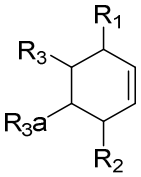
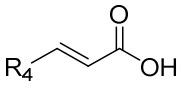
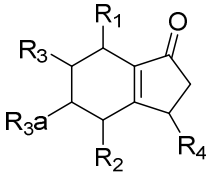
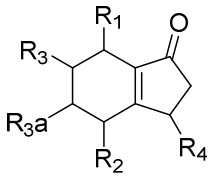
hydrogenation step. The instability or degradation could appear over a long period of time as discoloration and/or a change in molecular weight distribution of the polyolefin, or some other manifestation thereof.

[0008] The inventive method comprises synthesizing a cyclic organic compound via reaction of an unsubstituted or substituted cyclohexene with an unsubstituted or substituted acrylic acid in the presence of phosphoric and/or sulfonic acid reagent to make the cyclic organic compound. Also, a method of synthesizing a ligand for a transition metal, and a related substituted ligand-metal complex and catalyst, from the unsubstituted or substituted cyclohexene and unsubstituted or substituted acrylic acid. Also, the cyclic organic compound, ligand, and substituted ligand-metal complex and catalyst synthesized thereby. Also a method of polymerizing an olefin with the catalyst to give a polyolefin, and the polyolefin made thereby.

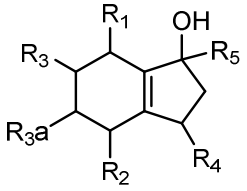
[0008a] In one aspect, the present disclosure refers to a method of synthesizing a bicyclo[4.3.0]nonene compound, the method comprising (A) contacting a compound of formula (1) ("compound (1)"):  (1), wherein R1, R2, R3, and R3a are independently H or (C_1-C_4)alkyl, or any two adjacent R1 to R3a groups are bonded together to form a (C_1-C_4)alkylene and each of the remaining groups of R1 to R3a independently is H or (C_1-C_4)alkyl, with a compound of formula (2) ("compound (2)"):  (2), wherein R4 is H or (C_1-C_4)alkyl, in the presence of an effective amount of a phosphoric and/or sulfonic acid reagent and under reaction conditions sufficient to make a compound of formula (3) ("compound (3)"):  (3) and/or its oxo/R4 regioisomer; wherein R1 to R4 are as defined above; and with the proviso that when each of R1 to R3a is H and R4 is methyl, the phosphoric and/or sulfonic acid reagent and contacting step (A) are free of a polyphosphoric acid (PPA); and wherein the phosphoric and/or sulfonic acid reagent is a mixture of a phosphorous pentoxide and methanesulfonic acid ("P_2O_5/H_3CSO_3H mixture"), or a reaction product thereof; or the phosphoric and/or sulfonic acid reagent is a combination of a

polyphosphoric acid (PPA) and a P_2O_5/H_3CSO_3H mixture, or a reaction product of thereof.

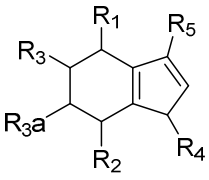
[0008b] In another aspect, the present disclosure refers to a method of synthesizing a ligand for a transition metal, the method comprising: (A) synthesizing the compound (3):



(3) and its oxo/R4 regioisomer, according to step (A) as disclosed herein, wherein R1 to R4 are as disclosed herein; (B) contacting the compound (3) and/or its oxo/R4 regioisomer with either a hydride-functional reducing agent or a (C_1-C_4)alkyl lithium, under reaction conditions sufficient to make a compound of formula (4) ("compound (4)"):

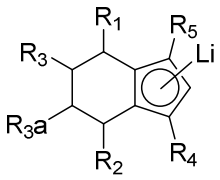


(4) and/or its (HO,R5)/R4 regioisomer, respectively, wherein R1 to R4 are as defined above and R5 is either H or (C_1-C_4)alkyl, respectively; and (C) contacting the compound (4) and/or its (HO,R5)/R4 regioisomer with dehydration reaction conditions to make a compound of formula (5) ("compound (5)"):

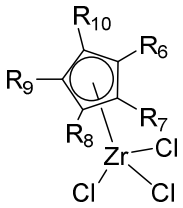
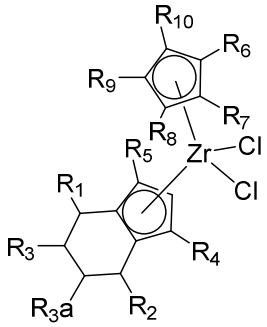


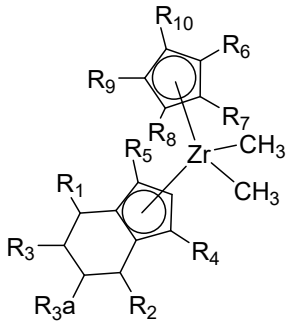
(5), and/or its R5/R4 regioisomer, respectively; wherein R1 to R5 are as defined above.

[0008c] In another aspect, the present disclosure refers to a method of synthesizing a zirconocene dichloride complex, the method comprising synthesizing the compound (5) and/or its R5/R4 regioisomer according to steps (A) to (C) as disclosed herein; (D) contacting the compound (5) and/or its R5/R4 regioisomer with an alkyl lithium under reaction conditions sufficient to make a compound of formula (6) ("compound (6)"):



(6) and/or its R5/R4 regioisomer, wherein R1 to R5 are as disclosed herein; and (E) contacting the compound (6) and/or its R5/R4 regioisomer with a

compound of formula (7) ("compound (7)"):  (7) under reaction conditions sufficient to make a compound of formula (8) ("compound (8)"):  (8) and/or its R5/R4 regioisomer, wherein R1 to R5 are as disclosed herein and each of R6 to R10 is independently H or (C_1-C_4)alkyl.

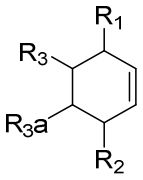
[0008d] In another aspect, the present disclosure refers to a method of synthesizing a zirconocene dimethyl complex, the method comprising synthesizing the compound (8) and/or its R5/R4 regioisomer according to steps (A) to (E) as disclosed herein; and (F) contacting the compound (8) and/or its R5/R4 regioisomer with an effective amount of methyl magnesium bromide under reaction conditions sufficient to make a compound of formula (9) ("compound (9)"):  (9) and/or its R5/R4 regioisomer, wherein R1 to R10 are as disclosed herein.

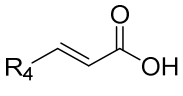
DETAILED DESCRIPTION

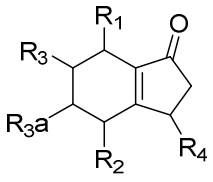
[0009] The Summary and Abstract are incorporated here by reference.

[0010] Certain inventive embodiments are described below as numbered aspects for easy cross-referencing. Additional embodiments are described elsewhere herein.

[0011] Aspect 1. A method of synthesizing a bicyclo[4.3.0]nonene compound, the method comprising (A) contacting a compound of formula (1) ("compound (1)"):

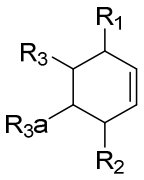


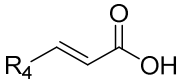
(1), wherein R1, R2, R3, and R3a are independently H or (C_1-C_4)alkyl, or any two adjacent R1 to R3a groups are bonded together to form a (C_1-C_4)alkylene and each of the remaining groups of R1 to R3a independently is H or (C_1-C_4)alkyl, with a compound of formula (2) ("compound (2)"): 

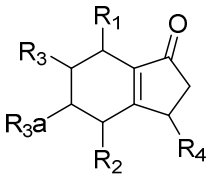
(2), wherein R4 is H or (C_1-C_4)alkyl, in the presence of an effective amount of a phosphoric and/or sulfonic acid reagent and under reaction conditions sufficient to make a compound of formula (3) ("compound (3)"): 

(3) and/or its oxo/R4 regioisomer; wherein R1 to R4 are as defined above; and with the proviso that when each of R1 to R3a is H (i.e., each of R1, R2, R3, and R3a is H) and R4 is methyl, the phosphoric and/or

CLAIMS

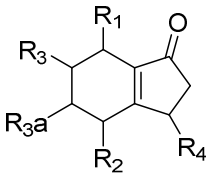
1. A method of synthesizing a bicyclo[4.3.0]nonene compound, the method comprising (A) contacting a compound of formula (1) ("compound (1)"): 

(1), wherein R1, R2, R3, and R3a are independently H or (C_1-C_4)alkyl, or any two adjacent R1 to R3a groups are bonded together to form a (C_1-C_4)alkylene and each of the remaining groups of R1 to R3a independently is H or (C_1-C_4)alkyl, with a compound of formula (2) ("compound (2)"): 

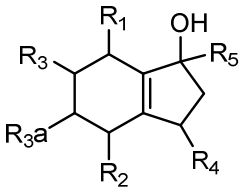
(2), wherein R4 is H or (C_1-C_4)alkyl, in the presence of an effective amount of a phosphoric and/or sulfonic acid reagent and under reaction conditions sufficient to make a compound of formula (3) ("compound (3)"): 

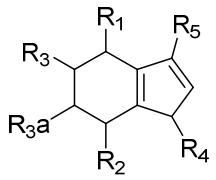
(3) and/or its oxo/R4 regioisomer; wherein R1 to R4 are as defined above; and with the proviso that when each of R1 to R3a is H and R4 is methyl, the phosphoric and/or sulfonic acid reagent and contacting step (A) are free of a polyphosphoric acid (PPA); and

wherein the phosphoric and/or sulfonic acid reagent is a mixture of a phosphorous pentoxide and methanesulfonic acid ("P_2O_5/H_3CSO_3H mixture"), or a reaction product thereof; or the phosphoric and/or sulfonic acid reagent is a combination of a polyphosphoric acid (PPA) and a P_2O_5/H_3CSO_3H mixture, or a reaction product of thereof.

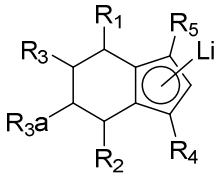
2. A method of synthesizing a ligand for a transition metal, the method comprising: (A) synthesizing the compound (3): 

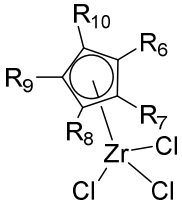
(3) and its oxo/R4 regioisomer, according to step (A) of claim 1, wherein R1 to R4 are as defined in claim 1; (B) contacting the compound (3) and/or its oxo/R4 regioisomer with either a hydride-functional reducing agent or a (C_1-C_4)alkyl lithium, under reaction conditions

sufficient to make a compound of formula (4) ("compound (4)"): 

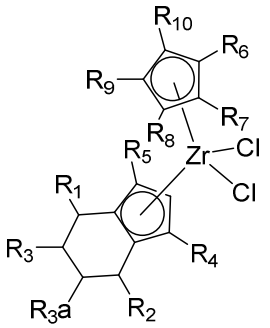
(4) and/or its (HO,R5)/R4 regioisomer, respectively, wherein R1 to R4 are as defined above and R5 is either H or (C_1-C_4)alkyl, respectively; and (C) contacting the compound (4) and/or its (HO,R5)/R4 regioisomer with dehydration reaction conditions to make a compound of formula (5) ("compound (5)"): 

(5), and/or its R5/R4 regioisomer, respectively; wherein R1 to R5 are as defined above.

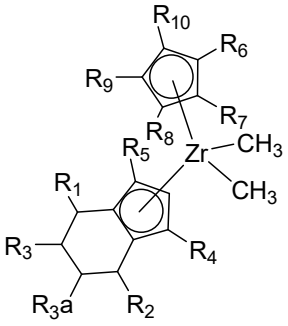
3. A method of synthesizing a zirconocene dichloride complex, the method comprising synthesizing the compound (5) and/or its R5/R4 regioisomer according to steps (A) to (C) of claim 2; (D) contacting the compound (5) and/or its R5/R4 regioisomer with an alkyl lithium under reaction conditions sufficient to make a compound of formula (6) ("compound (6)"): 

(6) and/or its R5/R4 regioisomer, wherein R1 to R5 are as defined in claim 2; and (E) contacting the compound (6) and/or its R5/R4 regioisomer with a compound of formula (7) ("compound (7)"): 

(7) under reaction conditions sufficient to make a

compound of formula (8) ("compound (8)"):  (8) and/or its R5/R4 regioisomer, wherein R1 to R5 are as defined in claim 2 and each of R6 to R10 is independently H or (C_1-C_4)alkyl.

4. A method of synthesizing a zirconocene dimethyl complex, the method comprising synthesizing the compound (8) and/or its R5/R4 regioisomer according to steps (A) to (E) of claim 3; and (F) contacting the compound (8) and/or its R5/R4 regioisomer with an effective amount of methyl magnesium bromide under reaction conditions sufficient to make a compound of formula (9) ("compound (9)"):

 (9) and/or its R5/R4 regioisomer, wherein R1 to R10 are as defined in claim 3.

5. The method of any one of claims 1 to 4, wherein the phosphoric and/or sulfonic acid reagent is the mixture of a phosphorous pentoxide and methanesulfonic acid ("P_2O_5/H_3CSO_3H mixture"), or a reaction product thereof.

6. The method of any one of claims 1 to 4, wherein the phosphoric and/or sulfonic acid reagent is the combination of the PPA and the P_2O_5/H_3CSO_3H mixture, or a reaction product thereof.

7. The method of any one of claims 1 to 6, characterized by any one of limitations (i) to (ix): (i) wherein at least one of R1 to R3a is a (C_1-C_4)alkyl or R4 is H; (ii) wherein each of R1 to R4 is H; (iii) wherein each of R1 to R3a is H and R4 is methyl; (iv) wherein in compound (1) each of R1, R2, and R3a is H and R3 is methyl; in compound (2) R4 is methyl; and in compound (3) each of R1, R2, and R3a is H and each of R3 and R4 is methyl; and in its oxo/R4 regioisomer each of R1, R2, and

R3 is H and each of R3a and R4 is each methyl; (v) wherein R1 and/or R2 is methyl and R3 and R3a is H; (vi) wherein R1 is methyl, R2 is 1-methylethyl (i.e., isopropyl), and R3 and R3a are H; (vii) wherein R1 is 1-methylethyl (i.e., isopropyl), R2 is methyl, and R3 and R3a are H; (viii) wherein R1 and R2 independently are (C_1-C_4)alkyl, R3 and R3a are H, and the stereochemistry of the carbon atom bonded to R1 is (R) and the stereochemistry to the carbon atom bonded to R2 is (S); and (ix) wherein R1 and R2 independently are (C_1-C_4)alkyl, R3 and R3a are H, and the stereochemistry of the carbon atom bonded to R1 is (S) and the stereochemistry to the carbon atom bonded to R2 is (R).