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PREPARATION OF POLYMERS

The invention relates to a process for the preparation of polymers of carbon monoxide with one or more olefinically unsaturated compounds, and to polymers thus obtainable.

It is known that linear polymers of carbon monoxide with one or more olefinically unsaturated compounds, in which polymers the units originating from carbon monoxide (on the one hand) and the units originating from the olefinically unsaturated compounds (on the other hand) occur in a substantially alternating order, can be prepared by contacting the monomers at an elevated temperature and pressure with a solution of a suitable catalyst (or catalyst composition), in the presence of a liquid, non-polymerizable diluent in which the polymers are insoluble or virtually insoluble.

The polymerization is conventionally carried out by introducing a catalyst solution into a reactor which contains the monomers and the diluent and which is at the desired temperature and pressure. During the polymerization the polymers are obtained in the form of a suspension in the diluent. When the required degree of polymerization has been achieved, the polymerization is terminated, conventionally by cooling the reaction mixture to room temperature and releasing the pressure. The polymer is removed from the suspension, washed and dried.

As regards the diluent to be used in the polymerization, lower aliphatic alcohols such as methanol are preferred, since it was found that the suitable catalyst compositions have the highest polymerization rate when dissolved in these. A drawback of the use of lower

aliphatic alcohols as diluent for the aforesaid polymerization is that the thus prepared polymers contain 4000-15,000 ppmw of the applied alcohol, which quantity of alcohol cannot be removed from the polymer, not even by prolonged and careful drying. It must be assumed that this quantity of alcohol is chemically bonded to the polymers, since it was found that the alcohol content is hardly changed after extrusion of the polymers at temperatures of around 270 °C.

The high alcohol content can be a problem if the present polymers are used as packaging material for foodstuffs. It is therefore desirable to lower this high alcohol content.

The applicant has carried out extensive research into this subject. Initially it was tried to achieve the desired goal by treating the polymers at high temperature with water or steam. Although the alcohol content of the polymers could be reduced in this way, the resulting deterioration in the properties of the polymers was such that these methods had to be rejected.

In the course of continued research by the applicant into this subject, it has now surprisingly been found that in the preparation of the aforesaid alternating polymers using one or more lower aliphatic alcohols as diluent, polymers with a reduced alcohol content can be prepared by adding water to the diluent.

It should be mentioned that (comparative) example 5 of EP-A-307027 describes the preparation of a CO/ethene/-propene terpolymer at 56 bar and 85 °C in the presence of a diluent consisting of 3 ml water, 1.5 ml toluene and 181.5 ml methanol, i.e. 2.0 pbw (parts by weight) water, 0.9 pbw toluene and 97.1 pbw methanol. This example was carried out to show that the presence of water in the (carbon monoxide) feed does not have any disadvantageous effect on the polymerisation rate, whereas other

impurities such as iron carbonyl or sulphidic sulphur have to be removed therefrom. There is no mention of residual methanol content in EP-A-307027, nor in any other document of the state of the art known to Applicant. However, the procedure of this example is not claimed in the said prior patent application.

The present patent application therefore relates to a process for the preparation of polymers, characterized in that linear polymers of carbon monoxide with one or more olefinically unsaturated compounds, in which polymers the units originating from carbon monoxide and the units originating from the olefinically unsaturated compounds occur in a substantially alternating order, are prepared by contacting the monomers at elevated temperature and pressure with a solution of a suitable catalyst, in the presence of a diluent at least consisting of one or more lower aliphatic alcohols and water, with the exclusion of the preparation of a CO/ethene/propene terpolymer at 56 bar and 85 °C in the presence of a diluent consisting of 0.9 %w toluene, 2.0 %w water and 97.1 %w methanol.

As stated above, it was found that when the present polymers are prepared in the conventional manner, i.e. in the presence of a diluent containing a lower aliphatic alcohol, they show a residual content of the applied alcohol of 4000 - 15000 ppmw (0.4 - 1.5 %w). Thus polymers having a lower alcohol content, when prepared in a process using a lower aliphatic alcohol as a liquid non-polymerisable diluent, are novel compounds. Accordingly, the present patent application also relates to linear polymers obtained by copolymerization of carbon monoxide with one or more olefinically unsaturated compounds in the presence of a diluent at least consisting of one or more lower aliphatic alcohols, in which polymers the units originating from carbon monoxide and the units originating from the olefinically unsaturated



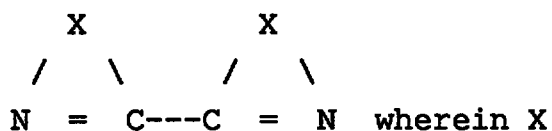
compounds occur in a substantially alternating order, characterised in that the polymers contain less than 4000 ppmw, particularly less than 100 ppmw, of the applied lower aliphatic alcohol.

The polymerization according to the invention is preferably carried out in the presence of a diluent that contains methanol as lower aliphatic alcohol. The term "lower aliphatic alcohol" as used herein comprises alcohols such as methanol, ethanol, 1- and 2-propanol, 1-butanol, 2-butanol and 2-methyl-2-propanol, and corresponding diols, but excludes unsaturated alcohols such as vinyl, allyl or crotyl alcohol, these participating in the polymerization in an unwanted way. The quantity of water in the diluent preferably amounts to at least 2.5%w. The diluent further preferably comprises a maximum of 15 %w water and in particular a maximum of 10 %w water.

In the process of the invention, a catalyst is used which, starting from a mixture of carbon monoxide and one or more olefinically unsaturated compounds, is capable of catalyzing the formation of the previously mentioned linear alternating polymers. Suitable catalysts for the present purpose are, inter alia, those which comprise a Group VIII metal. In this patent application, Group VIII metals are understood to be the noble metals ruthenium, rhodium, palladium, osmium, iridium and platinum, as well as the iron group metals iron, cobalt and nickel. Preference is given to catalysts which include palladium, nickel or cobalt as Group VIII metal. Particular preference is given to palladium as Group VIII metal. If the catalysts that are used in the process of the invention comprise a Group VIII metal, it is preferably incorporated in the catalyst in the form of a salt of a carboxylic acid, in particular in the form of an acetate. In addition to a Group VIII metal, the catalysts



preferably include a bidentate ligand which can form a complex with the Group VIII metal via two phosphorus-, nitrogen- or sulphur-containing dentate groups present in the bidentate ligand. If a nitrogen bidentate ligand is used, preference is given to compounds of the general formula



represents an organic bridge group containing three or four atoms in the bridge, at least two of which are carbon atoms, such as 2,2'-bipyridine and 1,10-phenanthroline. If a sulphur bidentate ligand is used, preference is given to compounds of the general formula $\text{R}^1\text{S}-\text{R}-\text{SR}^1$, wherein R^1 represents an optionally polar-substituted hydrocarbyl group and R represents a bivalent organic bridge group containing at least two carbon atoms in the bridge, such as 1,2-bis(ethylthio)ethane and cis-1,2-bis(benzylthio)ethene. Preference is given to the use of phosphorus bidentate ligands of the general formula $(\text{R}^1)_2\text{P}-\text{R}-\text{P}(\text{R}^1)_2$, wherein R and R^1 have the previously given meanings. Preference is further given to the use of phosphorus bidentate ligands of this type in which R^1 represents an aromatic hydrocarbyl group having at least one alkoxy substituent in the ortho position relative to the phosphorus atom to which it is attached. A very suitable compound for the present purpose is 1,3-bis[bis(2-methoxyphenyl)phosphino]propane. If a nitrogen or sulphur bidentate ligand is used in the catalysts, the quantity used is preferably 0.5-100 and in particular 1-50 mol per g.atom Group VIII metal. If a phosphorus bidentate ligand is used, the quantity used is preferably 0.5-2 and in particular 0.75-1.5 mol per g.atom Group VIII metal. In addition to a Group VIII metal and a phosphorus, nitrogen or sulphur bidentate

ligand, the catalysts preferably include an anion of an acid with a pKa of less than 4 and in particular an anion of an acid with a pKa of less than 2. Examples of suitable acids with a pKa of less than 2 are sulphonic acids such as para-toluenesulphonic acid and halogencarboxylic acids such as trifluoroacetic acid. The introduction of an anion of an acid with a pKa of less than 4 into the catalysts can take place in the form of an acid and/or in the form of a salt of a non-noble transition metal such as a chromium or iron salt. The anion is preferably present in the catalysts in a quantity of 1-100 and in particular 2-50 mol per g.atom Group VIII metal. In addition to catalysts on the basis of the three aforementioned components, viz. a) a Group VIII metal compound, b) an acid with a pKa of less than 4 or a non-noble transition metal salt thereof, and c) a bidentate ligand containing two phosphorus-, nitrogen- or sulphur-containing dentate groups, catalysts eligible for the present purpose can also be corresponding catalysts on the basis of two components by combining components a) and b) such as by the application of palladium trifluoroacetate or palladium para-tosylate or by combining components b) and c) such as by the application of ortho-(diphenylphosphino)benzenesulphonic acid or 3-(diphenylphosphino)propanesulphonic acid. In order to enhance the activity of the Group VIII metal-containing catalysts, a 1,4-quinone may be additionally incorporated therein. For that purpose, 1,4-benzoquinone and 1,4-naphthoquinone are very suitable. The quantity of 1,4-quinone used preferably amounts to 5-5000 and in particular 10-1000 mol per g.atom Group VIII metal.

Olefinically unsaturated compounds that can be polymerized with carbon monoxide by using the process of the invention may be compounds consisting exclusively of carbon and hydrogen, as well as compounds which contain,

in addition to carbon and hydrogen, one or more hetero-atoms. The process of the invention is preferably applied in the preparation of polymers of carbon monoxide with one or more olefinically unsaturated hydrocarbons. Examples of suitable hydrocarbon monomers are ethene, propene, butene-1, hexene-1, octene-1, styrene, cyclopentene, norbornene and dicyclopentadiene. The process of the invention is in particular very suitable for application in the preparation of copolymers of carbon monoxide with ethene and in the preparation of terpolymers of carbon monoxide with ethene and an α -olefin, in particular propene.

The quantity of catalyst composition employed in the process of the invention may vary within wide limits. If a Group VIII metal-containing catalyst is used, a quantity of catalyst is preferably used per mol of olefinically unsaturated compound to be polymerized which contains 10^{-7} - 10^{-3} and in particular 10^{-6} - 10^{-4} g.atom Group VIII metal.

The process of the invention is preferably carried out at a temperature of 25-150 °C and a pressure of 2-150 bar and in particular at a temperature of 30-130 °C and a pressure of 5-100 bar. The molar ratio of olefinically unsaturated compounds relative to carbon monoxide is preferably 10:1-1:10 and in particular 5:1-1:5.

The invention is further illustrated by the following examples.

Example 1

A carbon monoxide/ethene/propene terpolymer was prepared as follows. 144 g methanol was introduced into a stirred autoclave with a capacity of 300 ml. The air in the autoclave was driven out by forcing in carbon monoxide to a pressure of 50 bar and then releasing the pressure and repeating this procedure two more times. After the



contents of the autoclave had been brought to 78 °C, 19 bar propene was forced in, then 11 bar ethene and finally 30 bar carbon monoxide. After this, a catalyst solution was introduced into the autoclave, consisting of:

2 ml acetone,
0.01 mmol palladium acetate,
0.01 mmol 1,3-bis[bis(2-methoxyphenyl)phosphino]propane,
and
0.2 mmol trifluoroacetic acid.

During the polymerization the pressure in the autoclave was maintained by forcing in a 1:1 carbon monoxide/ethene mixture. After 2 hours the polymerization was terminated by cooling to room temperature and releasing the pressure. The terpolymer was filtered off, washed with methanol and dried at 70 °C. 13 g terpolymer was obtained with a methanol content of 7000 ppmw. The polymerization rate was 6.1 kg terpolymer/(g palladium.hour).

Example 2

A carbon monoxide/ethene/propene terpolymer was prepared in substantially the same way as in example 1, but with the difference that 0.8 g of the 144 g methanol was replaced by water.

14 g terpolymer was obtained with a methanol content of 3000 ppmw. The polymerization rate was 6.6 kg terpolymer/(g palladium.hour).

Example 3

A carbon monoxide/ethene/propene terpolymer was prepared in substantially the same way as in example 1, but with the difference that 2.9 g of the 144 g methanol was replaced by water.

16 g terpolymer was obtained with a methanol content of 1100 ppmw. The polymerization rate was 7.5 kg terpolymer/(g palladium.hour).

Example 4

A carbon monoxide/ethene/propene terpolymer was prepared in substantially the same way as in example 1, but with the difference that 7.2 g of the 144 g methanol was replaced by water.

15 g terpolymer was obtained with a methanol content of 100 ppmw. The polymerization rate was 7.1 kg terpolymer/(g palladium.hour).

Example 5

A carbon monoxide/ethene/propene terpolymer was prepared in substantially the same way as in example 1, but with the difference that 14.4 g of the 144 g methanol was replaced by water.

14 g terpolymer was obtained with a methanol content of < 50 ppmw. The polymerization rate was 6.6 kg terpolymer/(g palladium.hour).

The methanol content of the polymers was determined by extracting them for 20 hours at 120 °C with water and analyzing the aqueous phase with the aid of GLC. To establish that a complete extraction of methanol really had been accomplished in this way, the methanol content of the polymer prepared according to example 1 was also determined by dissolving the polymer in hexafluoroisopropanol and analyzing the solution with NMR. This procedure also gave a methanol content of 7000 ppmw.

Of the examples 1-5, examples 2-5 are according to the invention. In these examples the polymerization was carried out in the presence of a diluent consisting of methanol to which water had been added. Example 1 falls outside the scope of the invention and is included in the patent application for comparison. In this example no water was added to the methanol. It was established by NMR analysis that the polymers prepared according to examples 1-5 were built up of linear chains in which on the one hand the units from carbon monoxide and on the

other hand the units from ethene and propene occurred in an alternating arrangement. In the polymer chains the units from ethene and propene occurred in a randomly distributed manner.



C L A I M S

1. Process for the preparation of polymers, characterized in that linear polymers of carbon monoxide with one or more olefinically unsaturated compounds, in which polymers the units originating from carbon monoxide and the units originating from the olefinically unsaturated compounds occur in a substantially alternating order, are prepared by contacting the monomers at elevated temperature and pressure with a solution of a suitable catalyst, in the presence of a liquid, non-polymerizable diluent at least consisting of one or more lower aliphatic alcohols and water, with the exclusion of the preparation of a CO/ethene/propene terpolymer at 56 bar and 85 °C in the presence of a diluent consisting of 0.9 %w toluene, 2.0 %w water and 97.1 %w methanol.
2. Process according to claim 1, characterized in that the diluent contains methanol as lower aliphatic alcohol.
3. Process according to claim 1 or 2, characterized in that the diluent contains at least 2.5 %w water.
4. Process according to one or more of claims 1-3, characterized in that the diluent contains a maximum of 15 %w water.
5. Process according to one or more of claims 1-4, characterized in that the catalyst contains a Group VIII metal.
6. Process according to claim 5, characterized in that the catalyst contains in addition to a Group VIII metal a bidentate ligand which can form a complex with the Group VIII metal via two phosphorus-, nitrogen- or sulphur-containing dentate groups present in the bidentate ligand.





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7. Process according to claim 5 or 6, characterized in that per mol of olefinically unsaturated compound to be polymerized a quantity of Group VIII metal-containing catalyst is used which contains 10^{-7} - 10^{-3} g.atom Group VIII metal.

8. Process according to one or more of claims 1-7, characterized in that it is carried out at a temperature of 25-150 °C, a pressure of 2-150 bar and a molar ratio of the olefinically unsaturated compounds relative to carbon monoxide of 10:1 to 1:10.

9. Linear polymers obtained by copolymerization of carbon monoxide with one or more olefinically unsaturated compounds in the presence of a diluent at least consisting of one or more lower aliphatic alcohols, in which polymers the units originating from carbon monoxide and the units originating from the olefinically unsaturated compounds occur in a substantially alternating order, characterized in that the polymers contain less than 4000 ppmw of the applied lower aliphatic alcohol(s).

10. Polymers as claimed in claim 9, characterized in that the polymers contain less than 100 ppmw of the applied lower aliphatic alcohol(s).

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A B S T R A C T

PREPARATION OF POLYMERS

Process for the preparation of linear polymers of carbon monoxide with one or more olefinically unsaturated compounds, in which polymers the units originating from carbon monoxide and the units originating from the olefinically unsaturated compounds occur in a substantially alternating order, comprising contacting the monomers at elevated temperature and pressure with a solution of a suitable catalyst, in the presence of a liquid, non-polymerizable diluent at least consisting of one or more lower aliphatic alcohols and water. Such polymers having an alcohol content below 4000 ppmw, are novel compounds.

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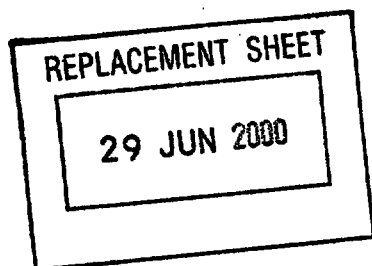
impurities such as iron carbonyl or sulphidic sulphur have to be removed therefrom. There is no mention of residual methanol contact in EP-A-307027, nor in any other document of the state of the art known to Applicant. However, the
 5 procedure of this example is not claimed in the said prior patent application.

The present patent application therefore relates to a process for the preparation of polymers, characterized in that linear polymers of carbon monoxide with one or more
 10 olefinically unsaturated compounds, in which polymers the units originating from carbon monoxide and the units originating from the olefinically unsaturated compounds occur in a substantially alternating order, are prepared by contacting the monomers at elevated temperature and pressure
 15 with a solution of a suitable catalyst, in the presence of a diluent at least consisting of one or more lower aliphatic alcohols and at least 0.56%w water, relative to the weight of the diluent, with the exclusion of the preparation of a CO/ethene/propene terpolymer at 56 bar and 85°C in the
 20 presence of a diluent consisting of 0.9%w toluene, 2.0%w water and 97.1%w methanol.

As stated above, it was found that when the present polymers are prepared in the conventional manner, i.e. in the presence of a diluent containing a lower aliphatic
 25 alcohol, they show a residual content of the applied alcohol of 4000-15000 ppmw (0.4 - 1.5%w). Thus polymers having a lower alcohol content, when prepared in a process using a lower aliphatic alcohol as a liquid non-polymerizable diluent, are novel compounds.

30 Accordingly, the present patent application also relates to linear polymers obtainable by copolymerization of carbon monoxide with one or more olefinically unsaturated

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compounds in the presence of a diluent at least consisting of one or more lower aliphatic alcohols, in which polymers the units originating from carbon monoxide and the units originating from the olefinically unsaturated compounds
5 occur in a substantially alternating order and which polymers contain chemically bonded lower aliphatic alcohol applied in the copolymerization, characterized in that the polymers contain less than 4000 ppmw of the lower aliphatic alcohol, with the exclusion of a CO/ethene/propene
10 terpolymer obtainable by copolymerizing the monomers at 56 bar and 85°C in the presence of a diluent consisting of 0.9%w toluene, 2.0%w water and 97.1%w methanol.

In a preferred embodiment, the polymers contain less than 100 ppmw of the applied lower aliphatic alcohol.

15 The polymerization according to the invention is preferably carried out in the presence of a diluent that contains methanol as lower aliphatic alcohol. The term "lower aliphatic alcohol" as used herein comprises alcohols such as methanol, ethanol, 1- and 2-propanol, 1-butanol, 2-
20 butanol and 2-methyl-2-propanol, and corresponding diols, but excludes unsaturated alcohols such as vinyl, allyl or crotyl alcohol, these participating in the polymerization in an unwanted way. The quantity of water in the diluent preferably amounts to at least 2.5%w. The diluent further
25 preferably comprises a maximum of 15%w water and in particular a maximum of 10%w water.

In the process of the invention, a catalyst is used which, starting from a mixture of carbon monoxide and one or more olefinically unsaturated compounds, is capable of
30 catalyzing the formation of the previously mentioned linear alternating polymers. Suitable catalysts for the present purpose are, inter alia, those which comprise a Group VIII

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metal. In this patent application, Group VIII metals are understood to be the noble metals ruthenium, rhodium, palladium, osmium, iridium and platinum, as well as the iron group metals iron, cobalt and nickel. Preference is given
5 to catalysts which include palladium, nickel or cobalt as Group VIII metal. Particular preference is given to palladium as Group VII metal. If the catalysts that are used in the process of the invention comprise a Group VIII metal, it is preferably incorporated in the catalyst in the
10 form of a salt of a carboxylic acid, in particular in the form of an acetate. In addition to a Group VIII metal, the catalysts

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in addition to carbon and hydrogen, one or more hetero-atoms. The process of the invention is preferably applied in the preparation of polymers of carbon monoxide with one or more olefinically unsaturated hydrocarbons. Examples of suitable hydrocarbon monomers are ethene, propene, butene-1, hexene-1, octene-1, styrene, cyclopentene, norbornene and dicyclopentadiene. The process of the invention is in particular very suitable for application in the preparation of copolymers of carbon monoxide with ethene and in the preparation of terpolymers of carbon monoxide with ethene and an α -olefin, in particular propene.

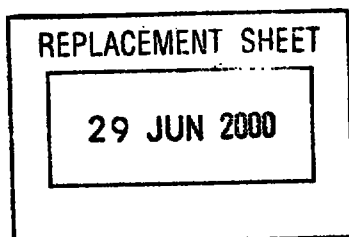
The quantity of catalyst composition employed in the process of the invention may vary within wide limits. If a Group VIII metal-containing catalyst is used, a quantity of catalyst is preferably used per mol of olefinically unsaturated compound to be polymerized which contains 10^{-7} - 10^{-3} and in particular 10^{-6} - 10^{-4} g. atom Group VIII metal.

The process of the invention is preferably carried out at a temperature of 25-150 °C and a pressure of 2-150 bar and in particular at a temperature of 30-130 °C and a pressure of 5-100 bar. The molar ratio of olefinically unsaturated compounds relative to carbon monoxide is preferably 10:1-1:10 and in particular 5:1-1:5.

The invention is further illustrated by the following examples which are provided for illustrative purposes only and which should not be construed as limiting on the invention in any way.

Example 1

A carbon monoxide/ethene/propene terpolymer was prepared as follows. 144g methanol was introduced into a stirred autoclave with a capacity of 300 ml. The air in the autoclave was driven out by forcing in carbon monoxide to a pressure of 50 bar and then releasing the pressure and repeating this procedure two more times. After the



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CLAIMS

1. Process for the preparation of polymers, characterized in that linear polymers of carbon monoxide with one or more olefinically unsaturated compounds, in which polymers the
5 units originating from carbon monoxide and the units originating from the olefinically unsaturated compounds occur in a substantially alternating order, are prepared by contacting the monomers at elevated temperature and pressure with a solution of a suitable catalyst, in the presence of a
10 liquid, non-polymerizable diluent at least consisting of one or more lower aliphatic alcohols and at least 0.56%w of water, relative to the weight of the diluent, with the exclusion of the preparation of a CO/ethene/propene terpolymer at 56 bar and 85°C in the presence of a diluent
15 consisting of 0.9%w toluene, 2.0%w water and 97.1%w methanol.
2. Process according to claim 1, characterized in that the diluent contains methanol as lower aliphatic alcohol.
3. Process according to claim 1 or 2, characterized in
20 that the diluent contains at least 2.5%w water.
4. Process according to one or more of claims 1-3, characterized in that the diluent contains a maximum of 15%w water.
5. Process according to one or more of claims 1-4,
25 characterized in that the catalyst contains a Group VIII metal.
6. Process according to claim 5, characterized in that the catalyst contains in addition to a Group VIII metal a bidentate ligand which can form a complex with the Group



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VIII metal via two phosphorus-, nitrogen- or sulphur-containing dentate groups present in the bidentate ligand.

7. Process according to claim 5 or 6, characterized in that per mol of olefinically unsaturated compound to be
5 polymerized a quantity of Group VIII metal-containing catalyst is used which contains 10^{-7} - 10^{-3} g.atom Group VIII metal.

8. Process according to one or more of claims 1-7, characterized in that it is carried out at a temperature of
10 25-150°C, a pressure of 2-150 bar and a molar ratio of the olefinically unsaturated compounds relative to carbon monoxide of 10:1 to 1:10.

9. Linear polymers obtainable by copolymerization of carbon monoxide with one or more olefinically unsaturated
15 compounds in the presence of a diluent at least consisting of one or more lower aliphatic alcohols, in which polymers the units originating from carbon monoxide and the units originating from the olefinically unsaturated compounds occur in a substantially alternating order and which
20 polymers contain chemically bonded lower aliphatic alcohol applied in the copolymerization, characterized in that the polymers contain less than 4000 ppmw of the lower aliphatic alcohol(s), with the exclusion of a CO/ethene/propene terpolymer obtainable by copolymerizing the monomers at 56
25 bar and 85°C in the presence of a diluent consisting of 0.9%w toluene, 2.0%w water and 97.1%w methanol.

10. Polymers as claimed in claim 9, characterized in that the polymers contain less than 100 ppmw of the applied lower aliphatic alcohol(s).