Claims

1. A method of upgrading a hydrocarbon feedstock, the method comprising:

supplying the hydrocarbon feedstock to an oxidation reactor, the hydrocarbon feedstock comprising sulfur-containing compounds and nitrogen-containing compounds;

contacting the hydrocarbon feedstock with an oxidant in the presence of a catalyst in the oxidation reactor under conditions sufficient to selectively oxidize sulfur-containing compounds present in the hydrocarbon feedstock to produce an oxidized hydrocarbon stream that comprises hydrocarbons, oxidized sulfur-containing compounds, and oxidized nitrogen-containing compounds;

separating the hydrocarbons and the oxidized sulfur- and nitrogen-containing compounds in the oxidized hydrocarbon stream by solvent extraction with a non-acidic polar organic solvent, the non-acidic polar organic solvent being dimethylformamide, to produce an extracted hydrocarbon stream and a mixed stream, the mixed stream comprising the non-acidic polar organic solvent, the oxidized sulfur-containing compounds, and the oxidized nitrogen-containing compounds, wherein the extracted hydrocarbon stream has a lower concentration of sulfur and nitrogen than the hydrocarbon feedstock;

separating the mixed stream using a distillation column into a first recovered non-acidic polar organic solvent stream and a first residue stream;

supplying the first residue stream to a deasphalting unit to produce a deasphalted oil stream and a pitch stream, wherein the pitch stream includes a substantial portion of the oxidized sulfur-containing compounds and the nitrogen-containing compounds removed from the hydrocarbon feedstock;

supplying the extracted hydrocarbon stream to an adsorption column, the adsorption column being charged with an adsorbent suitable for the removal of oxidized compounds present in the extracted hydrocarbon stream, the adsorption column producing a high purity hydrocarbon product stream and a second residue stream, the second residue stream containing a portion of the oxidized sulfur-containing compounds and the oxidized nitrogen-containing compounds, and a spent adsorbent stream, the spent adsorbent stream containing another portion of the oxidized sulfur-containing compounds and the oxidized nitrogen-containing compounds; and

supplying the spent adsorbent stream to the deasphalting unit to remove contaminants from the deasphalted oil in the deasphalting unit;

supplying the extracted hydrocarbon stream to a stripper to produce a second recovered non-acidic polar organic solvent stream and a stripped hydrocarbon stream; and

recycling the first recovered non-acidic polar organic solvent stream and the second non-acidic polar organic solvent stream to an extraction vessel for the step of separating the hydrocarbons and the oxidized sulfur compounds in the oxidized hydrocarbon stream.

2. The method of claim 1, further comprising:

recycling a portion of the high purity hydrocarbon product stream to the oxidation reactor.

3. The method of claim 1, wherein the oxidant is selected from the group consisting of air, oxygen, oxides of nitrogen, peroxides, hydroperoxidies, organic peracids, and combinations thereof.

4. The method of claim 1, wherein the catalyst is a metal oxide having the formula M_xO_y, wherein M is an element selected from Groups IVB, VB, and VIB of the periodic table.

5. The method of claim 1, wherein the oxidation reactor is maintained at a temperature of between about 20ºC and about 150ºC and at a pressure of between about 1 bar and about 10 bars.

6. The method of claim 1, wherein the ratio of the oxidant to sulfur containing compounds present in the hydrocarbon feedstock is between about 4:1 and 10:1.

7. The method of claim 1, wherein the non-acidic polar organic solvent has a Hildebrandt value of greater than about 19.

8. The method of claim 1, wherein the solvent extraction is conducted at a temperature of between about 20ºC and about 60ºC and at a pressure of between about 1 bar and about 10 bars.

9. The method of claim 1, further comprising:

supplying the second residue stream to the deasphalting unit.

10. The method of claim 1, wherein the adsorbent is selected from the group consisting of activated carbon, silica gel, alumina, natural clays, zeolites; fresh, used, regenerated, or rejuvenated catalysts, and combinations of the same.

11. The method of claim 1, wherein the adsorbent is a polymer coated support, wherein the support is selected from the group consisting of silica gel, alumina, and activated carbon, and the polymer is selected from the group consisting of polysulfone, polyacrylonitrile, polystyrene, polyester terephthalate, polyurethane and combinations of the same.

12. The method of claim 1, wherein the supplying the first residue stream to the deasphalting unit further comprises supplying a deasphalting solvent selected from a paraffinic solvent having between 3 and 7 carbon atoms to the deasphalting unit and extracting the first residue stream with the deasphalting solvent at a temperature and pressure at or below the critical temperature and pressure of the paraffinic solvent, wherein the deasphalted oil stream includes a major fraction of the paraffinic solvent.

13. A method of upgrading a hydrocarbon feedstock, the method comprising:

supplying the hydrocarbon feedstock to an oxidation reactor, the hydrocarbon feedstock comprising sulfur-containing compounds;

catalytically oxidizing the sulfur-containing compounds in the hydrocarbon feedstock in the oxidation reactor with an oxidant in the presence of a catalyst under conditions sufficient to selectively oxidize the sulfur-containing compounds present in the hydrocarbon feedstock to sulfones and produce a treated hydrocarbon stream comprising hydrocarbons and sulfones and a waste catalyst stream;

extracting the treated hydrocarbon stream with a non-acidic polar organic solvent, the non-acidic polar organic solvent being dimethylformamide, in an extraction vessel to produce an

extracted hydrocarbon stream and a mixed stream, the mixed stream comprising the non-acidic polar organic solvent and the sulfones, wherein the extracted hydrocarbon stream has a lower sulfur concentration than the hydrocarbon feedstock;

separating the mixed stream using a solvent regeneration column into a recovered non-acidic polar organic solvent stream and a residue stream comprising sulfones;

supplying the residue stream comprising sulfones to a deasphalting unit and extracting the residue stream with a paraffinic solvent having between 3 and 7 carbon atoms to produce a deasphalted oil stream and a pitch stream, wherein the extraction of the residue stream is conducted a temperature and pressure that is at or below the supercritical temperature and pressure of the paraffinic solvent;

supplying the extracted hydrocarbon stream to a distillation column and separating the extracted hydrocarbon stream into a high purity hydrocarbon product stream and a desulfurized deasphalted oil stream; and

recycling at least a portion of the recovered non-acidic polar organic solvent stream to the extraction vessel, wherein at least a portion of the recovered non-acidic polar organic solvent stream is combined with the non-acidic polar organic solvent.

14. The method of claim 13, further comprising:

recycling the deasphalted oil stream to the oxidation reactor.

15. The method of claim 13, wherein the hydrocarbon feedstock further comprises nitrogen-containing compounds, such that the step of catalytically oxidizing further comprises catalytically oxidizing the nitrogen-containing compounds in the hydrocarbon feedstock with the

oxidant in the presence of the catalyst, and wherein the residue stream supplied to the deasphalting unit includes the oxidized nitrogen-containing compounds.

16. The method of claim 13, wherein the oxidation reactor is maintained at a temperature of between about 20ºC and about 150ºC and at a pressure of between about 1 bar and about 10 bars and the solvent extraction is conducted at a temperature of between about 20ºC and about 60ºC and at a pressure of between about 1 bar and about 10 bars.

17. The method of claim 13, wherein the non-acidic polar organic solvent has a Hildebrandt value of greater than about 19.