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(57) **Abrégé/Abstract:**

Process for the carbonylation of an acetylenically unsaturated compound by reaction with carbon monoxide and a co-reactant in the presence of a catalyst system based on (a) a source of platinum; (b) a source of anions and (c) a diphosphine of the following formula (1) $R^1>P-R^2-PR^3R^4$ wherein R^2 represents a covalent bridging group, R^1 represents a bivalent radical that together with the phosphorus atom to which it is attached is an optionally substituted 2-phospha-tricyclo[3.3.1.1{3,7}]decyl group or a derivative thereof in which one or more of the carbon atoms are replaced by heteroatoms ("2-PA" group), and wherein R^3 and R^4 independently represent univalent radicals of up to 20 atoms or jointly form a bivalent radical of up to 20 atoms.



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(54) Title: PROCESS FOR THE CARBONYLATION OF AN ACETYLENICALLY UNSATURATED COMPOUND

(57) Abstract: Process for the carbonylation of an acetylenically unsaturated compound by reaction with carbon monoxide and a co-reactant in the presence of a catalyst system based on (a) a source of platinum; (b) a source of anions and (c) a diphosphine of the following formula (1) $R^1>P-R^2-PR^3R^4$ wherein R^2 represents a covalent bridging group, R^1 represents a bivalent radical that together with the phosphorus atom to which it is attached is an optionally substituted 2-phospha-tricyclo[3.3.1.1{3,7}]decyl group or a derivative thereof in which one or more of the carbon atoms are replaced by heteroatoms ("2-PA" group), and wherein R^3 and R^4 independently represent univalent radicals of up to 20 atoms or jointly form a bivalent radical of up to 20 atoms.

WO 01/28972 A1

CA 02387948 2002-04-18

- 1 -

TS 0937 PCT

PROCESS FOR THE CARBONYLATION OF AN ACETYLENICALLY
UNSATURATED COMPOUND

The invention is related to a process for the carbonylation of an acetylenically unsaturated compound by reaction with carbon monoxide and a co-reactant in the presence of a catalyst system based on (a) a source of platinum; (b) a source of anions and (c) a diphosphine. The invention is especially directed to a process in which linear carbonylation products are selectively prepared.

In view of the fact that for a number of outlets the availability of linear, rather than branched carbonylated products would be desirable, e.g. in the preparation of components of detergent compositions, efforts have been made to increase the selectivity with respect to linear carbonylation products. WO-A-9421585 describes a process, wherein use is made of a catalyst system based on platinum, a bisphosphine ligand and a source of anions, typically a strong acid. A disadvantage of this process is that the activity of this catalyst system is somewhat low, being in the order of 20 to 200 mole product per mole Pt per hour for acetylene as reactant.

A process having a higher catalyst activity is known from WO-A-9720803. A carbonylation of acetylene with carbon monoxide and t-butyl alcohol is described using a catalyst system consisting of 1,2-P,P'-bis(9-phosphabicyclononyl)ethane as the ligand, platinum(II)(acetylacetonate)₂ as the platinum source, methane sulphonic acid as the anion source, SnCl₂ and 2,5,8-tri-oxanonane.

A disadvantage of this process is that SnCl_2 has to be present in order to achieve an acceptable activity and selectivity. The use of SnCl_2 is not preferred because

when performing this process in a continuous manner SnCl_2 will be lost due to alcoholysis. This is not desirable because new SnCl_2 has to be added and the tin alkoxyde formed will have to be discharged resulting in obvious environmental problems. Furthermore when tin alkoxyde is removed from the process by means of a purge additional catalyst will be lost. It is therefore highly desirable to perform such a carbonylation process in the absence of tin chloride compounds like SnCl_2 .

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US-A-5719313 describes the carbonylation of propyne with CO and methanol using a catalyst system consisting of palladium (II) acetate, bisphenyl(2-pyridyl)phosphine and methanesulfonic acid. A disadvantage of this process is that the mono phosphine ligand is consumed in the process by 'quarternization' of the ligand with the acrylate product. A further disadvantage of this process is that mostly branched products are formed.

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EP-A-0441446 describes the carbonylation of ethene and the carbonylation of propyne with CO and a hydroxy group containing compound using a catalyst system consisting of palladium (II) acetate, a sulphonic acid, a bisphenyl(2-pyridyl) mono-phosphine and a tertiary amine as promoter. A disadvantage of this process is that a promoting compound in the form of a tertiary amine is necessary. A further disadvantage of this process is that mostly branched products are formed.

30
WO-A-9842717 describes the carbonylation of ethene with carbon monoxide and methanol in the presence of a catalyst system consisting of platinum (II) (acetyl-acetonate)₂, 1,3-P,P'-di(2-phospha-1,3,5,7-tetramethyl-6,9,10-trioxatricyclo[3.3.1.1{3.7}decyl)propane and methanesulphonic acid. The publication does not disclose

CA 02387948 2002-04-18

- 2a -

that acetylenically unsaturated compounds can be carbonylated using such a catalyst system.

5 The object of the present invention is a process for the carbonylation of acetylene to linear products, which process can be performed in the absence of SnCl_2 . Such a process is described below. Process for the carbonylation of an acetylenically unsaturated compound by reaction with carbon monoxide and a co-reactant in the presence of a catalyst system based on (a) a source of platinum; (b)
10 a source of anions and (c) a diphosphine of the following formula



wherein R^2 represents a covalent bridging group, R^1 represents a bivalent radical that together with the phosphorus atom to which it is attached is an optionally substituted 2-phospha-tricyclo[3.3.1.1{3,7}]decyl group or a derivative thereof in which one or more of the carbon atoms are replaced by heteroatoms ("2-PA" group), and wherein R^3 and R^4 independently represent univalent radicals of up to 20 atoms or jointly form a bivalent radical of up to 20 atoms.

With the above process the carbonylation can be performed with a good turn over rate, a high selectivity to the desired carbonylation products and in the absence of $SnCl_2$. It has furthermore been found that the ligand is stable over a prolonged period of time making it very suitable for use in a continuously operated commercial application.

Tricyclo[3.3.1.1{3,7}]decane is the systematic name for a compound more generally known as adamantane. Therefore, the optionally substituted 2-phospha-tricyclo[3.3.1.1{3,7}]decyl group will be referred to as "2-PA" group (as in 2-phosphadamantyl group) throughout the specification.

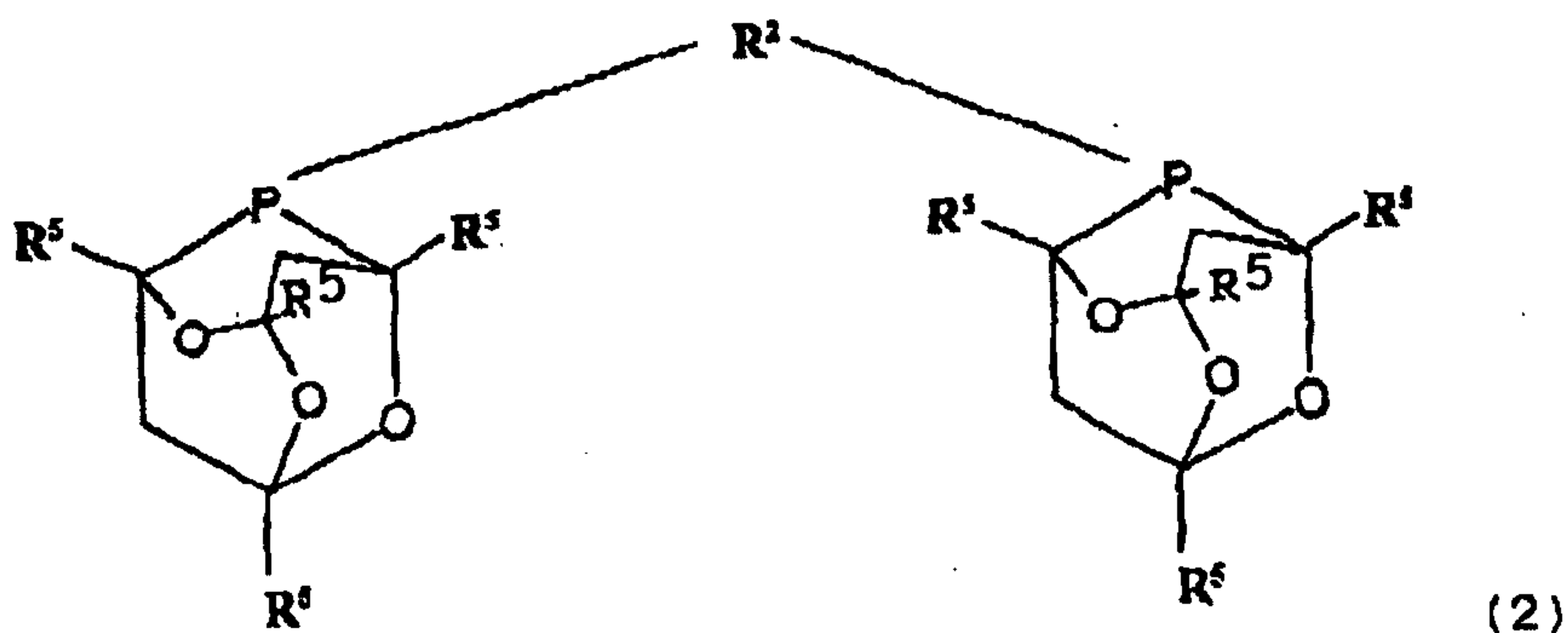
The 2-PA group has preferably additional heteroatoms other than the 2-phosphorus atom in its skeleton. Suitable heteroatoms are oxygen and sulphur atoms. Suitably, these heteroatoms are found in the 6, 9 and 10 positions. The most preferred bivalent radical is the 2-phospha-1,3,5,7-tetramethyl-6,9,10-trioxadamantyl group. Preferably, the 2-PA group is substituted on one or more of the 1, 3, 5 or 7 positions with a monovalent radical R^5 of up to 20 atoms. Typical examples of R^5 include methyl, trifluoromethyl, ethoxy, phenyl, and 4-dodecylphenyl. More preferably, the 2-PA group is

substituted on each of the 1, 3, 5 and 7 positions,
suitably with identical radicals R^5 .

Each of the monovalent radicals R^3 and R^4 may inde-
pendently be selected from (substituted) hydrocarbyl
5 groups such as, for instance, methyl, phenyl, pyridyl, or
o,o-di(t-butoxy)phenyl, and (substituted) heterohydro-
carbyl groups such as, for instance, trimethylsilyl or
alkoxy groups. Alternatively, R^3 and R^4 may together form
a bivalent radical, such as 1,6-hexylene, 1,3 or
10 1,4-cyclooctylene. Preferably, R^3 and R^4 together with
the phosphorus atom form a 2-PA group. Most preferably R^2
connects two identical 2-PA groups.

The bridging group R^2 can be an organic bivalent
group having up to 20 atoms. Examples of such bridging
15 groups are ferrocenyl and nickelocenyle. Preferably R^2
has 2 to 4 atoms in the shortest chain of atoms directly
connecting the two phosphorus atoms. Most preferably the
number of atoms in the shortest chain of atoms directly
connecting the two phosphorus atoms is 3. Preferably the
20 atoms in the chain are carbon atoms. Examples of
preferred bridging groups are ortho xylyl, ethylene and
tri-methylene groups.

A suitable example of such a ligand is one according
to the following general formula:



25 in which R^5 and R^2 can be as describes above.

Examples of ligands which may be used in the process according to the invention are exemplified in the above

cited WO-A-9842717. Most preferably 1,2-P,P'-di(2-phos-
pha-1,3,5,7-tetramethyl-6,9,10-trioxatricyclo-
[3.3.1.1{3.7}decyl)ethane (DPA2) and 1,3-P,P'-
5 di(2-phospha-1,3,5,7-tetramethyl-6,9,10-trioxatri-
cyclo[3.3.1.1{3.7}decyl)propane (DPA3) are used.

For the preparation of the catalyst system to be used
in the process of the invention, the amount of bidentate
ligand is suitably applied in some excess of the amount
of platinum, expressed as moles of bidentate ligand per
10 mole atom of platinum. The active species, however, is
believed to be based on an equimolar amount of bidentate
ligand per mole platinum. Thus, the molar amount of
bidentate ligand per mole of platinum is suitably in the
range of 1 to 3, preferably in the range of 1 to 2.

15 As regards the source of platinum, i.e.,
component (a) of the catalyst system, any platinum
compound allowing complexing between the metal and the
bidentate ligand may be used. Suitable compounds are for
instance, metallic platinum, zerovalent platinum
20 complexes, such as tetrakis(triphenylphosphine)platinum;
and tetra- or divalent platinum salts. In particular
platinum(II) salts are suitable, such as dipotassium
tetracyanoplatinate, disodium tetracyanoplatinate,
dipotassium tetrachloroplatinate, potassium trichloro
25 (ethylene) platinate, sodium trichloro (ethylene)
platinate, platinum-bis(cyanobenzene) disulphate and
platinum-bis(triphenylphosphine) disulphate. Salts of
platinum with carboxylic acids, in particular with
carboxylic acids having from 2 to 12 carbon atoms, are
30 also suitable, for example platinum diacetate, platinum
dipropionate and platinum dihexanoate. Organic
platinum(II) complexes are preferably applied as source
of platinum, platinum(II) acetylacetonate being
particularly suitable.

The molar amount of anion per mole of platinum is conveniently selected in the range of 1 to 12. Preferably the anion is applied in a molar amount per mole of platinum in the range of 1 to 8.

5 The process of the invention is carried out with catalytic amounts of the catalyst system, i.e. per mole of acetylenically unsaturated compound, 10^{-8} to 10^{-1} mole of platinum is present, preferably from 10^{-7} to 10^{-2} , on the same basis.

10 The catalyst systems used in the process of the invention comprises further a source of anions as component (b). It is believed that the size of the anion and the distribution of electric charge in the anion significantly contribute to the stability of the catalyst
15 system. Preferably, anions are used that are the conjugated base of acids having a pKa (measured at 18 °C in water) of less than 4. Suitable anions include anions derived from Bronsted acids, in particular from
20 carboxylic acids, such as 2,6-dichlorobenzoic acid, and 2,6-bis(trifluoromethyl)benzoic acid or trifluoroacetic acid; and from sulphonic acids, such as methanesulphonic acid, and trifluoromethanesulphonic acid.

The acetylenically unsaturated compounds which may suitably be employed as starting material in the process
25 of the invention, include compounds containing from 2 to 20 carbon atoms, optionally containing one or more inert substituents, such as halogen atoms or hydroxygroups. Preferably, the acetylenically unsaturated compounds has from 2 to 8 carbon atoms per molecule. The acetylenically
30 unsaturated bond is usually the only carbon-carbon unsaturation in the molecule. In view of the envisaged preparation of mainly linear carbonylated products, it is preferably located at a terminal position. Examples of suitable acetylenically unsaturated compounds are
35 acetylene (= ethyne), methylacetylene (= propyne),

1-butynes, 1-pentyne, 1-hexyne, 1-octyne, phenylacetylene and 3-hydroxybutyne. Acetylene is most preferred.

Suitable co-reactants in the process of the invention are hydrogen-containing compounds whereby a carbon monoxide molecule and at least one acetylenically unsaturated compound can be inserted into the bond between the hydrogen atom and the molecule of the co-reactant. Examples thereof include nucleophilic compounds containing at least one mobile hydrogen atom.

Preferred nucleophilic compounds include: water and alcohols, e.g., monohydric alcohols, such as methanol, ethanol, isopropanol and 1-butanol, and polyhydric alcohols, such as ethyleneglycol, 1,4-butanediol and glycerol; thiols; primary or secondary amines or amides; phenols and carboxylic acids, for example acetic acid, pivalic acid and propionic acid. Monohydric alcohols having from 1 to 6 carbon atoms are preferred, in particular methanol and butanol.

Another category of suitable co-reactants comprises hydride sources such as molecular hydrogen and compounds capable of generating molecular hydrogen. In particular for embodiments of the process whereby an acetylenically unsaturated compound is hydroformylated, molecular hydrogen is a preferred co-reactant.

Finally, also a combination of a nucleophilic compound and a hydride source as defined above may be used, to prepare a carbonylation-hydroformylation product.

The carbonylation process of the invention is generally carried out at a reaction temperature in the range of 40 to 200 °C, more suitably at a temperature in the range of 50 to 160 °C.

The total reaction pressure is usually in the range of 5 to 150 bar absolute (bara). Pressures between 10 and 80 bara and in particular between 30 and 60 bara are

preferred. In carbonylation reactions of the hydro-
formylation type, the total pressure is usually the sum
of the partial pressures of carbon monoxide and hydrogen.
The molar ratio between these gases may vary, but is
5 conveniently maintained in the range of 1:2 to 2:1.
Preferably, substantially equimolar amounts of carbon
monoxide and hydrogen are used. In other carbonylation
reactions, involving no hydrogen, or only insignificant
amounts thereof, the total pressure is roughly the same
10 as the carbon monoxide pressure.

The process of the invention may be carried out in
the absence of a separate diluent or solvent, if so
desired. However, it is often convenient to have a liquid
diluent or solvent present at the beginning of the
15 reaction, e.g. if a volatile acetylenic starting material
is used, or if the reaction requires a relatively long
induction period and continued thorough mixing of the
reactants is desirable. Suitable solvents are, in
particular, aprotic compounds such as ethers or ketones,
20 for example 2,5,8-trioxanonane, diethylether, acetone,
diglyme and methyl ethylketone.

The invention is further illustrated by the following
non-limiting examples.

Example 1

25 (a) A 250 ml "Hastelloy C" (trademark) magnetically
stirred autoclave was charged with acetylene (1.4 bara),
30 ml of 1-propanol, 0.1 mmol of Pt(acac)₂, 0.12 mmol of
DPA-3 ligand (see above), 0.25 mmol of methyl sulfonic-
acid and 30 ml diglyme as solvent.

30 The autoclave was pressurised with 40 bara carbon
monoxide and then sealed. The temperature of the mixture
was raised to 115 °C. Complete conversion of acetylene
was reached in shorter than 30 minutes at 115 °C and
Glc analysis after cooling and depressurizing, showed a
35 selectivity of 90 mol% to propyl acrylate. A propyl

acrylate formation rate of about 2000 t.o./hr/
mol Pt was calculated. Some byproducts are succinate and
malonate diesters; these are due to consecutive
carbonylation of acrylate at complete acetylene
conversion. In a commercial operation the selectivity
will be higher by keeping the acetylene conversion per
pass below the 100%.

Example 2

Example 1 was repeated except that the co-reactant
was 30 ml methanol and that as acetylenically unsaturated
compound 10 ml phenyl acetylene was used. The reaction
time was 1 hour. A phenyl acrylate formation rate of
1000 turnovers per hour per mol Pt was calculated. The
products consisted of 52% of linear 3-phenyl acrylate and
48% of 2-phenyl acrylate.

Example 3

Example 2 was repeated except that as acetylenically
unsaturated compound 10 ml 1-pentyne was used. The
reaction time was 1 hour. A pentyne consumption rate of
300 turnovers per hour per mol Pt was calculated. The
products consisted of 65% of linear methyl 2-hexenoate
and 35% of 2-methyloxy carbonyl 1-pentene.

Example 4

Example 1 was repeated except that as ligand DPA-2
(see above) was used and as co-reactant 30 ml methanol. A
methyl acrylate formation rate of about 290 t.o./hr/(mol
Pt) was calculated. The reaction time was one hour and
the selectivity towards methyl acrylate was 76 wt%.

CA 02387948 2002-04-18

- 10 -

TS 0937 PCTC L A I M S

1. Process for the carbonylation of an acetylenically unsaturated compound by reaction with carbon monoxide and a co-reactant in the presence of a catalyst system based on (a) a source of platinum; (b) a source of anions and
5 (c) a diphosphine of the following formula



wherein R^2 represents a covalent bridging group, R^1 represents a bivalent radical that together with the phosphorus atom to which it is attached is an optionally
10 substituted 2-phospha-tricyclo[3.3.1.1(3,7)]decyl group or a derivative thereof in which one or more of the carbon atoms are replaced by heteroatoms, and wherein R^3 and R^4 independently represent univalent radicals of up to 20 atoms or jointly form a bivalent radical of up to
15 20 atoms.

2. Process according to claim 1, wherein R^3 and R^4 together with the phosphorus atom to which it is attached form an optionally substituted 2-phospha-tricyclo-
20 [3.3.1.1(3,7)]decyl group or a derivative thereof in which one or more of the carbon atoms are replaced by hetero atoms, identical to the group formed by R^1 together with the phosphorus atom to which it is attached.

3. Process according to claim 2, wherein the optionally substituted 2-phospha-tricyclo[3.3.1.1(3,7)]decyl group or a derivative thereof in which one or more of the
25 carbon atoms are replaced by hetero atoms is substituted

CA 02387948 2002-04-18

- 11 -

on one or more of the 1, 3, 5 or 7 positions with a monovalent radical R⁵ of up to 20 atoms.

4. Process according to claim 3, wherein R⁵ is a radical selected from methyl, trifluoromethyl, ethoxy, phenyl, and 4-dodecylphenyl.

5. Process according to claim 4, wherein the optionally substituted 2-phospha-tricyclo[3.3.1.1(3,7)]decyl group or a derivative thereof in which one or more of the carbon atoms are replaced by hetero atoms is a 2-phospha-1,3,5,7-tetramethyl-6,9,10-trioxadamantyl group.

6. Process according to any one of claims 1-5, wherein R² has 2 to 4 atoms in the shortest chain of atoms directly connecting the two phosphorus atoms.

7. Process according to any one of claims 1-6, wherein the acetylenically compound has from 2 to 8 carbon atoms.

8. Process according to claim 7, wherein the acetylenically compound is acetylene.

9. Process according to any one of claims 1-8, wherein the co-reactant is a monohydric alcohols having from 1 to 6 carbon atoms.

10. Process according to any one of claims 1-9, wherein the source of anions is the conjugated base of acids having a pK_a, as measured at 18 °C in water, of less than 4.

11. Process according to claim 10, wherein the acid is methanesulfonic acid.

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