-1} to about 1450 cm^{-1}, of up to 15.

19. A process for producing a sulfided hydroprocessing catalyst composition, comprising sulfiding the catalyst precursor composition made according to the process of claim 10 under conditions sufficient to produce the sulfided hydroprocessing catalyst composition, wherein one or more of the following are satisfied:

the sulfided hydroprocessing catalyst composition exhibits a layered structure comprising a plurality of stacked layers of sulfided Group 6 metal, such that the average number of stacked layers is from about 1.5 to about 3.5;

the sulfided hydroprocessing catalyst composition exhibits a layered structure comprising a plurality of stacked layers of sulfided Group 6 metal, such that the average number of stacked layers is at least about 0.8 stacked layers less than an identical sulfided hydroprocessing catalyst composition that has not been treated using first or second organic compounds; upon exposure of the sulfided hydroprocessing catalyst composition to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided hydroprocessing catalyst composition exhibits a hydrodenitrogenation RMA of at least

57% greater than a sulfided catalyst composition that has not been treated using first or second organic compounds;

upon exposure of the sulfided hydroprocessing catalyst composition to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided hydroprocessing catalyst composition exhibits a hydrodenitrogenation RMA of up to 500% greater than a sulfided catalyst composition that has not been treated using first or second organic compounds;

upon exposure of the sulfided hydroprocessing catalyst composition to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided hydroprocessing catalyst composition exhibits a hydrodenitrogenation RMA at least 30% greater than a sulfided catalyst composition that has been treated with only a single organic compound having less than 10 carbon atoms; and

upon exposure of the sulfided hydroprocessing catalyst composition to a vacuum gasoil feedstock under hydroprocessing conditions, the sulfided hydroprocessing catalyst composition exhibits a hydrodenitrogenation RMA up to 500% greater than a sulfided catalyst composition that has been treated with only a single organic compound having less than 10 carbon atoms.

20. A process according to claim 19 in which the heating of the organically treated precursor catalyst composition is carried out in an oxidizing atmosphere.

21. A sulfide hydroprocessing catalyst composition produced by the process of claim 20.