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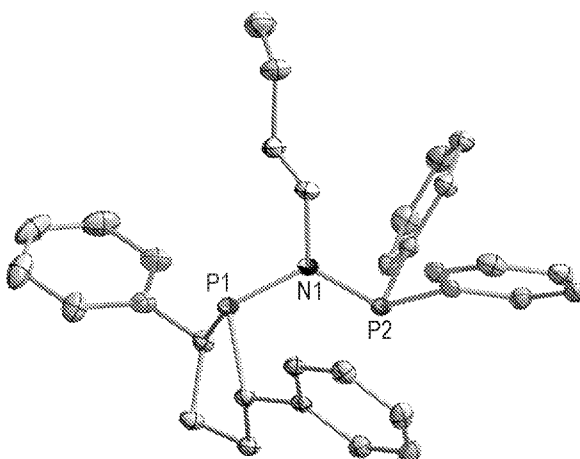
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[Continued on next page]

(54) Title: PHOSPHACYCLE-CONTAINING LIGAND FOR CHROMIUM COMPLEX AND OLEFIN OLIGOMERIZATION CATALYST THEREFROM

FIG. 7



(57) Abstract: The invention relates to oligomerization of olefins, such as ethylene, to higher olefins, such as a mixture of 1-hexene and 1-octene, using a catalyst system that comprises a) a source of chromium b) one or more activators and c) a phosphacycle-containing ligating compound. Additionally, the invention relates to a phosphacycle-containing ligating compound and a process for making said compound.

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INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER

INV. B01J31/24 B01J31/18 B01J31/14 C07C2/36 C07C2/30
C07F9/6568

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B01J C07C C07F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data, CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

8 August 2016

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/021702

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Y	page 14, lines 19-22 page 15, lines 1,12-14,16,17 page 16, lines 2-4,6,7,16-20 page 10, line 12 - page 11, line 15 page 19, lines 6-15 claims 12,14,15 -----	1
X	WO 2005/123633 A1 (SASOL TECH PTY LTD [ZA]; DIXON JOHN THOMAS [ZA]; MORGAN DAVID HEDLEY []) 29 December 2005 (2005-12-29)	1
Y	page 24, lines 21-23 page 25, lines 1,20,22 page 26, lines 13,14,16 page 27, lines 7-10 page 31, lines 15,16,18,19 examples 17,33,54,63.1,63,64 page 32, lines 12-21 page 18, lines 13-14 page 20, line 4 - page 21, line 10; claims 24,29 -----	1
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Y	paragraphs [0071] - [0086]; examples 39-44; table 1 -----	1
A	US 2014/221645 A1 (SYDORA ORSON L [US] ET AL) 7 August 2014 (2014-08-07) paragraphs [0169], [0170]; claims 3,12-18; tables 15,16; compounds D1,D6,B59 -----	1
A	WO 2007/057458 A1 (SHELL INT RESEARCH [NL]; DE BOER ERIC JOHANNES MARIA [NL]; VAN DER HEI) 24 May 2007 (2007-05-24) page 18, lines 7-12 page 20, line 1 claim 1; examples 1-11 -----	1
A	JONATHAN A. BAILEY ET AL: "A simple route to azaborinylphosphines: isoelectronic B-N analogues of arylphosphine ligands", CHEMICAL COMMUNICATIONS - CHEMCOM., vol. 50, no. 12, 9 December 2013 (2013-12-09), pages 1432-1434, XP055291951, ISSN: 1359-7345, DOI: 10.1039/C3CC49000A the whole document ----- -/--	1

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/021702

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A	Danan Dou ET AL: "Synthesis and Reactivity of New Diborylphosphbanes", Inorganic Chemistry, vol. 33, no. 10, 1 May 1994 (1994-05-01), pages 2151-2160, XP055292053, DOI: 10.1021/ic00088a017 Retrieved from the Internet: URL:http://pubs.acs.org/doi/pdf/10.1021/ic00088a017 [retrieved on 2016-07-28] page 2160; compounds 16-18,21 abstract -----	1
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A	BERNHARD KAUFMANN ET AL: "Some oxidative addition reactions with a diphosphadibora[1.1.0]bicyclobutane: formation of cage compounds and of an unusual trinuclear coordination compound of palladium", INORGANICA CHIMICA ACTA, vol. 269, no. 1, 3 March 1998 (1998-03-03), pages 101-110, XP055292088, NL ISSN: 0020-1693, DOI: 10.1016/S0020-1693(97)05783-6 figure 2; compounds 3,5-9 -----	1
2	-/--	

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/021702

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	TUQIANG CHEN ET AL: "Synthesis and Chemistry of Bis(borylphosphino)silanes and -germanes", INORGANIC CHEMISTRY, vol. 38, no. 22, 10 March 1999 (1999-03-10), pages 4993-4999, XP055292084, EASTON, US ISSN: 0020-1669, DOI: 10.1021/ic990507e abstract; compound 18 -----	1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/021702

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1(partially)

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= B atoms in the $-[L-(R5)q]p-$ unit, as otherwise defined in claim 1; X1 being N.

2. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= C atoms in the $-[L-(R5)q]p-$ unit, excluding L= B atoms, as otherwise defined in claim 1; X1 being N.

3. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= Si atoms in the $-[L-(R5)q]p-$ unit, excluding L= B and C atoms, as otherwise defined in claim 1; X1 being N.

4. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= Ge atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C and Si atoms, as otherwise defined in claim 1; X1 being N.

5. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= N atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C, Si and Ge atoms, as otherwise defined in claim 1; X1 being N.

6. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= P atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C, Si, Ge and N atoms, as otherwise defined in claim 1; X1 being N.

7. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= O atoms

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

in the $-[L-(R5)q]p-$ unit, excluding $L= B, C, Si, Ge, N$ and P atoms, as otherwise defined in claim 1; $X1$ being N .

8. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises $p= 1-6$ $L= S$ atoms in the $-[L-(R5)q]p-$ unit, excluding $L= B, C, Si, Ge, N, P$ and O atoms, as otherwise defined in claim 1; $X1$ being N .

9. claims: 9, 10(completely); 1, 2, 4-8(partially)

insofar as concerning a composition (I'') comprising a phosphacyclic ligand wherein Y comprises $p= 1-6$ $L= B$ atoms in the $-[L-(R5)q]p-$ unit, as otherwise defined in claim 1, $X1$ being P ; a composition (II') with $Y, X1$ as per composition (I''); a process to prepare a composition (I'') with $Y, X1$ accordingly; a process to prepare a cyclic phosphine halide (III').

10. claims: 1, 2, 4-8(all partially)

insofar as concerning a composition (I'') comprising a phosphacyclic ligand wherein Y comprises $p= 1-6$ $L= C$ atoms in the $-[L-(R5)q]p-$ unit, excluding $L= B$ atoms, as otherwise defined in claim 1, $X1$ being P ; a composition (II') with $Y, X1$ as per composition (I''); a process to prepare a composition (I'') with $Y, X1$ accordingly.

11. claims: 1, 2, 4-8(all partially)

insofar as concerning a composition (I'') comprising a phosphacyclic ligand wherein Y comprises $p= 1-6$ $L= Si$ atoms in the $-[L-(R5)q]p-$ unit, excluding $L= B$ and C atoms, as otherwise defined in claim 1, $X1$ being P ; a composition (II') with $Y, X1$ as per composition (I''); a process to prepare a composition (I'') with $Y, X1$ accordingly.

12. claims: 1, 2, 4-8(all partially)

insofar as concerning a composition (I'') comprising a phosphacyclic ligand wherein Y comprises $p= 1-6$ $L= Ge$ atoms in the $-[L-(R5)q]p-$ unit, excluding $L= B, C$ and Si atoms, as otherwise defined in claim 1, $X1$ being P ; a composition (II') with $Y, X1$ as per composition (I''); a process to prepare a composition (I'') with $Y, X1$ accordingly.

13. claims: 3(completely); 1, 2, 4-8(partially)

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

insofar as concerning a composition (I'') comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= N atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C, Si and Ge atoms, as otherwise defined in claim 1, X1 being P; a composition (II') with Y, X1 as per composition (I''); a process to prepare a composition (I'') with Y, X1 accordingly.

14. claims: 1, 2, 4-8(all partially)

insofar as concerning a composition (I'') comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= P atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C, Si, Ge and N atoms, as otherwise defined in claim 1, X1 being P; a composition (II') with Y, X1 as per composition (I''); a process to prepare a composition (I'') with Y, X1 accordingly.

15. claims: 1, 2, 4-8(all partially)

insofar as concerning a composition (I'') comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= O atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C, Si, Ge, N and P atoms, as otherwise defined in claim 1, X1 being P; a composition (II') with Y, X1 as per composition (I''); a process to prepare a composition (I'') with Y, X1 accordingly.

16. claims: 1, 2, 4-8(all partially)

insofar as concerning a composition (I'') comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= S atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C, Si, Ge, N, P and O atoms, as otherwise defined in claim 1, X1 being P; a composition (II') with Y, X1 as per composition (I''); a process to prepare a composition (I'') with Y, X1 accordingly.

17. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= B atoms in the $-[L-(R5)q]p-$ unit, as otherwise defined in claim 1; X1 being O.

18. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= C atoms in the $-[L-(R5)q]p-$ unit, excluding L= B atoms, as otherwise defined in claim 1; X1 being O.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

19. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= Si atoms in the $-[L-(R5)q]p-$ unit, excluding L= B and C atoms, as otherwise defined in claim 1; X1 being 0.

20. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= Ge atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C and Si atoms, as otherwise defined in claim 1; X1 being 0.

21. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= N atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C, Si and Ge atoms, as otherwise defined in claim 1; X1 being 0.

22. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= P atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C, Si, Ge and N atoms, as otherwise defined in claim 1; X1 being 0.

23. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= O atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C, Si, Ge, N and P atoms, as otherwise defined in claim 1; X1 being 0.

24. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= S atoms in the $-[L-(R5)q]p-$ unit, excluding L= B, C, Si, Ge, N, P and O atoms, as otherwise defined in claim 1; X1 being 0.

25. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= B atoms in the $-[L-(R5)q]p-$ unit, as otherwise defined in claim 1;

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

X1 being S.

26. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= C atoms in the $-[L-(R_5)q]p-$ unit, excluding L= B atoms, as otherwise defined in claim 1; X1 being S.

27. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= Si atoms in the $-[L-(R_5)q]p-$ unit, excluding L= B and C atoms, as otherwise defined in claim 1; X1 being S.

28. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= Ge atoms in the $-[L-(R_5)q]p-$ unit, excluding L= B, C and Si atoms, as otherwise defined in claim 1; X1 being S.

29. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= N atoms in the $-[L-(R_5)q]p-$ unit, excluding L= B, C, Si and Ge atoms, as otherwise defined in claim 1; X1 being S.

30. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= P atoms in the $-[L-(R_5)q]p-$ unit, excluding L= B, C, Si, Ge and N atoms, as otherwise defined in claim 1; X1 being S.

31. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= O atoms in the $-[L-(R_5)q]p-$ unit, excluding L= B, C, Si, Ge, N and P atoms, as otherwise defined in claim 1; X1 being S.

32. claim: 1(partially)

insofar as concerning a composition comprising a phosphacyclic ligand wherein Y comprises p= 1-6 L= S atoms

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

in the $-[L-(R_5)_q]p-$ unit, excluding $L = B, C, Si, Ge, N, P$
and O atoms, as otherwise defined in claim 1; X_1 being S.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Information on patent family members

International application No

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