What is claimed is:

1. A method comprising:

   (i) admixing allyl alcohol with CO and H_2 to form a starting material mixture; and

   (ii) reacting the starting material mixture in the presence of a catalyst under conditions capable of forming a product mixture comprising 4-hydroxybutanal and 2-methyl-3-hydroxypropanal;

   wherein the catalyst is a transition metal complex comprising a transition metal ion and a diphosphine ligand with a bite angle from about 70° to about 100°, and wherein the ratio of 4-hydroxybutanal to 2-methyl-3-hydroxypropanal in the product mixture is less than 1.5:1.

2. The method of claim 1, wherein the diphosphine ligand has a bite angle from about 85° to about 95°.

3. The method of claim 1, wherein the ratio of 4-hydroxybutanal to 2-methyl-3-hydroxypropanal is less than 0.75:1.

4. The method of claim 1, wherein the transition metal is a Rh, Re, or Co ion.

5. The method of claim 4, wherein the transition metal ion is a Rh ion.

6. The method of claim 1, wherein the reaction of step (ii) occurs at a temperature from about 20 °C to about 120 °C and at a pressure from about 20 psi to about 600 psi (about 140 to about 4,100 kPa).

7. The method of claim 1, wherein the starting material mixture further comprises a solvent.

8. The method of claim 7, wherein the amount of allyl alcohol in the starting material mixture is 5-40 wt%.

9. The method of claim 1, wherein the starting material mixture further comprises a $phosphine_{(C3-30)}$ or a $substituted\ phosphine_{(C3-30)}$.

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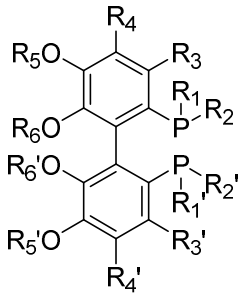
10. The method of claim 1, further comprising:

(iii) separating 2-methyl-3-hydroxypropanal from the product mixture to obtain purified 2-methyl-3-hydroxypropanal.

11. The method of claim 1, further comprising:

(iv) hydrogenating the product mixture in the presence of H_2 gas and a hydrogenation catalyst to produce a diol.

12. The method of claim 1, wherein the diphosphine ligand has the formula:



wherein:

R_1, R_2, R_1', and R_2' are each independently selected from $aryl_{(C6-12)}$ or substituted $aryl_{(C6-12)}$;

R_3, R_4, R_3', and R_4' are each independently selected from hydrogen, $alkyl_{(C1-12)}$, substituted $alkyl_{(C1-12)}$, $aryl_{(C6-12)}$, or substituted $aryl_{(C6-12)}$;

R_5 is $alkyl_{(C1-12)}$, substituted $alkyl_{(C1-12)}$, $aryl_{(C6-12)}$, or substituted $aryl_{(C6-12)}$; or is taken together with R_6 and is $alkanediyl_{(C1-6)}$ or substituted $alkanediyl_{(C1-6)}$;

R_5' is $alkyl_{(C1-12)}$, substituted $alkyl_{(C1-12)}$, $aryl_{(C6-12)}$, or substituted $aryl_{(C6-12)}$; or is taken together with R_6' and is $alkanediyl_{(C1-6)}$ or substituted $alkanediyl_{(C1-6)}$;

R_6 is $alkyl_{(C1-12)}$, substituted $alkyl_{(C1-12)}$, $aryl_{(C6-12)}$, or substituted $aryl_{(C6-12)}$; is taken together with R_5 and is $alkanediyl_{(C1-6)}$ or substituted $alkanediyl_{(C1-}$

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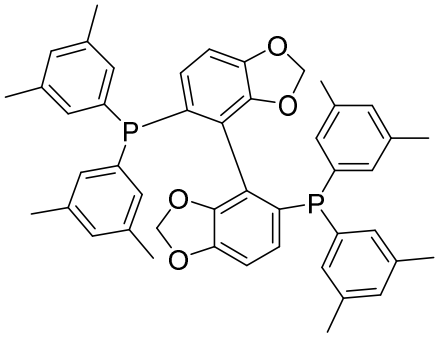
$_{6)}$; or is taken together with R_6' and is alkanediyl$_{(C1-6)}$ or substituted alkanediyl$_{(C1-6)}$; and

R_6' is alkyl$_{(C1-12)}$, substituted alkyl$_{(C1-12)}$, aryl$_{(C6-12)}$, or substituted aryl$_{(C6-12)}$; is taken together with R_5' and is alkanediyl$_{(C1-6)}$ or substituted alkanediyl$_{(C1-6)}$; or is taken together with R_6 and is alkanediyl$_{(C1-6)}$ or substituted alkanediyl$_{(C1-6)}$.

13. The method of claim 12, wherein the diphosphine ligand is further defined as:



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14. The method of claim 1, wherein the catalyst is present in the product mixture in an amount from about 10 ppm to about 1,000 ppm.

15. The method of claim 1, wherein the reaction time of step (ii) is from about 0.5 hours to about 4 hours.

16. The method of claim 1, wherein the method results in an HMPA yield greater than 50%.

17. The method of claim 1, wherein the method results in an allyl alcohol conversion percentage of greater than 75%.

18. A method comprising:

(i) admixing an α-olefin$_{(C3-24)}$ selected from hexene, allyl alcohol, allyl acetate and vinyl acetate, a substituted α-olefin$_{(C3-24)}$, or styrene with CO and H_2 to form a starting material mixture; and

(ii) reacting the starting material mixture in the presence of a catalyst under conditions capable of producing linear and branched aldehydes,

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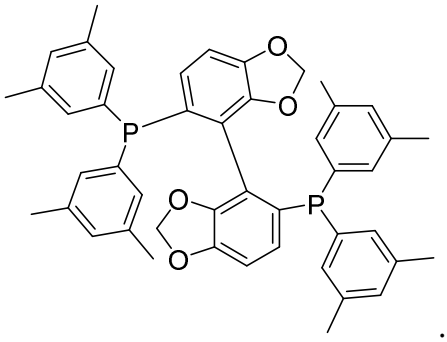
wherein the catalyst is a transition metal complex comprising a transition metal ion and a diphosphine ligand with a bite angle from about 70° to about 100°, and wherein the ratio of the linear to branched aldehydes is less than 1.5:1.

19. The method of claim 18, wherein the diphosphine ligand is further defined as:



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