CLAIMS

What is claimed is:

1. A process for preparing 2,5-bis-hydroxymethylfuran (BHMF) from 5-hydroxymethylfurfural (HMF) comprising:

reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in a continuous flow reactor in the presence of an organic solvent and a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag, Pt, Pd, Fe and Ru or a combination thereof to form the 2,5-bis-hydroxymethylfuran (BHMF), wherein the process further comprises one or more of (i)-(iii):

(i) forming the 2,5-bis-hydroxymethylfuran (BHMF) over an on-stream period of at least 150 hours;

(ii) feeding the 5-hydroxymethylfurfural (HMF) through a guard bed comprising a transition metal to the continuous flow reactor;

(iii) feeding the 5-hydroxymethylfurfural (HMF) to the continuous flow reactor for an on-stream period of at least 150 hours.

2. The process of claim 1, wherein the reaction proceeds with at least 85% conversion of the 5-hydroxymethylfurfural (HMF).

3. The process of any one of claims 1-2, wherein the process comprises forming the 2,5-bis-hydroxymethylfuran (BHMF) with at least about 90% selectivity.

4. The process of any one of claims 1-3, wherein (i) applies.

5. The process of any one of claims 1-4, wherein (ii) applies.

6. The process of claim 5, wherein the guard bed comprises at least one transition metal selected from the group consisting of Ag, Zn, Cu, Fe, Ni, Co and Pb or a salt or combination thereof.

7. The process of claim 6, wherein the guard bed comprises at least one transition metal selected from the group consisting of Ag, Zn, Cu and Pb or a salt or combination thereof.

8. The process of any one of claims 1-7, wherein (iii) applies.

9. The process of any one of claims 1-8, wherein the process comprises feeding the 5-hydroxymethylfurfural (HMF) to the continuous flow reactor at a concentration of greater than about 6 weight percent in the organic solvent.

10. The process of any one of claims 1-9, wherein the process comprises feeding the 5-hydroxymethylfurfural (HMF) to the continuous flow reactor at a concentration of greater than about 10 weight percent in the organic solvent.

11. The process of any one of claims 1-10, wherein the process comprises forming the 2,5-bis-hydroxymethylfuran (BHMF) with at least about 90% selectivity and at least 90% 5-hydroxymethylfurfural (HMF) conversion.

12. The process of any one of claims 1-11, wherein the process comprises forming the 2,5-bis-hydroxymethylfuran (BHMF) with at least about 95% selectivity and at least 90% 5-hydroxymethylfurfural (HMF) conversion.

13. The process of any one of claims 1-12, wherein the organic solvent comprises less than about 25 weight % water.

14. The process of any one of claims 1-12, wherein the organic solvent comprises less than about 10 weight % water.

15. The process of any one of claims 1-12, wherein the organic solvent is substantially free of water.

16. The process of any one of claims 1-15, wherein the organic solvent is selected from the group consisting of alcohols, esters, ethers and mixtures thereof.

17. The process of claim 16, wherein the organic solvent comprises an alcohol.

18. The process of claim 17, wherein the alcohol is selected from the group consisting of ethanol, n-propanol, isopropanol, n-butanol, t-butanol, iso-butanol and sec-butanol.

19. The process of claim 16, wherein the organic solvent comprises an ester.

20. The process of claim 19, wherein the ester is selected from the group consisting of methyl acetate, ethyl acetate, propyl acetate and butyl acetate.

21. The process of claim 16, wherein the organic solvent comprises an ether.

22. The process of claim 21, wherein the ether is selected from the group consisting of dioxane, dioxolane, glyme, diglyme, triglyme and tetraglyme.

23. The process of any one of claims 1-22, wherein the heterogeneous reduction catalyst comprises a combination of metals selected from the group consisting of Co-Cu, Ni-Cu, Ag-Ni, Ag-Co and Ag-Ru.

24. The process of any one of claims 1-23, wherein the heterogeneous reduction catalyst further comprises a modifier.

25. The process of claim 24, wherein the modifier is selected from the group consisting of Mn, Co, Au, W, Cu, Zn, Mo, Sb, Bi and Pb.

26. The process of any one of claims 1-25, wherein the heterogeneous reduction catalyst further comprises a catalyst support.

27. The process of claim 26, wherein the catalyst support is selected from the group consisting of carbons, aluminas, zirconias, silicas, alumina-silicas, titanias, alumina-titanias, silicon carbides and mixed phases thereof.

28. The process of any one of claims 1-27, wherein the 5-hydroxymethylfurfural (HMF) is reacted with hydrogen at a temperature in a range of about 50°C to about 150°C and at a pressure in a range of about 50 psi to about 2000 psi.

29. The process of any one of claims 1-28, further comprising reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen in a continuous flow reactor in the presence of an organic solvent and a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag, Pd, Pt and Ru or a combination thereof to form 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF).

30. The process of claim 29, wherein the heterogeneous reduction catalyst used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen is the same as the heterogeneous reduction catalyst used in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen.

31. The process of claim 29, wherein the heterogeneous reduction catalyst used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen is different from the heterogeneous reduction catalyst used in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen.

32. The process of any one of claims 29-31, wherein the temperature and pressure in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen are the same as the temperature and pressure in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen.

33. The process of any one of claims 29-31, wherein the temperature and pressure in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen are different from the temperature and pressure in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen.

34. The process of any one of claims 29-33, wherein the continuous flow reactor used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen is the same as the continuous flow reactor used in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen.

35. The process of any one of claims 29-33, wherein the continuous flow reactor used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen is different from the continuous flow reactor used in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen.

36. The process of any one of claims 29-35, wherein the organic solvent used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen comprises less than about 25 weight % water.

37. The process of any one of claims 29-36, further comprising reacting the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen in a continuous flow reactor in the presence of an aqueous or organic solvent and a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag, Pt and Ru or a combination thereof to form 1,2,6-hexanetriol (HTO).

38. The process of claim 37, wherein the heterogeneous reduction catalyst used in the reaction of the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen is the same as (i) the heterogeneous reduction catalyst used in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen or (ii) the heterogeneous reduction catalyst used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen.

39. The process of claim 37, wherein the heterogeneous reduction catalyst used in the reaction of the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen is different from (i) the heterogeneous reduction catalyst used in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen or (ii) the heterogeneous reduction catalyst used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen.

40. The process of any one of claims 37-39, wherein the temperature and pressure in the reaction of the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen are the same as (i) the temperature and pressure in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen or (ii) the temperature and pressure in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen.

41. The process of any one of claims 37-39, wherein the temperature and pressure in the reaction of the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen are different from (i) the temperature and pressure in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen or (ii) the temperature and pressure in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen.

42. The process of any one of claims 37-41, wherein the continuous flow reactor used in the reaction of the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen is the same as (i) the continuous flow reactor used in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen or (ii) the continuous flow reactor used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen.

43. The process of any one of claims 37-41, wherein the continuous flow reactor used in the reaction of the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen is different from (i) the continuous flow reactor used in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen or (ii) the continuous flow reactor used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen.

44. The process of any one of claims 37-43, wherein the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) is reacted with hydrogen in the presence of an organic solvent comprising less than about 25 weight % water.

45. The process of any one of claims 1-28, further comprising reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen in a continuous flow reactor at a pressure in a range of about 50 psi to about 2000 psi in the presence of an aqueous or organic solvent and a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag, Pt, Pd and Ru or a combination thereof to form 1,2,6-hexanetriol (HTO).

46. The process of claim 45, wherein the 2,5-bis-hydroxymethylfuran (BHMF) is reacted with hydrogen at a temperature in a range of about 80°C to about 180°C.

47. The process of claim 45 or 46, wherein the heterogeneous reduction catalyst used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen is the same as the heterogeneous reduction catalyst used in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen.

48. The process of claim 45 or 46, wherein the heterogeneous reduction catalyst used in the reaction of the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen is different from the heterogeneous reduction catalyst used in the reaction of the 5-hydroxymethylfurfural (HMF) with hydrogen.

49. The process of any one of claims 45-48, wherein the 2,5-bis-hydroxymethylfuran (BHMF) is reacted with hydrogen in the presence of an organic solvent comprising less than about 25 weight % water.

50. The process of any one of claims 37-49, further comprising reacting the 1,2,6-hexanetriol (HTO) with hydrogen in a continuous flow reactor in the presence of a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag, Pt and Ru or a combination thereof to form 1,6-hexanediol (HDO).

51. The process of claim 50, wherein the 1,2,6-hexanetriol (HTO) is reacted with hydrogen in a continuous flow reactor in the presence of an aqueous or organic solvent or a mixture thereof.

52. The process of claim 50, wherein the wherein the 1,2,6-hexanetriol (HTO) is reacted with hydrogen in a continuous flow reactor in the presence of an organic solvent comprising less than about 25 weight % water.

53. The process of claim 52, wherein the organic solvent used in the reaction of the 1,2,6-hexanetriol (HTO) with hydrogen is selected from the group consisting of alcohols, esters, ethers and mixtures thereof.

54. The process of any one of claims 50-53, wherein the heterogeneous reduction catalyst used in the reaction of the 1,2,6-hexanetriol (HTO) with hydrogen further comprises a modifier.

55. The process of claim 54, wherein the modifier used in the reaction of the 1,2,6-hexanetriol (HTO) with hydrogen is selected from the group consisting of Mn, Co, Au, W, Cu, Zn, Mo, Sb, Bi and Pb.

56. The process of any one of claims 50-55, wherein the heterogeneous reduction catalyst used in the reaction of the 1,2,6-hexanetriol (HTO) with hydrogen further comprises a catalyst support.

57. The process of claim 56, wherein the catalyst support used in the reaction of the 1,2,6-hexanetriol (HTO) with hydrogen is selected from the group consisting of carbons, aluminas, zirconias, silicas, alumina-silicas, titanias, alumina-titanias, silicon carbides and mixed phases thereof.

58. The process of any one of claims 50-57, wherein the 1,2,6-hexanetriol (HTO) is reacted with hydrogen at a temperature in a range of about 80°C to about 200°C and at a pressure in a range of about 50 psi to about 2000 psi.

59. A process for preparing 1,2,6-hexanetriol (HTO) from 5-hydroxymethylfurfural (HMF) comprising:

(a) feeding 5-hydroxymethylfurfural (HMF) to a continuous flow reactor at a concentration of greater than about 5 weight percent in a first organic solvent;

(b) reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in the continuous flow reactor in the presence of the first organic solvent and a first heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag, Pt, Pd, Fe and Ru or a combination thereof to form 2,5-bis-hydroxymethylfuran (BHMF) in a first reactor effluent stream or a first reactor zone effluent stream;

(c) reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen, without isolation or purification of the 2,5-bis-hydroxymethylfuran (BHMF) from the first reactor effluent stream or the first reactor zone effluent stream, in the presence of a second heterogeneous reduction

catalyst to form 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) in a second reactor effluent stream or a second reactor zone effluent stream; and

(d) reacting the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen, without isolation or purification of the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) from the second reactor effluent stream or the second reactor zone effluent stream, in the presence of a third heterogeneous reduction catalyst to form the 1,2,6-hexanetriol (HTO).

60. The process of claim 59, wherein the first organic solvent comprises less than about 25 weight % water.

61. The process of any one of claims 59-60, wherein the 2,5-bis-hydroxymethylfuran (BHMF) is reacted with hydrogen in the presence of a second organic solvent comprising less than about 25 weight % water.

62. The process of any one of claims 59-61, wherein the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) is reacted with hydrogen in the presence of a third organic solvent comprising less than about 25 weight % water.

63. The process of any one of claims 59-62, wherein the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) is reacted with hydrogen in the presence of an aqueous solvent.

64. A process for preparing 1,2,6-hexanetriol (HTO) from 5-hydroxymethylfurfural (HMF) comprising:

feeding the 5-hydroxymethylfurfural (HMF) to a continuous flow reactor at a concentration of greater than about 5 weight percent in a first organic solvent;

reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in the continuous flow reactor in the presence of the first organic solvent and a first heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag, Pt, Pd, Fe and Ru or a combination thereof to form 2,5-bis-hydroxymethylfuran (BHMF) in a first reactor effluent stream or a first reactor zone effluent stream; and

reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen, without isolation or purification of the 2,5-bis-hydroxymethylfuran (BHMF) from the first reactor effluent stream or

the first reactor zone effluent stream, in the presence of a second heterogeneous reduction catalyst to form the 1,2,6-hexanetriol (HTO).

65. The process of claim 64, wherein the organic solvent comprises less than about 25 weight % water.

66. The process of any one of claims 64-65, wherein the 2,5-bis-hydroxymethylfuran (BHMF) is reacted with hydrogen in the presence of a second organic solvent comprising less than about 25 weight % water.

67. The process of any one of claims 64-65, wherein the 2,5-bis-hydroxymethylfuran (BHMF) is reacted with hydrogen in the presence of an aqueous solvent.

68. The process of any one of claims 50-58, further comprising converting the 1,6-hexanediol (HDO) to one or more of HMDA, adipic acid, caprolactam, caprolactone, a polyol, a polyester polyol, a polyester and a polyurethane.

69. The process of any one of claims 1-49, further comprising converting the 2,5-bis-hydroxymethylfuran (BHMF), the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) or the 1,2,6-hexanetriol (HTO) to any one or more of a polyol, a polyester polyol, a polyester and a polyurethane.

70. The process of any one of claims 26, 27, 56, and 57, wherein the catalyst support is a shaped support.

71. The process of claim 70, wherein the shape of the catalyst support is selected from the group consisting of an extrudate, sphere, bead, cylinder, pellet, tablet, multi-lobed shape, ring, star, ripped cylinder, trihole, alpha and wheels.

72. The process of any one claims 1-71, wherein at least one of the heterogeneous reduction catalysts comprises at least one metal selected from the group consisting of Ag, Ru, Pd and Pt, and the total concentration of the metals is from at least 0.1 weight % to about 15 weight % of the total weight of the catalyst.

73. The process of any one of claims 1-71, wherein at least one of the heterogeneous reduction catalysts comprises at least one metal selected from the group consisting of Ni, Cu, Co and Fe, and the total concentration of the metals is from at least 0.5 weight % to about 40 weight % of the total weight of the catalyst.

74. A process for preparing 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) from 2,5-bis-hydroxymethylfuran (BHMF) comprising:

reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen in a continuous flow reactor at a pressure in a range of about 50 psi to about 2000 psi in the presence of:

(i) an organic solvent comprising less than about 25 weight % water, and

(ii) a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag, Pd, Pt and Ru or a combination thereof

to form the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF).

75. A process for preparing 1,2,6-hexanetriol (HTO) and 1,6-hexanediol (HDO) from 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) comprising:

reacting the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen in a continuous flow reactor at a pressure in a range of about 50 psi to about 2000 psi in the presence of:

(i) an organic solvent comprising less than about 25 weight % water, and

(ii) a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag, Pt and Ru or a combination thereof

to form the 1,2,6-hexanetriol (HTO) and the 1,6-hexanediol (HDO) with at least about 90% combined selectivity and at least 85% 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) conversion.

76. A process for preparing 2,5-bis-hydroxymethylfuran (BHMF) from 5-hydroxymethylfurfural (HMF) comprising:

reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in a continuous flow reactor at a pressure in a range of about 50 psi to about 2000 psi in the presence of

(i) an organic solvent comprising less than about 25 weight % water, and

(ii) a heterogeneous reduction catalyst comprising Cu

~~to form the 2,5-bis-hydroxymethylfuran (BHMF) with at least about 90% selectivity and at least 85% 5-hydroxymethylfurfural (HMF) conversion.~~

~~77. The process of claim 76, wherein the organic solvent comprises dioxane.~~

~~78. The process of claim 76, wherein the organic solvent comprises isopropanol.~~

~~79. The process of claim 76, wherein the organic solvent comprises glyme.~~

~~80. The process of any one of claims 76-79, wherein the organic solvent comprises from about 5 weight % to about 20 weight % water.~~

~~81. The process of any one of claims 76-80, wherein the heterogeneous reduction catalyst further comprises an alumina catalyst support.~~

~~82. A process for preparing 1,2,6-hexanetriol (HTO) from 5-hydroxymethylfurfural (HMF) comprising:~~

~~(a) reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in a continuous flow reactor in the presence of~~

~~(i) a first organic solvent comprising less than about 25 weight % water, and~~

~~(ii) a first heterogeneous reduction catalyst comprising Cu~~

~~to form 2,5-bis-hydroxymethylfuran (BHMF);~~

~~(b) reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen in the presence of~~

~~(i) a second organic solvent comprising less than about 25 weight % water, and~~

~~(ii) a second heterogeneous reduction catalyst comprising Ni~~

~~to form 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF); and~~

~~(c) reacting the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen in the presence of~~

~~i) a third organic solvent comprising less than about 25 weight % water, and~~

~~(ii) a third heterogeneous reduction catalyst comprising Pt~~

~~to form the 1,2,6-hexanetriol (HTO).~~

~~83. The process of claim 82, wherein the 2,5-bis-hydroxymethylfuran (BHMF) is formed in a first reactor effluent stream or a first reactor zone effluent stream and is reacted with hydrogen without isolation or purification of the 2,5-bis-hydroxymethylfuran (BHMF) from the first reactor effluent stream or the first reactor zone effluent stream.~~

~~84. The process of any one of claims 82-83, wherein the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) is formed in a second reactor effluent stream or a second reactor zone effluent stream and is reacted with hydrogen without isolation or purification of the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) from the second reactor effluent stream or the second reactor zone effluent stream.~~

~~85. The process of any one of claims 82-84, wherein one or more of the first, second, and third organic solvents comprises dioxane.~~

~~86. The process of claim 85, wherein each of the first, second, and third organic solvents comprises dioxane.~~

~~87. The process of claim any one of claims 82-84, wherein one or more of the first, second, and third organic solvents comprises isopropanol.~~

~~88. The process of claim 87, wherein each of the first, second, and third organic solvents comprises isopropanol.~~

~~89. The process of claim 82, wherein one or more of the first, second, and third organic solvents comprises glyme.~~

~~90. The process of claim 89, wherein each of the first, second, and third organic solvents comprises glyme.~~

~~91. The process of any one of claims 82-90, wherein the third heterogeneous reduction catalyst further comprises tungsten.~~

92. A process for preparing 1,6-hexanediol (HDO) from 5-hydroxymethylfurfural (HMF) comprising:

(a) reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in a continuous flow reactor in the presence of

(i) a first organic solvent comprising less than about 25 weight % water, and

(ii) a first heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Co, Mn, Ni, and Cu or a combination thereof

to form 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF);

(b) reacting the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen in a continuous flow reactor the presence of

(i) a second organic solvent comprising less than about 25 weight % water, and

(ii) a second heterogeneous reduction catalyst comprising Pt

to form the 1,6-hexanetriol (HDO).

93. The process of claim 92, wherein the second heterogeneous reduction catalyst further comprises tungsten.

94. The process of claim 92 or 93, wherein the reaction of step (a) occurs within a first reaction zone and the reaction of step (b) occurs within a second reaction zone, wherein the first and second reaction zones are contained within the same continuous flow reactor.

95. The process of claim 92 or 93, wherein the reaction of step (a) occurs within a first continuous flow reactor, and the reaction of step (b) occurs within a second continuous flow reactor.

96. The process of any one of claims 92-95, wherein the reaction of step (a) comprises formation of 2,5-bis-hydroxymethylfuran (BHMF), and at least a portion of the 2,5-bis-hydroxymethylfuran (BHMF) is reacted with hydrogen in the continuous flow reactor to form 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF).

97. The process of any one of claims 92-96, wherein the reaction of step (b) comprises formation of 1,2,6-hexanetriol (HTO), and at least a portion of the 1,2,6-hexanetriol (HTO) is reacted with hydrogen in the continuous flow reactor to form 1,6-hexanediol (HDO).

98. The process of any one of claims 92-97, wherein one or both of the first and second organic solvents comprises dioxane.

99. The process of any one of claims 92-97, wherein one or both of the first and second organic solvents comprises isopropanol.

100. The process of any one of claims 92-97, wherein one or both of the first and second organic solvents comprises glyme.

101. The process of any one of claims 92-100, wherein the temperature in the reaction of step (b) is higher than the temperature in the reaction of step (a).

102. The process of any one of claims 92-101, wherein the pressure in the reaction of step (b) is higher than the pressure in the reaction of step (a).

103. A continuous conversion system for producing a reduction product, wherein the continuous conversion system comprises:

(i) a first contained area for the reduction of a first reactant in the presence of hydrogen and a heterogeneous reduction catalyst comprising Cu;

(i) a second contained area for the reduction of a second reactant in the presence of hydrogen and a heterogeneous reduction catalyst comprising Ni; and

(ii) a third contained area for the reduction of a third reactant in the presence of hydrogen and a heterogeneous reduction catalyst comprising Pt;

wherein the contained areas are sequentially coupled such that the second reactant comprises the product of the first reduction reaction and the third reactant comprises the product of the second reduction reaction.

104. The continuous conversion system of claim 103, wherein the first and second contained areas are contained within a single continuous flow reactor.

105. The continuous conversion system of claim 103 or 104, wherein the second and third contained areas are contained within a single continuous flow reactor.

106. The continuous conversion system of any one of claims 103-105, wherein the reduction product comprises 1,2,6-hexanetriol (HTO).

107. The continuous conversion system of any one of claims 103-106, wherein the first reactant comprises 5-hydroxymethylfurfural (HMF), the second reactant comprises 2,5-bis-hydroxymethylfuran (BHMF), and the third reactant comprises 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF).

108. The continuous conversion system of any one of claims 103-106, further comprising a guard bed comprising a transition metal.

109. The continuous conversion system of claim 108, wherein the guard bed is coupled to the first contained area such that the first reactant can be fed through the guard bed to the first contained area.

CLAIMS

1. A process for preparing 2,5-bis-hydroxymethylfuran (BHMF) from 5-hydroxymethylfurfural (HMF) comprising:

reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in a continuous flow reactor in the presence of an organic solvent selected from the group consisting of alcohols, esters, ethers and mixtures thereof, optionally comprising water, and a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag and Pt or a combination thereof to form the 2,5-bis-hydroxymethylfuran (BHMF) over an on-stream period of at least 150 hours.

2. The process of claim 1, wherein the 2,5-bis-hydroxymethylfuran (BHMF) is formed with at least about 90% selectivity and at least 85% conversion of the 5-hydroxymethylfurfural (HMF).

3. The process of claim 1, wherein the organic solvent comprises less than about 25 weight % water.

4. The process of claim 1, wherein the heterogeneous reduction catalyst further comprises a modifier.

5. The process of claim 1, wherein the heterogeneous reduction catalyst further comprises a catalyst support.

6. The process of claim 1, wherein the 5-hydroxymethylfurfural (HMF) is reacted with hydrogen at a temperature in a range of about 50°C to about 150°C and at a pressure in a range of about 50 psi to about 2000 psi.

7. The process of claim 1, further comprising reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen in a continuous flow reactor in the presence of an organic solvent selected from the group consisting of alcohols, esters, ethers and mixtures thereof, optionally comprising water, and a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Pd, Pt and Ru or a combination thereof to form 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF).

8. The process of claim 7, further comprising reacting the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen in a continuous flow reactor in the presence of an aqueous or organic solvent selected from the group consisting of water, alcohols, esters, ethers, ketones and mixtures thereof, and a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Pt and Ru or a combination thereof to form 1,2,6-hexanetriol (HTO).

9. The process of claim 1, further comprising reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen in a continuous flow reactor at a pressure in a range of about 50 psi to about 2000 psi in the presence of an aqueous or organic solvent selected from the group consisting of water, alcohols, esters, ethers and mixtures thereof, and a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Co, Cu, Pt, and Pd or a combination thereof to form 1,2,6-hexanetriol (HTO).

10. The process of claim 8, further comprising reacting the 1,2,6-hexanetriol (HTO) with hydrogen in a continuous flow reactor in the presence of a heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag, Pt and Ru or a combination thereof to form 1,6-hexanediol (HDO).

11. A process for preparing 1,2,6-hexanetriol (HTO) from 5-hydroxymethylfurfural (HMF) comprising:

(a) feeding 5-hydroxymethylfurfural (HMF) to a continuous flow reactor at a concentration of greater than about 5 weight percent in a first organic solvent selected from the group consisting of alcohols, esters, ethers and mixtures thereof, optionally comprising water, for an on-stream period of at least 150 hours;

(b) reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in the continuous flow reactor in the presence of the first organic solvent and a first heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag and Pt or a combination thereof to form 2,5-bis-hydroxymethylfuran (BHMF) in a first reactor effluent stream or a first reactor zone effluent stream;

(c) reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen, without isolation or purification of the 2,5-bis-hydroxymethylfuran (BHMF) from the first reactor effluent stream or

the first reactor zone effluent stream, in the presence of a second heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Pd, Pt and Ru or a combination thereof to form 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) in a second reactor effluent stream or a second reactor zone effluent stream; and

(d) reacting the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen, without isolation or purification of the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) from the second reactor effluent stream or the second reactor zone effluent stream, in the presence of a third heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Pt and Ru or a combination thereof to form the 1,2,6-hexanetriol (HTO).

12. A process for preparing 1,2,6-hexanetriol (HTO) from 5-hydroxymethylfurfural (HMF) comprising:

feeding the 5-hydroxymethylfurfural (HMF) to a continuous flow reactor at a concentration of greater than about 5 weight percent in a first organic solvent selected from the group consisting of alcohols, esters, ethers and mixtures thereof, optionally comprising water, for an on-stream period of at least 150 hours;

reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in the continuous flow reactor in the presence of the first organic solvent and a first heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Ag and Pt or a combination thereof to form 2,5-bis-hydroxymethylfuran (BHMF) in a first reactor effluent stream or a first reactor zone effluent stream; and

reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen, without isolation or purification of the 2,5-bis-hydroxymethylfuran (BHMF) from the first reactor effluent stream or the first reactor zone effluent stream, in the presence of a second heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Ni, Co, Cu, Pt, Pd and Ru or a combination thereof to form the 1,2,6-hexanetriol (HTO).

13. A process for preparing 2,5-bis-hydroxymethylfuran (BHMF) from 5-hydroxymethylfurfural (HMF) comprising:

reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in a continuous flow reactor at a pressure in a range of about 50 psi to about 2000 psi in the presence of

(i) an organic solvent selected from the group consisting of alcohols, esters, ethers and mixtures thereof, comprising less than about 25 weight % water, and

(ii) a heterogeneous reduction catalyst comprising Cu

to form the 2,5-bis-hydroxymethylfuran (BHMF) with at least about 90% selectivity and at least 85% 5-hydroxymethylfurfural (HMF) conversion.

14. A process for preparing 1,2,6-hexanetriol (HTO) from 5-hydroxymethylfurfural (HMF) comprising:

(a) reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in a continuous flow reactor in the presence of

(i) a first organic solvent selected from the group consisting of alcohols, esters, ethers and mixtures thereof, comprising less than about 25 weight % water, and

(ii) a first heterogeneous reduction catalyst comprising Cu to form 2,5-bis-hydroxymethylfuran (BHMF);

(b) reacting the 2,5-bis-hydroxymethylfuran (BHMF) with hydrogen in the presence of

(i) a second organic solvent selected from the group consisting of alcohols, esters, ethers and mixtures thereof, comprising less than about 25 weight % water, and

(ii) a second heterogeneous reduction catalyst comprising Ni

to form 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF); and

(c) reacting the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen in the presence of

(i) a third organic solvent selected from the group consisting of alcohols, esters, ethers, ketones and mixtures thereof, comprising less than about 25 weight % water, and

(ii) a third heterogeneous reduction catalyst comprising Pt to form the 1,2,6-hexanetriol (HTO).

15. A process for preparing 1,6-hexanediol (HDO) from 5-hydroxymethylfurfural (HMF) comprising:

(a) reacting the 5-hydroxymethylfurfural (HMF) with hydrogen in a continuous flow reactor in the presence of

(i) a first organic solvent selected from the group consisting of alcohols, esters, ethers and mixtures thereof, comprising less than about 25 weight % water, and

(ii) a first heterogeneous reduction catalyst comprising at least one metal selected from the group consisting of Co, Mn, Ni, and Cu or a combination thereof to form 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF);

(b) reacting the 2,5-bis-hydroxymethyltetrahydrofuran (BHMTHF) with hydrogen in a continuous flow reactor the presence of

(i) a second organic solvent selected from the group consisting of alcohols, esters, ethers, ketones and mixtures thereof, comprising less than about 25 weight % water, and

(ii) a second heterogeneous reduction catalyst comprising Pt to form the 1,6-hexanetriol (HDO).

16. The process of claim 1 further comprising:

feeding the 5-hydroxymethylfurfural (HMF) through a guard bed comprising a transition metal to the continuous flow reactor.

17. The process of claim 1, wherein the organic solvent comprises an alcohol.

18. The process of claim 1, wherein the organic solvent comprises an ester.

19. The process of claim 1, wherein the organic solvent comprises an ether.

20. The process of claim 1, wherein the heterogeneous reduction catalyst comprises a combination of metals selected from the group consisting of Co-Cu, Ni-Cu, Ag-Ni, Ag-Co and Ag-Ru.