CLAIMS

1. A process for reducing the sulphur content of a hydrocarbon material containing sulphur compounds, the process comprising the steps of:

a) contacting the hydrocarbon material with one or more primary oxidants to provide a primary oxidised hydrocarbon material such that the primary oxidant oxidizes at least a portion of the sulphur compounds to sulphoxide and/or sulphone compounds,

wherein the primary oxidant is hydrogen peroxide catalysed by phosphotungstic acid and co-catalysed by a phase transfer catalyst (PTC) comprising a quaternary ammonium salt;

b) contacting the primary oxidised hydrocarbon material with an extractant such as acetonitrile, to allow at least a portion of the sulphoxide and/or sulphone compounds to be extracted into the extractant to give a sulphoxide and/or sulphone stream and a low sulphur hydrocarbon stream;

c) separating the sulphoxide and/or sulphone stream from the low sulphur hydrocarbon stream; and

d) contacting the low sulphur hydrocarbon stream from step c) with a secondary oxidant to provide a secondary oxidised hydrocarbon material, wherein the secondary oxidant is selected from one or more of the group consisting of hydroxyl radicals and hypofluorous acid in acetonitrile, prepared by bubbling a gaseous mixture comprising fluorine and nitrogen into liquid acetonitrile to form $HOF.CH_3CN$, wherein the concentration of fluorine mixed with nitrogen does not exceed 20% by weight fluorine blended with the nitrogen.

2. The process for reducing the sulphur content of a hydrocarbon material containing sulphur compounds according to claim 1, the process comprising the steps of:

a) contacting the hydrocarbon material with one or more primary oxidants to provide a primary oxidised hydrocarbon material such that the primary oxidant oxidizes at least a portion of the sulphur compounds to sulphoxide and/or sulphone compounds,

wherein the primary oxidant is catalysed by phosphotungstic acid and co-catalysed by a phase transfer catalyst (PTC) comprising a quaternary ammonium salt;

b) contacting the primary oxidised hydrocarbon material with an extractant, such as acetonitrile, to allow at least a portion of the sulphoxide and/or sulphone compounds to be extracted into the extractant to give a sulphoxide and/or sulphone stream and a low sulphur hydrocarbon stream;

c) separating the sulphoxide and/or sulphone stream from the low sulphur hydrocarbon stream;

d) contacting the low sulphur hydrocarbon stream from step c) with a secondary oxidant to provide a secondary oxidised hydrocarbon material, wherein the secondary oxidant is selected from one or more of the group consisting of hydroxyl radicals, and hypofluorous acid in acetonitrile, prepared by bubbling a gaseous mixture comprising fluorine and nitrogen into liquid acetonitrile to form $HOF.CH_3CN$, wherein the concentration of fluorine mixed with nitrogen does not exceed 20% by weight fluorine blended with the nitrogen,

such that the secondary oxidant oxidizes at least a portion of sulphur compounds to sulphoxide and/or sulphone compounds; and

e) contacting the sulphoxide and/or sulphone stream with a tertiary oxidant to give an aqueous sulphite stream and a low sulphur aromatic hydrocarbon stream, wherein the tertiary oxidant oxidises sulphone and/or sulphoxide compounds to sulphite compounds.

3. The process according to claim 1 or 2 wherein the PTC comprises a quaternary ammonium hydrogen sulphate.

4. The process according to claim 1 or 2 wherein the secondary oxidant is supplied to a secondary oxidizing reactor at less than 25˚C (77˚F) and at a pressure in the range of 30 PSI (140 kPa) to 100 PSI (700 kPa).

5. The process of any one of claims 1 to 4 wherein the extractant is a polar extraction solvent selected from the group consisting of acetonitrile, DMF, DMSO, methanol, water, brine and furfural or an ionic liquid (IL).

6. The process according to any one of claims 1 to 5 wherein the primary and/or secondary oxidised hydrocarbon material obtained from step a) and/or step d) are washed with water.

7. The process according to any one of claims 1 to 6 further comprising a water washing step before the sulphoxide and/or sulphone stream and the low sulphur hydrocarbon stream are separated.

8. The process according to claim 2 wherein the tertiary oxidant is a caustic solution, selected from the group consisting of:

i) sodium hydroxide,

ii) potassium hydroxide and

iii) hydroxyl radicals.

9. The process according to claim 2 or 8 wherein oxidation with the tertiary oxidant is carried out in a range of 40 to 95ºC.

10. The process according to claim 2, 8 or 9 wherein the tertiary oxidant is sodium hydroxide and an aqueous sodium sulphite solution is formed.

11. The process according to claim 10 wherein the sodium hydroxide solution is in a concentration of 30 to 60%.

12. The process according to claim 11 wherein the stoichiometric ratio of sulphone to sodium hydroxide is 1:1.

13. The process according to any one of claims 8 to 12 wherein the oxidation is carried out at a temperature in the range of 40 to 95ºC, the tertiary oxidant and the sulphoxide and/or sulphone stream are agitated for a period of up to 12 minutes.

14. A process for reducing the sulphur content of a hydrocarbon material containing sulphur compounds, the process comprising:

a) contacting the hydrocarbon material with one or more primary oxidants to provide a primary oxidised hydrocarbon material such that the primary oxidant oxidizes at least a portion of the sulphur compounds to sulphoxide and/or sulphone compounds,

wherein the primary oxidant is selected from one or more of the group consisting of N-chloroimide, hypobromous acid, hypochlorous acid, electrolyzed oxidizing water and catalysed and co-catalysed hydrogen peroxide;

b) contacting the primary oxidised hydrocarbon material with an extractant to allow at least a portion of the sulphoxide and/or sulphone compounds to be extracted into the extractant to give a sulphoxide and/or sulphone stream and a low sulphur hydrocarbon stream; and

c) separating the sulphoxide and/or sulphone stream from the low sulphur hydrocarbon stream,

wherein the process further includes a step of contacting the sulphoxide and/or sulphone stream with a tertiary oxidant to give an aqueous sulphite stream and a low sulphur aromatic hydrocarbon stream, wherein the tertiary oxidant oxidises sulphone and/or sulphoxide compounds to sulphite compounds and wherein the tertiary oxidant consists of hydroxyl radicals such that following addition of water, sulphuric acid forms.

15. The process according to any one of claims 2 and 8 to 14 wherein the tertiary oxidant is hydroxyl radicals such that following addition of water, sulphuric acid forms and the stoichiometric ratio of hydroxyl radicals to sulphone/sulphoxide is in the range of 1:1 to 4:1.

16. The process according to any one of claims 1 to 15 wherein the low sulphur hydrocarbon stream and the low sulphur aromatic stream are combined and recycled as low sulphur hydrocarbon fuel.

17. The process according to claim 2 wherein the process further comprises:

e) contacting the low sulphur hydrocarbon stream obtained in step c) with an adsorbent to remove residual sulphur compounds from the low sulphur hydrocarbon stream (LSD) to provide an ultra low sulphur hydrocarbon stream (ULSD).

18. The process according to claim 17 wherein the adsorbent is selected from physical or physiochemical adsorbents, Y-zeolite, activated carbon and Metal Oxide Framework (MOF).

19. The process according to claim 17 wherein following step e) the loaded absorbent is regenerated/purged using heater N2, stripping to desorb sulfur compounds from the adsorbent.

20. The process according to any one of claims 1 to 19 wherein the low sulphur hydrocarbon stream (LSD) is polished using adsorbents including MOF (Metal Organic Framework), (C18H6Cu3O12) – Copper Benzene-1,3,5-Tricarboxylate, Metal Oxide Purification Adsorbent group of adsorbents, CuCl2MIL-47 MOF, Y-Zeolite, Molecular Imprinted Chitosan or Activated Carbon.