CLAIMS

We claim:

1. A reforming method comprising:

(A) introducing a first hydrocarbon feed into a radial flow reactor comprising a catalyst bed, and contacting the first hydrocarbon feed with the catalyst bed under first reforming conditions to produce a first aromatic product; wherein:

the catalyst bed comprises an outer reforming zone and an inner reforming zone;

the outer reforming zone comprises a first aromatization catalyst comprising a first transition metal and a first catalyst support; and

the inner reforming zone comprises a second aromatization catalyst comprising a second transition metal and second catalyst support;

(B) performing step (A) for a time period sufficient to form a spent first aromatization catalyst in the outer reforming zone;

(C) introducing a catalyst poisoning agent into the radial flow reactor and contacting at least a portion of the spent first aromatization catalyst to form a poisoned aromatization catalyst in the outer reforming zone; and

(D) introducing a second hydrocarbon feed into the radial flow reactor comprising the catalyst bed, and contacting the second hydrocarbon feed with the catalyst bed under second reforming conditions to produce a second aromatic product; wherein:

the spent first aromatization catalyst comprises from 1 wt.% to 10 wt.% carbon;

the poisoned aromatization catalyst has an aromatics yield of less than 10 wt.%; and

the catalyst poisoning agent comprises a heavy hydrocarbon, a sulfur-containing compound, a phosphorus-containing compound, an oxygen-containing compound, a bromine-containing compound, an iodine-containing compound, an organometallic lead compound, an organometallic arsenic compound, or any combination thereof.

2. The method of claim 1, wherein:

the first aromatization catalyst comprises from 0.3 wt. % to 5 wt. % of the first transition metal; and

the second aromatization catalyst comprises from 0.3 wt. % to 5 wt. % of the second transition metal.

3. The method of claim 1, wherein:

the first transition metal and the second transition metal comprise platinum;

the first catalyst support and the second catalyst support comprise a KL-zeolite and a binder comprising alumina, silica, a mixed oxide thereof, or a mixture thereof; and

the first aromatization catalyst and the second aromatization catalyst further comprise chlorine and fluorine.

4. The method of claim 1, wherein:

the first aromatic product and the second aromatic product, independently, comprise benzene, toluene, or a combination thereof; and

the first reforming conditions and the second reforming conditions, independently, comprise a reforming temperature in a range from 350 °C to 600 °C.

5. The method of claim 1, wherein a weight ratio of catalyst in the outer reforming zone to the inner reforming zone is in a range from 1:1.5 to 1:5.

6. The method of claim 3, wherein the first aromatization catalyst and the second aromatization catalyst, independently, comprise from 0.5 wt.% to 2 wt.% of platinum.

7. The method of claim 1, wherein the catalyst poisoning agent is introduced at a molar ratio, based on moles of the catalyst poisoning agent to moles of the first transition metal in the spent first aromatization catalyst, in a range from 0.1:1 to 0.75:1.

8. The method of claim 7, wherein:

the first transition metal and the second transition metal comprise platinum;

the first catalyst support and the second catalyst support comprise a KL-zeolite and a binder comprising alumina, silica, a mixed oxide thereof, or a mixture thereof; and

the first aromatization catalyst and the second aromatization catalyst further comprise chlorine and fluorine.

9. The method of claim 1, wherein:

the aromatics yield of the second aromatization catalyst is greater than that of the spent first aromatization catalyst, under the same test conditions; and

the aromatics selectivity of the second aromatization catalyst is greater than that of the spent first aromatization catalyst, under the same test conditions.

10. The method of claim 1, wherein an aromatics yield of the second aromatic product in step (D) is greater than a yield of the first aromatic product produced after step (B) and before step (C).

11. The method of claim 1, wherein an aromatics selectivity of the second aromatic product in step (D) is greater than an aromatics selectivity of the first aromatic product produced after step (B) and before step (C).

12. A reforming method comprising:

(a) providing a radial flow reactor comprising a catalyst bed, the catalyst bed comprising an outer reforming zone and an inner reforming zone; wherein:

the outer reforming zone comprises a spent first aromatization catalyst comprising a first transition metal and a first catalyst support; and

the inner reforming zone comprises a second aromatization catalyst comprising a second transition metal and a second catalyst support;

(b) introducing a catalyst poisoning agent into the radial flow reactor and contacting at least a portion of the spent first aromatization catalyst to form a poisoned aromatization catalyst in the outer reforming zone; and

(c) introducing a hydrocarbon feed into the radial flow reactor comprising the catalyst bed, and contacting the hydrocarbon feed with the catalyst bed under reforming conditions to produce an aromatic product; wherein:

the spent first aromatization catalyst comprises from 1 wt.% to 10 wt.% carbon;

the poisoned aromatization catalyst has an aromatics yield of less than 10 wt.%; and

the catalyst poisoning agent comprises a heavy hydrocarbon, a sulfur-containing compound, a phosphorus-containing compound, an oxygen-containing compound, a bromine-containing compound, an iodine-containing compound, an organometallic lead compound, an organometallic arsenic compound, or any combination thereof.

13. The method of claim 12, wherein:

an aromatics yield of the aromatic product in step (c) is greater than a yield of an aromatic product produced after step (a) and before step (b); and

an aromatics selectivity of the aromatic product in step (c) is greater than an aromatics selectivity of an aromatic product produced after step (a) and before step (b).

14. The method of claim 13, wherein:

the first transition metal and the second transition metal comprise platinum;

the first catalyst support and the second catalyst support comprise a KL-zeolite and a binder comprising alumina, silica, a mixed oxide thereof, or a mixture thereof; and

the spent first aromatization catalyst and the second aromatization catalyst further comprise chlorine and fluorine.

15. The method of claim 14, wherein:

the spent first aromatization catalyst and the second aromatization catalyst, independently, comprise from 0.3 wt. % to 5 wt. % of platinum; and

the aromatic product comprises benzene, toluene, or a combination thereof.

16. The method of claim 15, wherein the spent first aromatization catalyst comprises from 1.5 wt. % to 7 wt. % carbon.

17. A reforming method comprising:

(A) introducing a first hydrocarbon feed into a radial flow reactor comprising a catalyst bed, and contacting the first hydrocarbon feed with the catalyst bed under first reforming conditions to produce a first aromatic product; wherein:

the catalyst bed comprises an outer reforming zone and an inner reforming zone;

the outer reforming zone comprises a first aromatization catalyst comprising a first transition metal and a first catalyst support; and

the inner reforming zone comprises a second aromatization catalyst comprising a second transition metal and a second catalyst support;

(B) performing step (A) for a time period sufficient to form a spent first aromatization catalyst in the outer reforming zone;

(C) introducing a catalyst poisoning agent into the radial flow reactor and contacting at least a portion of the spent first aromatization catalyst to form a poisoned aromatization catalyst in the outer reforming zone; and

(D) introducing a second hydrocarbon feed into the radial flow reactor comprising the catalyst bed, and contacting the second hydrocarbon feed with the catalyst bed under second reforming conditions to produce a second aromatic product; wherein:

the spent first aromatization catalyst comprises from 1 wt. % to 10 wt. % carbon;

the poisoned aromatization catalyst has an aromatics yield of less than 10 wt. %;

the catalyst poisoning agent comprises a heavy hydrocarbon, a sulfur-containing compound, a phosphorus-containing compound, an oxygen-containing compound, a bromine-containing compound, an iodine-containing compound, an organometallic lead compound, an organometallic arsenic compound, or any combination thereof;

an aromatics yield of the second aromatic product in step (D) is greater than a yield of the first aromatic product produced after step (B) and before step (C); and

an aromatics selectivity of the second aromatic product in step (D) is greater than an aromatics selectivity of the first aromatic product produced after step (B) and before step (C).

18. The method of claim 17, wherein the first aromatization catalyst and the second aromatization catalyst, independently, comprise from 0.5 wt. % to 2 wt. % of platinum.

19. The method of claim 18, wherein:

the first aromatic product and the second aromatic product, independently, comprise benzene, toluene, or a combination thereof; and

the first catalyst support and the second catalyst support comprise a silica-bound KL-zeolite.

20. The method of claim 17, wherein:

a weight ratio of catalyst in the outer reforming zone to the inner reforming zone is in a range from 1:1.5 to 1:5; and

the catalyst poisoning agent is introduced at a molar ratio, based on moles of the catalyst poisoning agent to moles of the first transition metal in the spent first aromatization catalyst, in a range from 0.1:1 to 0.75:1.