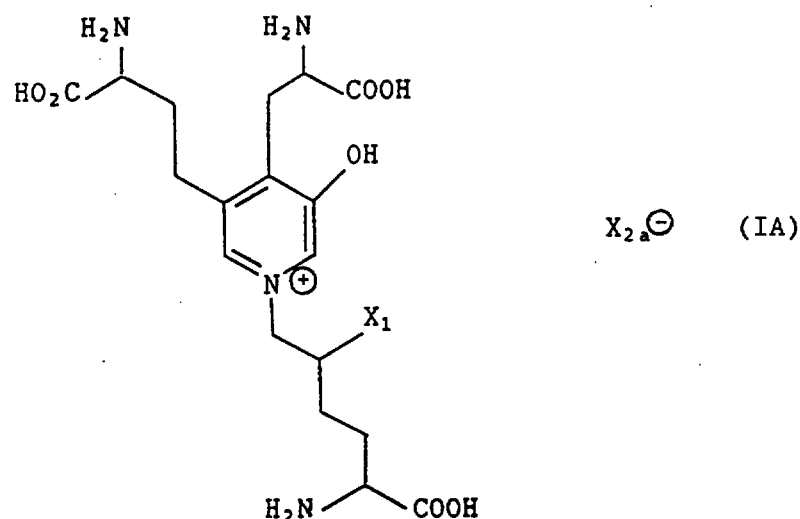


CASE 100-7839

PYRIDINE DERIVATIVES

The present invention relates to pyridine derivatives, processes for their production and their use in diagnosis to detect bone and other connective tissue disorders in humans and animals.

Compounds of formula IA



wherein X_1 is H or OH, and

X_{2a}^- is a chloride or acetate ion

have been extracted from urine either by hydrolysis with 6M HCl at about 108°C for approximately 24 hours (see Eyre et al., Ann. Rev. Biochem., 1984, 53, 717 - 748) or by chromatography using acetic acid as eluant (see D.R. Eyre et al. Anal. Biochem. 137, 380-388 (1984). Compounds of formula IA have been disclosed as an index of

collagen degradation in metabolic bone and cartilage diseases based on the quantitating of their concentration in urine excretion over a fixed period (see Wu and Eyre, *Biochemistry*, 1984, 23, 1850; Robins et al., *Analytical Biochem.*, 1988, 169, 197 - 203; D. Uebelhart et al., *Bone and Mineral*, 1990, 8, 87 - 96).

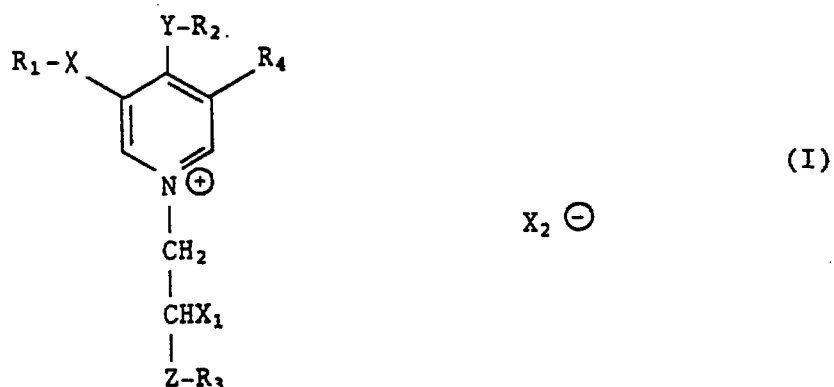
Interest in these compounds (referred to in literature as pyridinoline [$X_1=OH$] and deoxypyridinoline [$X_1=H$] crosslinks) as a marker for connective tissue metabolism abnormalities e.g. for measurements of bone resorption in human, is growing.

However, as the compounds of formula IA are until now natural compounds obtained by extraction, they do not meet the requirements for running standardized reproducible, reliable and non time-consuming assays.

There is a high need for defined standard pyridinoline crosslinks.

It is the purpose of the present invention to provide new pyridine derivatives and their production by chemical synthesis including the production of a compound of formula IA, in a substantially pure form in order to allow bone turn-over measurements under well standardized conditions.

More particularly, the present invention provides a compound of formula I



wherein

each of X, Y and Z, independently is C₁₋₈alkyl; C₁₋₈alkyl interrupted by one or two heteroatoms selected from O, N and S; cycloalkyl; cycloalkyl-C₁₋₄alkyl; (C₁₋₄alkyl)-cycloalkyl; (C₁₋₄alkyl)-cycloalkylene-C₁₋₄alkyl; optionally substituted aryl; optionally substituted heteroaryl; (C₁₋₄alkyl)-aryl; (C₁₋₄alkyl)-heteroaryl; (C₁₋₄alkyl)-arylene-C₁₋₄alkyl; (C₁₋₄alkyl)-heteroarylene-C₁₋₄alkyl; aryl-C₁₋₄alkyl; heteroaryl-C₁₋₄alkyl, the aryl or heteroaryl moieties of the above mentioned groups being optionally substituted;

R₃ is COOH or a functional derivative thereof; CHO; CN; C₁₋₈alkoxy; SO₂; -PO₃H or a functional derivative thereof; -SO₃H or a functional derivative thereof; a primary, secondary or tertiary amino group; a saturated or unsaturated cyclic amino group; or a radical of formula (a)



wherein

R₅ is a primary, secondary or tertiary amino group or a saturated or unsaturated cyclic amino group, and
R₆ is -COOH or a functional derivative thereof;

each of R₁ and R₂, independently, is hydrogen or has one of the significances given for R₃,

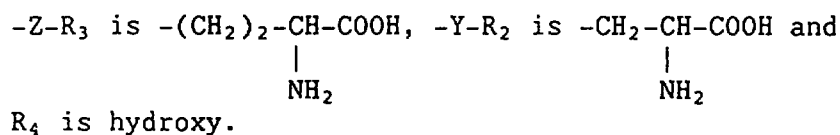
R₄ is hydroxy; C₁₋₆alkoxy; or polyalkylenoxy;

X₁ is H or OH, and

X₂[⊖] is an anion

with the proviso that

- i) when both X and Y comprise an alkyl moiety, the chain length of the alkyl moiety in -Y- is at least one carbon atom shorter than the alkyl moiety in -X-, and
- ii) X₂[⊖] is other than Cl[⊖] or CH₃COO[⊖] when each of -X-R₁ and



C₁₋₈alkyl is preferably C₁₋₆alkyl, more particularly C₁₋₄alkyl, especially C₁₋₂alkyl.

Preferably aryl means phenyl or 1- or 2-naphthyl, particularly phenyl. Aryl may be substituted, e.g. mono- di- or trisubstituted by hydroxy, C₁₋₄alkyl, C₁₋₄alkoxy and/or halogen. Preferably aryl is unsubstituted or monosubstituted phenyl.

Preferably heteroaryl means a saturated or unsaturated 5- or 6-membered heterocyclic ring, e.g. imidazolyl, thiazolyl, piperidinyl, piperazinyl or phthaloyl. When substituted, it may be mono-, di- or trisubstituted by hydroxy, alkyl, alkoxy and/or halogen. Preferably heteroaryl is unsubstituted.

When R₁, R₂, R₃ or R₅ is a secondary amino group, it is preferably -NHR_a wherein R_a is C₁₋₈alkyl; C₁₋₈alkyl optionally substituted by COOH or functional derivative thereof; C₂₋₈alkenyl; cycloalkyl; cycloalkyl-C₁₋₈alkyl; phenyl; phenyl-C₁₋₈alkyl; or R_a is a radical -Y_a or -Z_a-Y_b wherein Y_a is a protecting group or a group capable of covalently reacting with an antigen or a protecting group, Z_a is a spacer and Y_b is a protecting or antigenic group, biotinyl or a group derived from a molecule capable of forming a complex with another molecule like the biotin-avidin tool.

When R₁, R₂, R₃ or R₅ is a tertiary amino group, it is preferably -NR_aR_a' wherein R_a is as defined above and R_a' has independently one of the significances given for R_a; preferably R_a and R_a' are two substituents which do not hinder each other.

N-protecting groups as Y_a or Y_b include such groups as e.g. dis-

closed in "Protective Groups in Organic Synthesis", T. W. Greene, J. Wiley & Sons NY (1981), 219-287, for example acyl such as formyl, acetyl, trifluoroacetyl, methoxysuccinyl, hydroxysuccinyl or benzoyl optionally substituted on the phenyl ring with e.g. p-methoxycarbonyl, p-methoxy, p-nitro or p-phenylsulfonamidocarbonyl; alkoxycarbonyl such as t-butyloxycarbonyl, isobutyloxycarbonyl or methoxycarbonyl; allyloxycarbonyl; arylmethoxycarbonyl such as 9-fluorenylmethoxycarbonyl or benzyloxy carbonyl optionally substituted on the phenyl ring with p-methoxy, p-nitro, o- or p-chloro, m-phenyl or 3,4-dimethyl; trityl; arylmethyl such as benzyl optionally ring substituted with p-methoxy, p-nitro or p-chloro; or arylsulfonyl such as phenylsulfonyl optionally ring substituted with p-methyl or p-methoxy, or naphthylsulfonyl optionally ring substituted with e.g. amino or di(C₁₋₄alkyl)amino.

Examples of carboxylic acid functional derivatives are acid halides, acid anhydrides (including mixed acid anhydrides), active esters, active amides, etc. Among the acid halides, acid chloride is the most frequently used. Examples of the acid anhydrides include cyclic anhydrides and mixed anhydrides, such as dialkylphosphoric acid mixed anhydrides, dialkylphosphorous acid mixed anhydride etc. Example of the activated esters as R₁, R₂, R₃ or R₆ include C₁₋₈alkyl ester, e.g. methyl ester or ethyl ester, cyanomethyl ester, p-nitrophenyl ester, an ester with N-hydroxysuccinimide, optionally ring-substituted phenyl or benzyl ester, or fluorenylmethyl ester. Examples of active carboxylic acid amides as R₁, R₂, R₃ or R₆ include amides with imidazole, dimethylimidazole or triazole. Carboxylic amide groups as R₁, R₂, R₃ or R₆ may also be e.g. -CONH₂, -CONHR_a or -CONR_aR_a' as defined above.

Examples of functional derivatives of -SO₃H or -PO₃H are e.g. C₁₋₆alkyl, benzyl, phenyl, allyl or trimethylsilyl esters, acid halides, e.g. acid chloride, or lower dialkyl amides, e.g. diethyl or diisopropyl amides. Preferred are (alkoxy)(diamino)phosphines,

e.g. such a phosphine wherein "alcoxy" is methoxy, butoxy, allyloxy or benzoxy and "diamino" is diethylamino, dipropylamino or diisopropylamino.

Examples of an anion $X_2^\ominus$ include e.g. $OH^\ominus$, $Cl^\ominus$, $Br^\ominus$, $I^\ominus$, $CH_3COO^\ominus$, $CF_3COO^\ominus$.

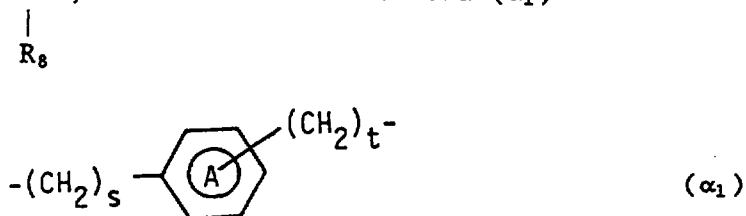
Suitable spacer groups as Z_a include e.g. a radical of formula (b)



wherein

X_3 is a divalent group derived from a functional moiety capable of covalently reacting with a protecting group or an antigen, and

R_7 is C_{1-6} alkylene optionally interrupted by one or more heteroatoms or radicals selected from oxygen, sulfur, CO, -NHCO-, -CO-NH-, -N(C_{1-4} alkyl)-CO-, -CO-N(C_{1-4} alkyl)-, -NH- and -N(C_{1-4} alkyl)-; hydroxy substituted C_{1-6} alkylene; C_{2-6} alkenylene; -CH-; or a radical of formula (α_1)



wherein each of s and t independently is 0, 1, 2 or 3, the ring A is optionally substituted and R_8 is an optionally protected residue as attached in C_α of a natural or non natural α -amino acid.

Each of Z_1 and X_3 independently may be for example -CO-, -CS- or -NH-.

Examples of R_8 include e.g. an optionally N-protected residue as present on the $C\alpha$ in Lys.

Suitable examples for the radical of formula (b) include e.g. succinyl, β -Ala or a divalent residue derived from 3-amino-propanoic acid, 3-aminoisobutanoic acid, 4-aminobutanoic acid, $NH_2-C(CH_3)_2-COOH$, 6-aminohexanoic acid, 1,8-diaminooctane, 1,6-diaminohexane or $NH_2-(CH_2)_{1-4}-CO-NH-(CH_2)_{1-6}-NH_2$.

Suitable groups capable of covalently reacting with an antigen or protecting group as Y_a include e.g. a radical of formula (b₁)



wherein

R_7 is as defined above, and

X_4 is a functional moiety capable of reacting with an antigen or a protecting group.

Examples of X_4 include e.g. carboxy, amino or a functional derivative thereof capable of reacting with an antigen or protecting group. In the radical of formula (b₁) R_7 is preferably C_{1-6} alkylene or C_{2-6} alkenylene.

By antigenic group is meant a group derived from a carrier molecule e.g. as used in the preparation of antibodies, for example bovine serum albumin, ovalbumin, thyroglobulin or keyhole limpet hemocyanin, or from an immunostimulant lipoamino acid or lipopeptide, e.g. such compounds wherein the lipophilic moiety is tripalmitoyl, for example as disclosed by G. Jung and al in Int. J. Peptide Protein Res. 37, 1991, 46-57, herein incorporated by reference. Examples of lipopeptides are N-palmitoyl-S-[2,3-bis(palmitoyloxy)-(2RS)-propyl]-[R]-cysteine (referred to as Pam₃Cys-OH), Pam₃Cys-Ser, Pam₃Cys-Ser-(Lys)₄ and Pam₃Cys-Ser-(Glu)₄.

In the compounds of formula I, the following significances are preferred either individually or in any combination or sub-combination:

1. X is $-(CH_2)_n-$ wherein n is an integer from 2 to 8. More preferably n is 2.
2. Y is $-(CH_2)_m-$ wherein m is n - 1. More preferably m is 1.
3. Z is $-(CH_2)_p-$ wherein p is an integer from 1 to 8. More preferably p is 2.
4. R_4 is OH.
5. R_1 is hydrogen, carboxy or a functional derivative thereof, primary, secondary or tertiary amino group, or a radical of formula (a), preferably a radical of formula (a).
6. R_2 is hydrogen, carboxy or a functional derivative thereof, primary, secondary or tertiary amino group, or a radical of formula (a), preferably a radical of formula (a).
7. R_3 is carboxy or a functional derivative thereof, primary, secondary or tertiary amino group, or a radical of formula (a).
8. The radical of formula (a) is $R'_5-CH-COOH$ or a functional derivative thereof, wherein R'_5 is $-NH_2$ or $-NHR_a$, e.g. such a group wherein R'_5 is $-NH_2$, $-NHY_a$ or $-NHZ_a-Y_b$ and the carboxy is replaced by a functional derivative thereof, e.g. an ester or amide.
9. In the radical of formula (a) R'_5 is $-NHZ_a-Y_b$.

10. In the radical of formula (a), when R'_5 is $-NHZ_a-Y_b$, Y_b is preferably an antigenic group, more preferably an antigenic group derived from bovine serum albumine or keyhole limpet hemocyanin.
11. The radical of formula (a) is $R'_5-CH-CO-NHR_a$ wherein R'_5 is NH_2 or NHY_a . R_a is preferably Z_a-Y_b . Y_b is preferably an antigenic group, more preferably an antigenic group derived from bovine serum albumine or keyhole limpet hemocyanin.

According to a preferred embodiment, the invention provides compounds of formula I wherein X is $-CH_2-CH_2-$, Y is $-CH_2-$, each of R_1 and R_2 is a residue of formula (a) wherein R_5 is $-NH_2$ or NHY'_a wherein Y'_a is a protecting group and R_6 is $-COOH$ or C_{2-7} alkoxycarbonyl, X_1 is H or OH, preferably H, Z is $-CH_2-CH_2-$ and R_3 is a residue of formula (a) wherein R_5 is $-NH_2$ or NHY'_a and R_6 is $-CONH-Z_a-Y_b$ or $-CONHY_a$.

According to another preferred embodiment, the invention provides compounds of formula I wherein X is $-CH_2-CH_2-$, Z is $-CH_2-CH_2-$, each of R_1 and R_3 is a residue of formula (a) wherein R_5 is $-NH_2$ or NHY'_a and R_6 is $-COOH$ or C_{2-7} alkoxycarbonyl, X_1 is H or OH, preferably H, Y is $-CH_2-$ and R_2 is a residue of formula (a) wherein R_5 is $-NH_2$ or $-NHY'_a$ and R_6 is $-CONH-Z_a-Y_b$ or $-CONHY_a$.

According to a further preferred embodiment, the invention provides compounds of formula I wherein Z is $-CH_2-CH_2-$, Y is $-CH_2-$, each of R_2 and R_3 is a residue of formula (a) wherein R_5 is $-NH_2$ or NHY'_a and R_6 is $-COOH$ or C_{2-7} alkoxycarbonyl, X_1 is H or OH, preferably H, X is $-CH_2-CH_2-$ and R_1 is a residue of formula (a) wherein R_5 is $-NH_2$ or $-NHY'_a$ and R_6 is $-CONH-Z_a-Y_b$ or $-CONHY_a$.

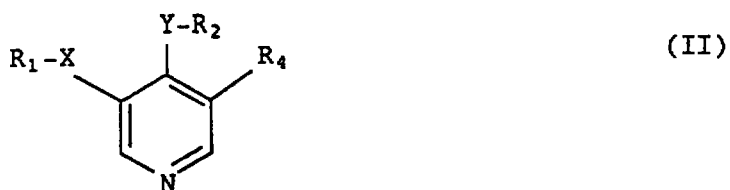
The compounds of formulae I and IA may exist e.g. in salt form. Salts include acid addition salts with e.g. organic salts,

polymeric acids or inorganic acids, for example hydrochloride and acetates, and salts forms obtainable with the carboxylic, sulfonic or phosphoric acid groups present in the molecule, e.g. alkali metal salts or substituted or unsubstituted ammonium salts and so-called internal salts when the molecule comprises at least one radical of formula (a).

The radical of formula (a) comprises an asymmetric carbon atom and may be present in D or L configuration. The compounds of formula I and IA also comprise an asymmetric carbon when X_1 is OH. The present invention is to be understood as embracing optical isomers as well as diastereoisomers of compounds of formula IA and compounds of formula I wherein X_1 is OH and up to three radicals of formula (a) are present in the molecule. Similar consideration apply in relation to starting materials comprising a radical of formula (a) or wherein X_1 is OH.

The present invention also provides a process for the production of a compound of formula I or IA, which process comprises

a) reacting a compound of formula II



wherein X, Y, R_1 , R_2 and R_4 are as defined above

with a compound of formula III



wherein

X_1 , Z and R_3 are as defined above, and

X_5 is a leaving group; or

- b) converting a compound of formula I or IA into another compound of formula I or IA

and recovering a compound of formula I or IA thus obtained in free form or in salt form.

In the compounds of formula III, X_5 may be e.g. halogenide, optionally substituted ammonium, methane- or ethanesulfonate, tosylate. When X_5 is halogenide, it may be converted into an anion as X_2^- .

Process step (a) may conveniently be carried out in an aprotic solvent, advantageously at a temperature from room temperature up to a temperature below the boiling point of the reaction mixture.

Process step (b) may be e.g. the removal of at least one protecting group from a compound of formula I in protected form or the introduction of at least one protecting or antigenic group in a compound of formula I or IA, optionally through a spacer group.

For the production of a compound of formula I comprising at least one antigenic group, a compound of formula IA or a compound of formula I wherein R_3 and/or R_1 and/or R_2 is carboxy, $-SO_3H$ or $-PO_3H$ or a functional derivative thereof, a primary, secondary or tertiary amino group or a radical of formula (a) free from an antigenic group, is reacted with an antigen optionally through a spacer group.

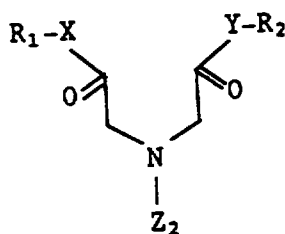
In the case the protecting group or the antigenic group is attached through a spacer group, the reaction may alternatively be performed with the spacer group being already attached either to the compound of formula I or IA or to the protecting group yielding compound or antigen. Alternatively a compound of formula I comprising a substituent Y_a may be reacted with a protecting group yielding compound or an antigen, each of which comprising a spacer group which is complementary to Y_a in order to obtain the desired spacer group Z_a .

The same considerations apply for the preparation of a compound of formula I wherein Y_b is biotinyl or a group having a similar marking function.

Compounds of formula II, used as starting materials, are also novel and form part of the invention.

Compounds of formula II may be prepared by a process comprising

- i) removing at least one protecting group from or adding at least one protecting group to an amino group or a carboxy group of a compound of formula II, optionally through a spacer group; or
- ii) cyclising a compound of formula IV



(IV)

wherein X, Y, R₁ and R₂ are as defined above, and
Z₂ is a leaving group

and, where required, etherifying a compound of formula II thus obtained wherein R₄ is OH into a compound of formula II wherein R₄ is alkoxy or polyalkylenoxy,

and recovering a compound of formula II thus obtained in free form or in salt form.

Process step (i) may be carried out in accordance with known techniques.

Process step (ii) may conveniently be effected in an inert solvent, preferably at room temperature. Cyclisation may advantageously be performed in the presence of a base, e.g. 1,5-diazabicyclo[4.3.0]non-5-ene (DBN) or 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU).

Insofar the preparation of the starting materials is not particularly disclosed they may be produced in analogy to Example 4.

The following examples are illustrative of the invention. All temperatures are in °C. BOC = t.-butoxycarbonyl

EXAMPLE 1

3-Hydroxy-1-(5-t.-butoxycarbonylamino-5-t.-butoxycarbonyl-pentyl)-4-(1-t.-butoxycarbonylamino-1-t.-butoxycarbonyl-2-ethyl)-5-(3-t.-butoxycarbonylamino-3-t.-butoxycarbonyl-propyl)-pyridinium iodide

2.0 g of 3-hydroxy-4-(1-t.-butoxycarbonylamino-1-t.-butoxycarbo-

nyl-2-ethyl)-5-(3-t.-butoxycarbonylamino-3-t.-butoxycarbonyl-propyl)pyridine and 1.9 g t.-butyl 6-iodo-2-t.-butoxycarbonylamino-hexanoate in 25 ml dioxan are heated to 110° for 1 hour. After evaporation the title compound is isolated by column chromatography on silica gel (methylenchloride/methanol/ammonia 95:5:0.5).
MS (FAB): M⁺ 881

EXAMPLE 2

3-Hydroxy-1-(5-amino-5-carboxy-pentyl)-4-(1-amino-1-carboxy-2-ethyl)-5-(3-amino-3-carboxy-propyl) pyridinium hydrochloride

206 mg of the title compound of example 1 are stirred in 20 ml trifluoroacetic acid/water 95:5 for 90 min. By addition of diethyl ether crude title compound is precipitated and filtered. This mixture is dissolved in 2 ml methanol and acidified to pH=1 with 2N HCl solution in diethyl ether. After evaporation the residue is purified by preparative HPLC.

Column: Macherey/Nagel SA5/SCX 5 m 4.6 x 200 mm

Solvents: A: 0.02 M LiCl

B: 0.2 M LiCl

Gradient: A + 0 - 100% B in 50 min.

Detection: UV 290 nm

The fractions containing the title compound are desalted by passing through a Bio-Gel P2 column(50-100 mesh) eluting with water. After freeze-drying pure title compound is isolated.

MS (FAB): M⁺ 413

EXAMPLE 3

2-t.-butoxycarbonylaminoamino-4-[3-hydroxy-4-(1-t.-butoxycarbonyl-1-amino-2-ethyl)-5-pyridinyl] butanoic acid t.-butyl ester

212 mg 1,13-di-t.-butyl 7-t.-butoxycarbonylaza-2,12-di-t.-butoxycarbonylamino-5,9-dioxo-tridecano-diate are dissolved in 10 ml tetrahydrofuran and 0.26 ml 1,8-diazabicyclo[5,4,0]-undec-7-en are added. This solution is stirred for 15 hours at room temperature and then evaporated. The mixture is separated by column chromatography on silica gel (methylene chloride/methanol 96:4), thus yielding the title compound.

MS (FAB): MH^+ 596

EXAMPLE 4

1,13-di-t.-butyl 7-t.-butoxycarbonylaza-2,12-di-t.-butoxycarbonylamino-5,9-dioxo-tridecano-diate, used as starting material in Example 3 may be prepared as follows:

a) T.-butyl 2-t.-butoxycarbonylamino-5,6-epoxy-hexanoate

13.1 g m-chloroperoxybenzoic acid (90%) are added to 13.8 g t.-butyl 2-t.-butoxycarbonylamino-5-hexenoate dissolved in 400 ml methylene chloride. After 18 hours stirring at room temperature the mixture is treated with ice/sat. $NaHCO_3$ solution. The aqueous part is extracted twice with methylene chloride. The organic solutions are combined, dried and evaporated. Chromatography on silica gel using ethyl acetate/hexane 1:2.5 yields the title compound 4a).

MS (FAB): MH^+ 286

b) 1,13-Di-t.-butyl 7-N-benzylaza-5,9-dihydroxy-2,12-di-t.-butoxycarbonylamino-tridecano-diate

A mixture of 1 g of title compound 4a) and 0.18 ml benzylamine is heated to 70° for 18 hours. This mixture is separated by column chromatography on silica gel (acetone/hexane 1:2), thus yielding the title compound 4b).

MS (FAB): MH⁺ 710

c) 1,13-Di-t.-butyl 7-aza-5,9-dihydroxy-2,12-di-t.-butoxycarbonylamino-tridecano-diate

9.48 g of the title compound 4b) are dissolved in 350 ml ethanol and hydrogenated in the presence of 1.4 g 10% Pd on charcoal at room temperature and normal pressure. This mixture is then filtered and evaporated. The title compound 4c) is purified by column chromatography on silica gel (methylene chloride/methanol 9:1)

MS (FAB): MH⁺ 620

d) 1,13-Di-t.-butyl 7-tert.butoxycarbonylaza-5,9-dihydroxy-2,12-di-t.-butoxycarbonylamino-tridecano-diate

4.1 g di-t.-butyl dicarbonate are quickly added to 7.7 g of the title compound 4c) dissolved in 310 ml tetrahydrofuran. The resulting solution is stirred for 3 hours at room temperature. After evaporation the title compound 4d) is purified by column chromatography on silica gel (hexane/ethyl acetate 6:4)

MS (FAB): MH⁺ 720

e) 1,13-Di-t.-butyl 7-t.-butoxycarbonylaza-2,12-di-t.-butoxycarbonylamino-5,9-dioxo-tridecano-diate

A solution of 4.0 ml dimethyl sulfoxide in 42 ml methylene chlo-

ride is added dropwise at -70° to a solution of 140 ml methylene chloride and 2.4 ml oxalyl chloride. After 15 min. a mixture of 8.0 g of the title compound 4d) in 80 ml methylene chloride is added slowly at -70° to the solution. After 3 hours stirring at -70° , 15.7 ml triethylamine are added at -50° . This mixture is then poured on ice/water. The fractions are separated and the aqueous part is extracted twice with diethyl ether. All organic fractions are combined, dried and evaporated. The residue is purified by column chromatography on silica gel (hexane/ethyl acetate 6:4), thus yielding pure title compound 4e).

MS (FAB): MH^{+} 716

EXAMPLE 5

3-Hydroxy-1-(2-hydroxy-5-amino-5-carboxy-pentyl)-4-(1-amino-1-carboxy-2-ethyl)-5-(3-amino-3-carboxy-propyl) pyridinium hydrochloride

The procedures of Examples 1 and 2 are repeated using t.-butyl-5-hydroxy-6-iodo-2-t.-butoxycarbonylamino-hexanoate.

MS (FAB): M^{+} 429

3-Hydroxy-1-(2-hydroxy-5-t.-butoxycarbonylamino-5-t.-butoxycarbonyl-pentyl)-4-(1-t.-butoxycarbonylamino-1-t.-butoxycarbonyl-2-ethyl)-5-(3-t.-butoxycarbonylamino-3-t.-butoxycarbonyl-propyl)-pyridinium iodide

MS (FAB): M^{+} 897

EXAMPLE 6

3-Hydroxy-1-[5-t.-butoxycarbonylamino-5-N-(1-methoxycarbonyl-2-ethyl)carboxamido-pentyl]-4-(1-t.-butoxycarbonylamino-1-t.-butoxycarbonyl-2-ethyl)-5-(3-t.-butoxycarbonylamino-3-

t.-butoxycarbonyl-propyl)-pyridinium iodide.

235 mg of the compound of Example 3 and 230 mg of ϵ -iodo-N-t.-butoxycarbonylamino-(methyl- β -alanyl)lysine in 1 ml dioxane are heated to 120° for 30 minutes. After evaporation the title compound is purified by chromatography on silica gel (ethyl acetate/methanol 7:3).

MS - FAB: M⁺ 910

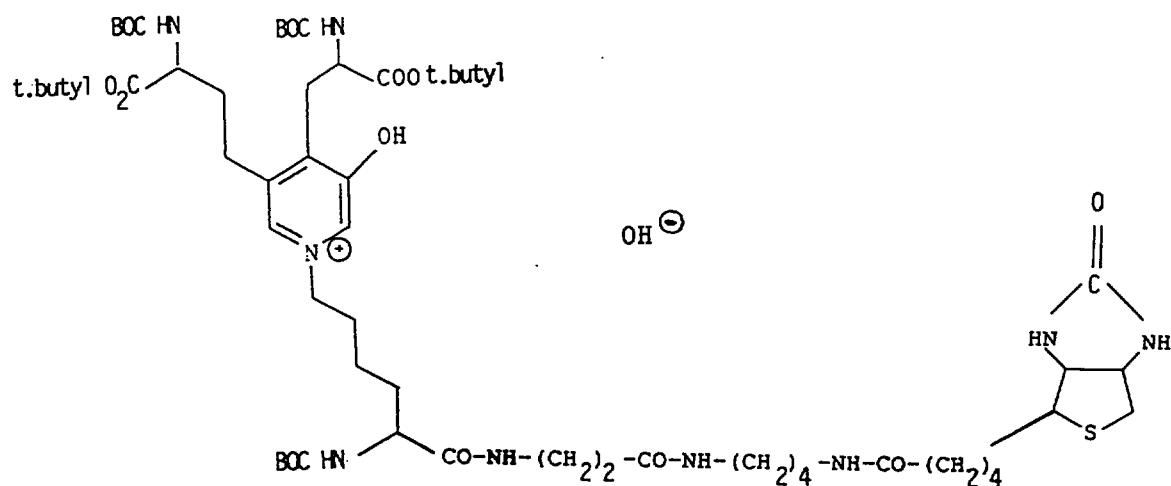
EXAMPLE 7

3-Hydroxy-1-[5-t.-butoxycarbonylamino-5-N-(1-carboxy-2-ethyl)carboxamido-pentyl]-4-(1-t.-butoxycarbonylamino-1-t.-butoxycarbonyl-2-ethyl)-5-(3-t.-butoxycarbonylamino-3-t.-butoxycarbonyl-propyl)-pyridinium hydroxide.

50 mg of the title-compound of Example 6 are dissolved in 5 ml methanol and 2 ml of 0.2 N sodium hydroxide and stirred for 5 hours at room temperature. Then 10 ml water and 10 ml methylene chloride are added and, under vigorous stirring, 0.2 N hydrochloric acid is added until pH = 2-3. The organic layer is separated, dried over sodium sulphate and evaporated. Chromatography on silica gel (methylene chloride/methanol 6:4) yields the title compound.

MS - FAB: M⁺ 896

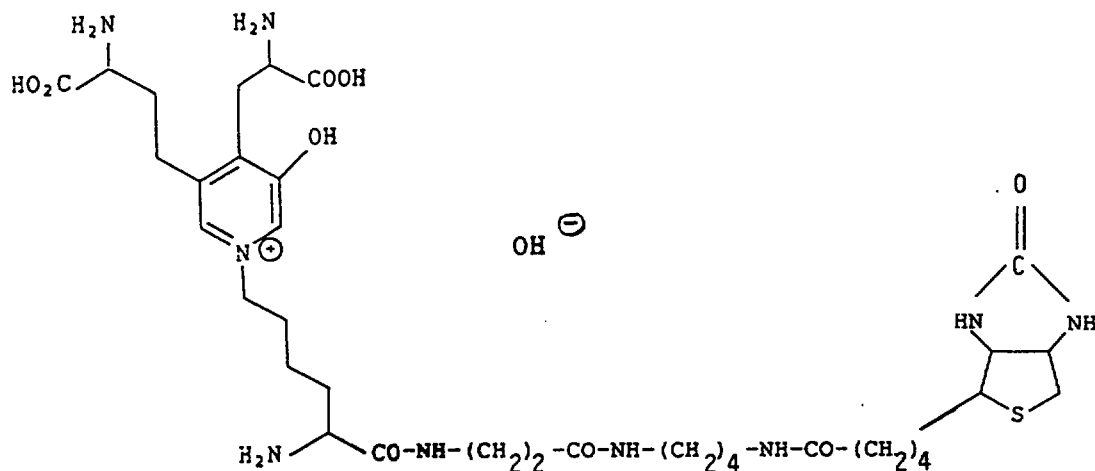
EXAMPLE 8



45 mg of the compound of Example 7 is dissolved in 1 ml N,N-dimethyl-formamide and 12 mg 1-hydroxybenzotriazole followed by 13 μ l diisopropyl-ethylamine (Huenig Base), 32 mg N-biotinyl-1,4-diaminobutane in 2 ml N,N-dimethyl-formamide, 15 mg N,N-dicyclohexylcarbodiimide are added. This mixture is stirred at room temperature for 23 hours. After evaporation and chromatography on silica gel (methylene chloride/methanol/ammonia 90/10/1) the title compound is isolated.

MS - FAB: M⁺ 1192

EXAMPLE 9



128 mg of the compound of Example 8 is dissolved in 25 ml tri-fluoroacetic acid/water 95:5 and stirred for 1 hour at room temperature. The solvents are evaporated and the residue purified by HPLC.

Column: Hypersil ODS 4.6 X 250 mm

Solvents: A: 100% H₂O , 1% CF₃COOH

B: 80% CH₃OH , 20 % H₂O , 1% CF₃COOH

Gradient: A + 20% B for 20 minutes

MS - FAB: M⁺ 780

EXAMPLE 10

Desoxypyridinolin-1-β-alanyl-BSA-Conjugate

14 mg of the compound of Example 7 is dissolved in 0.4 ml N,N-dimethyl-formamide, then 3.3 mg N-ethyl-N-(3-dimethylaminopropyl)-carbodiimide hydrochloride followed by 2.3 mg N-hydroxysuccinimide are added. This solution is stirred for 2 hours at room temperature, then 65 mg bovine serum albumin (BSA) in 2 ml phosphate buffer (pH=8) are added and stirring is continued for 6 hours. Then solvents are evaporated and the residue is dissolved in 10 ml trifluoroacetic acid/water 95:5 and stirred for 90 minutes at room temperature. After evaporation the residue is purified by chromatography on Bio-Gel P 6 (100-200 mesh) water/acetic acid 98:2. The "high" molecular part is collected and used for immunisation.

EXAMPLE 11

Desoxypyridinolin-1- β -alanyl-KLH-Conjugate

2.5 mg of the compound of Example 7 are dissolved in 2.5 ml N,N-dimethyl-formamide, then 0.7 mg N-ethyl-N-(3-dimethylaminopropyl)-carbodiimide hydrochloride followed by 0.5 mg N-hydroxysuccinimide are added. This mixture is stirred for 90 minutes at room temperature. Then 34.2 mg hemocyanin from keyhole limpets (KLH) in 0.5 ml 50% glycerol is added and stirring is continued at room temperature for 36 hours. Then 5 ml trifluoroacetic acid/water 95:5 are added and the solution stirred for 75 minutes at room temperature. Trifluoroacetic acid and water are removed by evaporation. The residue is washed (centrifuged) several times with water and then used for immunisation.

EXAMPLE 12

3-Hydroxy-4-(2-t.-butoxycarbonylamino-2-carboxy-ethyl)-5-(3-t.-butoxycarbonylamino-3-t.-butoxycarbonyl-propyl)-pyridine

0.5 g of the compound of Example 3 is dissolved in 10 ml water and 10 ml methanol and 1 g sodium hydroxide is added. The resulting solution is stirred for 3 hours at room temperature. and then worked up as disclosed in Example 8.

MS - FAB: MH⁺ 540

EXAMPLE 13

3-Hydroxy-4-[1-t.-butoxycarbonylamino-1-N-(1-ethyl-methoxycarbonyl)carboxamido-2-ethyl]-5-(3-t.-butoxycarbonylamino-3-t.-butoxycarbonyl-propyl)-pyridine

320 mg of the compound of Example 12, 200 mg 1-hydroxybenzotriazole, 300 mg N,N-dicyclohexylcarbodiimide, 200 mg β-alanine methyl ester are dissolved in 10 ml tetrahydrofuran and stirred overnight at room temperature. After evaporation of the solvent, the residue is purified on silica gel (methylene chloride/methanol 95:5).

MS - FAB: MH⁺ 625

EXAMPLE 14

3-Hydroxy-1-(5-t.-butoxycarbonylamino-5-t.-butoxycarbonyl-pentyl)-4-[1-t.-butoxycarbonylamino-1-N-(1-methoxycarbonyl-2-ethyl)-carboxamido-2-ethyl]-5-(3-t.-butoxycarbonylamino-3-t.-butoxycarbonyl-propyl)-pyridinium iodide.

This compound is prepared as disclosed in Example 1.

MS - FAB: M⁺ 910

EXAMPLE 15

3-Hydroxy-1-(5-t.-butoxycarbonylamino-5-t.-butoxycarbonyl-pentyl)-4-[1-t.-butoxycarbonylamino-1-N-(1-carboxy-2-ethyl)-carboxamido-2-ethyl]-5-(3-t.-butoxycarbonylamino-3-t.-butoxycarbonyl-propyl)-pyridinium hydroxide

This compound is prepared by following the procedure of Example 7.

MS - FAB: M⁺ 896

EXAMPLE 16

The title compound of Example 15 is coupled to BSA or KLH in the same way as described in Examples 10 and 11. The resulting compounds have either BSA or KLH attached to the carboxy group of the lateral chain in position 4 of the pyridinium ring, respectively.

EXAMPLE 17

2-amino-4-[3-hydroxy-4-(1-carboxy-1-amino-2-ethyl)-5-pyridinyl]butanoic acid

200 mg of the compound of Example 3 are treated with 20 ml of trifluoroacetic acid/water 95:5 for 90 min. then evaporated.

MS (FAB): MH⁺ 284

Compounds of formulae I and IA are useful in assessing the levels of pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation which are present in biological fluids, e.g. urine or serum. Conditions in humans and animals which are characterized by a high level of bone resorption or by an abnormal balance between bone formation and bone resorption are e.g. osteoporosis, Paget's disease, progress of benign or malignant tumors of bone and metastatic cancers, osteomalacia, primary hyperparathyroidism, therapies with a compound increasing bone resorption (e.g. glucocorticoids), osteoarthritis and rheumatoid arthritis.

The quantitating of these crosslink levels may be carried out using e.g. immunological methods, electrochemical titration, natural fluorescence spectroscopy or ultraviolet absorbance. These methods may be conducted directly upon a body fluid without further purification or after purification, e.g. if there are excessive quantities of contamination substances. Free crosslinks present in biological fluids or crosslinks liberated by hydrolysis from collagen degradation peptides and present in body fluids may be quantitated according to the invention. By total crosslink is meant the total amount or concentration of free crosslink and hydrolyzed crosslink present in the body fluid.

Preferably the quantitation of pyridinoline or deoxypyridinoline crosslinks in biological fluids is performed using immunological methods. Accordingly specific antibodies are prepared to compounds of formula I bearing at least one antigenic group referred to hereinafter as immunogen. Either polyclonal or monoclonal antibodies immunoreactive with a compound of formula I bearing at least one antigenic group and wherein X_1 is hydrogen and/or such a substituted compound wherein X_1 is hydroxy may be prepared. According to a preferred embodiment of the invention, specific antibodies immunoreactive with a compound of formula I bearing at least one antigenic group and wherein X_1 is H are prepared.

As mentioned above, in the compounds of formula I the antigenic group may be attached directly or indirectly at a defined position: for example the antigenic group may be present in R_1 , R_2 or R_3 , particularly in R_3 or R_2 . Preferably the antigenic group is attached through a spacer group. Compounds of formula IA produced according to the process of the invention are also useful to prepare a corresponding compound of formula I bearing one, two or three antigenic groups as disclosed above.

Antibody production may be effected by conventional techniques including injection of a compound of formula I bearing at least one antigenic group into suitable mammalian subjects such as mice, rabbits or sheep according to immunological techniques generally known in the art (Laboratory Techniques in Biochemistry and Molecular Biology, Campbell, A. M., 1986, 13, Elsevier). Sera are titrated to determine antibody formation with respect to the immunogen. Spleen cells or peripheral blood lymphocytes may be harvested, homogenized and thereafter fused with e.g. cancer cells to produce a fused cell hybrid which produces monoclonal antibodies immunoreactive with the desired crosslink compound of formula I according to the invention. Monoclonal antibody preparation may be carried out in accordance with techniques disclosed in G. Galfre and C. Milstein, 1981, Meth. Enzymol. 73,1.

Polyclonal or especially monoclonal antibodies or fragments thereof produced by the above procedures or equivalent procedures may be employed in various immunometric assays to quantitate the concentration of pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in biological fluids. These immunometric assays comprise a monoclonal antibody or antibody fragment coupled to a detectable marker. Examples of suitable detectable markers include e.g. enzymes, coenzymes, enzyme inhibitors, chromophores, fluorophores, chemiluminescent materials,

paramagnetic metals, spin labels and radionuclides. Examples of standard immunometric methods suitable for indexing bone resorption include e.g. enzyme linked immunosorbent assay (ELISA), radioimmunoassay (RIA) and sandwich immuno radiometric assay (IRMA).

A compound of formula I free from antigenic group or a compound of formula IA prepared according to the invention wherein X_1 is H or OH can be used as standard references for quantitating the concentration of pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid e.g. in any of the above mentioned quantitating method or kit based on such a quantitating method.

In accordance with the foregoing, the present invention provides

1. A method of determining connective tissue metabolism abnormalities, e.g. bone or cartilage resorption by quantitating the concentration of total or free pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid, which method comprises using a compound of formula I;
2. A method of determining connective tissue metabolism abnormalities, e.g. bone or cartilage resorption by quantitating the concentration of total or free pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid, which method comprises using a compound of formula IA as produced by the process of the invention;
3. A method of quantitating the concentration of total or free pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid, which method comprises contacting the biological fluid with specific poly-

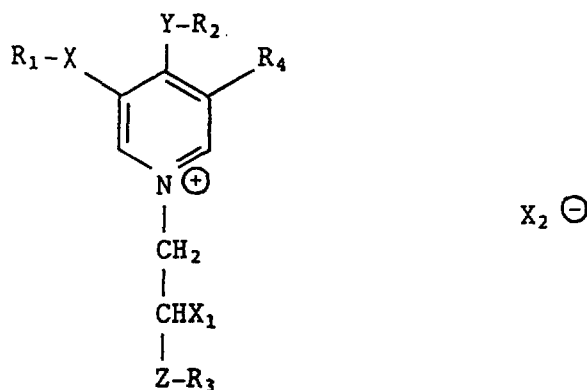
clonal or monoclonal antibodies immunoreactive with a compound of formula I bearing at least one antigenic group and wherein X_1 is H or OH;

4. Use of a compound of formula IA as produced by the process of the invention or of a compound of formula I free from antigenic group as a standard for quantitating the concentration of total or free pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid;
5. Polyclonal or monoclonal antibodies as disclosed above;
6. A cell line which secretes said monoclonal antibodies;
7. A method to produce said monoclonal antibodies;
8. A kit for immunoassay determination of the amount or concentration of total or free pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid, comprising a composition containing an antibody or immunologically reactive fragment thereof as disclosed above, and an additional reagent for conduct of said immunoassay along with instructions for the conduct of said assay, using as standard a compound of formula IA prepared according to the process of the invention or a compound of formula I free from an antigenic group, wherein X_1 is H or OH, particularly H.

CLAIMS



1. A process for the preparation of a compound of formula



wherein

- X, Y and Z, independently is C₁₋₈alkyl; C₁₋₈alkyl interrupted by one or two heteroatoms selected from O, N and S; cycloalkyl; cycloalkyl-C₁₋₄alkyl; (C₁₋₄alkyl)-cycloalkyl; (C₁₋₄alkyl)-cycloalkylene-C₁₋₄alkyl; optionally substituted aryl; optionally substituted heteroaryl; (C₁₋₄alkyl)-aryl; (C₁₋₄alkyl)-heteroaryl; (C₁₋₄alkyl)-arylene-C₁₋₄alkyl; (C₁₋₄alkyl)-heteroarylene-C₁₋₄alkyl; aryl-C₁₋₄alkyl; heteroaryl-C₁₋₄alkyl, the aryl or heteroaryl moieties of the above mentioned groups being optionally substituted;
- R₃ is COOH or a functional derivative thereof; CHO; CN; C₁₋₈alkoxy; SO₂; -PO₃H or a functional derivative thereof; -SO₃H or a functional derivative thereof; a primary, secondary or tertiary amino group; a saturated or unsaturated cyclic amino group; or a radical of formula (a)





wherein

R_5 is a primary, secondary or tertiary amino group or a saturated or unsaturated cyclic amino group, and

R_6 is $-COOH$ or a functional derivative thereof;

each of R_1 and R_2 , independently, is hydrogen or has one of the significances given for R_3 ,

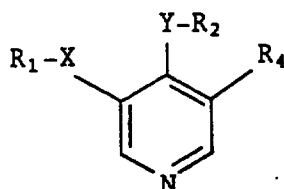
R_4 is hydroxy; C_{1-6} alkoxy; or polyalkylenoxy;

X_1 is H or OH, and

$X_2^\ominus$ is an anion

with the proviso that when both X and Y comprise an alkyl moiety, the chain length of the alkyl moiety in $-Y-$ is at least one carbon atom shorter than the alkyl moiety in $-X-$, which process comprises

a) reacting a compound of formula II



(II)

wherein X, Y, R_1 , R_2 and R_4 are as defined above

with a compound of formula III



(III)

wherein

X_1 , Z and R_3 are as defined above, and

X_5 is a leaving group; or

b) converting a compound of formula I or IA into another compound of formula I or IA

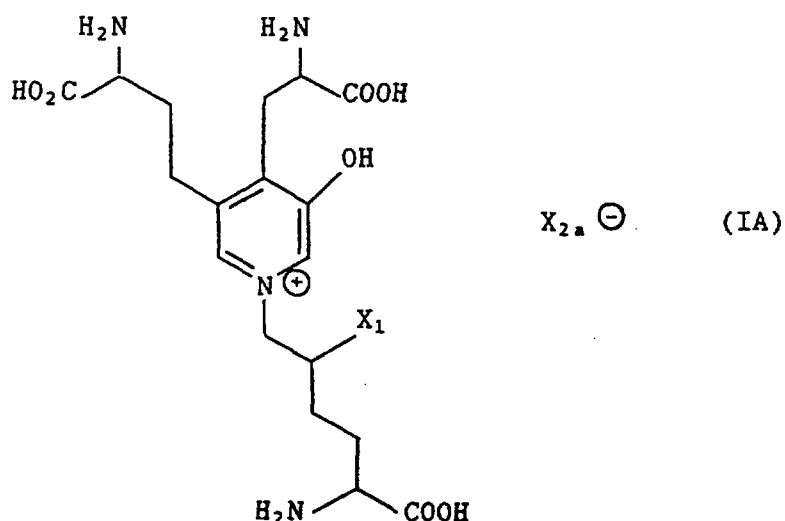
and recovering a compound thus obtained in



free form or in salt form.

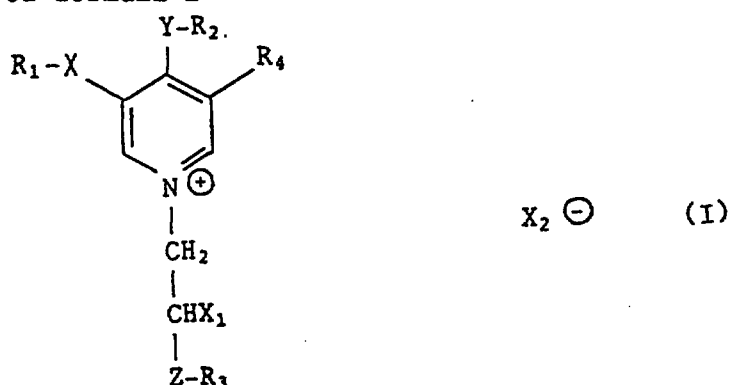


2. A compound of formula IA



wherein X_1 is H or OH and X_2^- is a chloride or acetate ion, produced by a process as defined in claim 1.

3. A compound of formula I



wherein X, Y and Z, independently is C_{1-8} alkyl; C_{1-8} alkyl interrupted by one or two heteroatoms selected from O, N and S; cycloalkyl; cycloalkyl- C_{1-4} alkyl; (C_{1-4} alkyl)-cycloalkyl; (C_{1-4} alkyl)-cycloalkylene- C_{1-4} alkyl; optionally substituted aryl; optionally substituted heteroaryl; (C_{1-4} alkyl)-aryl; (C_{1-4} alkyl)-heteroaryl; (C_{1-4} alkyl)-





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arylene- C_{1-4} alkyl; (C_{1-4} alkyl)-heteroarylene- C_{1-4} alkyl;
aryl- C_{1-4} alkyl; heteroaryl- C_{1-4} alkyl, the aryl or heteroaryl moieties of the above mentioned groups being optionally substituted;

R_3 is COOH or a functional derivative thereof; CHO; CN;
 C_{1-8} alkoxy; SO_2 ; $-PO_3H$ or a functional derivative thereof;
 $-SO_3H$ or a functional derivative thereof; a primary, secondary or tertiary amino group; a saturated or unsaturated cyclic amino group; or a radical of formula (a)



wherein

R_5 is a primary, secondary or tertiary amino group or a saturated or unsaturated cyclic amino group, and

R_6 is $-COOH$ or a functional derivative thereof;

each of R_1 and R_2 , independently, is hydrogen or has one of the significances given for R_3 ,

R_4 is hydroxy; C_{1-6} alkoxy; or polyalkylenoxy;

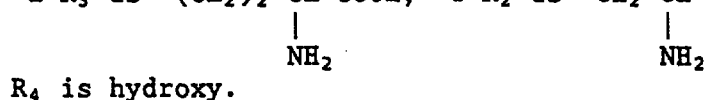
X_1 is H or OH, and

X_2^- is an anion

with the proviso that

i) when both X and Y comprise an alkyl moiety, the chain length of the alkyl moiety in $-Y-$ is at least one carbon atom shorter than the alkyl moiety in $-X-$, and

ii) X_2^- is other than Cl^- or CH_3COO^- when each of $-X-R_1$ and $-Z-R_3$ is $-(CH_2)_2-CH-COOH$, $-Y-R_2$ is $-CH_2-CH-COOH$ and



R_4 is hydroxy.

4. A compound according to claim 3 wherein X is $-CH_2-CH_2-$, Y is $-CH_2-$, each of R_1 and R_2 is a residue of formula (a) wherein R_5 is $-NH_2$ or NHY'_a wherein Y'_a is a protecting group and R_6 is $-COOH$ or C_{2-7} alkoxycarbonyl, X_1 is H or OH, Z is $-CH_2-CH_2-$

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and R_3 is a residue of formula (a) wherein R_5 is $-NH_2$ or NHY'_a and R_6 is $-CONH-Z_a-Y_b$ wherein Y_b is an antigenic group, or wherein X is $-CH_2-CH_2-$, Y is $-CH_2-$, Z is $-CH_2-CH_2-$, each of R_1 and R_3 is a residue of formula (a) wherein R_5 is $-NH_2$ or NHY'_a wherein Y'_a is a protecting group and R_6 is $-COOH$ or C_{2-7} alkoxycarbonyl, X_1 is H or OH , and R_2 is a residue of formula (a) wherein R_5 is $-NH_2$ or NHY'_a and R_6 is $-CONH-Z_a-Y_b$ wherein Y_b is an antigenic group.

5. Use of a compound of formula IA according to claim 2 or of a compound of formula I according to claim 3 which is free from antigenic group as a standard for quantitating the concentration of total or free pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid.
6. A method of determining connective tissue metabolism abnormalities, e.g. bone or cartilage resorption, by quantitating the concentration of total or free pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid, which method comprises using a compound of formula I according to claim 3 or a compound of formula IA according to claim 2.
7. A method of quantitating the concentration of total or free pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid, which method comprises contacting the biological fluid with specific polyclonal or monoclonal antibodies immunoreactive with a compound of formula I according to claim 3 bearing at least one antigenic group or a compound of formula I according to claim 4.
8. A polyclonal or monoclonal antibody or a fragment thereof specifically immunoreactive with a compound of formula I according to claim 3 bearing at least one antigenic group or a

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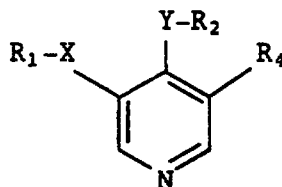
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compound of formula I according to claim 4.

9. A cell line which secretes a monoclonal antibody according to claim 8.
10. A kit for immunoassay determination of the amount or concentration of total or free pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid, comprising a composition containing an antibody or immunologically reactive fragment thereof as defined in claim 8, and an additional reagent for conduct of said immunoassay along with instructions for the conduct of said assay, using as standard a compound of formula IA according to claim 2 or a compound of formula I according to claim 3 free from an antigenic group.
11. A kit for determination of the amount or concentration of total or free pyridinoline or deoxypyridinoline crosslinks derived from collagen degradation in a biological fluid, comprising as standard a compound of formula IA according to claim 2 or a compound of formula I according to claim 3 free from an antigenic group.
12. A compound of formula II



(II)

wherein X, Y, R₁, R₂ and R₄ are as defined in claim 3.

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