clearly demonstrate the need for development of alternative, more efficient processes for the production of HDO.

SUMMARY

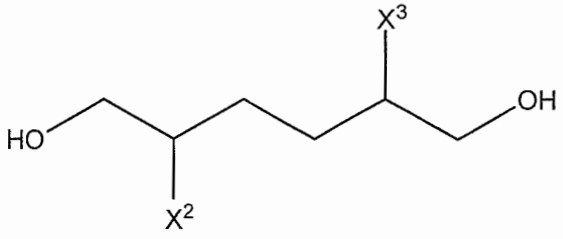
[0011] Briefly, therefore, the present disclosure is directed to processes for preparing hexamethylenediamine from a carbohydrate source by converting a carbohydrate source to a furfural substrate; reacting at least a portion of the furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst to produce 1,6-hexanediol; and, converting at least a portion of the 1,6-hexanediol to hexamethylenediamine. The present disclosure is also directed to processes for preparing hexamethylenediamine from a carbohydrate source by converting a carbohydrate source to a furfural substrate; reacting at least a portion of the furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt to produce a reaction product comprising 1,2,6-hexanetriol; converting at least a portion of the 1,2,6-hexanetriol to 1,6-hexanediol; and converting at least a portion of the 1,6-hexanediol to hexamethylenediamine. In some embodiments, the heterogeneous reduction catalyst comprises Pt. In other embodiments, the heterogeneous reduction catalyst further comprises at least one metal selected from the group consisting of Mo, La, Sm, Y, W, and Re. In other embodiments, the step of converting at least a portion of the 1,2,6-hexanetriol to 1,6-hexanediol is conducted in the presence of hydrogen and a hydrogenation catalyst comprising Pt. In other embodiments, the yield of 1,6-hexanediol is at least about 40%. In other embodiments, the yield of 1,6-hexanediol is at least about 50%. In other embodiments, the yield of 1,6-hexanediol is at least about 60%. In other embodiments, the reaction of the furfural substrate with hydrogen is carried out at a temperature in the range of about 60°C and about 200°C and a pressure of hydrogen in the range of about 200 psig to about 2000 psig. In other embodiments, the furfural substrate is 5-hydroxymethylfurfural. In other embodiments, the carbohydrate source is glucose, fructose, or a mixture comprising glucose and fructose. In other embodiments, the catalyst further comprises a support selected from the group consisting of zirconias, silicas and zeolites. In other embodiments, the reaction of the furfural substrate with hydrogen is carried out at a temperature in the range of about 100°C and about 180°C and a pressure of hydrogen in the range of about 200 psig to about 2000 psig. In other embodiments, the hydrogenation catalyst comprises Pt and W supported on zirconia. The present disclosure is also directed to hexamethylenediamine produced by the processes of any of the above embodiments.

[0012] The present disclosure is also directed to processes for preparing 1,6-hexanediol from a carbohydrate source by converting the carbohydrate source to a furfural substrate; and, reacting at least a portion of the furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt to produce 1,6-hexanediol. The present disclosure is also directed to processes for preparing 1,6-hexanediol from a carbohydrate source by converting the carbohydrate source to a furfural substrate; reacting at least a portion of the furfural substrate with hydrogen in the presence of a Pt containing heterogeneous reduction catalyst to produce a reaction product comprising 1,2,6-hexanetriol; and, converting at least a portion of the 1,2,6-hexanetriol to 1,6-hexanediol. In some embodiments, the heterogeneous catalyst further comprises at least one metal selected from the group consisting of Mo, La, Sm, Y, W, and Re. In other embodiments, the step of converting at least a portion of the 1,2,6-hexanetriol to 1,6-hexanediol is conducted in the presence of hydrogen and a hydrogenation catalyst comprising Pt. In other embodiments, the hydrogenation catalyst is a supported heterogeneous catalyst. In other embodiments, the yield of 1,6-hexanediol from the furfural substrate is at least 40%. In other embodiments, the yield of 1,6-hexanediol from the furfural substrate is at least 50%. In other embodiments, the yield of 1,6-hexanediol from the furfural substrate is at least 60%. In other embodiments, the reaction of the furfural substrate with hydrogen is carried out at a temperature in the range of about 60°C and about 200°C and a pressure of hydrogen in the range of about 200 psig to about 2000 psig. In other embodiments, the furfural substrate is 5-hydroxymethylfurfural. In other embodiments, the carbohydrate source is glucose, fructose, or a mixture comprising glucose and fructose. In other embodiments, the catalyst further comprises a support selected from the group consisting of zirconias, silicas and zeolites. In other embodiments, the reaction of the furfural substrate with hydrogen to produce 1,2,6-hexanetriol is carried out at a temperature in the range of about 100°C and about 140°C and a pressure of hydrogen in the range of about 200 psig to about 1000 psig. In other embodiments, the catalyst comprises Pt and W supported on zirconia. The present disclosure is also directed to 1,6-hexanediol produced by the processes of any of the above embodiments.

[0013] The present disclosure is also directed to processes for preparing hexamethylenediamine from a carbohydrate source by: (a) converting a carbohydrate source to a furfural substrate; (b) reacting at least a portion of the furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt to a reaction product comprising 1,2,6-hexanetriol; (c) reacting at least a portion of the 1,2,6-hexanetriol with

hydrogen in the presence of the heterogeneous reduction catalyst comprising Pt to produce 1,6-hexanediol; and (d) converting at least a portion of the 1,6-hexanediol to hexamethylenediamine, wherein steps b) and c) are conducted in a single reactor. The present disclosure is also directed to processes for preparing 1,6-hexanediol from a carbohydrate source by: (a) converting a carbohydrate source to a furfural substrate; (b) reacting at least a portion of the furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt to a reaction product comprising 1,2,6-hexanetriol; and (c) reacting at least a portion of the 1,2,6-hexanetriol with hydrogen in the presence of the heterogeneous reduction catalyst comprising Pt to produce 1,6-hexanediol, wherein steps b) and c) are conducted in a single reactor. In some embodiments, the heterogeneous reduction catalyst further comprises W. In other embodiments, steps (b) and (c) are carried out at a temperature in the range of about 60°C and about 200°C and a pressure of hydrogen in the range of about 200 psig to about 2000 psig. In other embodiments, the Pt containing catalysts of steps b) and c) are different and the temperatures and pressures at which steps b) and c) are conducted are substantially the same. In other embodiments, the temperatures and pressures at which steps b) and c) are conducted are different. In other embodiments, step b) is conducted at a temperature in the range of about 100°C to about 140°C and a pressure in the range of about 200 psig to about 1000 psig and step c) is conducted at a temperature in the range of about 120°C to about 180°C and a pressure in the range of about 200 psig to about 2000 psig. In other embodiments, the yield of 1,6-hexanediol from the furfural substrate is at least about 40%. In other embodiments, the yield of 1,6-hexanediol from the furfural substrate is at least about 50%. In other embodiments, the yield of 1,6-hexanediol from the furfural substrate is at least about 60%. In other embodiments, the carbohydrate source is glucose, fructose, or a mixture comprising glucose and fructose. In other embodiments, steps (b) and (c) are carried out in one reaction zone. In other embodiments, the catalyst comprises Pt and W supported on zirconia. The present disclosure is also directed to hexamethylenediamine produced by the processes of any of the above embodiments. The present disclosure is also directed to 1,6-hexanediol prepared by the process of any of the above embodiments.

[0014] The present disclosure is also directed to processes for preparing a compound of formula II



(II);

[0015] wherein each of X^2 and X^3 is selected from the group of hydrogen and hydroxyl; by converting a carbohydrate source to a furfural substrate; and, reacting at least a portion of the furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt to produce the compound of formula II. In some embodiments, the catalyst further comprises W. In other embodiments, the catalyst further comprises at least one metal selected from the group consisting of Mo, La, Sm, Y, W, and Re.

[0015a] In one aspect, there is provided a process for producing a product comprising 1,6-hexanediol, the process comprising: providing a reaction product mixture, wherein the reaction product mixture comprises 1,6-hexanediol, 1,2,6-hexanetriol, and one or more other products selected from the group consisting of 1,5-hexanediol, 1,2,5-hexanetriol, 1,2,5,6-hexanequatrol, 1-hexanol, and 2-hexanol; and subjecting the product mixture to fractional distillation under subatmospheric pressure, wherein the fractional distillation separates the 1,6-hexanediol from one or more products in the product mixture to produce a product comprising 1,6-hexanediol.

DETAILED DESCRIPTION

[0016] The following description sets forth exemplary methods, parameters and the like. It should be recognized, however, that such description is not intended as a limitation on the scope of the present invention.

[0017] In accordance with the present invention, applicants disclose processes for the chemocatalytic conversion of a furfural substrate, which may be derived from a carbohydrate source (e.g., glucose or fructose) to hexamethylenediamine, and intermediate processes and products along the pathway. In some embodiments, the processes are carried out by converting a carbohydrate source to a furfural substrate; reacting at least a portion of the furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst to produce 1,6-hexanediol; and, converting at least a portion of the 1,6-hexanediol to hexamethylenediamine. In other embodiments, the processes are carried out by converting a carbohydrate source to a furfural substrate; reacting at least a portion of the furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt to produce a reaction product comprising 1,2,6-hexanetriol; converting at least a portion of the 1,2,6-hexanetriol to 1,6-hexanediol; and converting at least a portion of the 1,6-hexanediol to hexamethylenediamine. In some embodiments, the processes are carried out by converting the carbohydrate source to a furfural substrate; and, reacting at least a portion of the furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt to produce 1,6-hexanediol. In other embodiments, the processes are carried out by converting

CLAIMS

We claim:

1. A process for producing a product comprising 1,6-hexanediol, the process comprising:

providing a reaction product mixture, wherein the reaction product mixture comprises 1,6-hexanediol, 1,2,6-hexanetriol, and one or more other products selected from the group consisting of 1,5-hexanediol, 1,2,5-hexanetriol, 1,2,5,6-hexanequatrol, 1-hexanol, and 2-hexanol; and

subjecting the product mixture to fractional distillation under subatmospheric pressure, wherein the fractional distillation separates the 1,6-hexanediol from one or more products in the product mixture to produce a product comprising 1,6-hexanediol.

2. The process of claim 1, wherein the reaction product mixture further comprises a solvent selected from the group consisting of water, an alcohol, an ester, an ether, a ketone, or a mixture thereof.

3. The process of claim 1, further comprising recycling the 1,2,6-hexanetriol to a reduction reaction to produce 1,6-hexanediol, wherein the reduction reaction comprises reacting the 1,2,6-hexanetriol with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt.

4. The process of claim 2, further comprising recycling the 1,2,6-hexanetriol to a reduction reaction to produce 1,6-hexanediol, wherein the reduction reaction comprises reacting the 1,2,6-hexanetriol with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt.

5. The process of claim 1, wherein the reaction product mixture further comprises 1,2-hexanediol.

6. The process of claim 1, further comprising reacting a furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt to provide the reaction product mixture.

7. The process of claim 1, further comprising converting the 1,6-hexanediol to hexamethylenediamine.

8. The process of claim 3, further comprising converting the 1,6-hexanediol to hexamethylenediamine.

9. The process of claim 4, further comprising reacting a furfural substrate with hydrogen in the presence of a heterogeneous reduction catalyst comprising Pt to provide the reaction product mixture.

10. The process of claim 9, wherein the reaction product mixture further comprises 1,2-hexanediol.

11. The process of claim 10, further comprising converting the 1,6-hexanediol to hexamethylenediamine.