WHAT IS CLAIMED IS:

1. A method comprising:

contacting a heated reaction gas comprising methane with a first catalyst and a second catalyst to catalyze production of an aromatic hydrocarbon,

wherein said first catalyst is more active than said second catalyst for catalyzing aromatization of methane, and said second catalyst is more active than said first catalyst for catalyzing aromatization of ethane, and

wherein said heated reaction gas initially contacts said first catalyst before contacting said second catalyst, or contacts a mixture of said first catalyst and said second catalyst.

2. The method of claim 1, wherein at least one of said first and second catalysts is an aluminosilicate zeolite modified by a transition metal.

3. The method of claim 2, wherein said first catalyst is a MCM-22 zeolite modified by a first transition metal, and said second catalyst is a ZSM-5 zeolite modified by a second transition metal.

4. The method of claim 3, wherein each of said first transition metal and said second transition metal is molybdenum.

5. The method of claim 4, wherein each one of said first and second catalysts comprises about 3 to about 12 wt% of molybdenum.

6. The method of claim 4, wherein each one of said first and second catalysts has a Si/2Al ratio of from 25 to 45.

7. The method of claim 1, wherein said heated reaction gas is heated to a temperature of about 600 to about 700 °C.

8. The method of claim 1, wherein, prior to said contacting, said first and second catalysts are heated to at least 300 °C in the presence of propane.

9. The method of claim 1, wherein the weight ratio of said first and second catalysts is about 1:1.

10. A reactor for producing aromatic hydrocarbons from a reaction gas comprising methane, comprising:

a conduit defining a reaction zone for the reaction gas to react therein; and

a first catalyst and a second catalyst in said reaction zone, wherein said first catalyst is more active than said second catalyst for catalyzing aromatization of methane, and said second catalyst is more active than said first catalyst for catalyzing aromatization of ethane, and wherein said first catalyst is upstream of said second catalyst or mixed with said second catalyst.

11. The reactor of claim 10, wherein at least one of said first and second catalysts is an aluminosilicate zeolite modified by a transition metal.

12. The reactor of claim 11, wherein said first catalyst is a MCM-22 zeolite modified by a first transition metal, and said second catalyst is a ZSM-5 zeolite modified by a second transition metal.

13. The reactor of claim 12, wherein each of said first transition metal and said second transition metal is molybdenum.

14. The reactor of claim 13, wherein each one of said first and second catalysts comprises about 3 to about 12 wt% of molybdenum.

15. The reactor of claim 13, wherein each one of said first and second catalysts has a Si/2Al ratio of from 25 to 45.

16. The reactor of claim 10, wherein the weight ratio of said first and second catalysts is about 1:1.

17. The reactor of claim 10, wherein said first catalyst is upstream of said second catalyst.

18. The reactor of claim 10, wherein said first catalyst is mixed with said second catalyst.

19. The method of claim 1, wherein said heated reaction gas contacts said first catalyst before contacting said second catalyst.

20. The method of claim 19, wherein said first catalyst is in an upstream reaction zone, and said second catalyst is in a downstream reaction zone.

21. The method of claim 1, wherein said first catalyst and said second catalyst form said mixture.

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1. A method comprising:

contacting a heated reaction gas comprising methane with a first catalyst and a second catalyst to catalyze production of an aromatic hydrocarbon,

wherein said first catalyst is more active than said second catalyst for catalyzing aromatization of methane, and said second catalyst is more active than said first catalyst for catalyzing aromatization of ethane, and

wherein said heated reaction gas initially contacts said first catalyst before contacting said second catalyst, or contacts a mixture of said first catalyst and said second catalyst.

2. The method of claim 1, wherein at least one of said first and second catalysts is an aluminosilicate zeolite modified by a transition metal.

3. The method of claim 2, wherein said first catalyst is a MCM-22 zeolite modified by a first transition metal, and said second catalyst is a ZSM-5 zeolite modified by a second transition metal.

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5. The method of claim 4, wherein each one of said first and second catalysts comprises about 3 to about 12 wt% of molybdenum.

6. The method of claim 4, wherein each one of said first and second catalysts has a Si/2Al ratio of from 25 to 45.

7. The method of claim 1, wherein said heated reaction gas is heated to a temperature of about 600 to about 700 °C.

8. The method of claim 1, wherein, prior to said contacting, said first and second catalysts are heated to at least 300 °C in the presence of propane.

9. The method of claim 1, wherein the weight ratio of said first and second catalysts is about 1:1.

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a conduit defining a reaction zone for the reaction gas to react therein; and

a first catalyst and a second catalyst in said reaction zone, wherein said first catalyst is more active than said second catalyst for catalyzing aromatization of methane, and said second catalyst is more active than said first catalyst for catalyzing aromatization of ethane, and wherein said first catalyst is upstream of said second catalyst or mixed with said second catalyst.

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21. The method of claim 1, wherein said first catalyst and said second catalyst form said mixture.

SUMMARY

[0005] It has been surprisingly discovered that heating simulated natural gas in the presence of a combination of different catalysts can produce aromatics with improved yield when the combination of catalysts includes a first catalyst that is more active for catalyzing aromatization of methane and a second catalyst that is more active for catalyzing aromatization of ethane. For example, the first catalyst may be a Mo/MCM-22 catalyst, and the second catalyst may be a Mo/ZSM-5 catalyst.

[0006] In accordance with an aspect of the present invention, there is provided a method in which a heated reaction gas comprising methane is contacted with a first catalyst and a second catalyst to catalyze production of an aromatic hydrocarbon. The first catalyst is more active than the second catalyst for catalyzing aromatization of methane, and the second catalyst is more active than the first catalyst for catalyzing aromatization of ethane. The heated reaction gas initially contacts the first catalyst before contacting the second catalyst, or contacts a mixture of the first catalyst and the second catalyst. At least one of the first and second catalysts may be an aluminosilicate zeolite modified by a transition metal. The first catalyst may be a MCM-22 zeolite modified by a first transition metal. The second catalyst may be a ZSM-5 zeolite modified by a second transition metal. The first transition metal and second transition metal may be molybdenum. Each catalyst may comprise about 3 to about 12 wt% of molybdenum. Each catalyst may have a Si/2Al ratio of from 25 to 45. The heated reaction gas may be heated to a temperature of about 600 to about 700 °C. Prior to contacting the reaction gas, the first and second catalysts may be heated to at least 300 °C in the presence of propane. The weight ratio of the first and second catalysts may be about 1:1.

[0007] In another aspect, there is provided a reactor for producing aromatic hydrocarbons from a reaction gas comprising methane. The reactor comprises a conduit defining a reaction zone for the reaction gas to react therein; and a first catalyst and a second catalyst in the reaction zone. The first catalyst is more active than the second catalyst for catalyzing aromatization of methane, and the second catalyst is more active than the first catalyst for catalyzing aromatization

of ethane. The first catalyst is upstream of the second catalyst or mixed with the second catalyst. At least one of the first and second catalysts may be an aluminosilicate zeolite modified by a transition metal. The first catalyst may be a MCM-22 zeolite modified by a first transition metal. The second catalyst may be a ZSM-5 zeolite modified by a second transition metal. The first transition metal and second transition metal may be molybdenum. Each catalyst may comprise about 3 to about 12 wt% of molybdenum. Each catalyst may have a Si/2Al ratio of from 25 to 45. The weight ratio of the first and second catalysts may be about 1:1.

[0008] Other aspects and features of the present invention will become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In the figures, which illustrate, by way of example only, embodiments of the present invention,

[0010] **FIG. 1** is a schematic diagram of an aromatization process using a reactor, exemplary of an embodiment of the present invention;

[0011] **FIG. 2** is a schematic sectional view of a reaction zone of the reactor of **FIG. 1**; and

[0012] **FIG. 3** is a data graph showing representative production results in example aromatization processes with different configurations of catalysts.

SUMMARY

[0005] It has been surprisingly discovered that heating simulated natural gas in the presence of a combination of different catalysts can produce aromatics with improved yield when the combination of catalysts includes a first catalyst that is more active for catalyzing aromatization of methane and a second catalyst that is more active for catalyzing aromatization of ethane. For example, the first catalyst may be a Mo/MCM-22 catalyst, and the second catalyst may be a Mo/ZSM-5 catalyst.

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[0007] In another aspect, there is provided a reactor for producing aromatic hydrocarbons from a reaction gas comprising methane. The reactor comprises a conduit defining a reaction zone for the reaction gas to react therein; and a first catalyst and a second catalyst in the reaction zone. The first catalyst is more active than the second catalyst for catalyzing aromatization of methane, and the second catalyst is more active than the first catalyst for catalyzing aromatization

of ethane. The first catalyst is upstream of the second catalyst or mixed with the second catalyst. At least one of the first and second catalysts may be an aluminosilicate zeolite modified by a transition metal. The first catalyst may be a MCM-22 zeolite modified by a first transition metal. The second catalyst may be a ZSM-5 zeolite modified by a second transition metal. The first transition metal and second transition metal may be molybdenum. Each catalyst may comprise about 3 to about 12 wt% of molybdenum. Each catalyst may have a Si/2Al ratio of from 25 to 45. The weight ratio of the first and second catalysts may be about 1:1.

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