(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 March 2009 (26.03.2009)

PCT

(10) International Publication Number
WO 2009/037235 A1

(51) International Patent Classification:
C07C 251/24 (2006.01) *C07C 249/02* (2006.01)
C07C 227/02 (2006.01)

(21) International Application Number:
PCT/EP2008/062269

(22) International Filing Date:
15 September 2008 (15.09.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
07465006.0 20 September 2007 (20.09.2007) EP

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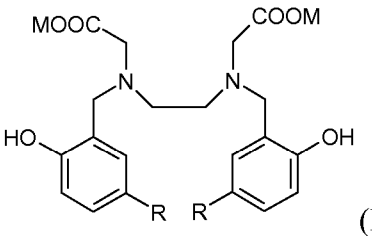
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

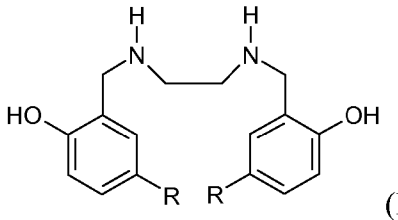
Declaration under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:
— *with international search report*

(54) **Title:** A PROCESS FOR THE PREPARATION OF N,N'-BIS(2-HYDROXYBENZYL)ETHYLENEDIAMINE-N,N'-DIACETIC ACID AND ITS DERIVATIVES



(I)



(II)

(57) **Abstract:** The invention relates to a process for the preparation of N,N'-bis(2-hydroxybenzyl)-ethylenediamine-N,N'-diacetic acid and its derivatives of general formula (I), wherein both R have the same meaning and are selected from H, C_1-C_4alkyl, CH_2OH, SO_3M, and COOM; and all M have the same meaning and represent hydrogen atom, Na, K or NH_4; which comprises reductive amination of glyoxylic acid with a salan compound of general formula (II), in the presence of an amine proton acceptor. The compounds of formula (I) can be used as chelating agents for micronutrients in fertilizer preparations for plants.

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A process for the preparation of N,N'-bis(2-hydroxybenzyl)ethylenediamine-N,N'-diacetic acid and its derivatives

The present invention relates to a process for the preparation of N,N'-bis(2-hydroxybenzyl)ethylenediamine-N,N'-diacetic acid and its derivatives substituted in phenyl ring, as well as their salts.

N,N'-Bis(2-hydroxybenzyl)ethylenediamine-N,N'-diacetic acid, also known under the name HBED, and its derivatives substituted in para position with respect to phenolic hydroxy group are well known for their ability to chelate III and IV groups of metal ions in aqueous solutions. They can be used as chelating agents for micronutrients in fertilizer preparations for plants, such as iron, zinc, copper or manganese micronutrients. Therefore a need exists of its industrial production in large scale.

One of known methods of the preparation of HBED is described in US 3,632,637 and comprises reaction of disodium N,N'-ethylenediaminediacetate with o-acetoxybenzyl bromide or chloride and then alkaline hydrolysis to remove acetoxy protecting group. The preparation of o-acetoxybenzyl bromide is complex and requires two reaction steps: reaction of o-hydroxybenzyl alcohol with acetic anhydride to form o-acetoxybenzyl acetate and then bromination with HBr. Furthermore, as later reported by Martell et al in Can. J. Chem., vol. 63(3), 449-456, 1986, that procedure suffered from the formation of a resinous polymeric by-product, which seemed to be promoted by treatment with acid or base and sometimes formed spontaneously during recrystallization of the material. Another disadvantage of this method is that disodium N,N'-ethylenediamine-diacetate is not easy available and must be prepared in the reaction of carboxymethylation of ethylenediamine which involves the use of cyanides (NaCN) and CH_2O.

Martell et al in Can. J. Chem., vol. 63(3), 449-456, 1986 reports two approaches for the synthesis of HBED and derivatives. The first approach, which is suitable for synthesis of HBED, involves conversion of N,N'-bis(2-hydroxybenzyl)ethylenediamine to the amide via reaction with formaldehyde and HCN followed by hydrolysis. A disadvantage of this approach is the use of HCN and difficulty of hydrolyzing diamide,

which requires the use of very pH sensitive metal catalysis. The second approach, which is suitable for synthesis of HBED derivatives substituted para to the phenolic hydroxy group, involves reaction of N,N'-ethylenediaminediacetic acid with para substituted phenols and formaldehyde and was found to be very sensitive to pH. Another disadvantage of this second approach is also the necessity of the synthesis of the starting N,N'-ethylenediaminediacetic acid.

Another synthetic approach for the preparation of HBED is described in WO01/46114 and comprises reaction of N,N'-bis(2-hydroxybenzyl)ethylenediamine with tert-butyl haloacetate and then hydrolysis of resulting N,N'-bis(2-hydroxybenzyl)ethylene-diamine-N,N'-diacetic acid di-tert-butyl ester with a weak acid, such as formic acid. The method was specifically designed to obtain neat HBED, which then could be easy converted into target mono-cationic salt while avoiding intermediate dihydrochloride formation and its neutralization into sodium chloride. However, the reaction of N,N'-bis(2-hydroxybenzyl)ethylenediamine acid with t-butyl bromoacetate is performed in DMSO solvent and takes a very long time. Hydrolysis with formic acid is also very time consuming and takes 5 days, the yield of hydrolysis being very low. Furthermore, t-butyl bromoacetate is expensive and not easy available on the industrial scale.

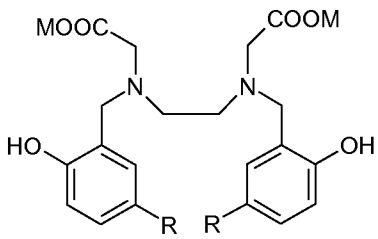
A synthetic approach for the preparation of HBED derivatives substituted in position para with respect to the phenolic OH group is known from US 2,967,196 and US 3,038,793 and comprises reacting formaldehyde with disodium N,N'-ethylene-diaminediacetate to form the dimethylol derivative which can condense in the position ortho to the phenolic OH group with para substituted phenols. A disadvantage of this method is that disodium N,N'-ethylenediaminediacetate must be prepared first in the reaction of carboxymethylation of ethylenediamine which involves the use of NaCN and CH_2O. This approach fails when applied to the preparation of HBED because of by-products formation due to the possibility of the reaction of methylolol group with phenol in positions both para and ortho to the phenolic OH group and formation of a complex mixture of compounds.

The object of the present invention is to provide a synthetic process, which applicable both for HBED itself and its derivatives substituted in para position with respect to

phenolic OH group and which could be carried out in the same reaction system and under similar conditions both in the case of HBED and its derivatives.

It is also the object of the present invention to provide a synthetic process having small number of steps and employing reagents which are either easy available or easy to synthesize on a large scale, as well as standard and simple industrial operations and equipment. It is also the object of the invention to eliminate the need of using toxic cyanides.

In accordance with the invention there is provided a process for the preparation of N,N'-bis(2-hydroxybenzyl)ethylenediamine-N,N'-diacetic acid and its derivatives of general formula I:



(I)

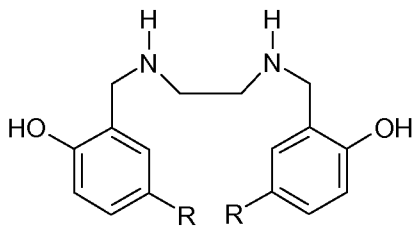
wherein:

both R have the same meaning and are selected from H, C_1-C_4alkyl, CH_2OH, SO_3M, and COOM; and

all M have the same meaning and represent hydrogen atom, Na, K or NH_4;

which comprises:

- reductive amination of glyoxylic acid with a salan compound of formula (II)



(II)

wherein R have the same meaning as defined above for formula (I), in the presence of an amine proton acceptor, to obtain the compound of formula (I), wherein M are hydrogen atoms, and

- if desired, converting it further into compound of formula (I) wherein M represent Na, K or NH_4 by the treatment with a corresponding base.

The term C_1-C_4alkyl group in the above formulas encompasses both straight (linear) or branched C_1-C_4alkyl group, such as methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, tert-butyl.

The most preferred compounds prepared by the process of the invention are compounds of formula (I) wherein R are hydrogen atoms or methyl groups.

The molar ratio salan compound:glyoxylic acid:amine is in the range from 1:2:2 to 1:4:5, preferably 1:3:3.5.

Any excess of reagents used in the reductive amination in the process of the invention can be easily recovered from the reaction medium after the reaction and used in a next batch of the reductive amination. The only inorganic by-product in the process is a salt, contrary to the processes known from the prior art.

Reductive amination can be preferably carried out by catalytic hydrogenation (reaction with hydrogen) in the presence of a hydrogenation catalyst.

For the catalytic hydrogenation the starting salan compound of formula (I)) can be dissolved in a polar solvent, preferably selected from C_1-C_3 alkanol or their mixtures or in a C_1-C_3 alkanol/water mixture containing 30 to 60% of the alkanol. Preferred solvent can be methanol, ethanol in a mixture with water and methanol, such as industrial methylated spirit. Then the solution of glyoxylic acid and amine in the same solvent is introduced to the solution of the salan compound. The molar ratio of glyoxylic acid to amine is about 1:1 or an excess of amine can be used.

Reductive amination can be also carried out in an aqueous-amine proton acceptor medium. In such a case the reaction is performed in a heterogeneous medium, where the mixture of glyoxylic acid and amine is dissolved in the aqueous phase and the salan compound and the catalyst remain undissolved.

The hydrogenation catalyst can be selected from conventional catalysts which include, without limitation, catalysts based on noble or transition metals such as palladium, platinum, rhodium, nickel, osmium and ruthenium. These catalysts can be used in a form bound to a support, carbon or charcoal being the supports most commonly used. The most preferred are Raney nickel (Ra-Ni) and palladium or platinum on a charcoal

(Pd/C, Pt/C). Hydrogenation is carried out by mixing reagents in a solvent in the atmosphere of hydrogen gas. The choice of a solvent, temperature of the reaction and the hydrogen pressure depends on a specific catalyst employed. Hydrogenation can be carried out under low hydrogen pressure of about 1 to 4 atm and relatively low temperature (typically when noble metals catalysts, such as platinum, are used) or under low- or medium pressure such as 30 to 50 atm (when Ra-Ni or Rh/C are used). Preferred catalysts are Pd/C or Ra-Ni, preferably in the amount of 1 to 5% by weight with respect to the starting salan compound.

Hydrogenation can be carried out at 30 to 70°C, preferably at about 50°C, until the hydrogen absorption ceases. The time of the reaction is usually 4 to 48 hrs.

Glyoxylic acid can be used in any convenient and commercially available form, preferably as free acid or its hydrate, like monohydrate, or their mixtures. It can be also used as its salt, such as sodium salt hydrate, like monohydrate. Preferably, glyoxylic acid monohydrate is used when reductive amination is carried out in alcoholic medium. Aqueous 50% solution is used preferably when the reaction is carried out in water. When the reaction is carried out in an alcoholic solvent, glyoxylic acid can also be present at least in part in a form of its acetal or hemiacetal. The use of glyoxylic acid ester is also contemplated by the invention. By "glyoxylic acid" any form thereof as described above or their mixtures are understood in accordance with the invention.

The amine proton acceptor can be any amine compound capable of binding proton in a reaction media, most preferably simple tertiary amine such as triethylamine or tributylamine. Amine serves also as a blocking agent for carboxylic group in glyoxylic acid.

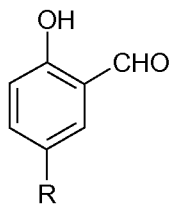
The compound of formula (I) wherein M are H is isolated in a form of a free acid or its monohydrochloride after separation of the hydrogenation catalyst by pressure filtration and subsequent evaporation of a solvent from the filtrate. The product in a monohydrochloride form can be crystallized from water after acidification to pH = 1.5 to 2.5 with hydrochloric acid. Conversion of the compound of formula (I) wherein M are H into its salt, i.e. the compound of formula (I) wherein M represent Na, K or NH_4 is carried out by the treatment with a corresponding base to pH 10 – 12.5, preferably 11.5. Such corresponding bases are preferably sodium, potassium or ammonium

hydroxides. After alkalization, 10 to 35% (by weight) aqueous solutions of the compound of formula (I) with M being Na, K or NH_4 are obtained, preferably 20% by weight.

The starting salan compounds of formula (II) can be prepared in two ways.

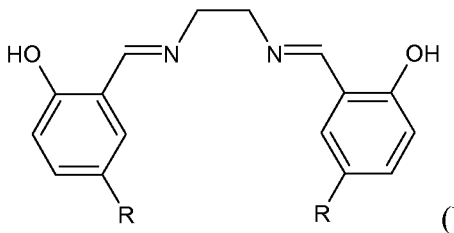
According to one approach, the starting salan compound of formula (II) can be prepared by condensation of ethylenediamine with 2 molar equivalents of salicylaldehyde or a corresponding salicylaldehyde derivative substituted with R substituent in position para with respect to hydroxy group and then reduction of thus obtained salen compound (Schiff's base). According to the second approach, the starting salan compound of formula (II) can be prepared by reaction of ethylenediamine, a formaldehyde source and phenol or phenol substituted with R substituent in para position (direct Mannich condensation). The second approach is applicable most preferably when R is C_1-C_4alkyl.

Therefore, in one variant of the invention, the process for the preparation of the compound of formula (I) wherein R are as described above comprises preparing salan compound of formula (II) by reaction of ethylenediamine with 2 molar equivalents of a compound of formula (IV)



(IV)

wherein R are as described for formula (I) above to obtain a corresponding compound of formula (V) wherein R are as described for formula (I)



(V)

and then reduction of the compound of formula (V) to obtain the compound of formula (II).

Compounds of formula (IV), i.e. salicylaldehyde and its derivatives substituted with R substituent in position para with respect to hydroxy group, are well known and easy commercially available materials.

Reaction of ethylenediamine with the compound of formula (IV) can be carried out in a known manner in a suitable solvent, such as lower alcohols or their mixtures at an ambient temperature.

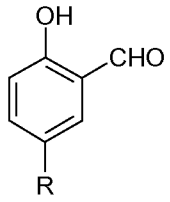
Reduction of the compound of formula (V) to obtain the compound of formula (II) can be generally carried out using any known reduction methods known in the art. One of such methods is the reduction with complex alkali metals hydrides, such as borohydrides, preferably sodium borohydride and lithium aluminium hydride. Preferred method of reduction is catalytic hydrogenation using the methods an catalysts as described above for the reaction of reductive amination of glyoxylic acid.

Most preferably, the reduction of the compound of formula (V) can be carried out by catalytic hydrogenation using hydrogen in the presence of a catalyst, such as palladium or nickel catalyst, like Pd/C or Ra-Ni. When the reduction is carried out by catalytic hydrogenation, intermediate compound of formula (II) without its isolation from the reaction medium can be directly reacted further with glyoxylic acid in the reductive amination in the same hydrogenation environment.

The yields of both the reaction of ethylenediamine with the compound of formula (IV) and the reduction of the intermediate compound of formula (V) are in principle quantitative. A further advantage is that reduction of the intermediate compound of formula (V) to form the compound of formula (II) and subsequent reductive amination of glyoxylic acid with the compound of formula (II) can be carried out under the same conditions and in the same equipment and using the same operations, which simplifies the whole process and lowers its costs.

An embodiment of the invention is therefore a process for the preparation of the compound of formula (I) wherein R are as described above, which comprises:

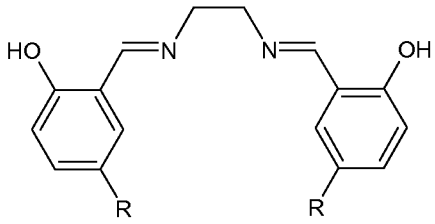
a) reaction of ethylenediamine with 2 molar equivalents of a compound of formula (IV)



(IV)

wherein R are as described for formula (I) above,

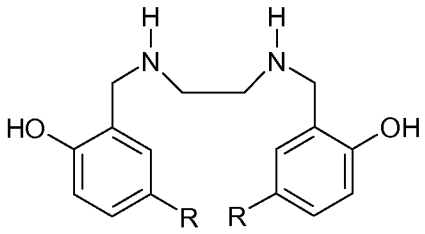
to obtain a corresponding compound of formula (V) wherein R are as described for formula (I)



(V)

b) reduction of the compound of formula (V) to obtain the compound of formula (II) wherein R are as described above;

c) reductive amination of glyoxylic acid with a salan compound of general formula (II)



(II)

wherein R have the same meaning as defined above for formula (I), in the presence of an amine proton acceptor, to obtain the compound of formula (I), wherein M are hydrogen atoms, and

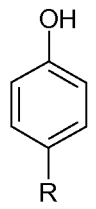
d) if desired, further converting the compound of formula (I) wherein M are hydrogen atoms into compound of formula (I) wherein M represent Na, K or NH_4 by the treatment with a corresponding base.

Preferably, in the above embodiment the reduction in step b) and the reductive amination in step c) are carried out in the same reaction vessel, without isolation of the intermediate compound of the formula (V).

Also preferably, all steps a) to c) can be carried out in the same reaction vessel, without isolation of intermediate compounds of the formula (IV) and (V).

Also preferably, both the reduction in step b) and the reductive amination in step c) are carried out by hydrogenation with hydrogen in the presence of a hydrogenation catalyst in a C_1-C_3 alkanol or their mixtures or in a C_1-C_3 alkanol/water mixture. Preferred hydrogenation catalysts are Ra-Ni and Pd/C.

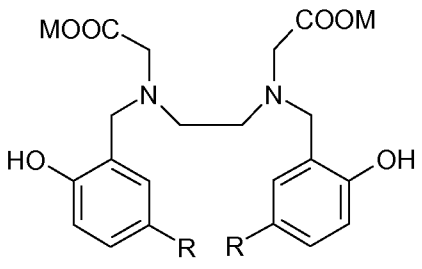
In a second variant of the invention, a process for the preparation of a compound of formula (I) wherein R is C_1-C_4alkyl comprises preparing a starting salan compound of formula (II) wherein R is C_1-C_4alkyl by reaction of ethylenediamine, a formaldehyde source and a phenol compound of formula (III)



(III)

wherein R is C_1-C_4alkyl, at a molar ratio ethylenediamine:formaldehyde:phenol compound about 1:2:2.

An embodiment of the invention is therefore a process for the preparation of N,N'-bis(2-hydroxybenzyl)ethylenediamine-N,N'-diacetic acid and its derivatives of general formula I:



(I)

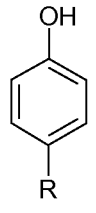
wherein:

both R have the same meaning and are selected from C_1-C_4alkyl; and

all M have the same meaning and represent hydrogen atom, Na, K or NH_4;

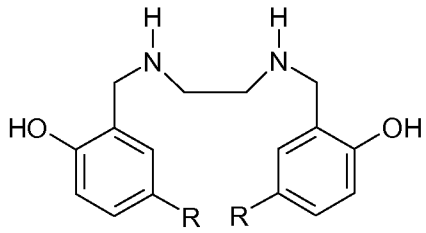
which comprises:

a) reaction of ethylenediamine, a formaldehyde source and the phenolic compound of formula (III)



(III)

wherein R is C_1-C_4alkyl, in a molar ratio ethylenediamine: formaldehyde: phenol compound of formula (III) of about 1:2:2, to obtain the salan compound of general formula (II)



(II)

wherein R have the same meaning as defined for formula (I), and

b) reductive amination of glyoxylic acid with the salan compound of the formula (II) in the presence of an amine proton acceptor, to obtain the compound of formula (I), wherein M are hydrogen atoms, and

c) if desired, converting it further into compound of formula (I), wherein M represent Na, K or NH_4 by the treatment with a corresponding base.

Phenol compounds of formula (III) are known and commercially available.

The formaldehyde source can be any conventional and commercially available formaldehyde source such as an aqueous formaldehyde solution, paraformaldehyde, trioxane or hexamethylenetetraamine HMTP (urotropine). Preferred formaldehyde source is the aqueous 35-40% formaldehyde solution, usually sold as a saturated aqueous solution with formaldehyde concentration of about 37%, stabilized with 10-15 % methanol (formalin or formol).

Most preferred formaldehyde sources are 37% aqueous formaldehyde solution and paraformaldehyde.

The reaction of ethylenediamine, the formaldehyde source and the phenol compound of formula (III) (direct Mannich condensation) can be carried out in a water-alcoholic mixture at reflux temperature, The product of formula (II) can be separated from the

reaction mixture as its hydrochloride or by evaporation of a solvent. The yield of the Mannich condensation is 80 to 95%.

The Examples which follow illustrate the invention without any intention to limit its scope to the embodiments shown in these Examples.

Example 1

General method of the preparation of compounds of formula (I) where R is C_1-C_4alkyl, using salan compounds prepared by direct Mannich condensation

To a 250 ml flask equipped with a mechanical stirrer and reflux condenser 100 ml of a solvent and 0.1 mol of ethylenediamine are introduced to obtain a solution. To the solution 0.2 mol of paraformaldehyde/37% formaldehyde aqueous solution and 0.2 to 0.4 ml of 37% hydrochloric acid are added portionwise. The mixture obtained is heated for 0.5 h at 50-60°C until complete homogeneity and then 50% solution of the phenol compound of formula (III) in the same solvent is added at the rate of 0.1 mol/h. The reaction mixture is heated at reflux for 4 to 30 h.

Salan compound of formula (II) thus obtained can be separated by crystallization:

- in a form of a salan monohydrochloride after acidification of the reaction mixture to pH 0.5-2.0 with concentrated hydrochloric acid, or
- in a form of a salan after evaporation of the solvent and crystallization from ethyl ether at 5 to 10°C.

Reductive amination can be performed in a closed reaction medium, such as heated autoclave equipped with a mechanical stirrer. Salan compound and the mixture containing glyoxylic acid, an amine and a solvent are introduced to the autoclave. After completing the addition of the total amount of salan compound the reaction mixture contains reactants salan:glyoxylic acid:amine at the molar ratio in the range from 1:2:2 to 1:4:5. The total concentration of reactants in the reaction mixture is in the range 2 to 10% by weight.

Then to the reaction mixture a catalyst is added, which is preferably Ni-Raney or Pd/C in the amount of 1 to 5% by weight with respect to the salan compound.

The air is removed from the reaction system using the flow of an inert gas, preferably argon, and the autoclave is pressurized with hydrogen gas.

Reductive amination is carried out for 4 to 48 h at the hydrogen pressure of 2 to 50 atm.

The product is isolated by filtration of the catalyst, evaporation of the solvent and crystallization of the product from water after acidifying the to the pH 1.5 to 2.5.

The overall yield after crystallization is in the range from 30 to 85%, depending on the type of the phenol compound of formula (III) used in the reaction. Structures of the products are confirmed by means of ^{1}H NMR analysis and their purities by means of HPLC and elemental analysis.

Example 2

N,N'-Bis(2-hydroxy-5-methylbenzyl)ethylenediamine-N,N'-diacetic acid, monohydrochloride trihydrate

2.1. N,N'-bis(2-hydroxy-5-methylbenzyl)ethylenediamine (salan compound)

Following the general procedure described in Example 1 ethylenediamine (6.0 g, 0.1 mol), 37% formaldehyde aqueous solution (14.9 ml, 0.2 mol), p-cresol (21.6 g, 0.2 mol) and ethanol (150 ml) as a solvent were introduced to the reaction system to form a homogenous reaction mixture. The reaction mixture was heated at 60°C for 12 h. The progress of the reaction was monitored by means of TLC analysis with ethanol: chloroform (9:2) developing system. When the completion of the reaction was confirmed, 9,2 ml (0.11 mol) of 37% hydrochloric acid was added dropwise to obtain pH=2.5. After 6 h of crystallization at ambient temperature white solid was obtained, which was filtered and washed three times with ethanol. The yield of the raw product so obtained was 24.6 g (82%). The raw product was then crystallized from the ethanol:water mixture, filtered and washed with ethanol (50 ml). The isolated product was dried in vacuum drier at 50°C for 3 h. The yield of crystallization was 70%.

The structure of N,N'-bis(2-hydroxy-5-methylbenzyl)ethylenediamine so obtained was confirmed by means of ^{1}H NMR. HPLC analysis shown the purity at the level of 96%.
^{1}H NMR ($CDCl_3$) δ: 7.26-6.72 (m, 8H, ArH), 3.95 (s, 4H, NCH_2CH_2), 2.82 (s, 4H, $ArCH_2N$), 2.24 (s, 6H, CH_3Ar)

2.2. N,N'-Bis(2-hydroxy-5-methylbenzyl)ethylenediamine-N,N'-diacetic acid, monohydrochloride trihydrate

The salan compound obtained as described above in 2.1. (3 g, 0.01 mol) was qualitatively transferred to an autoclave containing methanol (100 ml), Pd/C (0.05 g) and the mixture of glyoxylic acid monohydrate (2.8 g, 0.03 mol) with triethylamine (4.0 g, 0.04 mol) in methanol (40 ml) was added to obtain a final molar ratio 1:3:4 (salan:glyoxylic acid:triethylamine). The air remaining over the reaction mixture was removed using the flow of argon stream.

The reaction system was heated to 50°C and hydrogen was introduced at the pressure of 5 atm. The reaction of reductive amination was carried with stirring at 50°C out for 20 h. When the reaction was completed, the catalyst was filtered under vacuum and the solvent evaporated by means of a rotary vacuum evaporator. The solid obtained was dissolved in water and acidified with 10% hydrochloric acid until pH=2.0. The crystallization was then carried out at 8°C for 16 h.

3.8 g of the product was isolated (the yield 83%). The raw product was then crystallized at ambient temperature from the 85% ethanol. 2,8 g of the product was obtained after crystallization. The structure of the product N,N'–bis(2-hydroxy-5-methylbenzyl)ethylenediamine–N,N'–diacetic acid · HCl · $3H_2O$ was confirmed by means of ^1H NMR and its purity by means of elemental analysis.

^1H NMR (DMSO) δ: 7.03–6.86 (m, 8H, ArH), 4.01 (s, 4H, $HOOCCH_2N$), 3.64 (s, 4H, $ArCH_2N$), 3.21 (s, 4H, NCH_2CH_2), 2.14 (s, 6H, CH_3Ar)

Elemental analysis: Calculated for $C_{22}H_{28}N_2O_6 \cdot HCl \cdot 3H_2O$:

C 52.12, H 6.96, N 5.53, Found: C 52.02, H 7.01, N 5.49

Example 3

N,N'-Bis(2-hydroxy-5-propylbenzyl)ethylenediamine-N,N'-diacetic acid, monohydrochloride trihydrate

3.1. N,N'-bis(2-hydroxy-5-propylbenzyl)ethylenediamine (salan compound)

Following the general procedure described in Example 1, in a reaction system equipped with a reflux condenser and Dean-Stark trap ethylenediamine (6.0 g, 0.1 mol), 37% formaldehyde aqueous solution (14.9 ml, 0.2 mol), 4-propylphenol (27.2 g, 0.2 mol),

toluene (200 ml) as a solvent and 37% hydrochloric acid (0.3 ml) were introduced to form a homogenous reaction mixture. The reaction mixture was heated at 90-95°C for 4 h. The progress of the consumption of the reactants was monitored by measuring the amount of water formed in the reaction and collected in a Dean-Stark trap. When the reaction stopped, the mixture was heated for additional 2 h at 110-112°C. Then the solvent was evaporated from the reaction mixture and a thick oil obtained was washed twice with hexane at reflux temperature. 26.4 g of the raw product in a form of the thick oil was obtained with the yield 74%. The raw product was then dissolved in 150 ml of ethanol and acidified with 9.2 ml (0.11 mol) of 37% hydrochloric acid to pH=2.0. The white solid which precipitated was filtered under vacuum and then crystallized from ethanol-water system and filtered and washed with 50 ml of ethanol. The product was dried in vacuum for 3 h at 50°C. The yield of crystallization was 63%.

The structure of N,N'-bis(2-hydroxy-5-propylbenzyl)ethylenediamine product so obtained was confirmed by means of ^{1}H NMR. HPLC analysis shown the purity at the level of 97%.

^{1}H NMR ($CDCl_3$) δ: 7.26-6.72 (m, 8H, ArH), 3.95 (s, 4H, NCH_2CH_2), 2.82 (s, 4H, $ArCH_2N$), 2.45 (s, 6H, CH_2Ar), 1.61 (q, 4H, CH_2CH_2Ar), 0.92 (t, 6H, CH_3).

3.2. N,N'-Bis(2-hydroxy-5-propylbenzyl)ethylenediamine-N,N'-diacetic acid, hydrochloride trihydrate

The salan compound obtained as described in 3.1. above (3 g, 0.01 mol) was qualitatively transferred to an autoclave containing methanol (100 ml), Pd/C (0.15 g) and the mixture of glyoxylic acid monohydrate (2.8 g, 0.03 mol) with triethylamine (4.0 g, 0.04 mol) in methanol (50 ml) was added. The air remained over the reaction mixture was removed using the argon flow.

The reaction system was heated to 50°C and hydrogen gas was introduced at the pressure of 4 atm. The reaction of reductive amination was carried out at 50°C for 20 h. When the reaction was completed, the catalyst was filtered under vacuum and the solvent evaporated by means of a rotary vacuum evaporator. The solid residue obtained was dissolved in water and acidified with 10% hydrochloric acid up to pH=2.0. The crystallization was then carried out at 8°C for 16 h.

2.6 g of the product was isolated with the yield 45%. The raw solid product was then crystallized from the ethanol:water system. 1.8 g of the solid product was obtained. The

identity of the product N,N'–bis(2-hydroxy-5-propylbenzyl)ethylenediamine–N,N'–diacetic · HCl · $3H_2O$ acid was confirmed by means of ^1H NMR and the purity by means of elemental analysis.

^1H NMR (DMSO) δ: 7.03–6.86 (m, 8H, ArH), 4.01 (s, 4H, $HOOCCH_2N$), 3.64 (s, 4H, $ArCH_2N$), 3.21 (s, 4H, NCH_2CH_2), 2.54 (t, 6H, CH_2Ar), 1.58 (q, 4H, CH_2CH_2Ar), 0.98 (t, 6H, CH_3)

Elemental analysis: Calculated for $C_{26}H_{36}N_2O_6 \cdot HCl \cdot 3H_2O$: C 55.46, H 7.70, N 4.98, Found: C 55.42, H 7.79, N 4.99.

Example 4

N,N'-Bis(2-hydroxy-5-methylbenzyl)ethylenediamine-N,N'-diacetic acid, monohydrochloride trihydrate

Following the general procedure described in Example 1 ethylenediamine (0.1 mol) and 37% formaldehyde aqueous solution (0.2 mol) were added to the autoclave. The reaction mixture was heated at 80°C until it became homogenous. Then p-cresol (0.2 mol) was added dropwise at 50°C and the neat reaction mixture (with no solvent added) was heated at 90-95°C for 16 h. The conversion of reactants was monitored by means of TLC analysis with ethanol:chloroform (9:2) developing system. When the completion of the reaction was confirmed, water was decanted from the reaction mixture and the oil thus obtained was washed twice with hexane and three times with water at reflux temperature. The remaining solvent was removed on the rotary evaporator. The raw product was obtained with the yield of 66% and then dissolved in ethyl ether and left for crystallization. White solid thus obtained was filtered under vacuum and washed with 60 ml of ethanol, then dried in vacuum dryer for 2 h at 40°C . Subsequently it was crystallized from ethyl ether with the yield 83%.

The structure of N,N'-bis(2-hydroxy-5-methylbenzyl)ethylenediamine product thus obtained was confirmed by means of ^1H NMR. HPLC analysis shown the purity level of 98%.

Reductive amination carried out for 36 h following the procedure described above in Example 2.1. above gave the product with the isolated yield 90%. N,N'–bis(2-hydroxy-5-methylbenzyl)ethylenediamine–N,N'–diacetic acid monohydrochloride obtained after crystallization from ethanol:water system has the HPLC purity at the level of 96%.

Example 5

General procedure for the preparation of compounds of formula (I) using salan compounds of formula (II) prepared by reduction of salen compounds of formula (V)

A. Preparation of a salen compound

To the round-bottomed 250 ml flask equipped with a mechanical stirrer and a reflux condenser 100 ml of a solvent and 0.1 mol of ethylenediamine is introduced to obtain a solution. To the solution 0.2 mol of salicylaldehyde or its derivative of the formula (IV) are added portionwise. The mixture obtained is heated for 1 h at 50-60°C. As the reaction progresses a salen compound produced precipitates in a form of a fine crystalline solid.

B. Reduction of a salen compound

When the reaction is completed, the mixture containing the salen compound is transferred to a heated autoclave with a mechanical stirrer and hydrogenation catalyst is added in the amount of 1 to 5% by weight with respect to the salen compound. The air is removed from the reaction system by passing inert gas flow (preferably argon), the autoclave is pressurized with hydrogen gas and the hydrogenation is then carried out at 40-60°C at the hydrogen pressure 2 to 20 atm for 4 to 25 h until the absorption of hydrogen in the system ceases.

C. Reductive amination with glyoxylic acid

The salan compound prepared as above and the mixture glyoxylic acid/amine are added to an autoclave in the amounts such as to obtain the final molar ratio salan:glyoxylic acid:amine in the range from 1:2:2 to 1:4:5. The total concentration of reactants in the reaction mixture is in the range 2 to 20% by weight.

Then to the reaction mixture a heterogeneous catalyst is added, preferably Ni-Raney or Pd/C in the amount of 1 to 5% by weight with respect to the salan compound.

The air is removed from the reaction system by venting and passing over inert gas flow (preferably argon). Reductive amination is carried out for 4 to 48 h at the hydrogen pressure of 2 to 50 atm.

The product is isolated by filtration of the catalyst, evaporation of the solvent and crystallization of the product from water after acidifying to the pH 1.5 to 2.5.

If both the preparation of salen compound and its reduction are carried out in water, the salan compound produced is separated directly from the reaction mixture by acidification with a mineral acid, preferably with hydrochloric acid.

Structures of the products are confirmed by means of ^{1}H NMR analysis and their purities by means of HPLC and elemental analysis.

Example 6

N,N'–bis(2–hydroxybenzyl)ethylenediamine–N,N'–diacetic acid monohydrochloride trihydrate

Following the general procedure described above in Example 5, ethylenediamine (6.0 g, 0.1 mol), salicylaldehyde (24.4 g, 0.2 mol) and methanol (120 ml) were added to an autoclave. The reaction mixture was heated at 50°C for 3 h. The reaction progress was monitored by means of TLC analysis with ethanol:chloroform (9:2) developing system. When the completion of the reaction was confirmed the sample of a salen compound was isolated to perform the ^{1}H NMR analysis and confirm the structure of the product obtained.

^{1}H NMR ($CDCl_3$) δ: 13.2 (s, 2H, OH), 8.35 (s, 2H, ArCHN), 7.32-6.83 (m, 8H, ArH), 3.93 (s, 4H, NCH_2CH_2).

Then to the autoclave 0.2 g of the Pd/C was introduced, the air was removed and the reaction was carried out at 50°C in the atmosphere of hydrogen gas under the pressure 5 atm for 3 h. When hydrogen absorption ceased the mixture of glyoxylic acid monohydrate (27.6 g, 0.3 mol) and triethylamine (40.4 g, 0.4 mol) in methanol (100 ml) was introduced to the salan compound.

The reaction system was heated to 50°C and hydrogen was introduced under the pressure of 10 atm. The reductive amination was carried out for 15 h, then the catalyst was filtered and the solvent evaporated by means of a rotary vacuum evaporator. The solid (62 g) obtained was dissolved in water and acidified with 10% hydrochloric acid to pH=2.0. Crystallization was carried out for 12 h at 8°C.

37 g of the product N,N'–bis(2–hydroxybenzyl)ethylenediamine–N,N'–diacetic acid monohydrochloride trihydrate was separated with the overall yield 78% with respect to

the starting ethylenediamine. The raw product was recrystallized form 85% ethanol. The structure of the product was confirmed by means of ^{1}H NMR and the purity thereof by means of elemental analysis.

^{1}H NMR (DMSO) δ: 7.23–6.78 (m, 8H, ArH), 4.06 (s, 4H, $HOOCCH_2N$), 3.65 (s, 4H, $ArCH_2N$), 3.22 (s, 4H, NCH_2CH_2)

Elemental analysis: Calculated for $C_{20}H_{24}N_2O_6 \cdot HCl \cdot 3H_2O$: C 50.16, H 6.52, N 5.85, Found: C 50.15, H 6.58, N 5.81

Example 7

N,N'–bis(2–hydroxybenzyl)ethylenediamine–N,N'–diacetic acid monohydrochloride trihydrate

Following the general procedure described in Example 5 ethylenediamine (6 g, 0.1 mol), salicylaldehyde (24.4 g, 0.2 mol) and water (100 ml) were added to the autoclave. The reaction mixture was heated at 45°C for 5 h. The reaction progress was monitored by means of TLC analysis with ethanol:chloroform (9:2) developing system. When the completion of the reaction was confirmed the sample of a product was isolated to perform the ^{1}H NMR analysis and confirm the structure of the obtained salen product (analysis consistent with the data presented in Example 6).

Then to the autoclave 0.1 g of the Pd/C was introduced, the air was removed, the autoclave was pressurized with hydrogen and the reaction was carried out at 45-50°C under the hydrogen pressure of 6 atm for 14 h. When the absorption of hydrogen ceased, methanol (180 ml) and the mixture of glyoxylic acid monohydrate (27.8 g, 0.3 mol) and triethylamine (40.5 g, 0.4 mol) were introduced to the system.

The reaction system was heated to 50°C and hydrogen was introduced under the pressure of 10 atm. The reductive amination was carried out for 15 h, then the catalyst was filtered and the solvent evaporated by means of a rotary vacuum evaporator. The solid obtained was dissolved in water and acidified with 10% hydrochloric acid to pH=2.0. Crystallization was carried out for 10 h at 8°C.

35.5 g of the product N,N'–bis(2–hydroxybenzyl)ethylenediamine–N,N'–diacetic acid hydrochloride trihydrate was separated with the overall yield 84% with respect to the starting ethylenediamine. The raw product was recrystallized form the 85% ethanol. The

structure of the product was confirmed by means of ^{1}H NMR and the purity thereof by means of elemental microanalysis.

Example 8

N,N'–bis(5–carboxy–2–hydroxybenzyl)ethylenediamine–N,N'–diacetic acid monohydrochloride trihydrate

The above product was prepared following the general procedure described in Example 5 and using 3-formyl-4-hydroxybenzoic acid as a starting material for the preparation of salen compound. Condensation of 3-formyl-4-hydroxybenzoic acid with ethylenediamine and reduction of resulting salen compound to the salan compound were carried out in iso-propanol with the total yield 62%.

The salan product was isolated from the reaction mixture and reductive amination was carried out in water using 50% aqueous solution of glyoxylic acid and tributylamine at the molar ratio salan compound:glyoxylic acid:tributylamine equal to 1:2.5:3. The reductive amination was carried out for 35 h at 45 atm of hydrogen pressure in the presence of 1.5% by weight of a Ra-Ni catalyst with respect to the salan compound. The yield of the N,N'–bis(5–carboxy–2–hydroxybenzyl)ethylenediamine–N,N'–diacetic acid hydrochloride trihydrate was 37%.

The structure of the product was confirmed by means of ^{1}H NMR and the purity thereof by means of elemental microanalysis.

^{1}H NMR (DMSO) δ: 7.52–6.64 (m, 8H, ArH), 4.11 (s, 4H, $HOOCCH_2N$), 3.59 (s, 4H, $ArCH_2N$), 3.18 (s, 4H, NCH_2CH_2).

Elemental analysis: Calculated for $C_{22}H_{24}N_2O_{10}\cdot HCl \cdot 3H_2O$: C 46.61, H 5.51, N 4.94, Found: C 46.65, H 5.58, N 4.89.

Example 9

N,N'–bis(2–hydroxy–5–methylbenzyl)ethylenediamine–N,N'–diacetic acid monohydrochloride trihydrate

The above product was prepared following the general procedure described in Example 5 and using 5–methylsalicylaldehyde as a starting material for the preparation of the salen compound. Condensation of with 5–methylsalicylaldehyde with ethylenediamine and reduction of the resulting salen compound to the salan compound were carried out in ethanol with the total yield 92%.

The salan product was isolated from the reaction mixture and reductive amination was carried out in water using 50% aqueous solution of glyoxylic acid and tributylamine at the molar ratio salan compound/glyoxylic acid/tributylamine equal to 1:3:3. The reductive amination was carried out for 48 h at 45 atm of hydrogen pressure in the presence of 1.5% by weight of a Ra-Ni catalyst with respect to the salan compound. The yield of the product N,N'–bis(2–hydroxy-5–methylbenzyl)ethylenediamine–N,N'–diacetic acid hydrochloride trihydrate was 75%.

The structure of the product was confirmed by means of ^{1}H NMR and the purity thereof by means of elemental microanalysis.

^{1}H NMR (DMSO) δ: 7.03–6.86 (m, 8H, ArH), 4.01 (s, 4H, $HOOCCH_2N$), 3.64 (s, 4H, $ArCH_2N$), 3.21 (s, 4H, NCH_2CH_2), 2.14 (s, 6H, CH_3Ar)

Elemental analysis: Calculated for $C_{22}H_{28}N_2O_6 \cdot HCl \cdot 3H_2O$:

C 52.12, H 6.96, N 5.53, Found: C 52.02, H 7.01, N 5.49

Example 10

N,N'–bis(2–hydroxy-5-methylbenzyl)ethylenediamine–N,N'–diacetic acid, sodium salt

In a 50 ml beaker equipped with a mechanical stirrer 3 g (0,006 mol) of N,N'–bis(2–hydroxy-5-methylbenzyl)ethylenediamine–N,N'–diacetic acid monohydrochloride trihydrate prepared in Example 9 above and 24.5 ml of deionised water were introduced. Then 1 ml (0.018 mol) of the 50% NaOH aqueous solution was added dropwise. After stirring for 10 min a 10% aqueous solution of N,N'–bis(2–hydroxy-5-methylbenzyl)ethylenediamine–N,N'–diacetic acid sodium salt was obtained having the pH=11.5.

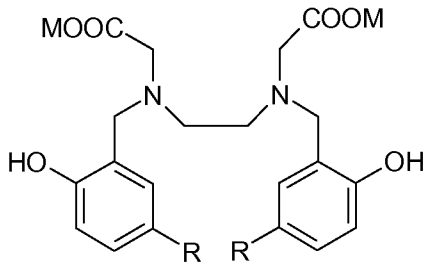
Example 11

N,N'–bis(2–hydroxybenzyl)ethylenediamine–N,N'–diacetic acid, potassium salt

In a 50 ml beaker equipped with a mechanical stirrer 2.5 g (0,0057 mol) of N,N'–bis(2–hydroxybenzyl)ethylenediamine–N,N'–diacetic acid monohydrochloride trihydrate prepared in Example 6 above and 24.5 ml of deionised water were introduced. Then 1.72 ml (0.0171 mol) of the 40% NaOH aqueous solution was added dropwise. After stirring for 10 min a 8% aqueous solution of N,N'–bis(2–hydroxybenzyl)-ethylenediamine–N,N'–diacetic acid sodium salt, pH=12.2, was obtained.

Claims

1. A process for the preparation of N,N'-bis(2-hydroxybenzyl)ethylenediamine-N,N'-diacetic acid and its derivatives of general formula I:



(I)

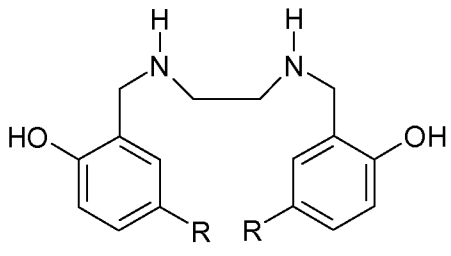
wherein:

both R have the same meaning and are selected from H, C_1-C_4alkyl, CH_2OH, SO_3M, and COOM; and

all M have the same meaning and represent hydrogen atom, Na, K or NH_4;

which comprises:

- reductive amination of glyoxylic acid with a salan compound of general formula (II)

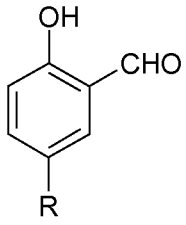


(II)

wherein R have the same meaning as defined for formula (I), in the presence of an amine proton acceptor, to obtain the compound of formula (I), wherein M are hydrogen atoms, and

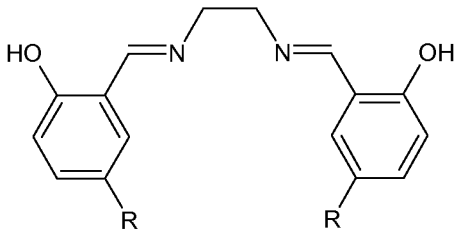
- if desired, converting it further into compound of formula (I), wherein M represent Na, K or NH_4 by the treatment with a corresponding base.

2. The process of claim 1 wherein said salan compound of formula (II) is prepared by reaction of ethylenediamine with 2 molar equivalents of a compound of formula (IV)



(IV)

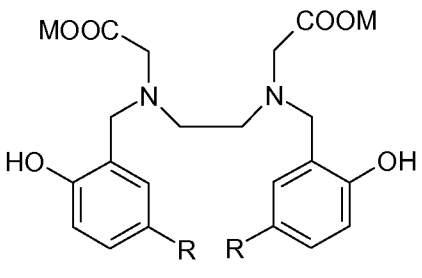
wherein R are as described for formula (I) to obtain a corresponding salen compound of formula (V)



(V)

wherein R are as described for formula (I), and then reduction of the salen compound of formula (V) to obtain the compound of formula (II).

3. A process for the preparation of N,N'-bis(2-hydroxybenzyl)ethylenediamine-N,N'-diacetic acid and its derivatives of general formula I:



(I)

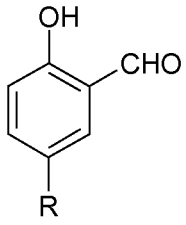
wherein:

both R have the same meaning and are selected from H, C_1-C_4alkyl, CH_2OH, SO_3M, and COOM; and

all M have the same meaning and represent hydrogen atom, Na, K or NH_4;

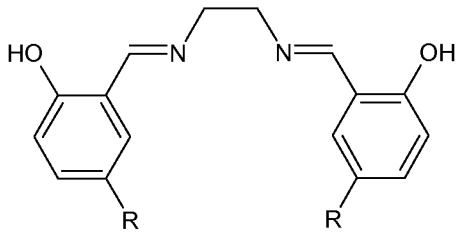
which comprises:

a) reaction of ethylenediamine with 2 molar equivalents of a compound of formula (IV)



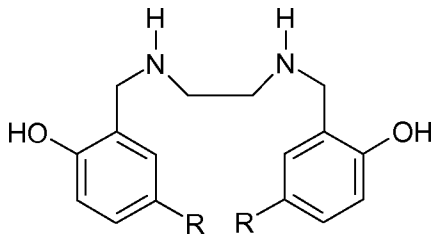
(IV)

wherein R is as defined for formula (I), to obtain a corresponding salen compound of formula (V)



(V)

b) reduction of the salen compound of formula (V) to obtain a compound of formula (II)



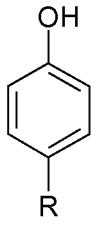
(II)

wherein R have the meanings as defined for formula (I),

c) reductive amination of glyoxylic acid with the compound of formula (II) in the presence of an amine proton acceptor, to obtain the compound of formula (I) wherein M are hydrogen atoms, and

d) if desired, converting it further into compound of formula (I) wherein M represent Na, K or NH_4 by the treatment with a corresponding base.

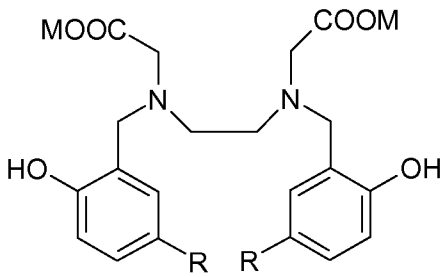
4. The process of the claim 1 for the preparation of the compound of formula (I) wherein R is C_1-C_4alkyl wherein said salan compound of formula (II) is prepared by reaction of ethylenediamine, a formaldehyde source and a phenol compound of formula (III)



(III)

wherein R is C_1-C_4alkyl in a molar ratio ethylenediamine: formaldehyde: phenol compound of about 1:2:2.

5. A process for the preparation of N,N'-bis(2-hydroxybenzyl)ethylenediamine-N,N'-diacetic acid derivatives of general formula I:



(I)

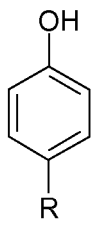
wherein

both R have the same meaning and are selected from C_1-C_4alkyl; and

all M have the same meaning and represent hydrogen atom, Na, K or NH_4;

which comprises:

b) reaction of ethylenediamine, a formaldehyde source and a phenol compound of formula (III)



(III)

wherein R is C_1-C_4alkyl in a molar ratio ethylenediamine: formaldehyde: the phenol compound of about 1:2:2, to obtain a salan compound of general formula (II)

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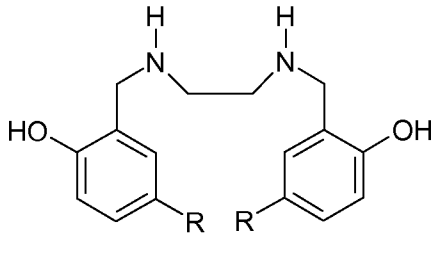

(II)

wherein R have the same meaning as defined above for formula (I), and

b) reductive amination of glyoxylic acid with the salan compound of formula (II) in the presence of an amine proton acceptor, to obtain the compound of formula (I), wherein M are hydrogen atoms, and

c) if desired, converting it further into compound of formula (I), wherein M represent Na, K or NH_4 by the treatment with a corresponding base.

6. The process of any one of claims 4 or 5 wherein said formaldehyde source is selected from an aqueous formaldehyde solution and paraformaldehyde.

7. The process of claim 6 wherein said formaldehyde source is the aqueous formaldehyde solution.

8. The process of any of claims 1 to 7 wherein a molar ratio compound of formula (II): glyoxylic acid: amine is in the range from 1:2:2 to 1:4:5.

9. The process of claim 8 wherein said molar ratio is about 1:3:3.5.

10. The process of any of claims 1 to 9 wherein the amine proton acceptor is triethylamine.

11. The process of any of the claims 1 to 10 wherein said reductive amination is carried out by hydrogenation with hydrogen in the presence of a hydrogenation catalyst in a C_1-C_3 alkanol or their mixtures or in a C_1-C_3 alkanol/water mixture.

12. The process of claim 7 wherein said reduction in step b) and reductive amination in step c) are carried out in the same reaction vessel, without isolation of the intermediate compound of formula (V).

13. The process of claim 7 wherein all steps a) to c) are carried out in the same reaction vessel, without isolation of intermediate compounds of formulas (IV) and (V).

14. The process of claim 12 or 13 wherein both reduction in step b) and reductive amination in step c) are carried out by hydrogenation with hydrogen in the presence of a hydrogenation catalyst in a C_1-C_3 alkanol or their mixtures or in a C_1-C_3 alkanol/water mixture.

15. The process of claim any of the claims 11 or 14 wherein said hydrogenation catalyst is nickel, palladium or platinum on a solid support.

16. The process of claim 15 wherein said hydrogenation catalyst is Ra-Ni or Pd/C.

17. The process of any one of claims 1 to 16 wherein R represent CH_3.

18. The process of any one of claims 1 or 6 to 16 wherein R represent H.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/062269

A. CLASSIFICATION OF SUBJECT MATTER
INV. C07C251/24 C07C227/02 C07C249/02

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C07C

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, BEILSTEIN Data, WPI Data, PAJ, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	ABDEL-MAGID A F ET AL: "Reductive amination of aldehydes and ketones with sodium triacetoxyborohydride. Studies on direct and indirect reductive amination procedures" JOURNAL OF ORGANIC CHEMISTRY, AMERICAN CHEMICAL SOCIETY. EASTON, vol. 61, no. 11, 1 May 1996 (1996-05-01), pages 3849-3862, XP002217704 ISSN: 0022-3263 page 3849 page 3854 page 3858	1-18

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 October 2008	11/11/2008

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/062269

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	WO 01/46114 A (GELTEX PHARMA INC [US]; MCKEARIN JAMES M [US]) 28 June 2001 (2001-06-28) cited in the application pages 2-3, steps A-E the whole document	1-18
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Y	JERRY MARCH: "Advanced organic chemistry" 1985, JOHN WILEY & SONS , USA , XP002491276 page 798 - page 801	1-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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