## CLAIMS

1. A method of producing para-xylene (*p*-xylene), the method comprising the steps of:

introducing a reformate feed to a dealkylation reactor, the reformate feed comprises aromatic hydrocarbons, wherein the aromatic hydrocarbons are selected from the group consisting of benzene, toluene, mixed xylenes, carbon-nine plus (C9+) aromatic hydrocarbons, and combinations of the same;

introducing a hydrogen feed to the dealkylation reactor, wherein the hydrogen feed comprises hydrogen gas, wherein the dealkylation reactor is configured to convert C9+ aromatic hydrocarbons to carbon-six (C6) to carbon-eight (C8) aromatic hydrocarbons;

converting the C9+ aromatic hydrocarbons and the hydrogen gas in the presence of a dealkylation catalyst in the dealkylation reactor to produce a dealkylation effluent, wherein the dealkylation reactor is at a dealkylation temperature, wherein the dealkylation reactor is at a dealkylation pressure, wherein the dealkylation effluent comprises aromatic hydrocarbons such that an amount of C9+ aromatic hydrocarbons in the dealkylation effluent is less than the amount of C9+ aromatic hydrocarbons in the reformate feed;

introducing the dealkylation effluent to a reformate splitter, the reformate splitter configured to separate the dealkylation effluent;

separating the dealkylation effluent in the reformate splitter to produce a light gases stream, a benzene stream, a heavy hydrocarbon, a carbon-nine (C9) aromatics stream, a xylene stream, and a toluene stream, wherein the C9 aromatics stream comprises C9 aromatic hydrocarbons, and wherein the xylene stream comprises mixed xylenes, wherein the mixed xylenes comprises *p*-xylenes, and wherein the toluene stream comprises toluene;

introducing the xylene stream to a *p*-xylene separation unit, the *p*-xylene separation unit configured to separate *p*-xylenes from the xylene stream;

separating the *p*-xylenes from the xylene stream in the *p*-xylene separation unit to produce a *p*-xylene product and a *p*-xylene depleted stream, wherein the *p*-xylene product comprises *p*-xylenes, wherein the *p*-xylene depleted stream comprises meta-xylene (*m*-xylene) and ortho-xylene (*o*-xylene);

introducing the *p*-xylene depleted stream to an isomerization unit, wherein the isomerization unit comprises an isomerization catalyst;

converting the *m*-xylene and *o*-xylene in the *p*-xylene depleted stream in the isomerization unit to produce an isomerization effluent, wherein the isomerization unit is at an isomerization temperature, wherein the isomerization unit is at an isomerization pressure, wherein the isomerization effluent comprises C8 aromatic hydrocarbons;

introducing the C9 aromatics stream and a hydrogen stream to a transalkylation reactor, the transalkylation reactor configured to convert C9+ aromatic hydrocarbons through transalkylation reactions;

reacting the C9 aromatics stream and the hydrogen stream in the presence of a transalkylation catalyst in the transalkylation reactor to produce a transalkylation effluent, wherein the transalkylation reactor is at a transalkylation temperature, wherein the transalkylation reactor is at a transalkylation pressure, wherein the transalkylation catalyst is operable to catalyze transalkylation reactions, wherein the transalkylation effluent comprises C6 to C9+ aromatic hydrocarbons;

introducing the isomerization effluent and the transalkylation effluent to a splitter column, the splitter column configured to separate C6 to C9+ aromatic hydrocarbons;

separating the C6 to C9+ aromatic hydrocarbons in the isomerization effluent and the transalkylation effluent in the splitter column to produce a benzene recycle, a toluene recycle, a xylene recycle and a C9+ recycle, wherein the benzene recycle comprises benzene, wherein the toluene recycle comprises toluene, wherein the xylene recycle comprises mixed xylenes, wherein the C9+ recycle comprises C9+ aromatic hydrocarbons;

recycling the xylene recycle to the *p*-xylene separation unit; and

recycling the benzene recycle, the toluene recycle, and the C9+ recycle to the transalkylation reactor.

2. The method of claim 1 further comprising the steps of:

introducing the toluene stream as a toluene split stream to the transalkylation reactor, wherein a flow rate of the toluene split stream is operable to maintain a ratio of toluene to trimethylbenzene in the transalkylation reactor in the range of 0.3 to 3.

3. The method of claim 1, further comprising the steps of:

separating the toluene stream to produce a fraction of the toluene stream and a toluene split stream;

introducing the fraction of the toluene stream to a toluene disproportionation reactor, wherein the toluene disproportionation reactor comprises a disproportion catalyst, wherein the toluene disproportionation reactor is configured to support a toluene disproportionation reaction;

reacting the fraction of the toluene stream in the toluene disproportionation reactor to produce a disproportionation effluent, wherein the disproportionation effluent comprises C6 to C8 aromatic hydrocarbons;

introducing the disproportionation effluent to the splitter column; and

introducing the toluene split stream to the transalkylation reactor, wherein a flow rate of the toluene split stream is operable to maintain a ratio of toluene to trimethylbenzene in the transalkylation reactor in the range of 0.3 to 3.

4. The method of claim 1, wherein the dealkylation temperature is between 200 °C. and 550 °C., wherein the dealkylation pressure is between 5 bar and 50 bar, and wherein a liquid hourly space velocity in the dealkylation reactor is between 1 $hr^{-1}$ and 20 $hr^{-1}$.

5. The method of claim 1, wherein the transalkylation temperature is between 200 °C. and 550 °C., wherein the transalkylation pressure is between 10 bar and 50 bar, wherein a liquid hourly space velocity in the transalkylation reactor is between 0.2 $hr^{-1}$ and 20 $hr^{-1}$.

6. The method of claim 1, wherein the isomerization temperature is between 200 °C. and 550 °C., wherein the isomerization pressure is between 10 bar and 50 bar, and wherein a liquid hourly space velocity in the isomerization unit is between 1 $hr^{-1}$ and 20 $hr^{-1}$.

7. A method of producing para-xylene (*p*-xylene), the method comprising the steps of:

introducing a reformate feed to a dealkylation reactor, the reformate feed comprises aromatic hydrocarbons, wherein the aromatic hydrocarbons are selected from the group consisting of benzene, toluene, mixed xylenes, carbon-nine plus (C9+) aromatic hydrocarbons, and combinations of the same;

introducing a hydrogen feed to the dealkylation reactor, wherein the hydrogen feed comprises hydrogen gas, wherein the dealkylation reactor is configured to convert C9+ aromatic hydrocarbons to carbon-six (C6) to carbon-eight (C8) aromatic hydrocarbons;

converting the C9+ aromatic hydrocarbons and the hydrogen gas in the presence of a dealkylation catalyst in the dealkylation reactor to produce a dealkylation effluent, wherein the dealkylation reactor is at a dealkylation temperature, wherein the dealkylation reactor is at a dealkylation pressure, wherein the dealkylation effluent comprises aromatic hydrocarbons such that an amount of C9+ aromatic hydrocarbons in the dealkylation effluent is less than the amount of C9+ aromatic hydrocarbons in the reformate feed;

introducing the dealkylation effluent to a reformate splitter, the reformate splitter configured to separate the dealkylation effluent;

separating the dealkylation effluent in the reformate splitter to produce a light gases stream, a mixed light aromatics stream, a heavy hydrocarbon, a carbon-nine (C9) aromatics stream, and a xylene stream, wherein the C9 aromatics stream comprises C9 aromatic hydrocarbons, and wherein the xylene stream comprises mixed xylenes, wherein the mixed xylenes comprises *p*-xylenes, and wherein the mixed light aromatics stream comprises toluene;

introducing the mixed light aromatics stream to an aromatic extraction unit, the aromatic extraction unit configured to separate aromatic hydrocarbons from non-aromatic hydrocarbons;

separating the non-aromatic hydrocarbons in the aromatic extraction unit to produce a non-aromatics raffinate stream and an aromatics extract stream, wherein the aromatics extract stream comprises aromatic hydrocarbons selected from the group consisting of toluene, benzene, and combinations of the same;

introducing the xylene stream to a *p*-xylene separation unit, the p-xylene separation unit configured to separate p-xylenes from the xylene stream;

separating the *p*-xylenes from the xylene stream in the *p*-xylene separation unit to produce a *p*-xylene product and a *p*-xylene depleted stream, wherein the *p*-xylene product comprises *p*-xylenes, wherein the *p*-xylene depleted stream comprises meta-xylene (*m*-xylene) and ortho-xylene (*o*-xylene);

introducing the *p*-xylene depleted stream to an isomerization unit, wherein the isomerization unit comprising an isomerization catalyst;

converting the *m*-xylene and *o*-xylene in the *p*-xylene depleted stream in the isomerization unit to produce an isomerization effluent, wherein the isomerization unit is at an isomerization temperature, wherein the isomerization unit is at an isomerization pressure, wherein the isomerization effluent comprises C8 aromatic hydrocarbons;

introducing the C9 aromatics stream and a hydrogen stream to a transalkylation reactor, the transalkylation reactor configured to convert C9+ aromatic hydrocarbons through transalkylation reactions;

reacting the C9 aromatics stream and the hydrogen stream in the presence of a transalkylation catalyst in the transalkylation reactor to produce a transalkylation effluent, wherein the transalkylation reactor is at a transalkylation temperature, wherein the transalkylation reactor is at a transalkylation pressure, wherein the transalkylation catalyst is operable to catalyze transalkylation reactions, wherein the transalkylation effluent comprises C6 to C9+ aromatic hydrocarbons;

introducing the aromatics extract stream, the isomerization effluent and the transalkylation effluent to a splitter column, the splitter column configured to separate C6 to C9+ aromatic hydrocarbons;

separating the C6 to C9+ aromatic hydrocarbons in the aromatics extract stream, the isomerization effluent and the transalkylation effluent in the transalkylation reactor to produce a benzene recycle, a toluene recycle, a xylene recycle and a C9+ recycle, wherein the benzene recycle comprises benzene, wherein the toluene recycle comprises toluene, wherein the xylene recycle comprises mixed xylenes, wherein the C9+ recycle comprises C9+ aromatic hydrocarbons;

recycling the xylene recycle to the *p*-xylene separation unit; and

recycling the benzene recycle, the toluene recycle, and the C9+ recycle to the transalkylation reactor.

8. The method of claim 7, wherein a flow rate of toluene recycle is operable to maintain a ratio of toluene to trimethylbenzene in the transalkylation reactor in a range of 0.3 to 3.

9. The method of claim 7, wherein the dealkylation temperature is between 200 °C. and 550 °C., wherein the dealkylation pressure is between 5 bar and 50 bar, and wherein a liquid hourly space velocity in the dealkylation reactor is between 1 $hr^{-1}$ and 20 $hr^{-1}$.

10. The method of claim 7, wherein the transalkylation temperature is between 200 °C. and 550 °C., wherein the transalkylation pressure is between 10 bar and 50 bar, wherein a liquid hourly space velocity in the transalkylation reactor is between 0.2 $hr^{-1}$ and 20 $hr^{-1}$.

11. The method of claim 7, wherein the isomerization temperature is between 200 °C. and 550 °C., wherein the isomerization pressure is between 10 bar and 50 bar, and wherein a liquid hourly space velocity in the isomerization unit is between 1 $hr^{-1}$ and 20 $hr^{-1}$.

12. A method of producing para-xylene (*p*-xylene), the method comprising the steps of:

introducing a reformate feed to a dealkylation reactor, the reformate feed comprises aromatic hydrocarbons, wherein the aromatic hydrocarbons are selected from the group consisting of benzene, toluene, mixed xylenes, carbon-nine plus (C9+) aromatic hydrocarbons, and combinations of the same;

introducing a hydrogen feed to the dealkylation reactor, wherein the hydrogen feed comprises hydrogen gas, wherein the dealkylation reactor is configured to convert C9+ aromatic hydrocarbons to carbon-six (C6) to carbon-eight (C8) aromatic hydrocarbons;

converting the C9+ aromatic hydrocarbons and the hydrogen gas in the presence of a dealkylation catalyst in the dealkylation reactor to produce a dealkylation effluent, wherein the dealkylation reactor is at a dealkylation temperature, wherein the dealkylation reactor is at a dealkylation pressure, wherein the dealkylation effluent comprises aromatic hydrocarbons such that an amount of C9+ aromatic hydrocarbons in the dealkylation effluent is less than the amount of C9+ aromatic hydrocarbons in the reformate feed;

introducing the dealkylation effluent to an aromatic extraction unit, the aromatic extraction unit configured to separate non-aromatics in the dealkylation effluent;

separating the dealkylation effluent in the aromatic extraction unit to produce a raffinate effluent and an aromatic feed, wherein the raffinate effluent comprises light gases;

introducing the aromatic feed to a reformate splitter, the reformate splitter configured to separate the aromatic feed;

separating the aromatic feed in the reformate splitter to produce a benzene stream, a heavy hydrocarbon, a carbon-nine (C9) aromatics stream, a xylene stream, and a toluene stream, wherein the C9 aromatics stream comprises C9 aromatic hydrocarbons, and wherein the xylene stream comprises mixed xylenes, wherein the mixed xylenes comprises *p*-xylenes, and wherein the toluene stream comprises toluene;

introducing the xylene stream to a *p*-xylene separation unit, the p-xylene separation unit configured to separate p-xylenes from the xylene stream;

separating the *p*-xylenes from the xylene stream in the *p*-xylene separation unit to produce a *p*-xylene product and a *p*-xylene depleted stream, wherein the *p*-xylene product comprises *p*-xylenes, wherein the *p*-xylene depleted stream comprises meta-xylene (*m*-xylene) and ortho-xylene (*o*-xylene);

introducing the *p*-xylene depleted stream to an isomerization unit, wherein the isomerization unit comprises an isomerization catalyst;

converting the *m*-xylene and *o*-xylene in the *p*-xylene depleted stream in the isomerization unit to produce an isomerization effluent, wherein the isomerization unit is at an isomerization temperature, wherein the isomerization unit is at an isomerization pressure, wherein the isomerization effluent comprises C8 aromatic hydrocarbons;

introducing the C9 aromatics stream and a hydrogen stream to a transalkylation reactor, the transalkylation reactor configured to convert C9+ aromatic hydrocarbons through transalkylation reactions;

reacting the C9 aromatics stream and the hydrogen stream in the presence of a transalkylation catalyst in the transalkylation reactor to produce a transalkylation effluent, wherein the transalkylation reactor is at a transalkylation temperature, wherein the transalkylation reactor is at a transalkylation pressure, wherein the transalkylation catalyst is operable to catalyze transalkylation reactions, wherein the transalkylation effluent comprises C6 to C9+ aromatic hydrocarbons;

introducing the isomerization effluent and the transalkylation effluent to a splitter column, the splitter column configured to separate C6 to C9+ aromatic hydrocarbons;

separating the C6 to C9+ aromatic hydrocarbons in the isomerization effluent, and the transalkylation effluent in the transalkylation reactor to produce a benzene recycle, a toluene recycle, a xylene recycle and a C9+ recycle, wherein the benzene recycle comprises benzene, wherein the toluene recycle comprises toluene, wherein the xylene recycle comprises mixed xylenes, wherein the C9+ recycle comprises C9+ aromatic hydrocarbons;

recycling the xylene recycle to the *p*-xylene separation unit; and

recycling the benzene recycle, the toluene recycle, and the C9+ recycle to the transalkylation reactor.

13. The method of claim 12, further comprising the steps of:

introducing the toluene stream as a toluene split stream to the transalkylation reactor, wherein a flow rate of the toluene split stream is operable to maintain a ratio of toluene to trimethylbenzene in the transalkylation reactor in a range of 0.3 to 3.

14. The method of claim 12, further comprising the steps of:

separating the toluene stream to produce a fraction of the toluene stream and a toluene split stream;

introducing the fraction of the toluene stream to a toluene disproportionation reactor, wherein the toluene disproportionation reactor comprises a disproportion catalyst, wherein the toluene disproportionation reactor is configured to support a toluene disproportionation reaction;

reacting the fraction of the toluene stream in the toluene disproportionation reactor to produce a disproportionation effluent, wherein the disproportionation effluent comprises C6 to C8 aromatic hydrocarbons;

introducing the disproportionation effluent to the splitter column; and

introducing the toluene split stream to the transalkylation reactor, wherein a flow rate of the toluene split stream is operable to maintain a ratio of toluene to trimethylbenzene in the transalkylation reactor in a range of 0.3 to 3.

15. The method of claim 12, wherein the dealkylation temperature is between 200 °C. and 550 °C., wherein the dealkylation pressure is between 5 bar and 50 bar, and wherein a liquid hourly space velocity in the dealkylation reactor is between 1 $hr^{-1}$ and 20 $hr^{-1}$.

16. The method of claim 12, wherein the transalkylation temperature is between 200 °C. and 550 °C., wherein the transalkylation pressure is between 10 bar and 50 bar, wherein a liquid hourly space velocity in the transalkylation reactor is between 0.2 $hr^{-1}$ and 20 $hr^{-1}$.

17. The method of claim 12, wherein the isomerization temperature is between 200 °C. and 550 °C., wherein the isomerization pressure is between 10 bar and 50 bar, and wherein a liquid hourly space velocity in the isomerization unit is between 1 $hr^{-1}$ and 20 $hr^{-1}$.