CLAIMS

1. A method of extracting 1–4 cycle heterocyclic compounds and 2–5 cycle polynuclear aromatic hydrocarbons from a hydrocarbon feedstock, the method comprising:

providing a hydrocarbon feedstock containing crude oil fractions comprising 1–4 cycle heterocyclic compounds and 2–5 cycle polynuclear aromatic hydrocarbons;

determining an A/R ratio and an asphaltene concentration of the hydrocarbon feedstock;

treating the hydrocarbon feedstock based upon the determination of the A/R ratio and asphaltene concentration to form a treatable hydrocarbon feedstock comprising fractions with a boiling point range of greater than 360 °C;

cracking the treatable hydrocarbon feedstock in a cracker to form a treated hydrocarbon feedstock comprising fractions having a boiling point range of 165 °C to 470 °C;

fractionating the treated hydrocarbon feedstock into a first fractionated stream having a boiling point range of less than 165 °C, a second fractionated stream having a boiling point range of 165 °C to 470 °C, and a third fractionated stream having a boiling point range of greater than 470 °C;

extracting at least one targeted portion of the 1–4 cycle heterocyclic compounds from the second fractionated stream with an aqueous solvent comprising an ionic liquid formed from pressurized carbon dioxide and water;

transferring to a PAH extractor a 1–4 cycle heterocyclic compound-lean stream containing the 2–5 cycle polynuclear aromatic hydrocarbons after all targeted portions of the 1–4 cycle heterocyclic compounds have been extracted from the second fractionated stream; and

extracting the 2–5 cycle polynuclear aromatic hydrocarbons from the heteroatom-lean stream in the PAH extractor with a solvent system comprising an aprotic solvent.

2. The method of claim 1, in which the treated hydrocarbon feedstock comprises greater than 90% by weight fractions having a boiling point range of less than 470 °C.

3. The method of claim 1, in which the hydrocarbon feedstock comprises at least one of heavy crude oil fractions, medium crude oil fractions, and mixtures thereof.

4. The method of claim 1, in which the cracking step comprises thermal cracking, steam cracking, or catalytic cracking.

5. The method of claim 1, in which the cracking step comprises catalytic cracking with a zeolite catalyst.

6. The method of claim 1, in which:

the hydrocarbon feedstock is determined to have an A/R ratio from 0.5:1 to 1.5:1 and an asphaltene concentration from 2.0 wt.% to 15 wt.%; and

treating the hydrocarbon feedstock comprises:

fractionating the hydrocarbon feedstock in a vacuum fractionator to form a first hydrocarbon stream with fractions having a boiling point range of 360 °C to 470 °C and a second hydrocarbon stream with fractions having a boiling point range of greater than 470 °C;

deasphalting the second hydrocarbon stream in a solvent deasphalter to form a deasphalted oil stream and an asphalt fraction; and

hydrocracking the deasphalted oil stream in a mild hydrocracker to form the treatable hydrocarbon feedstock.

7. The method of claim 6, in which the hydrocracking step is conducted at a pressure from 4 MPa to 16 MPa and a temperature from 330 °C to 440 °C.

8. The method of claim 1, in which:

the hydrocarbon feedstock is determined to have an A/R ratio from 0:1 to 0.5:1 and an asphaltene concentration from 0.0 wt.% to 2.0 wt.%; and

treating the hydrocarbon feedstock comprises fractionating the hydrocarbon feedstock in a fractionator to form the treatable hydrocarbon stream having fractions with a boiling point range of greater than 360 °C and a second hydrocarbon stream having fractions with a boiling point range of less than 360 °C.

9. The method of claim 1, in which:

the hydrocarbon feedstock is determined to have an A/R ratio from 0:1 to 0.5:1 and an asphaltene concentration from 0.0 wt. % to 2.0 wt. %; and

treating the hydrocarbon feedstock comprises fractionating the hydrocarbon feedstock to form a first fractionated stream having fractions with a boiling point range of less than 360 °C and the treatable feedstock having fractions with a boiling point range of greater than or equal to 360 °C.

10. The method of claim 1, in which extracting at least one targeted portion of the 1–4 cycle heterocyclic compounds from the second fractionated stream comprises:

extracting a first targeted portion of the 1–4 cycle heterocyclic compounds having a first polarity in a first extraction vessel operating at a first pressure;

extracting a second targeted portion of the 1–4 cycle heterocyclic compounds in a second extraction vessel after extracting the first portion, the second extraction vessel operating at a second pressure greater than the first pressure, the second portion of the heteroatom compounds having a second polarity that is less than the first polarity; and

extracting a third targeted portion of the 1–4 cycle heterocyclic compounds in a third extraction vessel after extracting the second portion of the 1–4 cycle heterocyclic compounds, the third extraction vessel operating at a third pressure greater than the first pressure and the second pressure, the

third portion of the 1–4 cycle heterocyclic compounds having a third polarity that is less than the second polarity.

11. The method of claim 1, in which the extraction of each targeted portion of the 1–4 cycle heterocyclic compounds from the second fractionated stream comprises:

feeding into an extraction vessel separately or as a mixture:

the second fractionated stream; and

the aqueous solvent,

whereby the combination of the second fractionated stream with the aqueous solvent in the extraction vessel forms an extraction mixture;

tuning the aqueous solvent to selectively form solvent complexes with the targeted portion of the 1–4 cycle heterocyclic compounds in the extraction mixture, whereby the extraction mixture separates into at least a 1–4 cycle heterocyclic-compound rich phase and a 1–4 cycle heterocyclic-compound lean phase, the 1–4 cycle heterocyclic-compound rich phase containing the solvent complexes;

removing the 1–4 cycle heterocyclic-compound lean phase from the extraction vessel as a 1–4 cycle heterocyclic-compound lean stream;

removing the 1–4 cycle heterocyclic-compound rich phase from the extraction vessel as a 1–4 cycle heterocyclic-compound rich stream; and

optionally transferring the 1–4 cycle heterocyclic-compound lean stream from the extraction vessel as a feed stream derived from the hydrocarbon feedstock to an additional extraction vessel for extraction of an additional targeted portion of heteroatom compounds from the feed stream.

12. The method of claim 11, in which:

tuning the aqueous solvent system comprises establishing an extraction pressure and an extraction temperature of the extraction mixture in the extraction vessel that together tune the aqueous solvent to selectively form a solvent complex with the targeted portion of the 1–4 cycle heterocyclic compounds;

the extraction pressure is from 2 bar to 300 bar; and

the extraction temperature of the extraction mixture is from greater than the critical temperature of carbon dioxide to 150 °C.

13. The method of claim 1, in which extracting the 2–5 cycle polynuclear aromatic hydrocarbons comprises:

combining the 1–4 cycle heterocyclic-compound lean phase with the solvent system in the PAH extractor, whereby the 1–4 cycle heterocyclic-compound lean phase separates into a PAH-rich phase and a PAH-lean phase, the PAH-rich phase comprising a mixture of polynuclear aromatic hydrocarbons;

removing the PAH-rich phase from the PAH extractor as a PAH recovery stream; and

removing the PAH-lean phase from the PAH extractor as a lean raffinate.

14. The method of claim 13, further comprising:

transferring the PAH recovery stream to a PAH fractionator;

separating the mixture of polynuclear aromatic hydrocarbons in the PAH recovery stream in the PAH fractionator into multiple PAH solute fractions; and

recovering polynuclear aromatic hydrocarbons from the PAH solute fractions.

15. The method of claim 1, in which:

the heteroatom compounds comprise pyrrole, pyridine, quinoline, carbazole, indole, nickel tetraphenylporphyrin, vanadyl tetraphenylporphyrin, thiophene, benzothiophene, dibenzothiophene, 7,8,9,10-tetrahydro-benzo[b]naphtho[2,3-d]thiophene, or combinations thereof; and

the 2–4 cycle polynuclear aromatic hydrocarbons comprise benzanthracenes, naphthalenes, anthracenes, pyrenes, phenanthrenes, tetracenes, or combinations thereof.

16. A method of extracting 1–4 cycle heterocyclic compounds and 2–5 cycle polynuclear aromatic hydrocarbons from a hydrocarbon feedstock, the method comprising:

providing a hydrocarbon feedstock comprising having an A/R ratio from 0:1 to 0.5:1 and an asphaltene concentration from 0.0 wt.% to 2.0 wt.%, the hydrocarbon feedstock containing crude oil fractions comprising 1–4 cycle heterocyclic compounds and 2–5 cycle polynuclear aromatic hydrocarbons;

cracking hydrocarbon feedstock in a cracker to form a treated hydrocarbon feedstock comprising fractions having a boiling point range of 165 °C to 470 °C;

fractionating the treated hydrocarbon feedstock into a first fractionated stream having a boiling point range of less than 165 °C, a second fractionated stream having a boiling point range of 165 °C to 470 °C, and a third fractionated stream having a boiling point range of greater than 470 °C;

extracting at least one targeted portion of the 1–4 cycle heterocyclic compounds from the second fractionated stream with an aqueous solvent comprising an ionic liquid formed from pressurized carbon dioxide and water;

transferring to a PAH extractor a 1–4 cycle heterocyclic compound-lean stream containing the 2–5 cycle polynuclear aromatic hydrocarbons after all targeted portions of the 1–4 cycle heterocyclic compounds have been extracted from the second fractionated stream; and

extracting the 2–5 cycle polynuclear aromatic hydrocarbons from the heteroatom-lean stream in the PAH extractor with a solvent system comprising an aprotic solvent.

17. The method of claim 16, in which the treated hydrocarbon feedstock comprises greater than 90% by weight fractions having a boiling point range of less than 470 °C.

18. The method of claim 16, in which the cracking step comprises thermal cracking, steam cracking, or catalytic cracking.

19. The method of claim 16, in which extracting at least one targeted portion of the 1–4 cycle heterocyclic compounds from the second fractionated stream comprises:

extracting a first targeted portion of the 1–4 cycle heterocyclic compounds having a first polarity in a first extraction vessel operating at a first pressure;

extracting a second targeted portion of the 1–4 cycle heterocyclic compounds in a second extraction vessel after extracting the first portion, the second extraction vessel operating at a second pressure greater than the first pressure, the second portion of the heteroatom compounds having a second polarity that is less than the first polarity; and

extracting a third targeted portion of the 1–4 cycle heterocyclic compounds in a third extraction vessel after extracting the second portion of the 1–4 cycle heterocyclic compounds, the third extraction vessel operating at a third pressure greater than the first pressure and the second pressure, the third portion of the 1–4 cycle heterocyclic compounds having a third polarity lesser that is less than the second polarity.

20. The method of claim 1, in which extracting the 2-5 cycle polynuclear aromatic hydrocarbons comprises:

combining the 1-4 cycle heterocyclic-compound lean phase with the solvent system in the PAH extractor, whereby the 1-4 cycle heterocyclic-compound lean phase separates into a PAH-rich phase and a PAH-lean phase, the PAH-rich phase comprising a mixture of polynuclear aromatic hydrocarbons;

removing the PAH-rich phase from the PAH extractor as a PAH recovery stream; and

removing the PAH-lean phase from the PAH extractor as a lean raffinate.