

Process for the direct conversion of alkenes to carboxylic acids

5 The invention relates to a process for the direct conversion of alkenes to carboxylic acids.

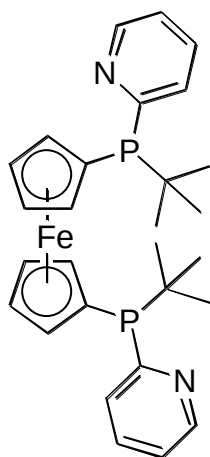
Carboxylic acids are used in the preparation of polymers, pharmaceuticals, solvents and food additives. The routes leading to carboxylic acids generally include the oxidation of hydrocarbons, alcohols or aldehydes, the oxidative cleavage of olefins by ozonolysis, the
10 hydrolysis of triglycerides, nitriles, esters or amides, the carboxylation of Grignard or organolithium reagents, and the halogenation and subsequent hydrolysis of methyl ketones in the haloform reaction.

The object of the invention was to provide a process with which alkenes can be directly
15 converted to a carboxylic acid.

In the context of this application, "direct conversion" is intended to mean that the reaction takes place in one step, i.e. without separation or work-up or similar of an intermediate product.
20 This does not exclude, in the course of the reaction, intermediates forming which are directly converted onward.

The object is achieved by a process according to Claim 1.

25 Process comprising the process steps of:
a) addition of an alkene;
b) addition of a complex, comprising a compound according to structure (1) and also Pd, or a compound according to structure (1) and a substance comprising Pd



(1)

- c) feeding in CO;
 d) heating the reaction mixture such that the alkene is converted to a carboxylic acid, wherein the alkene is directly converted to the carboxylic acid.

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In a variant of the process, the substance in process step b) is selected from:
 PdCl_2 , PdBr_2 , $\text{Pd}(\text{acac})_2$, $\text{Pd}(\text{dba})_2$ (dba = dibenzylideneacetone), $\text{PdCl}_2(\text{CH}_3\text{CN})_2$.

In a variant of the process, the substance in process step b) is $\text{Pd}(\text{acac})_2$.

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In a variant of the process, the process comprises the additional process step e):
 e) addition of acetic acid.

In a variant of the process, the process comprises the additional process step f):

15

f) addition of water.

In a variant of the process, the process comprises the additional process step g):
 g) addition of p-toluenesulfonic acid (PTSA).

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In a variant of the process, the reaction mixture is heated to a temperature in the range from 80°C to 160°C in process step d).

In a preferred variant of the process, the reaction mixture is heated to a temperature in the range from 100°C to 140°C in process step d).

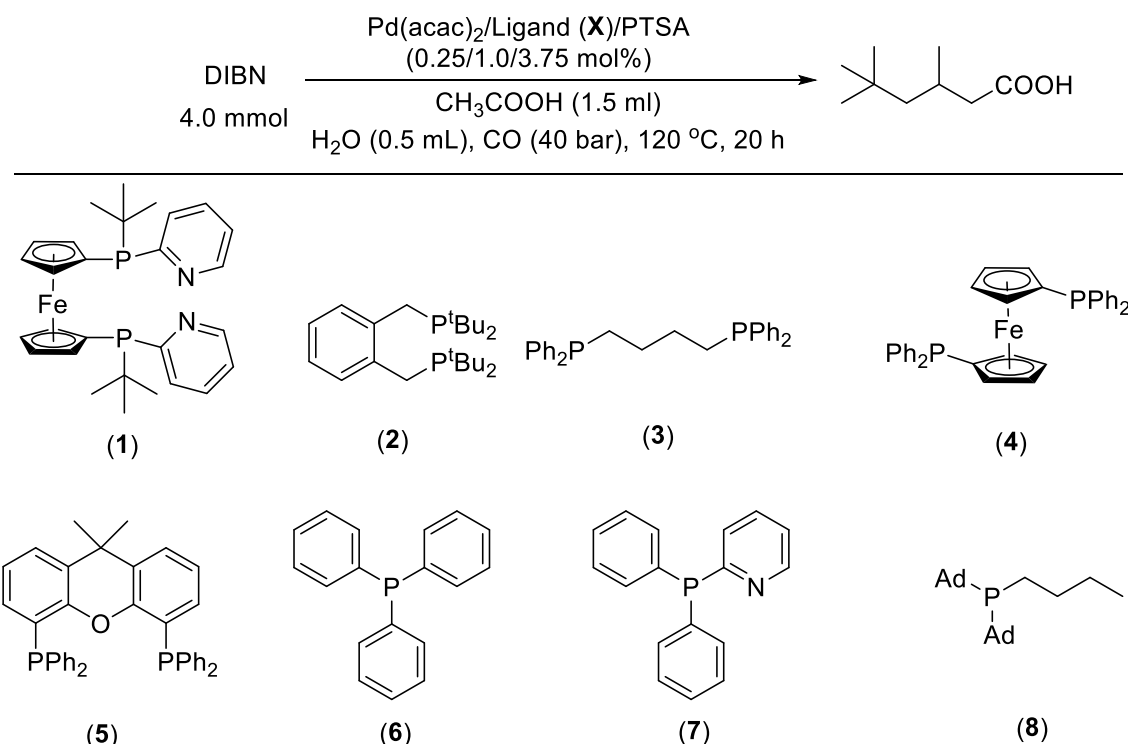
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In a variant of the process, the CO is fed in in process step c) such that the reaction proceeds under a CO pressure in the range from 20 bar to 60 bar.

In a preferred variant of the process, the CO is fed in in process step c) such that the reaction proceeds under a CO pressure in the range from 30 bar to 50 bar.

The invention is more particularly elucidated hereinbelow with reference to working examples.

Variation of the ligand



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A 4 ml vial was charged with $[\text{Pd}(\text{acac})_2]$ (3.05 mg, 0.25 mol%), ligand (X) (1.0 mol%), para-toluenesulfonic acid (28.5 mg, 3.75 mol%) and an oven-dried stirrer bar. The vial was then sealed with septa (PTFE-coated styrene-butadiene rubber) and a phenol resin cap. The vial was evacuated and refilled with argon three times. H_2O (0.5 ml), acetic acid (1.5 ml) and diisobutene (DIBN) (4.0 mmol) were added to the vial with a syringe. The vial was placed in an alloy plate, which was transferred to an autoclave (300 ml) of the 4560 series from Parr Instruments under argon atmosphere. After flushing the autoclave three times with CO, the pressure of CO was increased to 40 bar at room temperature. The reaction was conducted at 120°C for 20 h. On conclusion of the reaction, the autoclave was cooled down to room temperature and cautiously decompressed. Isooctane (100 μl) was then added as internal standard. Conversion was measured by GC analysis.

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The above-described experiment was carried out with variation of the ligand (**X**), with **X** = **1** to **8**.

The results are compiled in the following table 1:

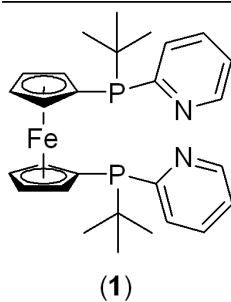
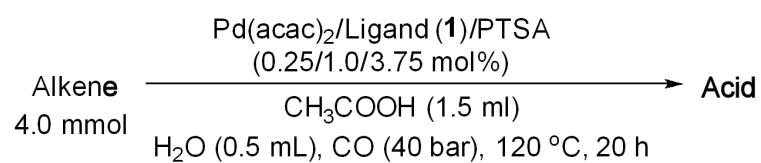
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Table 1:

Ligand	Yield (%)
(1) [*]	> 99
(2)	7
(3)	39
(4)	26
(5)	16
(6)	8
(7)	13
(8)	29

* inventive process

10 Variation of the alkene

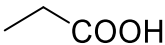
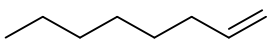
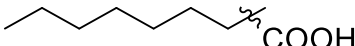
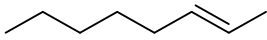
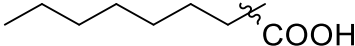
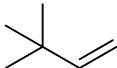
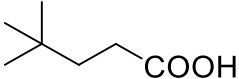
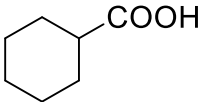
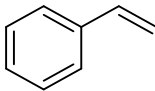
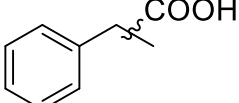
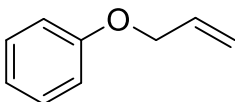
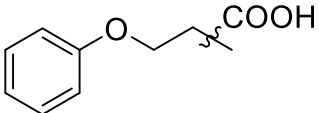


A 4 ml vial was charged with [Pd(acac)₂] (3.07 mg, 0.25 mol%), ligand (**1**) (20.64 mg, 1.0 mol%), p-toluenesulfonic acid (28.5 mg, 3.75 mol%) and an oven-dried stirrer bar. The vial was then sealed with septa (PTFE-coated styrene-butadiene rubber) and a phenol resin cap. The vial was then connected to the atmosphere with a needle. The vial was
5 evacuated and refilled with argon three times. H₂O (0.5 ml), acetic acid (1.5 ml) and alkene (4.0 mmol) were added to the vial with a syringe. The vial was placed in an alloy plate, which was transferred to an autoclave (300 ml) of the 4560 series from Parr Instruments under argon atmosphere. After flushing the autoclave three times with CO, the pressure of CO was increased to 40 bar at room temperature. The reaction was
10 conducted at 120°C for 20 h. On conclusion of the reaction, the autoclave was cooled down to room temperature and cautiously decompressed. Isooctane (100 µl) was then added as internal standard. Conversion was measured by GC analysis.

The experiment described above was repeated with variation of the alkene.

The results are compiled in the following table 2:

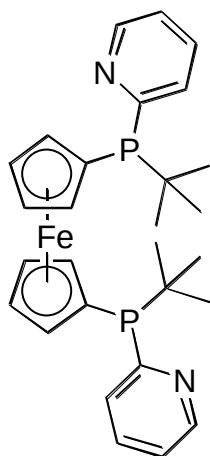
Table 2:

Alkene	Acid	Yield
		99%
		98%, n/iso mixture
		97%, iso mixture
		99%
		80%
		95%, n/iso mixture
		94%, n/iso mixture

- 5 As the experimental results show, the object is achieved by a process according to the invention.

Claims

1. Process comprising the process steps of:
 - a) addition of an alkene;
 - 5 b) addition of a complex, comprising a compound according to structure (1) and also Pd,
 - or a compound according to structure (1) and a substance comprising Pd



(1)

- c) feeding in CO;
 - 10 d) heating the reaction mixture such that the alkene is converted to a carboxylic acid,
 - wherein the alkene is directly converted to the carboxylic acid.
2. Process according to Claim 1,
 - 15 wherein the substance in process step b) is selected from:
 PdCl_2 , PdBr_2 , $\text{Pd}(\text{acac})_2$, $\text{Pd}(\text{dba})_2$ (dba = dibenzylideneacetone), $\text{PdCl}_2(\text{CH}_3\text{CN})_2$.
3. Process according to either of Claims 1 and 2,
 - wherein the process comprises the additional process step e):
 - 20 e) addition of acetic acid.
4. Process according to any of Claims 1 to 3,
 - wherein the process comprises additional process step f):
 - 25 f) addition of water.

5. Process according to any of Claims 1 to 4,
wherein the process comprises the additional process step g):
g) addition of p-toluenesulfonic acid.
- 5 6. Process according to any of Claims 1 to 5,
wherein the reaction mixture is heated to a temperature in the range from 80°C to
160°C in process step d).
- 10 7. Process according to any of Claims 1 to 6,
wherein the CO is fed in in process step c) such that the reaction proceeds under a
CO pressure in the range from 20 bar to 60 bar.