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(54) PREPARATION OF RUTHENIUM-BASED OLEFIN METATHESIS CATALYSTS

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Publication Classification

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(52) **U.S. Cl.** **502/150**; 502/152; 502/155; 502/162; 502/167

(57) ABSTRACT

A synthetic method leading to the isolation of ruthenium-based olefin metathesis catalysts relies on the cross metathesis reaction between $(L_1)Ru(L_2)$(3-phenylindenylid-1-ene)Cl_2 (where L_1 and L_2 can be two-electron donors) and an olefin. This method leads to the isolation of numerous ruthenium olefin metathesis catalysts.

PREPARATION OF RUTHENIUM-BASED OLEFIN METATHESIS CATALYSTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Priority of my prior U.S. provisional patent application Ser. No. 60/479,771, filed 19 Jun. 2003, incorporated herein by reference, is hereby claimed.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable

REFERENCE TO A "MICROFICHE APPENDIX"

[0003] Not applicable

BACKGROUND OF THE INVENTION

[0004] 1. Field of the Invention

[0005] The present invention relates to olefin metathesis. More particularly, the present invention relates to synthesis of olefin metathesis catalysts.

[0006] 2. General Background of the Invention

[0007] The advent of well-defined, highly reactive catalysts for olefin metathesis (ring-closing metathesis, RCM; ring-opening metathesis polymerization, ROMP; cross metathesis, CM; and their combinations) has made this technique a powerful tool in organic synthesis and polymer chemistry.[1] Metal-carbene complexes of the type $(PCy_3)_2Ru({=}C(H)Ph)Cl_2$ (1)[2], and its analogues modified with nucleophilic carbenes $(PCy_3)Ru(IMes)({=}C(H)Ph)Cl_2$[3] (2), and $(PCy_3)Ru(SIMes)({=}C(H)Ph)Cl_2$ (3)[4] where IMes=1,3-bis(2,4,6-trimethylphenyl)imidazol-2-ylidene and SIMes=1,3-bis(2,4,6-trimethylphenyl)-4,5-dihydroimidazol-2-ylidene, are highly efficient catalyst precursors. The inventor and his colleagues have shown that the complexes of unsaturated "C_α" ligands other than the alkylidenes such as $(PCy_3)_2Ru$(3-phenylindenylid-1-ene)Cl_2 (4) and (PCy_3)(IMes)Ru(3-phenylindenylid-1-ene)Cl_2 (5) are also active catalyst precursors in the ring-closing metathesis of dienes (FIG. 1).[5]

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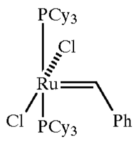

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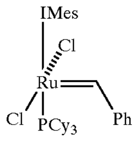

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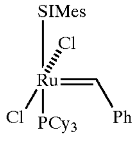

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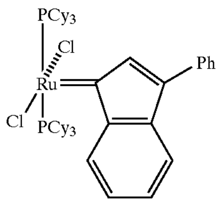

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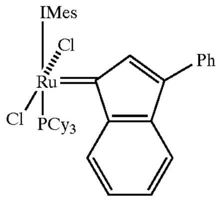
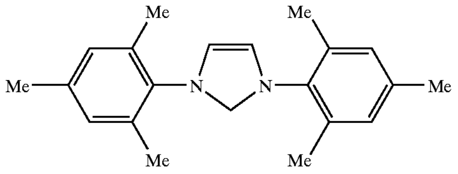
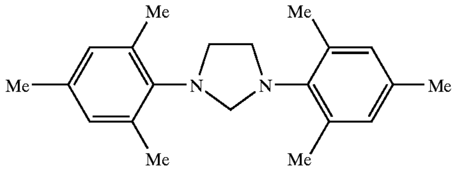




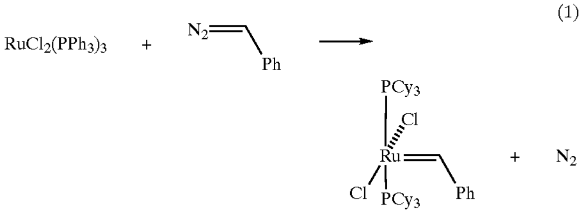
IMes



SIMes

[0008] In its most widely used preparation, complex 1 has been synthesized by reaction of $RuCl_2(PPh_3)_3$ with diazo compound according to eq. 1.

(1)



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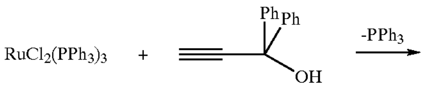
[0009] Complexes 4 and 5 are of particular interest since they are easily synthesized from $RuCl_2(PPh_3)_3$ and an alkynol followed by simple ligand substitution reactions according to eq. 2.

(2)



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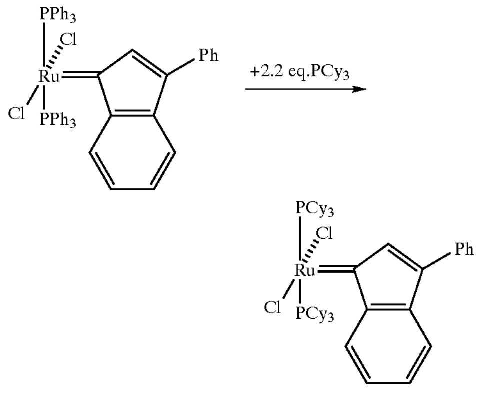

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[0010] This unusual rearrangement of an alkyn-ol into an indenylidene results in ruthenium complexes that are quite active in a number of olefin metathesis transformations.

[0011] The following US patents are incorporated herein by reference:

[0012] U.S. Pat. No. 6,403,802 Use of catalyst system comprising nickel, palladium, or platinum and imidazoline-2-ylidene or imidazolidine-2-ylidene in amination reactions

[0013] U.S. Pat. No. 6,403,801 Use of a catalyst system comprising nickel, palladium, or platinum and imidazoline-2-ylidene of imidazolidine-2-ylidene in Suzuki coupling reactions

[0014] U.S. Pat. No. 6,369,265 Use of a catalyst system comprising nickel, palladium, or platinum and imidazoline-2-ylidene or imidazolidine-2-ylidene in Kumada coupling reactions

[0015] U.S. Pat. No. 6,362,357 Use a catalyst system comprising nickel palladium or platinum and imidazoline-2-ylidene or imidazolidine-2-ylidene in stille coupling reactions

[0016] U.S. Pat. No. 6,316,380 Catalyst system comprising transition metal and imidazoline-2-ylidene or imidazolidine-2-ylidene.

[0017] U.S. Pat. No. 6,586,599 Catalyzed coupling reactions of aryl halides with silanes;

[0018] U.S. Pat. No. 6,583,307 Convenient and efficient Suzuki-Miyaura cross-coupling catalyzed by a palladium/diazabutadiene system;

[0019] U.S. Pat. No. 6,403,802 Use of catalyst system comprising nickel, palladium, or platinum and imidazoline-2-ylidene or imidazolidine-2-ylidene in amination reactions;

[0020] U.S. Pat. No. 6,403,801 Use of a catalyst system comprising nickel, palladium, or platinum and imidazoline-2-ylidene of imidazolidine-2-ylidene in suzuki coupling reactions;

[0021] U.S. Pat. No. 6,369,265 Use of a catalyst system comprising nickel, palladium, or platinum and imidazoline-2-ylidene or imidazolidine-2-ylidene in kumada coupling reactions;

[0022] U.S. Pat. No. 6,362,357 Use a catalyst system comprising nickel palladium or platinum and imidazoline-2-ylidene or imidazolidine-2-ylidene in stille coupling reactions;

[0023] U.S. Pat. No. 6,316,380 Catalyst system comprising transition metal and imidazoline-2-ylidene or imidazolidine-2-ylidene;

[0024] U.S. Pat. No. 5,110,948 Organosamarium catalysts for the hydroamination of olefins;

[0025] US Patent Application 20020198423 A1 Convenient and efficient suzuki-miyaura cross-coupling catalyzed by a palladium/diazabutadiene system;

[0026] United States Patent Application 20020173650 A1 Metal complexes for hydrogenation of unsaturated compounds;

[0027] All of my prior US patent applications are incorporated herein by reference, including Ser. Nos. 09/392,869, 09/507,958, 09/907,526, 10/011,680 (application published as US2002/0173650), No. 60/407,073.

BRIEF SUMMARY OF THE INVENTION

[0028] The present invention includes a process for the preparation of ruthenium-based olefin metathesis catalysts. The inventor has discovered that Ru-carbene complexes can be made from the Ru-indenylidene complex by cross metathesis. Other prior art routes are described above in the Background of the Invention.

[0029] The present invention thus includes a process for the preparation of ruthenium-based olefin metathesis catalysts, comprising making Ru-carbene complexes from a Ru-indenylidene complex by cross metathesis. Preferably, the process includes providing a Ru-indenylidene complex and an excess of an olefin. The present invention includes a process for the preparation of ruthenium-based olefin metathesis catalysts, comprising eq. 3 or a process similar to eq. 3, with one or more of the following variations:

[0030] in place of Cl one could use other halides, pseudohalides, alkoxides, aryloxides, anionic species etc.;

[0031] PCy_3 can be N-heterocyclcic carbene (NHC), and mixed NHC/PR_3 combinations;

[0032] either of the PCy_3 can be any 2-electron donor.

[0033] The present invention includes a synthetic method leading to the isolation of ruthenium-based olefin metathesis catalysts comprising a cross metathesis reaction between (Li)Ru(L_2)(3-phenylindenylid-1-ene)Cl_2 (where L_1 and L_2 can be two-electron donors) and an olefin.

[0034] In any process or method of the present invention, at least one of the following ruthenium olefin metathesis catalysts is preferably isolated:

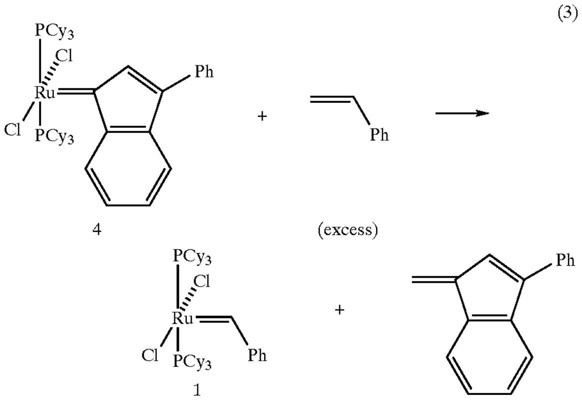
[0035] $RuCl_2(PCy_3)_2$ (C(H)R), $RuCl_2(PCy_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PCy_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, $RuCl_2(pyridine)_2$ (L)(C(H)R) where L=IMes, SIMes, $RuCl_2(PPh_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-

2-ylidene, $RuCl_2(PPh_3)(SIMes)$ (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, where R=Ph, vinyl, etc.

[0036] Though a specific example is shown in the Detailed Description, the scope of the present invention includes general ancillary ligands (in place of Cl one could use other halides, pseudohalides, alkoxides, aryloxides, anionic species etc.); PCy3 can be N-heterocyclcic carbene (NHC), and mixed NHC/PR_3 combinations; in general either of the PCy_3 can be any 2-electron donor.

DETAILED DESCRIPTION OF THE INVENTION

[0037] To further capitalize on the activity of the indenylidene complexes, the present inventor reasoned that complex 1 could be synthesized via a cross metathesis reaction according to eq. 3 eliminating the need for hazardous handling of a diazo reagent.



[0038] The described method appears general and various alkylidenes can be synthesized in this manner.

[0039] Though a specific example is shown above, the scope of the present invention includes general ancillary ligands (in place of Cl one could use other halides, pseudohalides, alkoxides, aryloxides, anionic species etc.); PCy3 can be N-heterocyclcic carbene (NHC), and mixed NHC/PR_3 combinations; in general either of the PCy_3 can be any 2-electron donor.

[0040] The present invention thus includes a process for the preparation of ruthenium-based olefin metathesis catalysts, including those mentioned above in the Background of the Invention. The inventor has discovered that Ru-carbene complexes can be made from the Ru-indenylidene complex by cross metathesis.

[0041] The present invention thus includes a process for the preparation of ruthenium-based olefin metathesis catalysts, comprising making Ru-carbene complexes from a Ru-indenylidene complex by cross metathesis. Preferably, the process includes providing a Ru-indenylidene complex and an excess of an olefin. The present invention includes a process for the preparation of ruthenium-based olefin metathesis catalysts, comprising eq. 3 or a process similar to eq. 3, with one or more of the following variations:

[0042] in place of Cl one could use other halides, pseudohalides, alkoxides, aryloxides, anionic species etc.;

[0043] PCy_3 can be N-heterocyclcic carbene (NHC), and mixed NHC/PR_3 combinations;

[0044] either of the PCy3 can be any 2-electron donor.

[0045] The present invention includes a synthetic method leading to the isolation of ruthenium-based olefin metathesis catalysts comprising a cross metathesis reaction between (Li)Ru(L_2)(3-phenylindenylid-1-ene)$C1_2$ (where L_1 and L_2 can be two-electron donors) and an olefin.

[0046] In any process or method of the present invention, at least one of the following ruthenium olefin metathesis catalysts is preferably isolated:

[0047] $RUCl_2(PCy_3)_2$ (C(H)R), $RuCl_2(PCy_3)(IMes)$ (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PCy_3)(SIMes)$ (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, $RuCl_2(pyridine)_2$ (L)(C(H)R) where L=IMes, SIMes, $RuCl_2(PPh_3)(IMes)$ (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PPh_3)(SIMes)$ (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, where R=Ph, vinyl, etc.

References and Notes (All Incorporated Herein by Reference)

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[0051] (4) (a) Scholl, M.; Ding, S.; Lee, C. W.; Grubbs, R. H. *Organic Lett.* 1999, 1, 953-956. (b) Chatterjee, A. K.; Morgan, J. P.; Scholl, M.; Grubbs, R. H. *J. Am. Chem. Soc.* 2000, 122, 3783-3784. (c) Chatterjee, A. K.; Grubbs, R. H. *Organic Lett.* 1999, 1, 1751-1753.

[**0052**] (5) (a) Fürstner, A.; Hill, A. F.; Liebl, M.; Wilton-Ely, J. D. E. T. *Chem. Commun.* 1999, 601-602. (b) Jafarpour, L.; Schanz, H.-J.; Stevens, E. D.; Nolan, S. P. *Organometallics* 1999, 18, 5416-5419.

[**0053**] All measurements disclosed herein are at standard temperature and pressure, at sea level on Earth, unless indicated otherwise.

[**0054**] The foregoing embodiments are presented by way of example only; the scope of the present invention is to be limited only by the following claims.

1. A process for the preparation of ruthenium-based olefin metathesis catalysts, comprising making Ru-carbene complexes from a Ru-indenylidene complex by cross metathesis.

2. The process of claim 1, comprising:

providing a Ru-indenylidene complex and an excess of an olefin.

3. A process for the preparation of ruthenium-based olefin metathesis catalysts, comprising eq. 3.

4. A process for the preparation of ruthenium-based olefin metathesis catalysts, comprising a process similar to eq. 3, with one or more of the following variations:

in place of Cl one could use other halides, pseudohalides, alkoxides, aryloxides, anionic species etc.;

PCy_3 can be n-heterocyclcic carbene (nhc), and mixed nhc/pr_3 combinations;

either of the PCy3 can be any 2-electron donor.

5. A synthetic method leading to the isolation of ruthenium-based olefin metathesis catalysts comprising a cross metathesis reaction between $(L_1)Ru(L_2)$(3-phenylindenylid-1-ene)Cl_2 (where L_1 and L_2 can be two-electron donors) and an olefin.

6. The method of claim 5, wherein at least one of the following ruthenium olefin metathesis catalysts is isolated:

$RuCl_2(PCy_3)_2$ (C(H)R), $RuCl_2(PCy_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PCy_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, $RuCl_2$(pyridine)$_2$ (L)(C(H)R) where L=IMes, SIMes, $RuCl_2(PPh_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PPh_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, where R=Ph, vinyl, etc.

7. The process of claim 4, wherein at least one of the following ruthenium olefin metathesis catalysts is isolated: $RuCl_2(PCy_3)_2$ (C(H)R), $RuCl_2(PCy_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PCy_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, $RuCl_2$(pyridine)$_2$ (L)(C(H)R) where L=IMes, SIMes, $RuCl_2(PPh_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PPh_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, where R=Ph, vinyl, etc.

8. The process of claim 3, wherein at least one of the following ruthenium olefin metathesis catalysts is isolated: $RUCl_2(PCY_3)_2$ (C(H)R), $RuCl_2(PCy_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PCy_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, $RuCl_2$(pyridine)$_2$ (L)(C(H)R) where L=IMes, SIMes, $RuCl_2(PPh_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PPh_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, where R=Ph, vinyl, etc.

9. The process of claim 2, wherein at least one of the following ruthenium olefin metathesis catalysts is isolated: $RuCl_2(PCy_3)_2$ (C(H)R), $RuCl_2(PCy_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PCy_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, $RuCl_2$(pyridine)$_2$ (L)(C(H)R) where L=IMes, SIMes, $RuCl_2(PPh_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PPh_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, where R=Ph, vinyl, etc.

10. The process of claim 1, wherein at least one of the following ruthenium olefin metathesis catalysts is isolated: $RuCl_2(PCy_3)_2$ (C(H)R), $RuCl_2(PCy_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PCy_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, $RuCl_2$(pyridine)$_2$ (L)(C(H)R) where L=IMes, SIMes, $RuCl_2(PPh_3)$(IMes) (C(H)R) where IMes is bis(2,4,6 trimethylphenyl imidazol-2-ylidene, $RuCl_2(PPh_3)$(SIMes) (C(H)R) where SIMes is bis(2,4,6 trimethylphenyl imidazolidine, where R=Ph, vinyl, etc.

11. The invention(s) substantially as shown and/or described herein.

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