CLAIMS

1. A process, comprising:

providing a hydrocarbon-containing feedstock to a mixing zone, where the hydrocarbon-containing feedstock is selected to contain at least 20 wt.% hydrocarbons having a boiling point of greater than 538°C as determined in accordance with ASTM Method D5307;

providing at least one metal-containing catalyst to the mixing zone, wherein any metal-containing catalyst provided to the mixing zone has an acidity as measured by ammonia chemisorption of at most 200 μmol ammonia desorbed from the catalyst per gram of catalyst;

continuously or intermittently providing hydrogen to the mixing zone;

blending the hydrogen, hydrocarbon-containing feedstock, and the metal-containing catalyst in the mixing zone at a temperature of from 375°C to 500°C and at a pressure of from 3.4 MPa to 27.5 MPa to produce:

a) a vapor comprised of hydrocarbons that are vaporizable at the temperature and the pressure within the mixing zone; and

b) a hydrocarbon-depleted feed residuum comprising hydrocarbons that are liquid at the temperature and pressure within the mixing zone;

continuously or intermittently separating at least a portion of the vapor from the mixing zone while retaining in the mixing zone at least a portion of the hydrocarbon-depleted feed residuum comprising hydrocarbons that are liquid at the temperature and pressure within the mixing zone, wherein the vapor separated from the mixing zone comprises a first hydrocarbon-containing product containing one or more hydrocarbon compounds that are liquid at STP; and

apart from the mixing zone, contacting the first hydrocarbon-containing product with hydrogen and a catalyst comprising a Column 6 metal of the Periodic Table or a compound thereof at a temperature of from 270°C to 425°C and a pressure of from 3.4 MPa to 27.5 MPa to produce a second hydrocarbon-containing product.

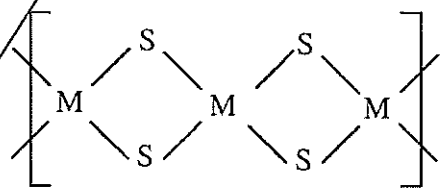
2. The process of claim 1 wherein the catalyst comprising a Column 6 metal further comprises a support material selected from alumina, silica, titania, zirconia, or mixtures thereof.

3. The process of claim 1 or claim 2 wherein the catalyst comprising a Column 6 metal further comprises a Column 7-10 metal of the Periodic Table or compound thereof.

4. The method of claim 1 or any of claims 2-3 wherein each metal-containing catalyst provided to the mixing zone has an acidity as measured by ammonia chemisorption of at most 100 μmol ammonia desorbed from the catalyst per gram of catalyst.

5. The process of claim 1 or any of claims 2-4 wherein at least one metal-containing catalyst provided to the mixing zone comprises a metal of Column 6, 14, or 15 of the Periodic Table or a compound thereof and a metal of Column(s) 3 or 7-15 of the Periodic Table or a compound thereof.

6. The process of claim 1 or any of claims 2-5 wherein at least one metal-containing catalyst provided to the mixing zone is comprised of a material comprised of a first metal and a second metal where the first metal comprises a metal selected from the group consisting of Cu, Ni, Co, Fe, Ag, Mn, Zn, Sn, Ru, La, Ce, Pr, Sm, Eu, Yb, Lu, Dy, Pb, Sb, and Bi, where the second metal comprises a metal selected from the group consisting of Mo, W, Sn, and Sb, where the second metal is not the same as the first metal, wherein at least a portion of the material comprised of the first metal and the second metal has a structure according to formula (III)

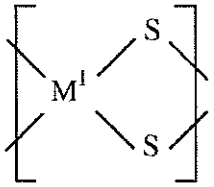


(III)

where M is either the first metal or the second metal, and at least one M is the first metal and at least one M is the second metal.

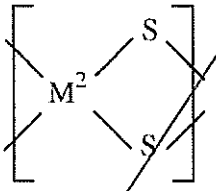
7. The process of claim 1 any of claims 2-5 wherein at least one metal-containing catalyst provided to the mixing zone is comprised of a material comprised of a first metal and a second metal where the first metal comprises a metal selected from the group consisting of Cu, Ni, Co, Fe, Ag, Mn, Zn, Sn, Ru, La, Ce, Pr, Sm, Eu, Yb,

Lu, Dy, Pb, Sb, and Bi, where the second metal comprises a metal selected from the group consisting of Mo, W, Sn, and Sb, where the second metal is not the same as the first metal, and wherein the material is comprised of at least three linked chain elements, the chain elements comprising a first chain element including the first metal and having a structure according to formula (I) and a second chain element including the second metal and having a structure according to formula (II)



(I)

where M^1 is the first metal



(II)

where M^2 is the second metal

where at least one chain element in the material is a first chain element and at least one chain element in the material is a second chain element, and where chain elements in the material are linked by bonds between the two sulfur atoms of a chain element and the metal of an adjacent chain element.

8. The process of claim 1 or any of claims 2-7 wherein hydrogen sulfide is provided to the mixing zone at a mole ratio of hydrogen sulfide to hydrogen of at least 1:10, or at least 1:5, or at least 1:4, or at least 3:10, or at least 3.5 to 10, or at least 2:5.

9. The process of claim 1 or any of claims 2-9 wherein the hydrocarbon-containing feedstock is continuously provided to the mixing zone, hydrogen is continuously provided to the mixing zone, and at least a portion of the vapor is continuously separated from the mixing zone for a period of at least 48 hours.

10. The process of claim 1 or any of claims 2-9 wherein the temperature in the mixing zone is selected and controlled to be at least 430°C or at least 450°C.

11. The process of claim 1 or any of claims 2-10 wherein the combined volume of the hydrocarbon-depleted feed residuum, the metal-containing catalyst(s), and the hydrocarbon-containing feedstock in the mixing zone defines a mixture volume in the mixing zone, and the hydrocarbon-containing feedstock is provided to the mixing zone at a rate selected to be at least 400, or at least 500, or at least 600, or at least 700, or at least 800, or at least 900, or at least 1000 kg/hr m^3 of the mixture volume in the mixing zone.

12. The process of claim 11 wherein the mixing zone is located in reactor;
the reactor has a reactor volume;
the combined volume of the hydrocarbon-containing feedstock and the metal-containing catalyst(s) initially provided to the mixing zone defines an initial mixture volume, where the initial mixture volume is from 5% to 97% of the reactor volume;and where the mixture volume of the metal-containing catalyst(s) in the mixing zone, the hydrocarbon-depleted feed residuum, and the hydrocarbon-containing feed is maintained at a level of at least 10% of the initial mixture volume.

13. The process of claim 1 or any of claims 2-12 wherein the first hydrocarbon-containing product has a sulfur content and the sulfur content of the second hydrocarbon-containing product is at most 10 wt.% of the sulfur content of the first hydrocarbon-containing product.

14. The process of claim 1 or any of claims 2-13 wherein the first hydrocarbon-containing product has a nitrogen content and the nitrogen content of the second hydrocarbon-containing product is at most 50 wt. % of the nitrogen content of the first hydrocarbon-containing product.

15. The process of claim 1 or any of claims 2-14 wherein the weight ratio of combined mono-aromatic and di-aromatic hydrocarbon compounds to poly-aromatic hydrocarbon compounds containing at least three aromatic rings in the second hydrocarbon-containing product is at least 4:1.

CLAIMS

1. A process, comprising:

providing a hydrocarbon-containing feedstock to a mixing zone, where the hydrocarbon-containing feedstock is selected to contain at least 20 wt.% hydrocarbons having a boiling point of greater than 538°C as determined in accordance with ASTM Method D5307;

providing at least one metal-containing catalyst to the mixing zone, wherein any metal-containing catalyst provided to the mixing zone has an acidity as measured by ammonia chemisorption of at most 200 μmol ammonia desorbed from the catalyst per gram of catalyst and wherein at least one metal-containing catalyst provided to the mixing zone comprises an element of Column 6, 14, or 15 of the Periodic Table or a compound thereof and an element of Column(s) 3 or 7-15 of the Periodic Table or a compound thereof;

continuously or intermittently providing hydrogen to the mixing zone;

blending the hydrogen, hydrocarbon-containing feedstock, and the metal-containing catalyst in the mixing zone at a temperature of from 375°C to 500°C and at a pressure of from 3.4 MPa to 27.5 MPa to produce:

a) a vapor comprised of hydrocarbons that are vaporizable at the temperature and the pressure within the mixing zone; and

b) a hydrocarbon-depleted feed residuum comprising hydrocarbons that are liquid at the temperature and pressure within the mixing zone;

continuously or intermittently separating at least a portion of the vapor from the mixing zone while retaining in the mixing zone at least a portion of the hydrocarbon-depleted feed residuum comprising hydrocarbons that are liquid at the temperature and pressure within the mixing zone, wherein the vapor separated from the mixing zone comprises a first hydrocarbon-containing product containing one or more hydrocarbon compounds that are liquid at STP; and

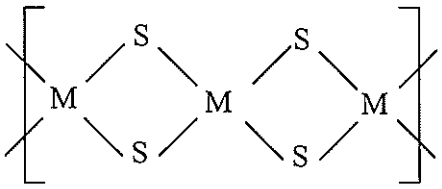
apart from the mixing zone, contacting the first hydrocarbon-containing product with hydrogen and a catalyst comprising a Column 6 metal of the Periodic Table or a compound thereof at a temperature of from 270°C to 425°C and a pressure of from 3.4 MPa to 27.5 MPa to produce a second hydrocarbon-containing product.

2. The process of claim 1 wherein the catalyst comprising a Column 6 metal further comprises a support material selected from alumina, silica, titania, zirconia, or mixtures thereof.

3. The process of claim 1 wherein the catalyst comprising a Column 6 metal further comprises a Column 7-10 metal of the Periodic Table or compound thereof.

4. The method of claim 1 wherein each metal-containing catalyst provided to the mixing zone has an acidity as measured by ammonia chemisorption of at most 100 μmol ammonia desorbed from the catalyst per gram of catalyst.

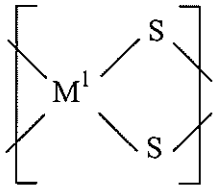
5. The process of claim 1 wherein at least one metal-containing catalyst provided to the mixing zone is comprised of a material comprised of a first metal and a second metal where the first metal comprises a metal selected from the group consisting of Cu, Ni, Co, Fe, Ag, Mn, Zn, Sn, Ru, La, Ce, Pr, Sm, Eu, Yb, Lu, Dy, Pb, Sb, and Bi, where the second metal comprises a metal selected from the group consisting of Mo, W, Sn, and Sb, where the second metal is not the same as the first metal, wherein at least a portion of the material comprised of the first metal and the second metal has a structure according to formula (III)



(III)

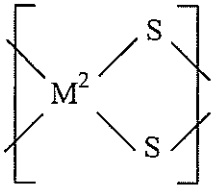
where M is either the first metal or the second metal, and at least one M is the first metal and at least one M is the second metal.

6. The process of claim 1 wherein at least one metal-containing catalyst provided to the mixing zone is comprised of a material comprised of a first metal and a second metal where the first metal comprises a metal selected from the group consisting of Cu, Ni, Co, Fe, Ag, Mn, Zn, Sn, Ru, La, Ce, Pr, Sm, Eu, Yb, Lu, Dy, Pb, Sb, and Bi, where the second metal comprises a metal selected from the group consisting of Mo, W, Sn, and Sb, where the second metal is not the same as the first metal, and wherein the material is comprised of at least three linked chain elements, the chain elements comprising a first chain element including the first metal and having a structure according to formula (I) and a second chain element including the second metal and having a structure according to formula (II)



(I)

where M1 is the first metal



(II)

where M2 is the second metal

where at least one chain element in the material is a first chain element and at least one chain element in the material is a second chain element, and where chain elements in the material are linked by bonds between the two sulfur atoms of a chain element and the metal of an adjacent chain element.

7. The process of claim 1 wherein hydrogen sulfide is provided to the mixing zone at a mole ratio of hydrogen sulfide to hydrogen of at least 1:10.

8. The process of claim 1 wherein the hydrocarbon-containing feedstock is continuously provided to the mixing zone, hydrogen is continuously provided to the mixing zone, and at least a portion of the vapor is continuously separated from the mixing zone for a period of at least 48 hours.

9. The process of claim 1 wherein the temperature in the mixing zone is selected and controlled to be 450°C to 500°C.

10. The process of claim 1 wherein the combined volume of the hydrocarbon-depleted feed residuum, the metal-containing catalyst(s), and the hydrocarbon-containing feedstock in the mixing zone defines a mixture volume in the mixing zone, and the hydrocarbon-containing feedstock is provided to the mixing zone at a rate selected to be at least 400 kg/hr m^3 of the mixture volume in the mixing zone.

11. The process of claim 10 wherein the mixing zone is located in reactor; the reactor has a reactor volume; the combined volume of the hydrocarbon-containing feedstock and the metal-containing catalyst(s) initially provided to the mixing zone defines an initial mixture volume, where the initial mixture volume is from 5% to 97% of the reactor volume; and where the mixture volume of the metal-containing catalyst(s) in the mixing zone, the hydrocarbon-depleted feed residuum, and the hydrocarbon-containing feed is maintained at a level of at least 10% of the initial mixture volume.

12. The process of claim 1 wherein the first hydrocarbon-containing product has a sulfur content and the sulfur content of the second hydrocarbon-containing product is at most 10 wt.% of the sulfur content of the first hydrocarbon-containing product.

13. The process of claim 1 wherein the first hydrocarbon-containing product has a nitrogen content and the nitrogen content of the second hydrocarbon-containing product is at most 50 wt. % of the nitrogen content of the first hydrocarbon-containing product.

14. The process of claim 1 wherein the weight ratio of combined mono-aromatic and di-aromatic hydrocarbon compounds to poly-aromatic hydrocarbon compounds containing at least three aromatic rings in the second hydrocarbon-containing product is at least 4:1.