CLAIMS

1. A process for dehydrogenating cyclohexane, the process comprising:

(1A) obtaining a benzene-containing stream from a vapor phase at a vapor outlet of a condensation separation system, wherein the vapor phase is in equilibrium with a liquid phase in the condensation separation system and has a controlled partial pressure of benzene;

(1B) supplying benzene, hydrogen and cyclohexane into a dehydrogenation reactor, wherein at least a portion of the benzene is supplied from the benzene-containing stream; and

(1C) contacting at least a portion of the cyclohexane with a dehydrogenating catalyst in the reactor under a dehydrogenation condition to produce a dehydrogenation effluent;

wherein the molar ratio of hydrogen to benzene in the dehydrogenation reactor is controlled within a range from 0.2 to 4 by controlling the temperature of the vapor outlet.

2. The process of claim 1, wherein step (1B) further comprises supplying methylcyclopentane into the dehydrogenation reactor at a concentration from 100 ppm to 5 wt%, based on the total weight of benzene, cyclohexane, and methylcyclopentane.

3. The process of claim 1 or claim 2, wherein step (1B) comprises supplying at least a portion of the benzene, a portion of the hydrogen and a portion of the cyclohexane in a single stream to the dehydrogenation reactor.

4. The process of claim 3, wherein step (1B) comprises supplying all of the benzene, all of the hydrogen and all of the cyclohexane and optionally all of the methylcyclopentane via the benzene-containing stream provided in step (1A) into the dehydrogenation reactor.

5. The process of claim 4, wherein the benzene-containing stream is supplied from a single vapor outlet of a single condensation separation system.

6. The process of any of the preceding claims, wherein in step (1B) the molar ratio of hydrogen to benzene in the dehydrogenation reactor is controlled within a range from ~~0.2~~1.0 to 43.

7. The process of any of the preceding claims, wherein in step (1B) the partial pressure of hydrogen in the dehydrogenation reactor is maintained in a range from 60 kPa to 800 kPa.

8. The process of any of the preceding claims, wherein in step (1B) the variation of the total absolute pressure at the vapor outlet of the condensation separation system is controlled within 50 kPa.

9. The process of any of the preceding claims, wherein in step (1B) the average of the total absolute pressure at the vapor outlet is in a range from 50 kPa to 300 kPa.

10. The process of any of the preceding claims, wherein the dehydrogenation condition comprises a temperature in a range from 350°C to 550°C.

11. The process of any of the preceding claims, wherein the partial pressure of benzene supplied in step (1B) is controlled by controlling the temperature of the vapor phase of the condensation separation system.

12. The process of any of the preceding claims, wherein the temperature of the vapor phase is controlled within a range from 40°C to 170°C.

13. The process of claim 12, wherein the variation of the temperature of the vapor phase is controlled within 20°C.

14. The process of any of the preceding claims, wherein step (1A) comprises:

(1A-I) producing a material stream comprising benzene, cyclohexane, and hydrogen;

(1A-II) separating the material stream into the liquid phase and the vapor phase in equilibrium in the condensation separation system; and

(1A-III) providing the vapor phase as the benzene-containing stream.

15. The process of claim 14, wherein step (1A-I) comprises:

(1A-I-1) contacting benzene with hydrogen in the presence of a hydroalkylation catalyst under a hydroalkylation condition to produce a hydroalkylation effluent comprising benzene, cyclohexane, hydrogen, and cyclohexylbenzene;

(1A-I-2) separating at least a portion of the hydroalkylation effluent to produce a first fraction comprising cyclohexylbenzene at a concentration higher than the hydroalkylation effluent and a second fraction comprising benzene, cyclohexane, and hydrogen; and

(1A-I-3) obtaining the material stream comprising benzene, cyclohexane, and hydrogen from the second fraction.

16. The process of claim 15, wherein in step (1A-I-1), the hydroalkylation effluent further comprises methylcyclopentane, and in step (1A -I-3), the material stream further comprises methylcyclopentane at a concentration in a range from 100 ppm to 5 wt%, based on the total weight of benzene, cyclohexane, and methylcyclopentane therein.

17. A process for making cyclohexylbenzene, the process comprising:

(2A) contacting benzene with hydrogen in the presence of a hydroalkylation catalyst under a hydroalkylation condition to produce a hydroalkylation effluent comprising benzene, cyclohexylbenzene, cyclohexane, and hydrogen;

(2B) separating at least a portion of the hydroalkylation effluent to produce a first fraction comprising cyclohexylbenzene at a higher concentration than the hydroalkylation effluent and a second fraction comprising benzene, cyclohexane, and hydrogen;

(2C) separating at least a portion of the second fraction in a condensation separation system into a liquid phase and a vapor phase in equilibrium with the liquid phase, where the partial pressure of benzene in the vapor phase is controlled;

(2D) supplying the vapor phase from the condensation separation system into a dehydrogenation reactor; and

(2E) contacting at least a portion of the cyclohexane in the vapor phase with a dehydrogenation catalyst in the dehydrogenation reactor under a dehydrogenation condition to produce a dehydrogenation effluent comprising benzene and hydrogen;

wherein the molar ratio of hydrogen to benzene in the dehydrogenation reactor is controlled within a range from 0.2 to 4 by controlling the temperature of the vapor phase.

18. The process of claim 17, wherein in step (2A), the hydroalkylation effluent further comprises methylcyclopentane, and in step (2D), the vapor phase comprises methylcyclopentane at a concentration in a range from 100 ppm to 5 wt%, based on the total weight of benzene, cyclohexane, and methylcyclopentane in the reaction medium.

19. The process of claim 17 or claim 18, the process further comprising:

(2F) recycling at least a portion of the benzene and/or the hydrogen contained in the dehydrogenation effluent from step (2E) to the contacting step (2A).

20. The process of any of claims 17 to 19, wherein in step (2C), the partial pressure of hydrogen is controlled within a range from 5 kPa to 300 kPa.

21. The process of any of claims 17 to 20, wherein in step (2C), the partial pressure of benzene is controlled by controlling the temperature of the vapor phase within a range from 40°C to 170°C.

22. The process of claim 21, wherein in step (2C), the variation of the temperature of the vapor phase is controlled within 20°C.

23. The process of any of claims 17 to 22, wherein in step (2E), the dehydrogenation condition comprises at least one of:

(a) a temperature of the reaction medium in the dehydrogenation reactor in a range from 350°C to 550°C; and

(b) an absolute pressure in the dehydrogenation reactor in a range from 60 kPa to 800 kPa.

24. The process of any of claims 17 to 23, wherein in step (2E), the dehydrogenation catalyst comprises a group 8-10 metal supported on an oxide substrate.

25. A process for making phenol and/or cyclohexanone, the process comprising:

(3A) producing cyclohexylbenzene in a process according to any of claims 17 to 24;

(3B) oxidizing at least a portion of the cyclohexylbenzene to obtain cyclohexylbenzene hydroperoxide; and

(3C) subjecting at least a portion of the cyclohexylbenzene hydroperoxide to a cleavage reaction to obtain a cleavage reaction effluent comprising phenol and cyclohexanone.