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;

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

supplying the hydrocarbon stream to an extraction vessel and separating the hydrocarbon stream into an extracted hydrocarbon stream and a mixed stream by extracting the hydrocarbon stream with a non-acidic polar organic solvent, the non-acidic polar organic solvent being dimethylformamide, the mixed stream comprising the non-acidic polar organic solvent and the oxidized sulfur-containing compounds and wherein the extracted hydrocarbon stream has a lower concentration of the sulfur containing-compounds 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 coker to produce a volatile component stream;

recycling at least a portion of the volatile component stream to the oxidation reactor to selectively oxidize sulfur compounds in the volatile component stream, the recycled portion of the volatile component stream comprising at least one of light coker gas oils and heavy coker gas oils;

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 separating the hydrocarbons and the oxidized sulfur-containing compounds in the oxidized hydrocarbon stream.

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

3. The method of claim 1, wherein the oxidation reactor 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.

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

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

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

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

8. The method of claim 1, wherein the hydrocarbon feedstock further comprises nitrogen-containing compounds, such that the step of contacting the hydrocarbon feedstock with the oxidant in the presence the catalyst oxidizes at least a portion of the nitrogen-containing compounds, and wherein the residue stream supplied to the coker includes the oxidized nitrogen-containing compounds.

9. The method of any one of claims 1-12, further comprising:

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 compounds.

10. The method of claim 9, further comprising:

supplying the second residue stream to the coker.

11. The method of claim 9, wherein the adsorbent is selected from the group consisting of activated carbon, silica gel, alumina, natural clays, and combinations of the same.

12. The method of claim 9, 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.

13. A method for upgrading a hydrocarbon feedstock comprising sulfur-containing compounds, the method for upgrading the hydrocarbon feedstock comprising:

supplying the hydrocarbon feedstock having a boiling point of up to about 500ºC to reaction zone where the hydrocarbon feedstock is contacted with an oxidant in the presence of a catalyst to oxidize at least a portion of the sulfur-containing compounds in the hydrocarbon feedstock and produce an intermediate product stream comprising hydrocarbons and oxidized sulfur-containing compounds;

supplying the intermediate product stream comprising hydrocarbons and oxidized sulfur-containing compounds to an extraction vessel, wherein the intermediate product stream is contacted with a non-acidic polar organic solvent, the non-acidic polar organic solvent being dimethylformamide, wherein the non-acidic polar organic solvent selectively extracts oxidized sulfur-containing compounds from the intermediate product stream, to produce a first hydrocarbon product stream comprising hydrocarbons and having a lower concentration of sulfur-containing compounds than the hydrocarbon feedstock and a mixed stream comprising the non-acidic polar organic solvent and the extracted oxidized sulfur containing compounds;

separating the mixed stream by distillation to produce a recovered polar solvent stream comprising a major portion of the non-acidic polar organic solvent, and a residue stream comprising the oxidized sulfur-containing compounds;

supplying the residue stream to a coker to produce a recovered hydrocarbon product stream comprising condensed coker vapors and gas oil and solid coke, wherein the coker includes a coker furnace and a coker drum, and wherein the coker furnace is operated at a temperature of at least about 400ºC and the coker drum is operated at a temperature of at least about 425ºC and a pressure in the range of between about 1 and 50 bars;

recycling at least a portion of the recovered hydrocarbon product stream to the oxidation reactor to selectively oxidize sulfur compounds in the hydrocarbon product stream, the recycled portion of the hydrocarbon product stream comprising at least one of light coker gas oils and heavy coker gas oils; 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, wherein the step of oxidizing at least a portion of the sulfur-containing compounds in the hydrocarbon feedstock is characterized by contacting the hydrocarbon feedstock with the oxidant and catalyst in the oxidation reaction, wherein the oxidation reactor is maintained at a temperature of between about 20ºC and 150ºC and a pressure of between about 1 and 20 bars for a contact time of between about 5 and 60 minutes.

15. The method of claim 14, wherein the ratio of catalyst to oil is between about 0.1% and 10% by weight.

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

17. The method of claim 13, wherein the extraction vessel is maintained at a temperature of between about 20ºC and 60ºC.

18. The method of claim 13, wherein the hydrocarbon feedstock further comprises nitrogen-containing compounds, such that the step of supplying the hydrocarbon feedstock to be contacted with the oxidant in the presence the catalyst oxidizes at least a portion of the nitrogen-containing compounds, and wherein the residue stream supplied to the coker includes the oxidized nitrogen-containing compounds.