CLAIMS:

What is claimed is:

1. A multi-stage hydrocarbon upgrading process, comprising:

(I) contacting a hydrocarbon-containing feed with a first catalyst comprising a Group 8-10 element disposed on a support within a first conversion zone to effect one or more of dehydrogenation, dehydroaromatization, and dehydrocyclization of a portion of the hydrocarbon-containing feed to produce a first conversion zone effluent comprising one or more upgraded hydrocarbons, molecular hydrogen, and unconverted hydrocarbon-containing feed;

(II) contacting the first conversion zone effluent with a second catalyst comprising a Group 8-10 element disposed on a support within a second conversion zone to effect one or more of dehydrogenation, dehydroaromatization, and dehydrocyclization of at least a portion of the unconverted hydrocarbon-containing feed to produce a second conversion zone effluent comprising an additional quantity of one or more upgraded hydrocarbons and molecular hydrogen; wherein:

the hydrocarbon-containing feed comprises one or more of C_2-C_{16} linear or branched alkanes, one or more of C_4-C_{16} cyclic alkanes, one or more of C_8-C_{16} alkyl aromatic hydrocarbons, or a mixture thereof;

the hydrocarbon-containing feed and the first catalyst are contacted for a time period in a range from 0.1 seconds to 3 hours, under a hydrocarbon partial pressure of at least 20 kPa-absolute, wherein the hydrocarbon partial pressure is the total partial pressure of any C_2-C_{16} alkanes and any C_8-C_{16} alkyl aromatic hydrocarbons in the hydrocarbon-containing feed;

the first conversion zone effluent and the second catalyst are contacted for a time period in a range from 0.1 seconds to 3 hours, under a hydrocarbon partial pressure of at least 20 kPa-absolute, wherein the hydrocarbon partial pressure is the total partial pressure of any C_2-C_{16} alkanes and any C_8-C_{16} alkyl aromatic hydrocarbons in the first conversion zone effluent;

the first conversion zone effluent has a temperature in a range from 300°C to 850°C;

the second conversion zone effluent has a temperature in a range from 350°C to 900°C;

the temperature of the second conversion zone effluent is greater than the temperature of the first conversion zone effluent;

the first catalyst and the second catalyst have the same composition or a different composition;

the first catalyst and the second catalyst each comprise from 0.05 wt% to 6 wt% of the Group 8-10 element based on the weight of the support;

the one or more upgraded hydrocarbons comprise a dehydrogenated hydrocarbon, a dehydroaromatized hydrocarbon, a dehydrocylized hydrocarbon, or a mixture thereof; and

at least one of the following is met:

(a) in step (I), the hydrocarbon-containing feed and the first catalyst are contacted in the presence of steam at an amount from 0.1 vol% to 50 vol%, based on a total volume of any C_2-C_{16} alkanes, any C_4-C_{16} cyclic alkanes, and any C_8-C_{16} alkyl aromatics in the hydrocarbon-containing feed; and

(b) in step (II), the first conversion zone effluent and the second catalyst are contacted in the presence of steam at an amount from 0.1 vol% to 50 vol%, based on a total volume of any C_2-C_{16} alkanes, any C_4-C_{16} cyclic alkanes, and any C_8-C_{16} alkyl aromatics in the first conversion zone effluent.

2. The process of claim 1, wherein at least one of the first catalyst and the second catalyst is disposed within a fixed bed; and/or a least one of the first conversion zone and the second conversion zone is disposed within a fixed-bed reactor.

3. The process of claim 1, wherein at least one of the first catalyst and the second catalyst is in the form of fluidized catalyst particles.

4. The process of claim 1, wherein at least one of the following is met:

(i) the first catalyst and the second catalyst are in the form of fluidized catalyst particles; and

(ii) and the first and second conversion zones are substantially adiabatic.

5. The process of claim 4, wherein at least one of the following is met:

(i) a ratio of the first catalyst to a combined amount of any C_2-C_{16} alkanes and any C_8-C_{16} alkyl aromatics in the hydrocarbon-containing feed within the first conversion zone is in a range of 1 to 100 on a weight to weight basis;

(ii) a ratio of the second catalyst to a combined amount of any C_2-C_{16} alkanes and any C_8-C_{16} alkyl aromatics in the first conversion zone effluent within the second conversion zone is in a range of 1 to 50 on a weight to weight basis; and

(iii) a ratio of a combined amount of the first catalyst and the second catalyst to a combined amount of any C_2-C_{16} alkanes and any C_8-C_{16} alkyl aromatics in the first conversion zone effluent within the second conversion zone is in a range of 2 to 150.

6. The process of claim 4, wherein at least one of the following is met:

(i) when the first catalyst is initially contacted with the hydrocarbon-containing feed, the first catalyst has a temperature that is in a range of from 10°C to 200°C greater than a temperature of the first conversion zone effluent; and

(ii) when the second catalyst is initially contacted with the first conversion zone effluent, the second catalyst has a temperature that is in a range of 30°C to 300°C greater than a temperature of the second conversion zone effluent.

7. The process of claim 4, wherein the first conversion zone and the second conversion zone are disposed within a riser reactor or a downer reactor.

8. The process of claim 1, wherein contacting the hydrocarbon-containing feed with the first catalyst produces a coked first catalyst and contacting the first conversion zone effluent with the second catalyst produces a coked second catalyst, the process further comprising:

(III) contacting the coked first catalyst, the coked second catalyst, or the coked first catalyst and the coked second catalyst with an oxidant to effect combustion of at least a portion of the coke to produce a combustion gas and a regenerated first catalyst, a regenerated second catalyst, or a regenerated first catalyst and a regenerated second catalyst.

9. The process of claim 8, wherein in step (III), at least one of the following is met:

(i) the coked first catalyst particles, the coked second catalyst particles, or the coked first catalyst particles and the coked second catalyst particles and oxidant are contacted at a temperature in a range from 580°C to 1,100°C; and

(ii) the coked first catalyst particles, the coked second catalyst particles, or the coked first catalyst particles and the coked second catalyst particles and oxidant are contacted under an oxidant partial pressure in a range from 5 kPa-absolute to 1,000 kPa-absolute.

10. The process of claim 8, further comprising (IV) contacting at least a portion of any regenerated first catalyst, at least a portion of any regenerated second catalyst, or at least a portion of any regenerated first catalyst and at least a portion of any regenerated second catalyst with a reducing gas to produce a regenerated and reduced first catalyst, a regenerated and reduced second catalyst, or a regenerated and reduced first catalyst and a regenerated and reduced second catalyst.

11. The process of claim 10, wherein the reducing gas comprises molecular hydrogen, carbon monoxide, methane, ethane, ethylene, propane, propylene, steam, molecular nitrogen, argon, carbon dioxide, or a mixture thereof.

12. The process of claim 10, wherein in step (IV), at least one of the following is met:

(i) the at least a portion of any regenerated first catalyst, the at least a portion of any regenerated second catalyst, or the at least a portion of any regenerated first catalyst and the at least a portion of any regenerated second catalyst and reducing gas are contacted at a temperature in a range from 450°C to 900°C; and

(ii) the at least a portion of any regenerated first catalyst, the at least a portion of any regenerated second catalyst, or the at least a portion of any regenerated first catalyst and the at least a portion of any regenerated second catalyst and reducing gas are contacted under a reducing gas partial pressure in a range from 0.01 kPa-absolute to 1,000 kPa-absolute.

13. The process of claim 1, wherein each of the following is met:

(a) in step (I), the hydrocarbon-containing feed and the first catalyst are contacted in the presence of steam at an amount from 0.1 vol% to 50 vol%, based on a total volume of any C_2-C_{16} alkanes, any C_4-C_{16} cyclic alkanes, and any C_8-C_{16} alkyl aromatics in the hydrocarbon-containing feed; and

(b) in step (II), the first conversion zone effluent and the second catalyst are contacted in the presence of steam at an amount from 0.1 vol% to 50 vol%, based on a total volume of any C_2-C_{16} alkanes, any C_4-C_{16} cyclic alkanes, and any C_8-C_{16} alkyl aromatics in the first conversion zone effluent.

14. The process of claim 1, wherein the temperature of the first conversion zone effluent is in a range from 350°C to 700°C.

15. The process of claim 1, wherein in step (I), the hydrocarbon-containing feed and the first catalyst are contacted under a hydrocarbon partial pressure in a range from 20 kPa-absolute to 1,000 kPa-absolute.

16. The process of claim 1, wherein the temperature of the second conversion zone effluent is in a range from 400°C to 900°C.

17. The process of claim 1, wherein in step (II), the first conversion zone effluent and the second catalyst are contacted under a hydrocarbon partial pressure in a range from 20 kPa-absolute to 1,000 kPa-absolute.

18. The process of claim 1, wherein at least one of the first catalyst and the second catalyst further comprise a promoter.

19. The process of claim 18, wherein the promoter comprises Sn, Ga, Zn, Ge, In, Re, Ag, Au, Cu, a combination thereof, or a mixture thereof.

20. The process of claim 19, wherein at least one of the first catalyst and the second catalyst comprises up to 10 wt% of the promoter based on the total weight of the support.

21. A multi-stage hydrocarbon upgrading process, comprising:

(I) contacting a hydrocarbon-containing feed with a first catalyst comprising a Group 8-10 element disposed on a support within a first conversion zone to effect one or more of dehydrogenation, dehydroaromatization, and dehydrocyclization of a portion of the hydrocarbon-containing feed to produce a first conversion zone effluent comprising one or more upgraded hydrocarbons, molecular hydrogen, and unconverted hydrocarbon-containing feed;

(II) contacting the first conversion zone effluent with a second catalyst comprising a Group 8-10 element disposed on a support within a second conversion zone to effect one or more of dehydrogenation, dehydroaromatization, and dehydrocyclization of at least a portion of the unconverted hydrocarbon-containing feed to produce a second conversion zone effluent comprising an additional quantity of one or more upgraded hydrocarbons and molecular hydrogen; wherein:

the hydrocarbon-containing feed comprises one or more of C_2-C_{16} linear or branched alkanes, one or more of C_4-C_{16} cyclic alkanes, one or more of C_8-C_{16} alkyl aromatic hydrocarbons, or a mixture thereof;

the hydrocarbon-containing feed and the first catalyst are contacted for a time period in a range from 0.1 seconds to 3 hours, under a hydrocarbon partial pressure of at least 20 kPa-absolute, wherein the hydrocarbon partial pressure is the total partial pressure of any C_2-C_{16} alkanes and any C_8-C_{16} alkyl aromatic hydrocarbons in the hydrocarbon-containing feed;

the first conversion zone effluent and the second catalyst are contacted for a time period in a range from 0.1 seconds to 3 hours, under a hydrocarbon partial pressure of at least 20 kPa-absolute,

wherein the hydrocarbon partial pressure is the total partial pressure of any C_2-C_{16} alkanes and any C_8-C_{16} alkyl aromatic hydrocarbons in the first conversion zone effluent;

the first conversion zone effluent has a temperature in a range from 300°C to 850°C;

the second conversion zone effluent has a temperature in a range from 350°C to 900°C;

the temperature of the second conversion zone effluent is greater than the temperature of the first conversion zone effluent;

the first catalyst and the second catalyst have the same composition or a different composition;

the first catalyst and the second catalyst each comprise from 0.05 wt% to 6 wt% of the Group 8-10 element based on the weight of the support;

at least one of the first catalyst and the second catalyst comprise an alkali metal element disposed on the support; and

the one or more upgraded hydrocarbons comprise a dehydrogenated hydrocarbon, a dehydroaromatized hydrocarbon, a dehydrocyclized hydrocarbon, or a mixture thereof.

22. The process of claim 21, wherein the alkali metal element comprises Li, Na, K, Rb, Cs, a combination thereof, or a mixture thereof.

23. The process of claim 22, wherein at least one of the first catalyst and the second catalyst comprise up to 5 wt% of the alkali metal element based on the total weight of the support.

24. The process of claim 1, wherein the support comprises a mixed Mg/Al metal oxide.

25. A multi-stage hydrocarbon upgrading process, comprising:

(I) contacting a hydrocarbon-containing feed with a first catalyst comprising a Group 8-10 element disposed on a support within a first conversion zone to effect dehydrogenation of a portion of the hydrocarbon-containing feed to produce a first conversion zone effluent comprising one or more upgraded hydrocarbons, molecular hydrogen, and unconverted hydrocarbon-containing feed;

(II) contacting the first conversion zone effluent with a second catalyst comprising a Group 8-10 element disposed on a support within a second conversion zone to effect dehydrogenation of at least a portion of the unconverted hydrocarbon-containing feed to produce a second conversion zone effluent comprising an additional quantity of one or more upgraded hydrocarbons and molecular hydrogen; wherein:

the hydrocarbon-containing feed comprises one or more of C_2-C_{16} linear or branched alkanes, one or more of C_4-C_{16} cyclic alkanes, one or more of C_8-C_{16} alkyl aromatic hydrocarbons, or a mixture thereof;

the hydrocarbon-containing feed and the first catalyst are contacted for a time period in a range from 0.1 seconds to 3 hours, under a hydrocarbon partial pressure of at least 20 kPa-absolute, wherein the hydrocarbon partial pressure is the total partial pressure of any C_2-C_{16} alkanes and any C_8-C_{16} alkyl aromatic hydrocarbons in the hydrocarbon-containing feed;

the first conversion zone effluent and the second catalyst are contacted for a time period in a range from 0.1 seconds to 3 hours, under a hydrocarbon partial pressure of at least 20 kPa-absolute, wherein the hydrocarbon partial pressure is the total partial pressure of any C_2-C_{16} alkanes and any C_8-C_{16} alkyl aromatic hydrocarbons in the first conversion zone effluent;

the first conversion zone effluent has a temperature in a range from 300°C to 850°C;

the second conversion zone effluent has a temperature in a range from 350°C to 900°C;

the temperature of the second conversion zone effluent is greater than the temperature of the first conversion zone effluent;

the first catalyst and the second catalyst have the same composition or a different composition;

the first catalyst and the second catalyst each comprise from 0.05 wt% to 6 wt% of the Group 8-10 element based on the weight of the support;

the support comprises a mixed Mg/Al metal oxide; and

the one or more upgraded hydrocarbons comprise a dehydrogenated hydrocarbon.

26. The process of claim 1, wherein at least one of the following is met:

(a) in step (I), the hydrocarbon-containing feed and the first catalyst are contacted in the presence of steam at an amount from 0.1 vol% to 50 vol%, based on a total volume of any C_2-C_{16} alkanes, any C_4-C_{16} cyclic alkanes, and any C_8-C_{16} alkyl aromatics in the hydrocarbon-containing feed; and

(b) in step (II), the first conversion zone effluent and the second catalyst are contacted in the presence of steam at an amount from 0.1 vol% to 50 vol%, based on a total volume of any C_2-C_{16} alkanes, any C_4-C_{16} cyclic alkanes, and any C_8-C_{16} alkyl aromatics in the first conversion zone effluent.