



Office de la Propriété
Intellectuelle
du Canada

Un organisme
d'Industrie Canada

Canadian
Intellectual Property
Office

An agency of
Industry Canada

CA 2166055 C 2006/10/17

(11)(21) **2 166 055**

(12) **BREVET CANADIEN
CANADIAN PATENT**

(13) **C**

(86) Date de dépôt PCT/PCT Filing Date: 1993/06/24
(87) Date publication PCT/PCT Publication Date: 1995/01/05
(45) Date de délivrance/Issue Date: 2006/10/17
(85) Entrée phase nationale/National Entry: 1995/12/22
(86) N° demande PCT/PCT Application No.: US 1993/006051
(87) N° publication PCT/PCT Publication No.: 1995/000562

(51) Cl.Int./Int.Cl. *C08F 10/06* (2006.01),
C08F 10/00 (2006.01), *C08F 110/06* (2006.01),
C08F 4/64 (2006.01), *C08F 4/659* (2006.01),
C08F 4/6592 (2006.01)
(72) Inventeur/Inventor:
CANICH, JO ANN MARIE, US
(73) Propriétaire/Owner:
EXXONMOBIL CHEMICAL PATENTS INC., US
(74) Agent: BORDEN LADNER GERVAIS LLP

(54) Titre : METHODE DE PREPARATION DE POLY- α -OLEFINES AMORPHES EN PRESENCE D'UN SYSTEME
CATALYTIQUE A BASE D'UN METAL DE TRANSITION MONOCYCLOPENTADIENYLIQUE
(54) Title: PROCESS FOR PRODUCING AMORPHOUS POLY- α -OLEFINS WITH A MONOCYCLOPENTADIENYL
TRANSITION METAL CATALYST SYSTEM

(57) **Abrégé/Abstract:**

The invention is a catalytic process using a Group IV B transition metal component and an alumoxane component to polymerize α -olefins to produce amorphous poly- α -olefins.



PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ :

C08F 10/00, 4/64

2166055

A1

(11) International Publication Number:

WO 95/00562

(43) International Publication Date:

5 January 1995 (05.01.95)

(21) International Application Number: PCT/US93/06051

(22) International Filing Date: 24 June 1993 (24.06.93)

(71) Applicant: EXXON CHEMICAL PATENTS INC. [US/US];
5200 Bayway Drive, Baytown, TX 77520 (US).

(72) Inventor: CANICH, Jo, Ann, Marie; 900 Henderson Avenue,
Apartment 808, Houston, TX 77058 (US).

(74) Agents: SMITH, Charles, E. et al.; Exxon Chemical Company,
P.O. Box 5200, Baytown, TX 77522 (US).

(81) Designated States: CA, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published

With international search report.

With amended claims.

(54) Title: PROCESS FOR PRODUCING AMORPHOUS POLY- α -OLEFINS WITH A MONOCYCLOPENTADIENYL TRANSITION METAL CATALYST SYSTEM

(57) Abstract

The invention is a catalytic process using a Group IV B transition metal component and an alumoxane component to polymerize α -olefins to produce amorphous poly- α -olefins.

- 1 -

PROCESS FOR PRODUCING AMORPHOUS POLY- α -OLEFINS WITH
A MONOCYCLOPENTADIENYL TRANSITION METAL CATALYST
SYSTEM

5 FIELD OF THE INVENTION

This invention relates to a process for
polymerizing α -olefins which utilizes certain
monocyclopentadienyl metal compounds of a Group IV B
transition metal of the Periodic Table of Elements
10 in an alumoxane activated catalyst system to
produce, amorphous, and low crystallinity poly- α -
olefins, particularly polypropylene and α -olefin
copolymers of propylene. In U.S. Patent No.
5,026,798 an invention was disclosed and claimed for
15 a process for production of crystalline poly- α -
olefins. It has further been discovered that by
careful choice of the components of the
monocyclopentadienyl metal compounds that the same
process can also be used to elegantly produce
20 amorphous poly- α -olefins that may have stereoregular
regions within the polymer chain.

25

2166055

- 2 -

BACKGROUND OF THE INVENTION

As is well known, various processes and catalysts exist for the homopolymerization or copolymerization of olefins. For some applications it is of primary importance for a polyolefin to have a high weight average molecular weight while having a relatively narrow molecular weight distribution. A high weight average molecular weight, (M_w), when accompanied by a narrow molecular weight distribution, (MWD), provides a polyolefin with high strength properties. For other applications, such as compatibilization or adhesion, a low or medium weight average M_w with a relatively narrow MWD is a primary concern.

Traditional Ziegler-Natta catalysts systems -- a transition metal compound cocatalyzed by an aluminum alkyl -- are capable of producing polyolefins having a high or low molecular weight but a broad molecular weight distribution.

More recently a catalyst system has been developed wherein the transition metal compound has two or more cyclopentadienyl ring ligands -- such transition metal compound being referred to herein as a "metallocene" -- which catalyzes the production of olefin monomers to polyolefins. Accordingly, titanocenes and zirconocenes, have been utilized as the transition metal component in such "metallocene" containing catalyst systems for the production of polyolefins and ethylene- α -olefin copolymers. When such metallocenes are cocatalyzed with an aluminum alkyl -- as is the case with a traditional type Ziegler-Natta catalyst system -- the catalytic activity of such metallocene catalyst system is generally too low to be of any commercial interest.

- 3 -

It has since become known that such metallocenes may be cocatalyzed with an alumoxane -- rather than an aluminum alkyl -- to provide a metallocene catalyst system of high activity for the
5 production of polyolefins.

The zirconocenes, as cocatalyzed or activated with an alumoxane, are commonly more active than their hafnium or titanium analogues for the polymerization of ethylene alone or together with an
10 α -olefin comonomer. When employed in a non-supported form -- i.e., as a homogeneous or soluble catalyst system -- to obtain a satisfactory rate of productivity even with the most active zirconocene species typically requires the use of a quantity of
15 alumoxane activator sufficient to provide an aluminum atom to transition metal atom ratio (Al:TM) of at least greater than 1000:1; often greater than 5000:1, and frequently on the order of 10,000:1. Such quantities of alumoxane impart to a polymer
20 produced with such catalyst system an undesirable content of catalyst metal residue, i.e., an undesirable "ash" content (the nonvolatile metal content). In high pressure polymerization procedures using soluble catalyst systems wherein
25 the reactor pressure exceeds about 500 bar only the zirconium or hafnium species of metallocenes may be used. Titanium species of metallocenes are generally unstable at such high pressures unless deposited upon a catalyst support. A wide
30 variety of Group IV B transition metal compounds have been named as possible candidates for an alumoxane cocatalyzed catalyst system. Although bis(cyclopentadienyl) Group IV B transition metal

2166055

- 4 -

compounds have been the most preferred and heavily investigated for use in alumoxane activated catalyst systems for polyolefin production, suggestions have appeared that mono and tris(cyclopentadienyl) transition metal compounds may also be useful. See, for example U.S. Patent Nos. 4,522,982; 4,530,914 and 4,701,431. Such mono(cyclopentadienyl) transition metal compounds as have heretofore been suggested as candidates for an alumoxane activated catalyst system are mono(cyclopentadienyl) transition metal trihalides and trialkyls.

More recently, International Publication No. WO 87/03887 describes the use of a composition comprising a transition metal coordinated to at least one cyclopentadienyl and at least one heteroatom ligand as a transition metal component for use in an alumoxane activated catalyst system for α -olefin polymerization. The composition is broadly defined as a transition metal, preferably of Group IV B of the Periodic Table, which is coordinated with at least one cyclopentadienyl ligand and one to three heteroatom ligands, the balance of the transition metal coordination requirement being satisfied with cyclopentadienyl or hydrocarbyl ligands. Catalyst systems described by this reference are illustrated solely with reference to transition metal compounds which are metallocenes, i.e., bis(cyclopentadienyl) Group IV B transition metal compounds.

Even more recently, at the Third Chemical Congress of North American held in Toronto, Canada in June 1988, John Bercaw reported upon efforts to use a compound of a Group III B transition metal

- 5 -

coordinated to a single cyclopentadienyl heteroatom
bridged ligand as a catalyst system for the
polymerization of olefins. Although some catalytic
activity was observed under the conditions employed,
5 the degree of activity and the properties observed
in the resulting polymer product were discouraging
of a belief that such monocyclopentadienyl
transition metal compound could be usefully employed
for commercial polymerization processes.

10 A need still exists for discovering catalyst
systems that permit the selective production of
higher or lower molecular weight polyolefins and
desirably with a narrow molecular weight
distribution. It is further desirable that a
15 catalyst be discovered which will be capable of
catalyzing the polymerization of α -olefin monomer(s)
to produce a stereoregular low crystallinity or
amorphous form of poly- α -olefin when desired.

There are at least three different types of
20 stereoregular polymers. These polymers are
comprised of α -olefin monomers where hydrocarbyl
groups are pendant from the polymer backbone chain.
Relative to the polymer backbone chain, the pendant
hydrocarbyl groups may be arranged in different
25 stereochemical configurations which are denominated
as, for example, atactic, isotactic, or syndiotactic
pendant group configuration.

The degree and type of tacticity of a
polyolefin molecule are critical determinants of the
30 physical properties which a resin composed of such
polymer molecules will exhibit. Other critical
determinants of the properties which a resin will
exhibit are the type and relative concentration of

2166055

- 6 -

monomers and comonomers, the weight average molecular weight (M_w) of the polymer molecules comprising the resin bulk, the molecular weight distribution (MWD) and the composition distribution of the resin.

Important from a commercial standpoint is the rate or productivity at which a catalyst system will produce a poly- α -olefin resin of a desired set of properties in terms of tacticity, weight average molecular weight and molecular weight distribution.

The weight average molecular weight (M_w) of a poly- α -olefin is an important physical property determinant of the practical uses to which such polymer can be put. For end use applications which require high strength and low creep, the M_w of such a resin must generally be in excess of 100,000. Where the M_w is lower than 100,000 the polymer can be used for other applications such as adhesives and compatibilizers. Further, for such high strength applications, the poly- α -olefin resin must generally have a high degree of crystallinity. Low crystallinity and amorphous poly- α -olefins are useful in adhesive compositions, in compatibilizing applications, as additives, etc. The degree of crystallinity which a poly- α -olefin is capable of obtaining is, in major part, determined by the stereochemical regularity of the hydrocarbyl groups which are pendent to the polymer molecule backbone, i.e., the tacticity of the polymer.

Five types of tacticity have been described in poly- α -olefins: atactic, normal isotactic, isotactic stereoblock, syndiotactic, and hemiisotactic. Although all of these tacticity configurations have

2186055

- 7 -

been primarily demonstrated in the case of polypropylene, in theory each is equally possible for polymers comprised of any α -olefin, cyclic olefin or internal olefin.

5 Atactic poly- α -olefins are those wherein the hydrocarbyl groups pendent to the polymer molecule backbone assume no regular order with reference to the backbone. This random, or atactic, structure is represented by a polymer backbone of alternating
10 methylene and methine carbons, with randomly oriented branches substituting the methine carbons. The methine carbons randomly have R and S configurations, creating adjacent pairs either of like configuration (a "meso" or "m" dyad) or of
15 unlike configuration (a "racemic" or "r" dyad). The atactic form of a polymer contains approximately equal fractions of meso and racemic dyads. Atactic poly- α -olefins, particularly atactic polypropylene, are soluble in aliphatic and aromatic solvents at
20 ambient temperature. Since atactic polymers exhibit no regular order or repeating unit configurations in the polymer chain, such atactic polymers are amorphous materials. An amorphous material tends to lack a molecular lattice structure and have poorly
25 defined melting points. Thus typical atactic poly- α -olefins are amorphous, and generally have no measurable melting point. Atactic polymers exhibit little if any crystallinity, hence they are generally unsuitable for high strength applications
30 regardless of the weight average molecular weight of the resin.

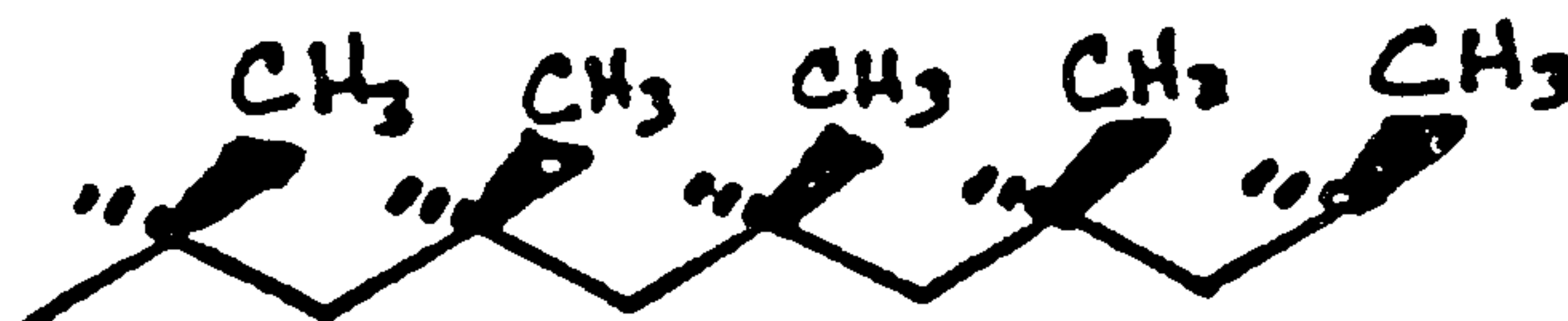
Isotactic poly- α -olefins are those wherein the pendent hydrocarbyl groups are ordered in space to

2166055

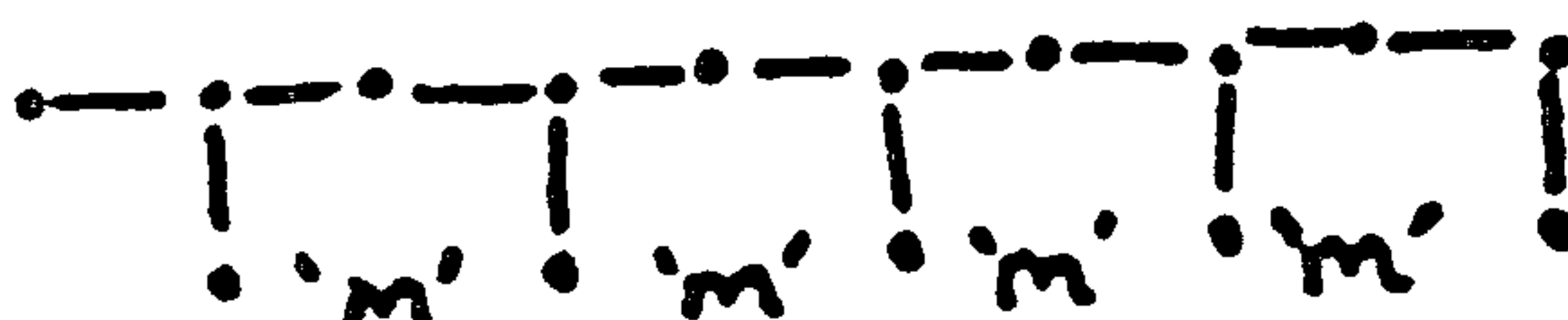
- 8 -

the same side or plane of the polymer backbone chain. Using isotactic polypropylene as an example, the isotactic structure is typically described as having the pendent methyl groups attached to the
5 ternary carbon atoms of successive monomeric units on the same side of a hypothetical plane through the carbon backbone chain of the polymer, e.g., the methyl groups are all above or below the plane as shown below.

10



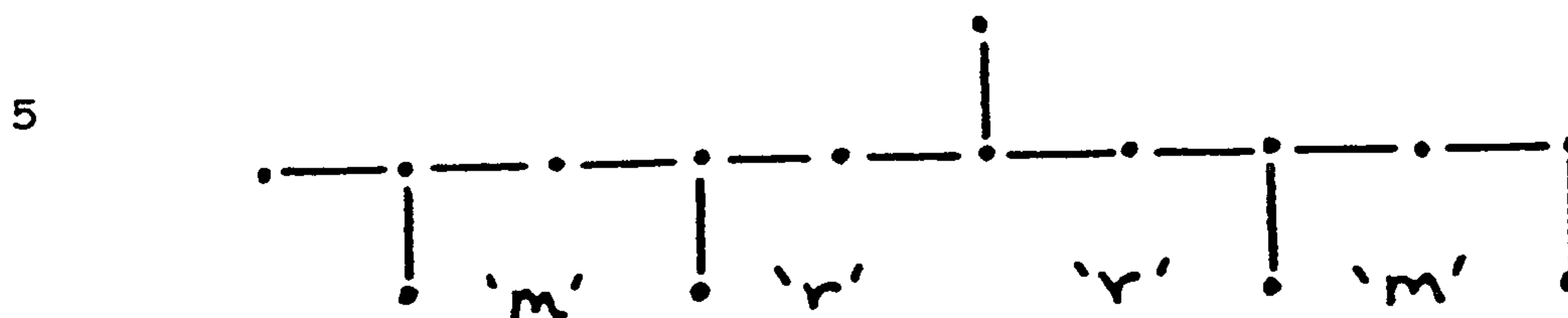
15



The degree of isotactic regularity may be measured by NMR techniques. Bovey's NMR nomenclature for an
20 isotactic pentad is ... mmmm ... with each "m" representing a "meso" dyad or successive methyl groups on the same side in the plane.

In the normal isotactic structure of a poly- α -olefin, all of the monomer units have the same
25 stereochemical configuration, with the exception of random errors which appear along the polymer. Such random errors almost always appear as isolated inversions of configuration which are corrected in the very next α -olefin monomer insertion to restore
30 the original R or S configuration of the propagating polymer chain. Single insertions of inverted configuration give rise to rr triads, which

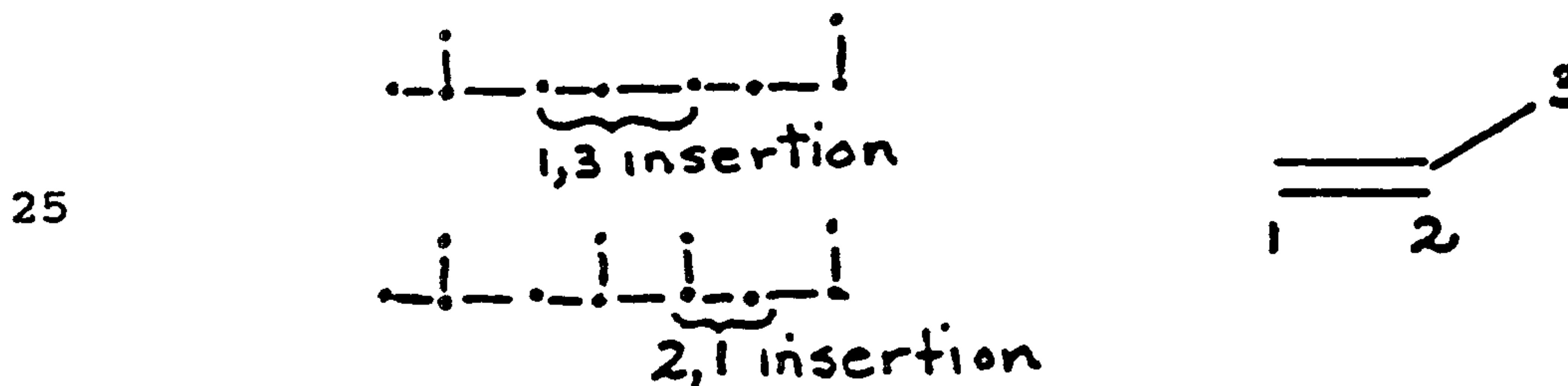
distinguish this isotactic structure in its NMR from the isotactic stereoblock form.



10

As is known in the art, any deviation or inversion in the regularity of the structure of the chains lowers the degree of isotacticity and hence the crystallinity of which the polymer is capable.

15 There are two other types of "errors" which have been observed in isotactic polymers prepared using metallocene-alumoxane catalyst systems which act to lower the melting point and/or T_g of the material. These errors, as shown below arise when a monomer is
20 added to the growing polymer chain in a 1, 3 or 2, 1 fashion.

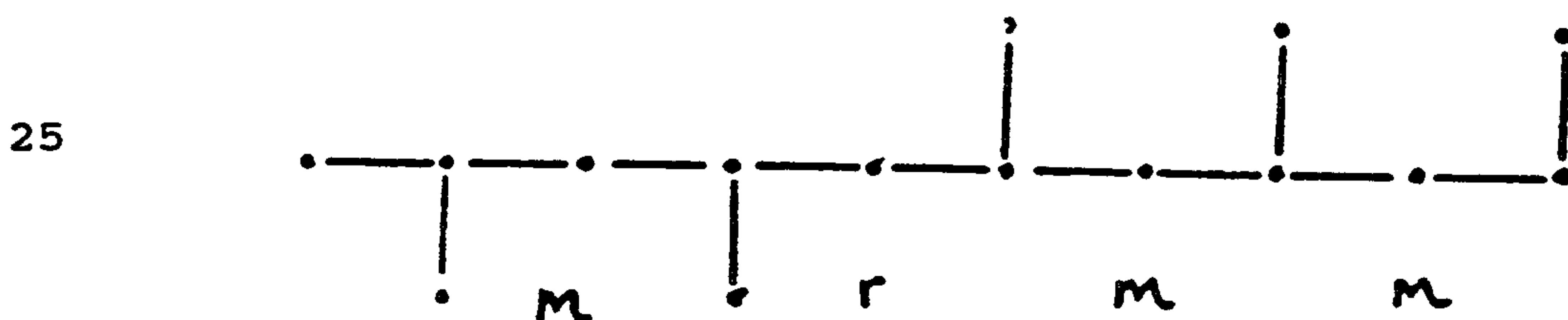


Long before anyone had discovered a catalyst
30 system which produced the isotactic stereoblock form of a poly- α -olefin, the possible existence of a polymer of such micro-structure had been recognized and mechanisms for its formation had been proposed

2166055

- 10 -

based on conventional Ziegler-Natta mechanisms in Langer, A.W., Lect. Bienn. Polym. Symp. 7th (1974); Ann. N.Y. Acad. Sci. 295, 110-126 (1977). The first example of this form of polypropylene and a catalyst which produces it in a pure form were reported in U.S. Patent No. 4,522,982. The formation of stereoblock isotactic polymer differs from the formation of the normal isotactic structure in the way that the propagation site reacts to a stereochemical error in the chain. As mentioned above, the normal isotactic chain will return to the original configuration following an error because the stereochemical regulator, the catalytic active metal species and its surrounding ligands, continue to dictate the same stereochemical preference during monomer insertion. In stereoblock propagation, the catalytic active metal site itself changes from one which dictates a monomer insertion of R configuration to one which dictates an S configuration for monomer insertion. The isotactic stereoblock form is shown below.



30 This occurs either because the metal and its ligands change to the opposite stereochemical configuration or because the configuration of the last added monomer, rather than the metal chirality, controls

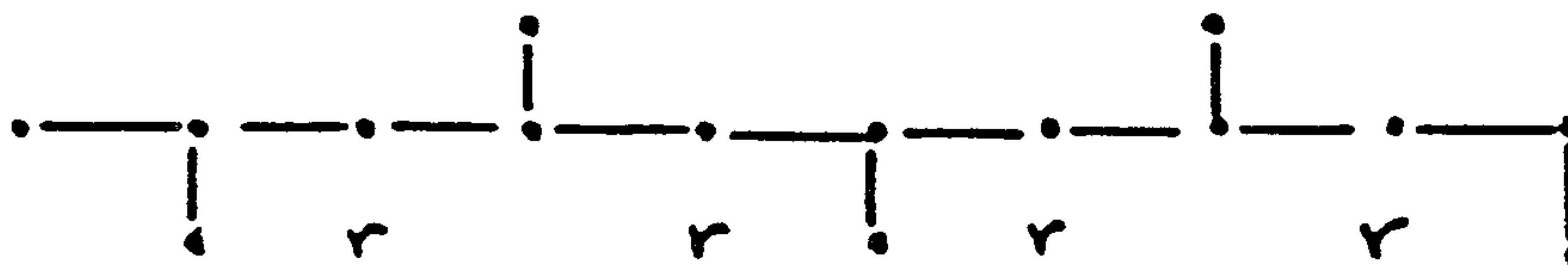
- 11 -

the configuration of the next added monomer. In Ziegler-Natta catalysts, including the above referenced system, the exact structure and dynamic properties of the active site are not well understood, and it is virtually impossible to distinguish between the "site chirality exchange" and "chain end control" mechanisms for the formation of isotactic stereoblock poly- α -olefins.

Unlike normal isotactic polymers, the lengths of individual blocks of the same configuration in the stereoblock structure vary widely due to changing reaction conditions. Since only the erroneous parts of the chains affect the crystallinity of the resin product, in general, normal isotactic polymers and isotactic stereoblock polymers of long block length (greater than 50 isotactic placements) have similar properties.

Highly isotactic poly- α -olefins are insoluble in xylene and are capable of exhibiting a high degree of crystallinity and are in part characterizable by their melting point temperature. Accordingly, isotactic poly- α -olefins are, depending upon their weight average molecular weight exceeding about 100,000, well suited to high strength end use applications.

Syndiotactic poly- α -olefins are those wherein the hydrocarbyl groups pendent to the polymer molecular backbone alternate sequentially in order from one side or plane to the opposite side or plane relative to the polymer backbone, as shown below.



2166055

5

In NMR nomenclature, this pentad is described as ...
rrrr ... in which each r represents a "racemic"
dyad, i.e., successive methyl groups on alternate
sides of the plane. The percentage of r dyads in
10 the chain determines the degree of syndiotacticity
of the polymer.

Syndiotactic propagation has been studied for
over 25 years; however, only a few good
syndiospecific catalysts have been discovered, all
15 of which are extremely sensitive to monomer
bulkiness. As a result, well-characterized
syndiotactic polymers are limited only to
polypropylenes. The molecular chain backbone of a
syndiotactic polymer can be considered to be a
20 copolymer of olefins with alternating stereochemical
configurations. Highly syndiotactic polymers are
generally highly crystalline and will frequently
have high melting points similar to their isotactic
polymorphs.

25 Like isotactic poly- α -olefins, syndiotactic
poly- α -olefins are capable of exhibiting a high
degree of crystallinity, hence are suitable for high
strength applications provided their M_w exceeds
about 100,000. Syndiotactic poly- α -olefins are in
30 part characterized by their exhibition of a melting
point temperature.

Amorphous poly- α -olefins, generally regarded to
be atactic, noncrystalline and lacking in a

2166055

- 13 -

5 molecular lattice structure which is characteristic of the solid state, tend to lack well defined melting points. Such amorphous poly- α -olefins have uses in adhesives and as compatibilizers among other things.

10 For any of the above described materials the final resin properties and their suitability for particular applications depends on the type of tacticity, (stereoregularity), the melting point, the average molecular weight, the molecular weight distribution, the type and level of monomer and comonomer, the sequence distribution, and the presence or absence of head or end group functionality. Accordingly, the catalyst system by
15 which such a stereoregular poly- α -olefin resin is to be produced should, desirably, be versatile in terms of M_w , MWD, tacticity type and level, and comonomer choice. Further, the catalyst system should be capable of producing these polymers with or without
20 head and/or end group functionality, such as olefinic unsaturation. Still further, such catalyst system must be capable, as a commercially practical constraint, of producing such resins at an acceptable production rate. Most preferably, the
25 catalyst system should be one which, at its productivity rate, provides a resin product which does not require a subsequent treatment to remove catalyst residue to a level which is acceptable for the resin in the end use application desired.
30 Finally, an important feature of a commercial catalyst system is its adaptability to a variety of processes and conditions.

2166055

- 14 -

Conventional titanium based Ziegler-Natta catalysts for the preparation of isotactic polymers are well known in the art. These commercial catalysts are well suited for the production of highly crystalline, high molecular weight materials. The systems are, however, limited in terms of molecular weight, molecular weight distribution, and tacticity control. The fact that the conventional catalysts contain several types of active sites further limits their ability to control the composition distribution in copolymerization.

More recently a new method of producing isotactic polymers from an alumoxane cocatalyzed, or activated, metallocene which in its natural state has chirality centered at the transition metal of the metallocene, was reported in Ewen, J.A., J. Amer. Chem. Soc., v. 106, p. 6355 (1984) and Kaminsky, W., et al., Angew. Chem. Int. Ed. Eng.; 24, 507-8 (1985).

Catalysts that produce isotactic polyolefins are also disclosed in Patent No. 4,794,096. This patent discloses a chiral, stereorigid metallocene catalyst which is activated by an alumoxane cocatalyst which is reported to polymerize olefins to isotactic polyolefin forms. Alumoxane cocatalyzed metallocene structures which have been reported to polymerize stereoregularly are the ethylene bridged bis-indenyl and bis-tetrahydroindenyl titanium and zirconium (IV) catalyst. Such catalyst systems were synthesized and studied in Wild et al., J. Organomet. Chem. 232, 233-47 (1982), and were later reported in Ewen and Kaminsky et al., mentioned above, to polymerize α -olefins

- 15 -

stereoregularly. Further reported in West German
Off DE 3443087A1 (1986), but without giving
experimental verification, is that the bridge length
of such stereorigid metallocenes can vary from a C₁
5 to C₄ hydrocarbon and the metallocene rings can be
simple or bi-cyclic but must be asymmetric.

Metallocene-alumoxane catalyst generally
require a high content of alumoxane cocatalyst to be
sufficiently productive for commercial use.
10 Accordingly, metallocene-alumoxane produced
isotactic poly- α -olefin resins generally have a
higher than desired catalyst residue content.
Hafnocene systems, which yield polymers of higher
average M_w than the zirconium analogues, have very
15 low activities even at high alumoxane
concentrations.

Syndiotactic polyolefins were first disclosed
by Natta et al. in U.S. Patent No. 3,258,455. As
reported, Natta obtained syndiotactic polypropylene
20 by using a catalyst prepared from titanium
trichloride and diethyl aluminum monochloride. A
later patent to Natta et al., U.S. Patent No.
3,305,538, discloses the use of vanadium
triacetylacetonate or halogenated vanadium compounds
25 in combinations with organic aluminum compounds for
production of syndiotactic polypropylene.

More recently, a metallocene based catalyst
system has been disclosed which is stated to be
capable of production of syndiotactic polypropylene
30 of high stereoregularity. U.S. Patent No. 4,892,851
describes catalyst systems consisting of a bridged
metallocene having at least two differently
substituted cyclopentadienyl ring ligands which,

2166055

- 16 -

when cocatalyzed with an alumoxane, is stated to be capable of production of syndiotactic polypropylene. Again, in commercial production to obtain a sufficient productivity level with such catalyst system, the content of alumoxane is undesirably high and consequently the catalyst residue in the resin so produced is undesirably high.

In all methylalumoxane/metallocene catalyst systems the polymer characteristics (M_w , MWD, tacticity type, comonomer incorporation, etc.) are controlled either by modifications to the structure of the metallocene precursor or by adjustment of the process conditions (temperature, pressure, concentrations). In general, adjustment of process conditions does not allow independent control of tacticity level, M_w and comonomer content. Addition of chain transfer agents such as hydrogen gas to the reactor gives lower molecular weight products without affecting tacticity, however, the resulting polymer no longer has unsaturated end groups. End group functionalization is often an important feature in the application of low molecular weight polymers. Given these limitations, one must prepare a wide variety of differently substituted metallocene precursors to access the entire range of desired materials.

In view of the difficulty and practical limitations in the synthesis of bridged metallocene complexes necessary for the production of an alumoxane activated metallocene catalyst system capable of producing poly- α -olefins, it would be desirable to develop new catalytic processes which could produce high or low molecular weight, tactic,

- 17 -

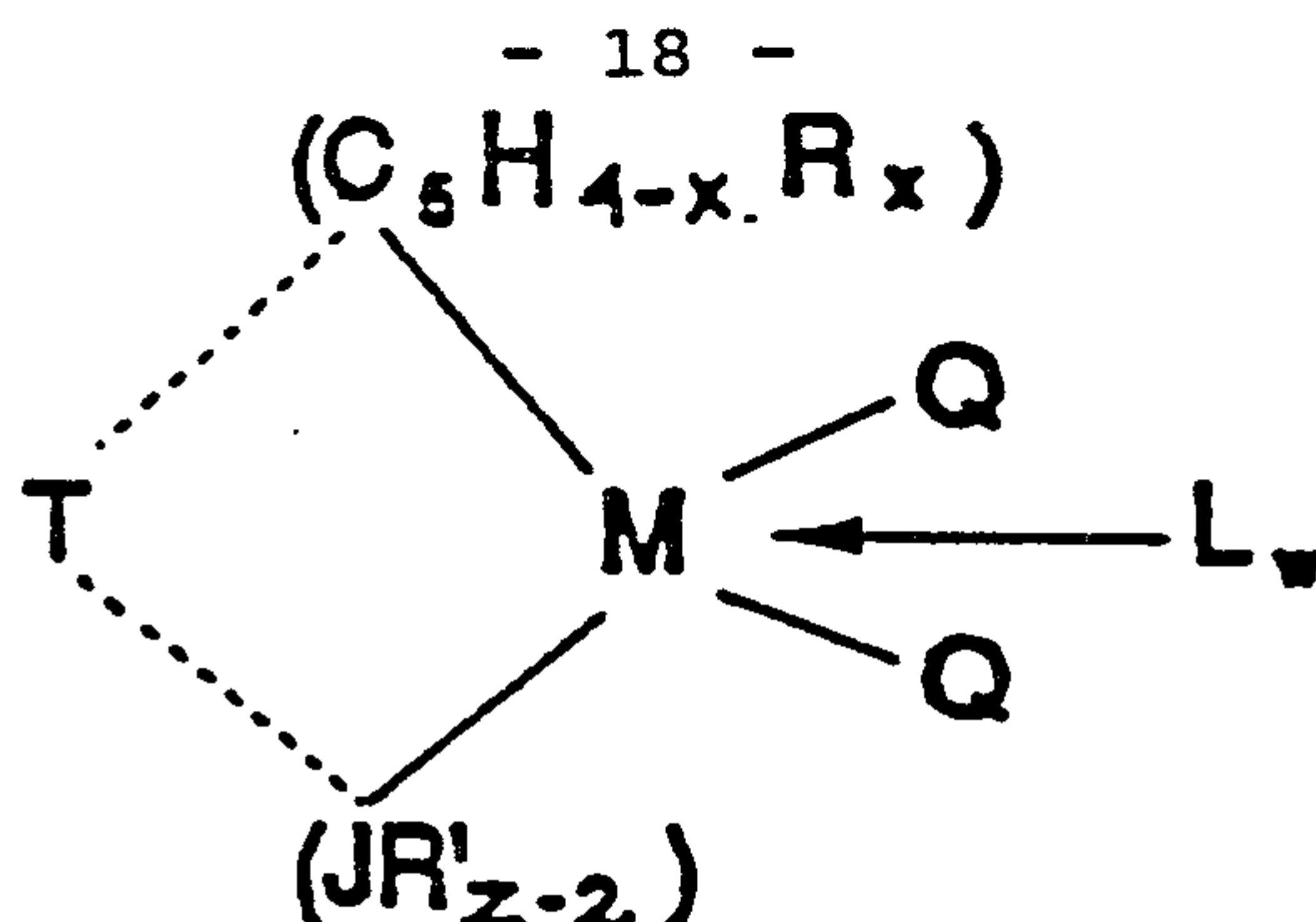
amorphous poly- α -olefins or low crystallinity poly- α -olefins of relatively narrow MWD.

SUMMARY OF THE INVENTION

5 The process of this invention employs a catalyst
system previously disclosed in U.S. Patent No. 5,055,438,
issued October 8, 1991, which is comprised of a
transition metal component from Group IV B of the
Periodic Table of the Elements (CRC Handbook of
10 Chemistry and Physics, 68th ed. 1987-1988) and an
alumoxane component. The catalyst system may be
employed in solution, slurry, gas phase or bulk
phase polymerization procedure to produce poly- α -
olefins of high or low weight average molecular
15 weight and relatively narrow molecular weight
distribution. The present invention relates to
using the catalyst of U.S. Patent No. 5,055,438 to
produce atactic amorphous poly- α -olefins of high or
low molecular weight and narrow MWD.
20 Atactic, amorphous poly- α -olefin is herein defined
to mean a poly- α -olefin that lacks or has a poorly
defined melting point and may or may not have low
amounts of crystallinity. The amorphous product of
this invention is substantially, preferably
25 completely, atactic.

 The catalyst of this invention comprises a
Group IVB transition metal component and an
alumoxane. The "Group IV B transition metal
component" of the catalyst system is represented by
30 the formula:

2166055



5

wherein: M is Zr, Hf or Ti in its highest formal oxidation state (+4, d^0 complex);

- ($C_5H_{4-x}R_x$) is a cyclopentadienyl ring which is symmetrically substituted with from zero to four substituent groups R, "x" is 0, 1, 2, 3, or 4 denoting the degree of substitution, and each substituent group R is, independently, a radical selected from a group consisting of C_1 - C_{20} hydrocarbyl radicals, substituted C_1 - C_{20} hydrocarbyl radicals wherein one or more hydrogen atoms is replaced by a halogen radical, an amido radical, a phosphido radical, an alkoxy radical or any other radical containing a Lewis acidic or basic functionality, C_1 - C_{20} hydrocarbyl-substituted metalloid radicals wherein the metalloid is selected from the Group IV A of the Periodic Table of Elements; and halogen radicals, amido radicals, phosphido radicals, alkoxy radicals, alkylborido radicals or any other radical containing Lewis acidic or basic functionality; or ($C_5H_{4-x}R_x$) is a cyclopentadienyl ring in which at least two adjacent R-groups are joined forming a C_4 - C_{20} ring to give a saturated or unsaturated polycyclic cyclopentadienyl ligand such as indenyl, tetrahydroindenyl.
- Symmetrical substitution exists when two R groups of approximately equal steric bulk are substituted at symmetric sites, i.e. 2,5; 3,4; etc.). A C_4 - C_{20}

- 19 -

ring can be considered symmetrically balanced with the bridging group, T.

(JR'_{z-2}) is a heteroatom ligand in which J is an element with a coordination number of three from Group V A or an element with a coordination number of two from Group VI A of the Periodic Table of Elements, preferably nitrogen, phosphorus, oxygen or sulfur, and each R' is, independently a radical selected from a group consisting of C₁-C₂₀ hydrocarbyl radicals, substituted C₁-C₂₀ hydrocarbyl radicals wherein one or more hydrogen atoms are replaced by a halogen radical, an amido radical, a phosphido radical, an alkoxy radical or any other radical containing a Lewis acidic or basic functionality, and "z" is the coordination number of the element J;

each Q may be independently any univalent anionic ligand such as a halide, hydride, or substituted or unsubstituted C₁-C₂₀ hydrocarbyl, alkoxide, aryloxy, amide, arylamide, phosphide or arylphosphide, provided that where any Q is a hydrocarbyl such Q is different from (C₅H₄-xR_x), or both Q together may be an alkylidene or a cyclometallated hydrocarbyl or any other divalent anionic chelating ligand;

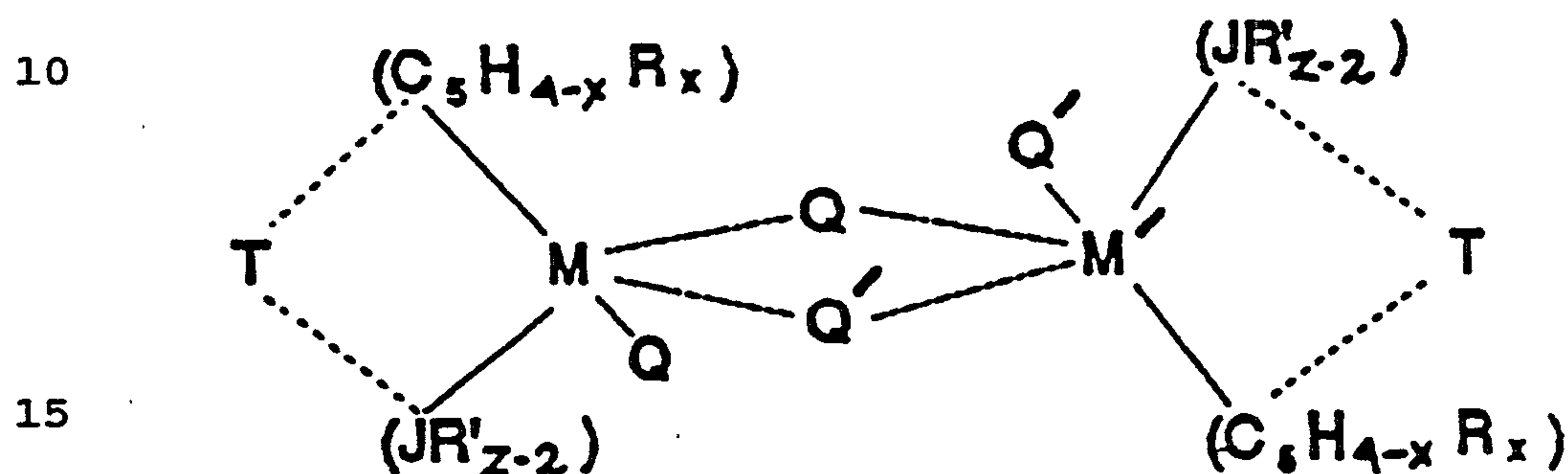
T is a covalent bridging group containing a Group IV A or V A element such as, but not limited to, a dialkyl, alkylaryl or diaryl silicon or germanium radical, alkyl or aryl phosphine or amine radical, or a hydrocarbyl radical such as methylene, ethylene and the like;

L is a neutral Lewis base such as diethylether, tetraethylammonium chloride, tetrahydrofuran,

2166055

- 20 -

dimethylaniline, aniline, trimethylphosphine, *n*-butylamine, and the like; and "w" is a number from 0 to 3. L can also be a second transition metal compound of the same type such that the two metal centers M and M' are bridged by Q and Q', wherein M' has the same meaning as M and Q' has the same meaning as Q. Such dimeric compounds are represented by the formula:



The alumoxane component of the catalyst may be represented by the formulas: (R³-Al-O)_m; R⁴(R⁵-Al-O)_mAlR⁶₂ or mixtures thereof, wherein R³-R⁶ are, independently, a C₁-C₅ alkyl group or halide and "m" is an integer ranging from 1 to about 50 and preferably is from about 13 to about 25.

Catalyst systems of the invention may be prepared by placing the "Group IV B transition metal component" and the alumoxane component in common solution in a normally liquid alkane or aromatic solvent, which solvent is preferably suitable for use as a polymerization diluent for the liquid phase polymerization of an α -olefin monomer.

Those species of the Group IV B transition metal component wherein the metal is titanium have been found to impart beneficial properties to a catalyst system which are unexpected in view of what

- 21 -

is known about the properties of
bis(cyclopentadienyl) titanium compounds which are
cocatalyzed by alumoxanes. Whereas titanocenes in
their soluble form are generally unstable in the
5 presence of aluminum alkyls, the
monocyclopentadienyl titanium metal components of
this invention, particularly those wherein the
heteroatom is nitrogen, generally exhibit greater
stability in the presence of aluminum alkyls and
10 higher catalyst activity rates.

Further, the titanium species of the Group IV B
transition metal component catalyst of this
invention generally exhibit higher catalyst
activities and the production of poly- α -olefins of
15 greater molecular weight than catalyst systems
prepared with the zirconium or hafnium species of
the Group IV B transition metal component.

A typical polymerization process of the
invention such as for the polymerization or
20 copolymerization of propylene or ethylene comprises
the steps of contacting propylene, ethylene or
other C₄-C₂₀ α -olefins alone, or with other
unsaturated monomers including C₃-C₂₀ α -olefins, C₄-
C₂₀ diolefins, and/or acetylenically unsaturated
25 monomers either alone or in combination with other
olefins and/or other unsaturated monomers, with a
catalyst comprising, in a suitable polymerization
diluent, a Group IV B transition metal component
illustrated above; and a methylalumoxane in an
30 amount to provide a molar aluminum to transition
metal ratio of from about 1:1 to about 20,000:1 or
more; and reacting such monomer in the presence of
such catalyst system at a temperature of from about

2166055

- 22 -

-100°C to about 300°C for a time of from about 1 second to about 10 hours to produce a poly- α -olefin having a weight average molecular weight of from about 1,000 or less to about 2,000,000 or more and a molecular weight distribution of from about 1.5 to about 15.0.

As discussed further hereafter, by proper selection of the type and pattern R substituents for the cyclopentadienyl ligand in relationship to the type of R' substituent of the heteroatom ligand, the transition metal component for the catalyst system may be tailored to function in the catalyst system to produce low crystallinity poly- α -olefins or tactic amorphous poly- α -olefins.

15

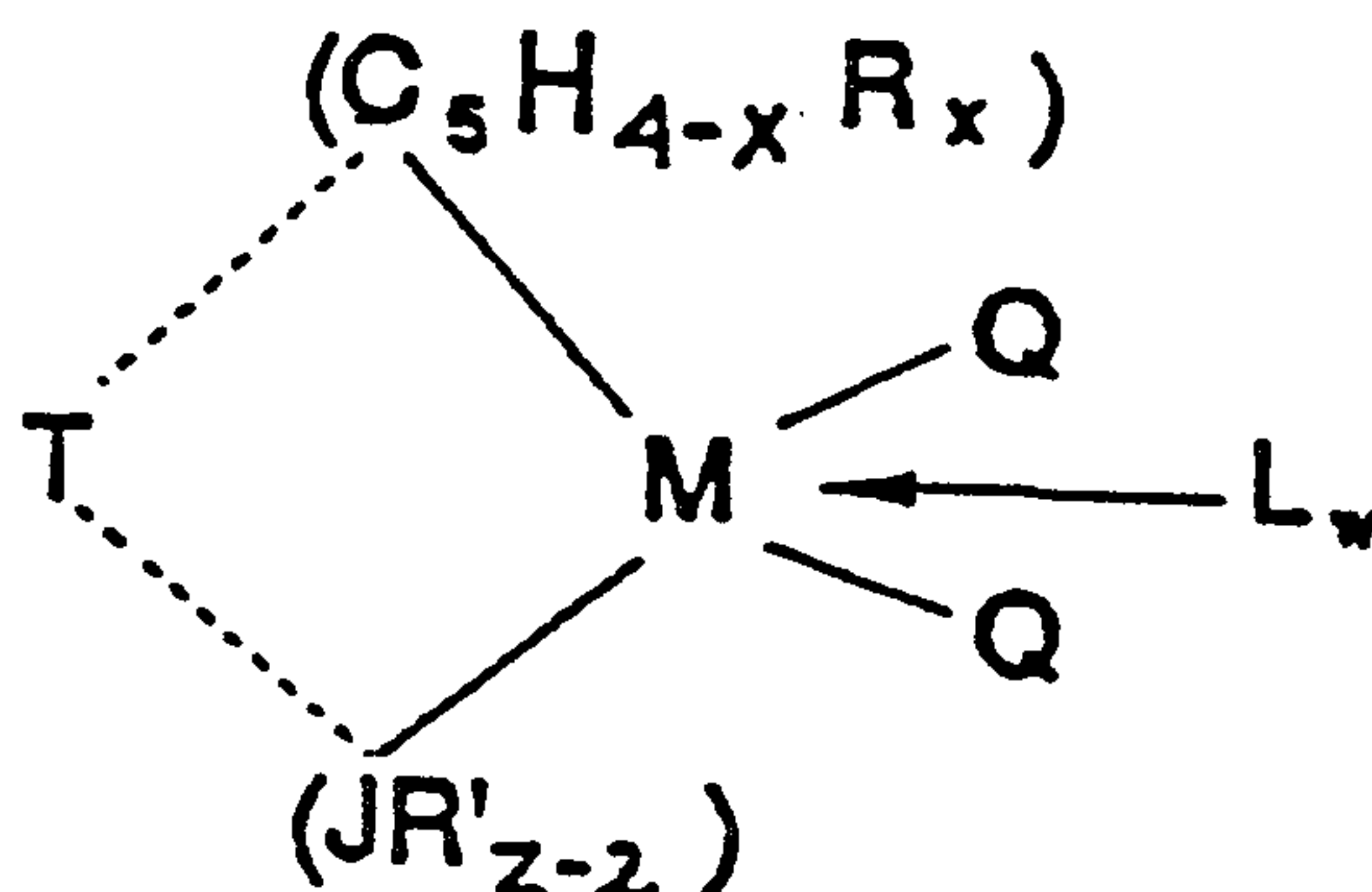
DETAILED DESCRIPTION

Catalyst Component

The Group IV B transition metal component of the catalyst system is represented by the general formula:

20

25



wherein M is Zr, Hf or Ti in its highest formal oxidation state (+4, d^0 complex);

30

$(\text{C}_5\text{H}_{4-x}\text{R}_x)$ is a cyclopentadienyl ring which is symmetrically substituted with from zero to four substituent groups R, "x" is 0, 1, 2, 3, or 4

- 23 -

denoting the degree of substitution, and each substituent group R is, independently, a radical selected from a group consisting of C₁-C₂₀ hydrocarbyl radicals, substituted C₁-C₂₀ hydrocarbyl radicals wherein one or more hydrogen atoms is replaced by a halogen radical, an amido radical, a phosphido radical, and alkoxy radical or any other radical containing a Lewis acidic or basic functionality, C₁-C₂₀ hydrocarbyl-substituted metalloids wherein the metalloid is selected from the Group IV A of the Periodic Table of Elements; and halogen radicals, amido radicals, phosphido radicals, alkoxy radicals, alkylborido radicals or any other radical containing Lewis acidic or basic functionality; or (C₅H₄-xR_x) is a cyclopentadienyl ring in which two adjacent R-groups are joined forming C₄-C₂₀ ring to give a saturated or unsaturated polycyclic cyclopentadienyl ligand. Symmetrically substituted is defined to mean that the cyclopentadienyl ring is substituted with R groups that are of approximately of the same steric bulk. Typically the size of these R groups are within 2 carbons of each other. However, if two adjacent R groups are linked to form a ring, then the bridge (T) may function as the other "part" of the symmetrical "pair." Likewise, the cyclopentadienyl ring may be substituted at all four sites with R groups and be considered symmetric as long as each of the symmetrical pairs were of similar steric bulk. Thus a cyclopentadienyl substituted at the 2 and the 5 positions with methyl and ethyl respectively, and substituted at the 3 and

2166055

- 24 -

the 4 positions with hexyl and octyl, respectively, would be considered symmetric.

(JR'_{z-2}) is a heteroatom ligand in which J is an element with a coordination number of three from Group V A or an element with a coordination number of two from Group VI A of the Periodic Table of Elements, preferably nitrogen, phosphorus, oxygen or sulfur with nitrogen being preferred, and each R' is, independently a radical selected from a group consisting of C₁-C₂₀ hydrocarbyl radicals, substituted C₁-C₂₀ hydrocarbyl radicals wherein one or more hydrogen atoms is replaced by a halogen radical, an amido radical, a phosphido radical, an alkoxy radical or any other radical containing a Lewis acidic or basic functionality, and "z" is the coordination number of the element J;

each Q is, independently, any univalent anionic ligand such as a halide, hydride, or substituted or unsubstituted C₁-C₂₀ hydrocarbyl, alkoxide, aryloxide, amide, arylamide, phosphide or arylphosphide, provided that where any Q is a hydrocarbyl such Q is different from (C₅H₄-xR_x), or both Q together may be an alkylidene or a cyclometallated hydrocarbyl or any other divalent anionic chelating ligand;

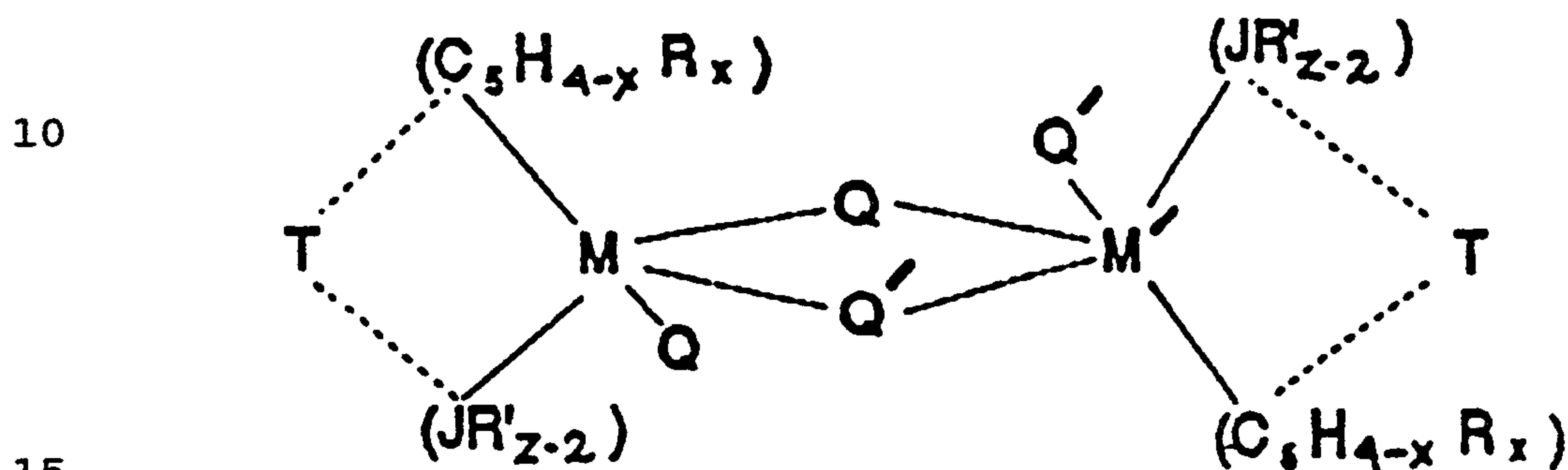
T is a covalent bridging group containing a Group IV A or V A element such as, but not limited to, a dialkyl, alkylaryl or diaryl silicon or germanium radical, alkyl or aryl phosphine or amine radical, or a hydrocarbyl radical such as methylene, ethylene and the like;

and L is a neutral Lewis base such as diethylether, tetrahydrofuran, dimethylaniline,

2166055

- 25 -

aniline, trimethylphosphine, *n*-butylamine, and the like; and "w" is a number from 0 to 3; L can also be a second transition metal compound of the same type such that the two metal centers M and M' are bridged by Q and Q', wherein M' has the same meaning as M and Q' has the same meaning as Q. Such compounds are represented by the formula:



Examples of the T group which are suitable as a constituent group of the Group IV B transition metal component of the catalyst system are identified in column 1 of Table 1 under the heading "T".

20 Suitable, but not limiting, Group IV B transition metal compounds which may be utilized in the catalyst system of this invention include those wherein the T group bridge is a dialkyl, diaryl or alkylaryl silane, or methylene or ethylene.

25 Exemplary of the more preferred species of bridged Group IV B transition metal compounds are dimethylsilyl, methylphenylsilyl, diethylsilyl, ethylphenylsilyl, diphenylsilyl, ethylene or methylene bridged compounds. Most preferred of the
30 bridged species are dimethylsilyl, diethylsilyl and methylphenylsilyl bridged compounds.

Exemplary hydrocarbyl radicals for Q are methyl, ethyl, propyl, butyl, amyl, isoamyl, hexyl,

2166055

- 26 -

isobutyl, heptyl, octyl, nonyl, decyl, cetyl, 2-ethylhexyl, phenyl and the like, with methyl being preferred. Exemplary halogen atoms for Q include chlorine, bromine, fluorine and iodine, with chlorine being preferred. Exemplary alkoxides and aryloxides for Q are methoxide, phenoxide and substituted phenoxides such as 4-methylphenoxide. Exemplary amides of Q are dimethylamide, diethylamide, methylethylamide, di-t-butylamide, diisoproylamide and the like. Exemplary aryl amides are diphenylamide and any other substituted phenyl amides. Exemplary phosphides of Q are diphenylphosphide, dicyclohexylphosphide, diethylphosphide, dimethylphosphide and the like. Exemplary alkyldiene radicals for both Q together are methylenidene, ethylenidene and propylenidene. Examples of the Q group which are suitable as a constituent group or element of the Group IV B transition metal component of the catalyst system are identified in column 4 of Table 1 under the heading "Q".

Suitable hydrocarbyl and substituted hydrocarbyl radicals, which may be substituted as an R group for at least one hydrogen atom in the cyclopentadienyl ring, will contain from 1 to about 20 carbon atoms and include straight and branched alkyl radicals, cyclic hydrocarbon radicals, alkyl-substituted cyclic hydrocarbon radicals, aromatic radicals and alkyl-substituted aromatic radicals, amido-substituted hydrocarbon radicals, phosphido-substituted hydrocarbon radicals, alkoxy-substituted hydrocarbon radicals, and cyclopentadienyl rings containing one or more fused saturated or

- 27 -

unsaturated rings. Suitable organometallic radicals, which may be substituted as an R group for at least one hydrogen atom in the cyclopentadienyl ring, include trimethylsilyl, triethylsilyl, ethyldimethylsilyl, methyldiethylsilyl, triphenylgermyl, trimethylgermyl and the like. Other suitable radicals that may be substituted for one or more hydrogen atom in the cyclopentadienyl ring include halogen radicals, amido radicals, phosphido radicals, alkoxy radicals, alkylborido radicals and the like. Examples of cyclopentadienyl ring groups ($C_5H_4-xR_x$) which are suitable as a constituent group of the Group IV B transition metal component of the catalyst system are identified in Column 2 of Table 1 under the heading ($C_5H_4-xR_x$).

Suitable hydrocarbyl and substituted hydrocarbyl radicals, which may be substituted as an R' group for at least one hydrogen atom in the heteroatom J ligand group, will contain from 1 to about 20 carbon atoms and include straight and branched alkyl radicals, cyclic hydrocarbon radicals, alkyl-substituted cyclic hydrocarbon radicals, aromatic radicals and alkyl-substituted aromatic radical, halogen radicals, amido radicals, phosphido radicals and the like. Examples of heteroatom ligand groups (JR'_{z-2}) which are suitable as a constituent group of the Group IV B transition metal component of the catalyst system are identified in column 3 of Table 1 under the heading (JR'_{z-2}).

Table 1 depicts representative constituent moieties for the "Group IV B transition metal component", the list is for illustrative purposes

2166055

- 28 -

only and should not be construed to be limiting in any way. A number of final components may be formed by permuting all possible combinations of the constituent moieties with each other. Illustrative compounds are:

dimethylsilyl(tetramethylcyclopentadienyl)
(cyclohexylamido) zirconium dichloride, and
dimethylsilyl(3,4-dimethylcyclopentadienyl)
(cyclohexylamido) hafnium dichloride.

As noted, titanium species of the Group IV B transition metal compound have generally been found to yield catalyst systems which in comparison to their zirconium or hafnium analogous, are of higher activity. Illustrative, but not limiting of the titanium species which may exhibit such superior properties are;

dimethylsilyl(tetramethylcyclopentadienyl) (t-butylamido) titanium dichloride, dimethylsilyl(3,4-di-t-butylcyclopentadienyl) (cyclododecylamido) titanium dichloride, dimethylsilyl(2,5-dimethylcyclopentadienyl) cyclododecylamido titanium dichloride.

For illustrative purposes, the above compounds and those permuted from Table 1 include the neutral Lewis base ligand (L). The conditions under which complexes containing neutral Lewis base ligands such as ether or those which form dimeric compounds is determined by the steric bulk of the ligands about the metal center. For example, the t-butyl group in $\text{Me}_2\text{Si}(\text{Me}_4\text{C}_5)(\text{N-t-Bu})\text{ZrCl}_2$ has greater steric requirements than the phenyl group in $\text{Me}_2\text{Si}(\text{Me}_4\text{C}_5)(\text{NPh})\text{ZrCl}_2 \cdot \text{Et}_2\text{O}$ thereby not permitting ether coordination in the former compound.

2166055

- 29 -

Similarly, due to the decreased steric bulk of the trimethylsilylcyclopentadienyl group in $[\text{Me}_2\text{Si}(\text{Me}_3\text{SiC}_5\text{H}_3)(\text{N}-\text{t-Bu})\text{ZrCl}_2]_2$ versus that of the tetramethylcyclopentadienyl group in $\text{Me}_2\text{Si}(\text{Me}_4\text{C}_5)(\text{N}-\text{t-Bu})\text{ZrCl}_2$, the former compound is dimeric and the latter is not.

To illustrate members of the Group IV B transition metal component, select any combination of the species in Table 1. An example of a bridged species would be dimethylsilylcyclopentadienyl (t-butylamido)dichloro zirconium.

TABLE 1

T	(C ₅ H ₄ -x)R _x	(JR'z-2)	Q	M
dimethylsilyl	cyclopentadienyl	t-butylamido	hydride	zirconium
diethylsilyl	3,4-dimethylcyclopentadienyl	phenylamido	methyl	hafnium
di-n-propylsilyl	2,5-dimethylcyclopentadienyl	p-n-butylphenylamido	ethyl	titanium
di-isopropylsilyl	2-indenyl	cyclohexylamido	phenyl	
di-n-butylsilyl	3,4-diethylcyclopentadienyl	perfluorophenylamido	n-propyl	
di-t-butylsilyl	2,5-diethylcyclopentadienyl	n-butylamido	isopropyl	
di-n-hexylsilyl	tetramethylcyclopentadienyl	methylamido	n-butyl	L
methylphenylsilyl	tetraethylcyclopentadienyl	ethylamido	amyl	ethylene
ethylmethylsilyl	tetraphenylcyclopentadienyl	n-propylamido	isoamyl	propylene
diphenylsilyl	tetra-n-propylcyclopentadienyl	isopropylamido	hexyl	1-butene
di(p-t-butylphenethylsilyl)	3,4-di-n-butylcyclopentadienyl	benzylamido	isobutyl	1,4-hexadiene
n-hexylmethylsilyl	3,4-dicyclohexylcyclopentadienyl	cyclododecylamido	heptyl	1,3-butadiene
cyclopentamethylsilyl	2,5-di-n-butylcyclopentadienyl	s-butylamido	octyl	1,3-hexadiene
cyclotetramethylsilyl	2,5-dicyclohexylcyclopentadienyl	t-butylphosphido	nonyl	acetylene
cyclotrimethylsilyl	3-n-octyl-4-n-hexylcyclopentadienyl	ethylphosphido	decyl	methylacetylene
dimethylgermanyl	2-tetrahydroindenyl	phenylphosphido	cetyl	benzynes
diethylgermanyl	3-ethyl-4-n-propylcyclopentadienyl	cyclohexylphosphido	chloro	diethylether
phenylamido	3-isopropyl-4-t-butylcyclopentadienyl	oxo	fluoro	dimethylether
t-butylamido	3-phenyl-4-benzylcyclopentadienyl	sulfido	bromo	trimethylamine
methylamido	3,4-diphenylcyclopentadienyl		iodo	triphenylamine
t-butylphosphido	2,5-diphenylcyclopentadienyl		methoxy	triethylamine
ethylphosphido	3,4-bis(trimethylgermyl)cyclopentadienyl		ethoxy	triphenyl-
phenylphosphido	3,4-bis(trimethylstanny)cyclopentadienyl		propoxy	phosphine
methylene	3,4-bis(trimethylplumbyl)cyclopentadienyl		butoxy	tetrahydrofuran
dimethylmethylene	2-ethyl-5-n-propylcyclopentadienyl		phenoxy	thiophene
diethylmethylene	2-methyl-5-t-butylcyclopentadienyl		dimethylamido	dimethylsulfide
ethylene	2,5-bis(trifluoromethyl)cyclopentadienyl		diethylamido	
dimethylethylene	3,4-bis(trimethylsilyl)cyclopentadienyl		methylethylamido	
propylene	3,4-bis(N,N-dimethylamido)-cyclopentadienyl		diphenylphosphido	
dimethylpropylene	3,4-bis(dimethylphosphido)-cyclopentadienyl		dicyclohexylphosphido	
diethylpropylene	3,4-bis(dimethylphosphido)-cyclopentadienyl		dimethylphosphido	
1,1-dimethyl-3,3-dimethylpropylene	2,5-dimethyl-3,4-diethylcyclopentadienyl		ethyleneglycol	
tetramethyldisiloxane	2,5-diethyl-3,4-dimethylcyclopentadienyl		dianion (both Q)	
1,1,4,4-tetramethyldisilyl	2,5-dimethyl-3,4-di-t-butylcyclopentadienyl		methylidene (both Q)	
ethylene			ethylidene (both Q)	
			propylidene (both Q)	

- 31 -

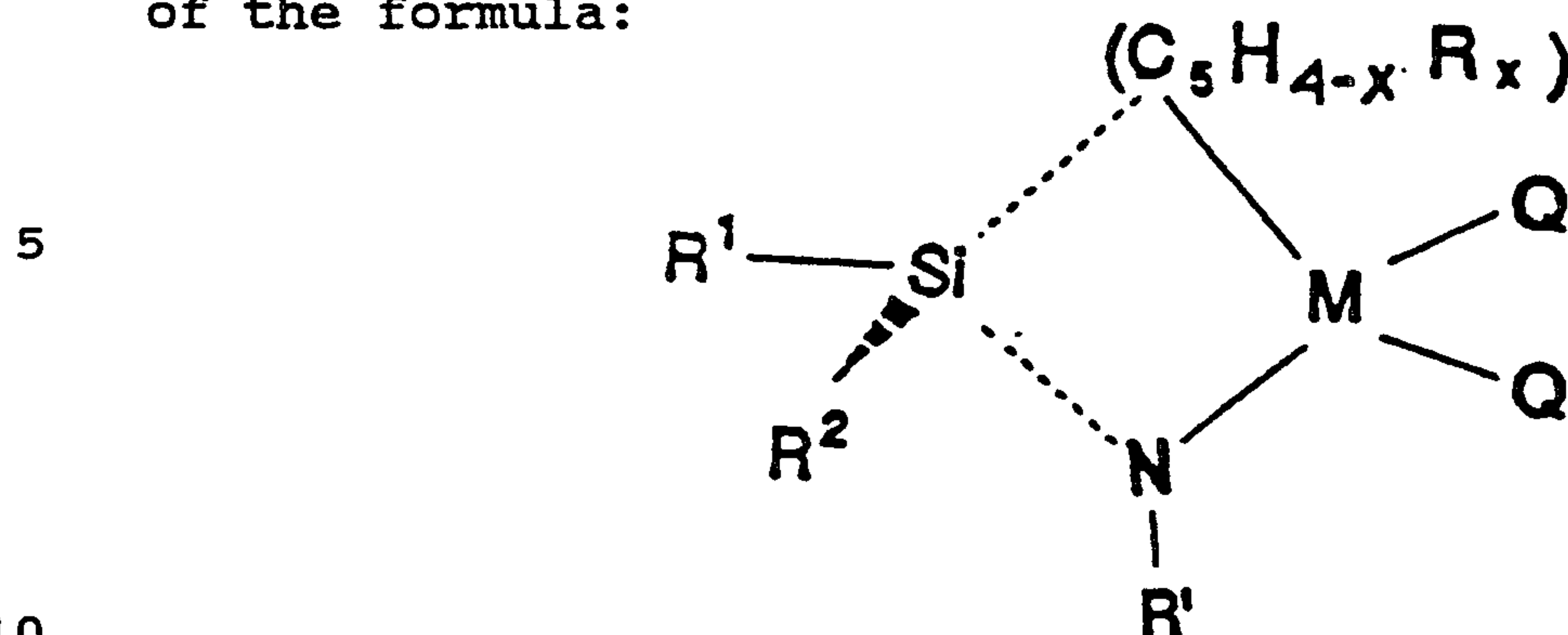
The Group IV B transition metal compounds can be prepared by reacting a cyclopentadienyl lithium compound with a dihalo compound, whereupon a lithium halide salt is liberated and a monohalo substituent is covalently bound to the cyclopentadienyl compound. The so substituted cyclopentadienyl reaction product is next reacted with a lithium salt of a phosphide, oxide, sulfide or amide (for the sake of illustrative purposes, a lithium amide) whereupon the halo element of the monohalo substituent group of the reaction product reacts to liberate a lithium halide salt and the amine moiety of the lithium amide salt is covalently bound to the substituent of the cyclopentadienyl reaction product. The resulting amine derivative of the cyclopentadienyl product is then reacted with an alkyl lithium reagent whereupon the labile hydrogen atoms, at the carbon atom of the cyclopentadienyl compound and at the nitrogen atom of the amine moiety covalently bound to the substituent group, react with the alkyl of the lithium alkyl reagent to liberate the alkane and produce a dilithium salt of the cyclopentadienyl compound. Thereafter the bridged species of the Group IV B transition metal compound is produced by reacting the dilithium salt cyclopentadienyl compound with a Group IV B transition metal preferably a Group IV B transition metal halide.

The class of transition metal components preferred for use in the process for production of poly- α -olefins is that wherein the covalent bridging group T contains silicon and the heteroatom J of the heteroatom ligand is nitrogen. Accordingly, a

2166055

- 32 -

preferred class of transition metal components are of the formula:



wherein Q, L, R', R, "x" and "w" are as previously defined and R¹ and R² are each independently a C₁ to C₂₀ hydrocarbyl radicals, substituted C₁ to C₂₀ hydrocarbyl radicals wherein one or more hydrogen atom is replaced by a halogen atom; R¹ and R² may also be joined forming a C₃ to C₂₀ ring which incorporates the silicon bridge.

THE ALUMOXANE COMPONENT

The alumoxane component of the catalyst system is an oligomeric compound which may be represented by the general formula (R³-Al-O)_m which is a cyclic compound, or may be R⁴(R⁵-Al-O)_m-AlR⁶₂ which is a linear compound. An alumoxane is generally a mixture of both the linear and cyclic compounds. In the general alumoxane formula R³, R⁴, R⁵ and R⁶ are, independently a C₁-C₅ alkyl radical, for example, methyl, ethyl, propyl, butyl or pentyl and "m" is an integer from 1 to about 50. Most preferably, R³, R⁴, R⁵ and R⁶ are each methyl and "m" is at least 4.

When an alkyl aluminum halide is employed in the preparation of the alumoxane, one or more R³⁻⁶ groups may be halide.

- 33 -

As is now well known, alumoxanes can be prepared by various procedures. For example, a trialkyl aluminum may be reacted with water, in the form of a moist inert organic solvent; or the
5 trialkyl aluminum may be contacted with a hydrated salt, such as hydrated copper sulfate suspended in an inert organic solvent, to yield an alumoxane. Generally, however prepared, the reaction of a trialkyl aluminum with a limited amount of water
10 yields a mixture of both linear and cyclic species of alumoxane.

Suitable alumoxanes which may be utilized in the catalyst systems of this invention are those prepared by the hydrolysis of a trialkylaluminum;
15 such as trimethylaluminum, triethylaluminum, tripropylaluminum; triisobutylaluminum, dimethylaluminumchloride, diisobutylaluminumchloride, diethylaluminumchloride, and the like. The most preferred alumoxane for use
20 is methylalumoxane (MAO). Methylalumoxanes having an average degree of oligomerization of from about 4 to about 25 ("m" = 4 to 25), with a range of 13 to 25, are the most preferred.

Catalyst Systems

25 The catalyst systems employed in the method of the invention comprise a complex formed upon admixture of the Group IV B transition metal component with an alumoxane component. The catalyst system may be prepared by addition of the requisite
30 Group IV B transition metal and alumoxane components to an inert solvent in which olefin polymerization can be carried out by a solution, slurry, gas phase or bulk phase polymerization procedure.

2166055

- 34 -

The catalyst system may be conveniently prepared by placing the selected Group IV B transition metal component and the selected alumoxane component, in any order of addition, in an alkane or aromatic hydrocarbon solvent -- preferably one which is also suitable for service as a polymerization diluent. When the hydrocarbon solvent utilized is also suitable for use as a polymerization diluent, the catalyst system may be prepared in situ in the polymerization reactor. Alternatively, the catalyst system may be separately prepared, in concentrated form, and added to the polymerization diluent in a reactor. If desired, the components of the catalyst system may be prepared as separate solutions and added to the polymerization diluent in a reactor, in appropriate ratios, as is suitable for a continuous liquid phase polymerization reaction procedure. Alkane and aromatic hydrocarbons suitable as solvents for formation of the catalyst system and also as a polymerization diluent are exemplified by, but are not necessarily limited to, straight and branched chain hydrocarbons such as isobutane, butane, pentane, hexane, heptane, octane and the like, cyclic and alicyclic hydrocarbons such as cyclohexane, cycloheptane, methylcyclohexane, methylcycloheptane and the like, and aromatic and alkyl-substituted aromatic compounds such as benzene, toluene, xylene and the like. Suitable solvents also include liquid olefins which may act as monomers or comonomers including ethylene, propylene, 1-butene, 1-hexene and the like.

2166055

- 35 -

In accordance with this invention optimum results are generally obtained wherein the Group IV B transition metal compound is present in the polymerization diluent in a concentration of from
5 about 0.0001 to about 1.0 millimoles/liter of diluent and the alumoxane component is present in an amount to provide a molar aluminum to transition metal ratio of from about 1:1 to about 20,000:1. Sufficient solvent should be employed so as to
10 provide adequate heat transfer away from the catalyst components during reaction and to permit good mixing.

The catalyst system ingredients -- that is, the Group IV B transition metal, the alumoxane, and
15 polymerization diluent -- can be added to the reaction vessel rapidly or slowly. The temperature maintained during the contact of the catalyst components can vary widely, such as, for example, from -100° to 300°C. Greater or lesser temperatures
20 can also be employed. Preferably, during formation of the catalyst system, the reaction is maintained within a temperature of from about 25° to 100°C, most preferably about 25°C.

At all times, the individual catalyst system
25 components, as well as the catalyst system once formed, are protected from oxygen and moisture. Therefore, the reactions to prepare the catalyst system are performed in an oxygen and moisture free atmosphere and, where the catalyst system is
30 recovered separately it is recovered in an oxygen and moisture free atmosphere. Preferably, therefore, the reactions are performed in the presence of an

2166055

- 36 -

inert dry gas such as, for example, helium or nitrogen.

Polymerization Process

5 In a preferred embodiment of the process of this invention the catalyst system is utilized in the liquid phase (slurry, solution, suspension or bulk phase or combination thereof), high pressure fluid phase or gas phase polymerization of an α -olefin monomer. These processes may be employed
10 singularly or in series. The liquid phase process comprises the steps of contacting an α -olefin monomer with the catalyst system in a suitable polymerization diluent and reacting said monomer in the presence of said catalyst system for a time and
15 at a temperature sufficient to produce an amorphous poly- α -olefin as desired.

The monomer for such process comprises an α -olefin having 3 to 20 carbon atoms. Propylene is a preferred monomer. Homopolymers of higher α -olefin
20 such as ethylene, butene, styrene and copolymers thereof with ethylene and/or C_4 or higher α -olefins, diolefins, cyclic olefins and internal olefins can also be prepared. Conditions most preferred for the homo- or copolymerization of the α -olefin are those
25 wherein an α -olefin is submitted to the reaction zone at pressures of from about 0.019 psia to about 50,000 psia and the reaction temperature is maintained at from about -100° to about 300°C . The aluminum to transition metal molar ratio is
30 preferably from about 1:1 to 20,000 to 1. A more preferable range would be 1:1 to 2000:1. The reaction time is preferably from about 10 seconds to about 10 hours. Without limiting in any way the

- 37 -

scope of the invention, one means for carrying out the process of the present invention for production of a copolymer is as follows: in a stirred-tank reactor liquid α -olefin monomer is introduced, such as propylene. The catalyst system is introduced via nozzles in either the vapor or liquid phase. The reactor contains a liquid phase composed substantially of the liquid α -olefin monomer together with a vapor phase containing vapors of the monomer. The reactor temperature and pressure may be controlled via reflux of vaporizing α -olefin monomer (autorefrigeration), as well as by cooling coils, jackets etc. The polymerization rate is controlled by the concentration of catalyst.

By appropriate selection of (1) Group IV B transition metal component for use in the catalyst system; (2) the type and amount of alumoxane used; (3) the polymerization diluent type and volume; (4) reaction temperature; and (5) reaction pressure, one may tailor the product polymer to the weight average molecular weight value desired while still maintaining the molecular weight distribution to a value below about 6.0, preferably below 4.0. Optionally, higher molecular weight distributions can be tailored.

The preferred polymerization diluents for practice of the process of the invention are aromatic diluents, such as toluene, or alkanes, such as hexane. Optionally, the α -olefin itself may be used as the solvent.

The resins that are prepared in accordance with this invention can be used to make a variety of

2166055

- 38 -

products including films and fibers, adhesives,
compatibilizers and the like.

- 39 -

EXAMPLES

In the examples which illustrate the practice of the invention the analytical techniques described below were employed for the analysis of the

5 resulting polyolefin products. Molecular weight determinations for polyolefin products were made by Gel Permeation Chromatography (GPC) according to the following technique. Molecular weights and molecular weight distributions were measured using a Waters

10 150 gel permeation chromatograph equipped with a differential refractive index (DRI) detector and a Chromatix KMX-6 on-line light scattering photometer. The system was used at 135°C with 1,2,4-trichlorobenzene as the mobile phase. Shodex (Showa

15 Denko America, Inc.) polystyrene gel columns 802, 803, 804 and 805 were used. This technique is discussed in "Liquid Chromatography of Polymers and Related Materials III", J. Cazes editor, Marcel Dekker. 1981, p. 207. No corrections for column spreading

20 were employed; however, data on generally accepted standards, e.g. National Bureau of Standards Polyethylene 1484 and anionically produced hydrogenated polyisoprenes (an alternating ethylene-propylene copolymer) demonstrated that such

25 corrections on Mw/Mn (= MWD) were less than 0.05 units. Mw/Mn was calculated from elution times. The numerical analyses were performed using the commercially available Beckman/CIS customized LALLS software in conjunction with the standard Gel

30 Permeation package, run on a HP 1000 computer. Calculations involved in the characterization of polymers by ¹³CNMR follow the work of F. A. Bovey in

2166055

- 40 -

"Polymer Conformation and Configuration" Academic Press, New York, 1969.

The following examples are intended to illustrate specific embodiments of the invention and
5 are not intended to limit the scope of the invention.

- 41 -

EXAMPLES PRODUCING AMORPHOUS POLY- α -OLEFIN

All procedures were performed under an inert atmosphere of helium or nitrogen. Solvent choices were often optional, for example, in most cases
5 either pentane or 30-60 petroleum ether could be interchanged. The choice between tetrahydrofuran (thf) and diethyl ether (ether) is a bit more restricted, but in several reactions, either could be used. The lithiated amides were prepared from
10 the corresponding amines and either n-BuLi or MeLi. Published methods for preparing LiHC_5Me_4 include C. M. Fendrick et al., Organometallics 1984, 3, 819 and F. H. Kohler and K. H. Doll, Z. Naturforsch 1982, 376, 144. Other lithiated substituted
15 cyclopentadienyl compounds are typically prepared from the corresponding cyclopentadienyl ligand and n-BuLi or MeLi, or by reaction of MeLi with the proper fulvene. TiCl_4 was typically used in its etherate form. The etherate can be prepared by
20 simply adding TiCl_4 to ether and filtering off the solid product which is then vacuum dried. TiCl_4 , ZrCl_4 , HfCl_4 , amines, silanes, substituted and unsubstituted cyclopentadienyl compounds or precursors, and lithium reagents were purchases from
25 Aldrich Chemical Company, Petrarch Systems or Cerac. Methylalumoxane was supplied by either Schering or Ethyl Corporation.

Example A

Compound A: Part 1. (10.0 g, 0.078 mol) was
30 slowly added to a Me_2SiCl_2 (11.5 ml, 0.095 mol, in 225 ml of tetrahydrofuran solution). The solution was stirred for 1 hour to insure a complete reaction. The solvent was then removed in vacuo.

- 42 -

2166055

Pentane was added to precipitate the LiCl which was filtered off. The solvent was then removed from the filtrate leaving behind the pale yellow liquid, $(C_5Me_4H)SiMe_2Cl$ (15.34 g, 0.071 mol).

5 Part 2. $(C_5Me_4H)SiMe_2Cl$ (10.0 g, 0.047 mol) was slowly added to a suspension of LiHN-t-Bu (3.68 g, 0.047 mol, approximately 100 ml of thf). The mixture was stirred overnight. The thf was then removed in vacuo. Petroleum ether (approximately
10 100 ml) was added to precipitate the LiCl which was filtered off. The solvent was removed from the filtrate leaving behind the pale yellow liquid, $Me_2Si(C_5Me_4H)(HN-t-Bu)$ (11.4 g, 0.044 mol).

15 Part 3. $Me_2Si(C_5Me_4H)(HN-t-Bu)$ (11.14 g, 0.044 mol) was diluted with approximately 100 ml of ether. MeLi (1.4 M, 64 ml, 0.090 mol) was slowly added. The mixture was allowed to stir for 1/2 hour after the final addition of MeLi. The ether was reduced in volume prior to filtering off the product. The
20 product, $Li_2[Me_2Si(C_5Me_4)(N-t-Bu)]$, was washed with several small portions of ether, then vacuum dried.

25 Part 4. $Li_2[Me_2Si(C_5Me_4)(N-t-Bu)]$ (3.0 g, 0.011 mol) was suspended in approximately 150 ml of ether. $ZrCl_4$ (2.65 g, 0.011 mol) was slowly added and the resulting mixture was allowed to stir overnight. The ether was removed in vacuo. Pentane was added to precipitate the LiCl which was filtered off. The pentane was significantly reduced in volume and the pale yellow solid was filtered off
30 and washed with solvent. $Me_2Si(C_5Me_4)(N-t-Bu)ZrCl_2$ (1.07 g, 0.0026 mole) was recovered. Additional $Me_2Si(C_5Me_4)(N-t-Bu)ZrCl_2$ was recovered from the

- 43 -

filtrate by repeating the recrystallization procedure. Total yield: 1.94 g, 0.0047 mol.

Example B

5 Compound B: Part 1. $(C_5Me_4H)SiMe_2Cl$ was prepared as described in Example A for the preparation of compound A, Part 1.

10 Part 2. $(C_5Me_4H)SiMe_2Cl$ (8.0 g, 0.037 mol) was slowly added to a suspension of $LiHNC_{12}H_{23}$ ($C_{12}H_{23}$ = cyclododecyl, 7.0 g, 0.037 mol, approximately 80 ml thf). The mixture was stirred overnight. The thf was then removed via a vacuum to a cold trap held at $-196^\circ C$. Petroleum ether and toluene were added to precipitate the $LiCl$. The mixture was filtered through Celite. The solvent was removed from the
15 filtrate. $Me_2Si(C_5Me_4H)(NHC_{12}H_{23})$ (11.8 g, 0.033 mol) was isolated as a pale yellow liquid.

Part 3. $Me_2Si(C_5Me_4H)(NHC_{12}H_{23})$ (11.9 g, 0.033 mol) was diluted with approximately 150 ml of ether. $MeLi$ (1.4 M, 47 ml, 0.066 mol) was slowly added.
20 The mixture was allowed to stir for 2 hours after the final addition of $MeLi$. The ether was reduced in volume prior to filtering off the product. the product, $[Me_2Si(C_5Me_4H)(NC_{12}H_{23})]Li_2$ (3.0 g, 0.008 mol) was washed with several small portions of
25 ether, then vacuum dried to yield 11.1 g (0.030 mol) of product.

Part 4. $[Me_2Si(C_5Me_4H)(NC_{12}H_{23})]Li_2$ (3.0 g, 0.008 mol) was suspended in cold ether. $TiCl_4 \cdot 2Et_2O$ (2.7 g, 0.008 mol) was slowly added and the
30 resulting mixture was allowed to stir overnight. The ether was removed via a vacuum to a cold trap held at $-196^\circ C$. Methylene chloride was added to precipitate the $LiCl$. The mixture was filtered

2166055

- 44 -

through Celite. The solvent was significantly reduced in volume and petroleum ether was added to precipitate out the product. This mixture was refrigerated prior to filtration in order to maximize precipitation. The solid collected was recrystallized from methylene chloride and $\text{Me}_2\text{Si}(\text{C}_5\text{Me}_4)(\text{NC}_{12}\text{H}_{23})\text{TiCl}_2$ was isolated (1.0 g, 2.1 mmol).

Polymerization Example - I

Using the same reactor design and general procedure already described, 100 ml of toluene, 400 ml of propylene, 7 ml 1.0 M MAO, and 6.9 mg of preactivated compound A (6 ml of a 11.5 mg of compound A plus 0.5 ml of 1 M MAO in 9.5 ml of toluene) were added into the reactor. The reactor was then heated to 50°C. The polymerization reaction was limited to 30 minutes. The reaction was ceased by rapidly cooling and venting the system. The solvent was evaporated off of the polymer by a stream of nitrogen. Atactic polypropylene was recovered (2.9 g, MW = 5100, MWD = 1.86, $r = 0.452$, $\text{rrrr} = .049$, $m = 0.548$, $\text{mmmm} = 0.086$).

Polymerization Example II

Using the same reactor design and general procedure already described, 500 ml of propylene, 1 ml of 1.0 M MAO, and 1 mg of compound B in 1.0 ml of 1.0 M MAO were added to the reactor. The reactor was heated at 60°C and the reaction was allowed to run for 2 hours, followed by rapidly cooling and venting the system. After evaporation of the excess propylene, 113 g of polypropylene was recovered (MW = 723,700, MWD = 1.849, $r = 0.586$, $\text{rrrr} = 0.074$, $m =$

2166055

- 45 -

0.432, mmmm = 0.034). The polymer exhibited a slight melting point at 129°C.

Polymerization Example III

Using the same reactor design and general
5 procedure already described, 400 ml of propylene, 2
ml of 1.0 M MAO, and 1 mg of compound B in 1.0 ml of
1.0 M MAO were added to the reactor. The reactor
was heated at 40°C and the reaction was allowed to
run for 1 hour, followed by rapidly cooling and
10 venting the system. After evaporation of the excess
propylene, 126 g of polypropylene was recovered (MW
= 1,255,000, MWD = 1.90, r = 0.56, rrr = -.07, m =
0.44, mmmm = 0.04).

The characterization Data for Examples I-III
15 are presented in Table 2. The data show that these
products are amorphous.

With respect to the whole of the present
invention, by appropriate selection of (1) Group IVB
transition metal component for use in the catalyst
20 system; (2) the type and amount of alumoxane used;
(3) the polymerization diluent type and volume; and
(4) reaction temperature, one may tailor the product
polymer to the weight average molecular weight value
desired and to the tacticity desired while still
25 maintaining the molecular weight distribution at a
value below about 6.0, preferably below 4.0.

The resins that are prepared in accordance
with this invention can be used to make a variety of
products including films, fibers, adhesives,
30 compatibilizers and molded articles.

The invention has been described with reference
to its preferred embodiments. Those of ordinary
skill in the art may, upon reading this disclosure,

2166055

- 46 -

appreciate changes or modifications which do not depart from the scope and spirit of the invention as described above or claimed hereafter.

2166055

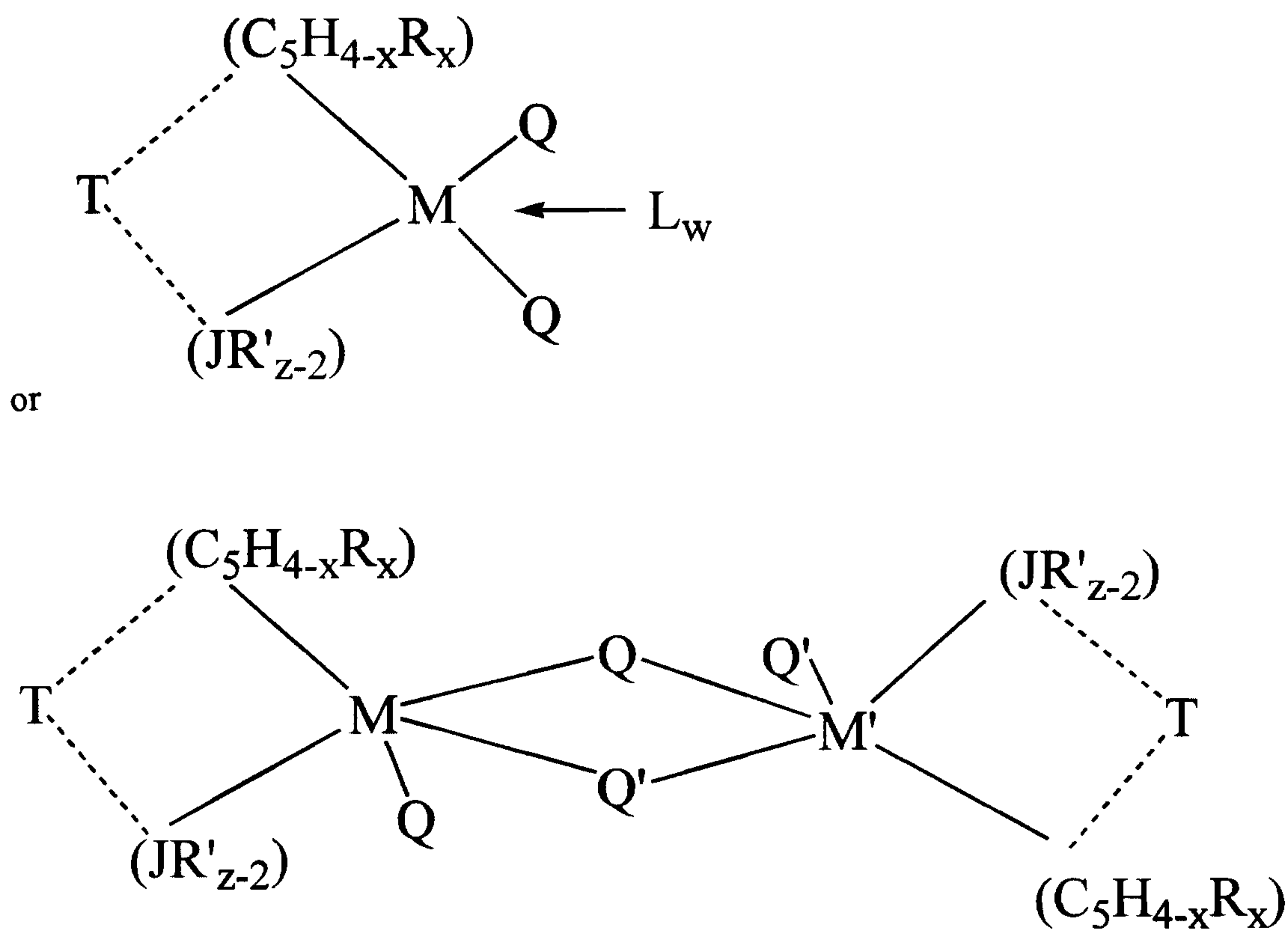
- 47 -

Table 2

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Example #	Catalyst	TMC (mmol)	MAO (mmol)	AVTMC	Temp (C)	C3 (ml)	Toluene (ml)	Run Time (hr)	Yield (g)	gP/mmolTM.hr	MW	MWD	M.P. (C)	m	mmmm	r	rrrr
1	A	1.68E-02	7.3	435	50	400	100	0.5	2.9	346	5,100	1.861	-	-	-	-	-
2	B	2.09E-03	2.0	957	60	500	0	2.0	113.0	27033	723,700	1.849	-	0.432	0.034	0.568	0.074
3	B	2.10E-03	3.0	1429	40	400	0	1.0	125.7	59857	1,255,400	1.903	-	0.440	0.040	0.560	0.070

CLAIMS:

1. A process for producing amorphous polypropylene comprising the steps of:
- (i) contacting propylene under polymerization conditions with a catalyst system comprising;
 - (A) an activator, and
 - (B) a transition metal component represented by the formulae:



wherein M is Ti in its highest formal oxidation state;

$(C_5H_{4-x}R_x)$ is a cyclopentadienyl ring which is symmetrically substituted with two or four substituent groups R, with "x" denoting the degree of substitution ($x = 2$ or 4) and each R is, independently, a radical selected from a group consisting of C_1 - C_{20} hydrocarbyl radicals, substituted C_1 - C_{20} hydrocarbyl radicals wherein one or more hydrogen atoms is

replaced by a halogen radical, an amido radical, a phosphido radical, an alkoxy radical or any other radical containing a Lewis acidic or basic functionality, C_1-C_{20} hydrocarbyl-substituted metalloid radicals wherein the metalloid is selected from the Group IV A of the Periodic Table of Elements, and halogen radicals, amido radicals, phosphido radicals, alkoxy radicals, alkylborido radicals and a radical containing Lewis acidic or basic functionality, and at least two adjacent R-groups are joined forming C_4-C_{20} ring to give a saturated or unsaturated polycyclic cyclopentadienyl ligand.

(JR'_{z-2}) is a heteroatom ligand in which J is an element with a coordination number of three from Group V A or an element with a coordination number of two from Group VI A of the Periodic Table of Elements, and each R' is, independently, a radical selected from a group consisting of C_1-C_{20} hydrocarbyl radicals, substituted C_1-C_{20} hydrocarbyl radicals where one or more hydrogen atom is replaced by a halogen radical, an amido radical, a phosphido radical, and alkoxy radical or any other radical containing a Lewis acidic or basic functionality, and "z" is the coordination number of the element J;

each Q is, independently, a halide, hydride, or a substituted or unsubstituted C_1-C_{20} hydrocarbyl, alkoxide, aryloxide, amide, arylamide, phosphide or arylphosphide, or both Q together are an alkylidene, or a cyclometallated hydrocarbyl or any divalent anionic chelating ligand;

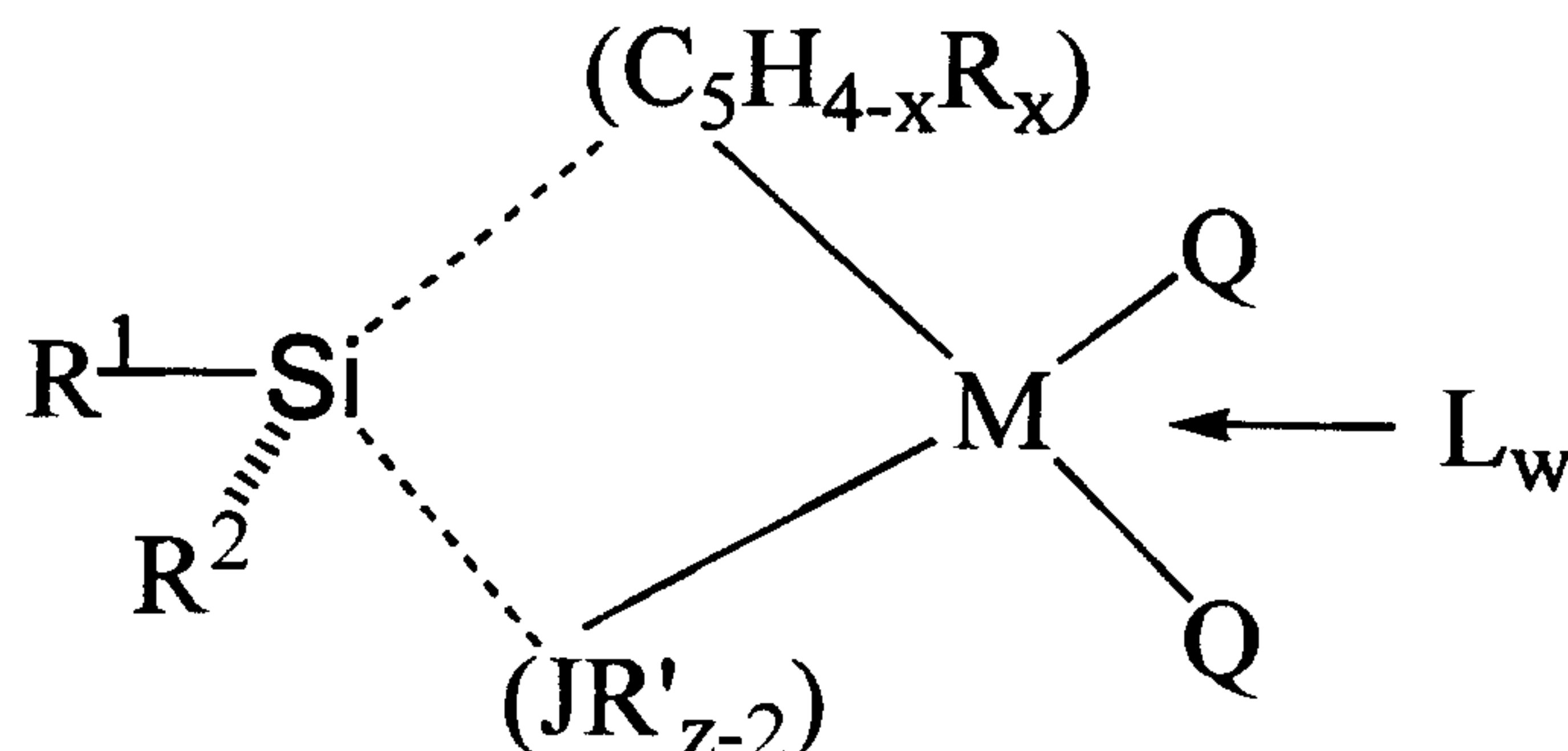
T is a covalent bridging group containing a Group IV A or V A element;

M' has the same meaning as M and Q' has the same meaning as Q;

L is a neutral Lewis base where "w" denotes a number from 0 to 3; and

(ii) recovering an amorphous polypropylene.

2. The process of claim 1 wherein the Group IV B transition metal component is of the formula:



wherein R^1 and R^2 are, independently, a C_1 to C_{20} hydrocarbyl radical, substituted C_1 to C_{20} hydrocarbyl radical wherein one or more hydrogen atom is replaced by a halogen atom; R^1 and R^2 may also be joined forming a C_3 to C_{20} ring.

3. The processes of claims 1 or 2 wherein the activator is an alumoxane.
4. The processes of claim 3, wherein J is nitrogen.
5. The process of any one of claims 1 to 4 wherein R is a C_1 to C_{20} hydrocarbyl radical and R' is a C_6 to C_{20} cyclohydrocarbyl radical or an aromatic radical.
6. The process of any one of claims 1 to 4 wherein R' is an alkyl radical or cyclic radical.
7. The process of any one of claims 1 to 6 wherein comonomer is present and is selected from the group consisting of C_3 to C_{20} alpha-olefins.
8. The process of any one of claims 1 to 7 where the transition metal component is selected from the group consisting of dimethylsilyl (tetramethylcyclopentadienyl) (t-butylamido) titanium dichloride, dimethylsilyl (3,4-di-t-butylcyclopentadienyl) (cyclododecylamido) titanium dichloride and dimethylsilyl (2,5-dimethylcyclopentadienyl) cyclododecylamido titanium dichloride.
9. A completely atactic amorphous polypropylene having a weight average molecular weight greater than 200,000.
10. A substantially atactic amorphous polypropylene having a weight average molecular weight greater than 500,000.

any other radical containing a Lewis acidic or basic functionality, C_1 - C_{20} hydrocarbyl-substituted metalloid radicals wherein the metalloid is selected from the Group IV A of the Periodic Table of Elements, and halogen radicals, amido radicals, phosphido radicals, alkoxy radicals, alkylborido radicals and a radical containing Lewis acidic or basic functionality, and at least two adjacent R-groups are joined forming C_4 - C_{20} ring to give a saturated or unsaturated polycyclic cyclopentadienyl ligand;

(JR'_{z-2}) is a heteroatom ligand in which J is an element with a coordination number of three from Group V A or an element with a coordination number of two from Group VI A of the Periodic Table of Elements, and each R' is, independently, a radical selected from a group consisting of C_1 - C_{20} hydrocarbyl radicals, substituted C_1 - C_{20} hydrocarbyl radicals where one or more hydrogen atom is replaced by a halogen radical, an amido radical, a phosphido radical, and alkoxy radical or any other radical containing a Lewis acidic or basic functionality, and "z" is the coordination number of the element J;

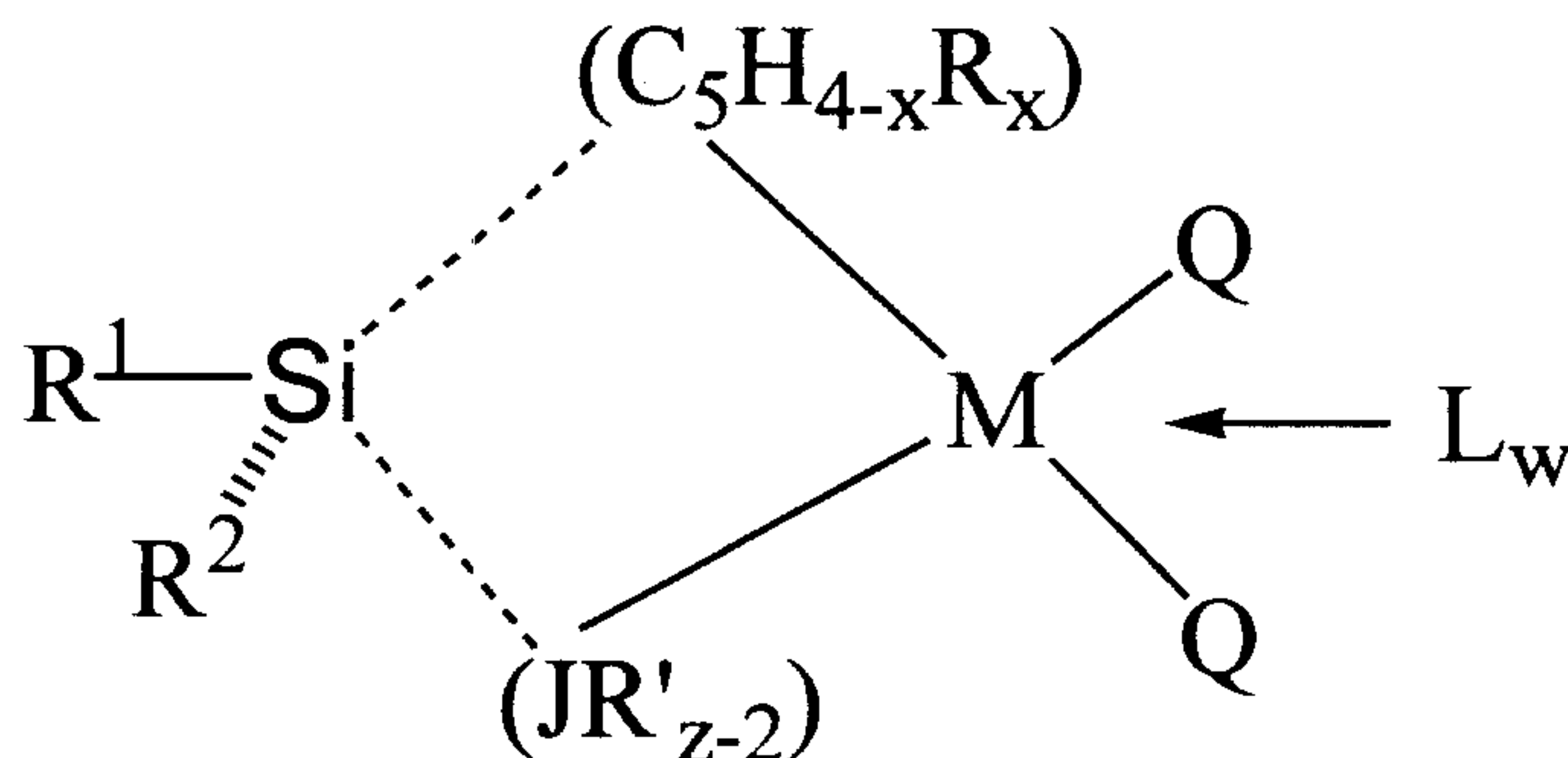
each Q is, independently, a univalent anionic ligand selected from a halide, hydride, or a substituted or unsubstituted C_1 - C_{20} hydrocarbyl, alkoxide, aryloxide, amide, arylamide, phosphide or arylphosphide, or both Q together are an alkylidene, or a cyclometallated hydrocarbyl or any divalent anionic chelating ligand; Q' has the same meaning as Q;

T is a covalent bridging group containing a Group IV A or V A element;

L is a neutral Lewis base where "w" denotes a number from 0 to 3; and

(ii) recovering an amorphous polypropylene.

12. The amorphous polypropylene of claim 11 wherein the transition metal component is a compound represented by this formula:



wherein R^1 and R^2 are, independently, a C_1 - C_{20} hydrocarbyl radicals, substituted C_1 to C_{20} hydrocarbyl radicals wherein one or more hydrogen atom is replaced by a halogen atom; R^1 and R^2 may also be joined forming a C_3 to C_{20} ring.

13. The polypropylene of claim 11 which is atactic.

14. The polypropylene of claim 11 which has a weight average molecular weight of greater than 500,000.

15. An article of manufacture comprising the polypropylene of claim 14.

16. The polypropylene of claim 12 which is atactic.

17. The polypropylene of claim 12 which has a weight average molecular weight of greater than 500, 000.

18. An article of manufacture comprising the polypropylene of claim 17.