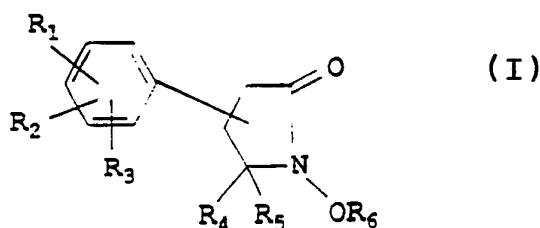




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<p>(21) International Application Number: PCT/FI91/00123</p> <p>(22) International Filing Date: 26 April 1991 (26.04.91)</p> <p>(30) Priority data: 9009395.6 26 April 1990 (26.04.90) GB</p> <p>(71) Applicant (for all designated States except US): ORION-YHTYMÄ OY [FI/FI]; Orionintie 1, SF-02100 Espoo (FI).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only) : BÄCKSTRÖM, Reijo [FI/FI]; Poutamäentie 14 F 68, SF-00360 Helsinki (FI). HONKANEN, Erkki [FI/FI]; Koivusyrjä 7 F, SF-02130 Espoo (FI). RAASMAJA, Atso [FI/FI]; Kalevanvainio 4 A 36, SF-02100 Espoo (FI). LINDÉN, Inge-Britt [FI/FI]; Vattuniemenkatu 4 C 52, SF-00210 Helsinki (FI).</p>	<p>(74) Agent: ORION CORPORATION; Orion Pharmaceutica, Patent Department, P.O. Box 65, SF-02101 Espoo (FI).</p> <p>(81) Designated States: AT (European patent), AU, BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GB (European patent), GR (European patent), HU, IT (European patent), JP, KR, LU (European patent), NL (European patent), NO, PL, SE (European patent), SU, US.</p> <p>Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	

(54) Title: CYCLIC HYDROXAMIC ACIDS AND THEIR USE



(57) Abstract

Substituted cyclic hydroxamic acids of general formula (I) in which R₁, R₂ and R₃ are independently hydrogen, halogen, lower alkyl, lower alkoxy, cycloalkoxy, aryloxy which is optionally substituted by 1 to 3 halogen, or aralkyloxy, which is optionally substituted by 1 to 3 halogen, or R₁ and R₂ together form a -O-CH₂-O-group; with the proviso that R₃ is not hydrogen when R₁ and R₂ are both hydrogen; R₄ and R₅ are independently hydrogen or lower alkyl, R₆ is hydrogen or lower alkyl, and physiologically acceptable salts and esters thereof are selective inhibitors of phosphodiesterase IV activity and leukotriene B₄ and C₄ synthesis without showing any significant effect on phosphodiesterase III activity, and are therefore useful in the treatment of hypersensitivity and inflammatory diseases.

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CYCLIC HYDROXAMIC ACIDS AND THEIR USE

The present invention relates to new substituted cyclic hydroxamic acids and physiologically acceptable salts and esters thereof. The invention also relates to the pharmaceutical compositions containing these compounds and to the method for the preparation of the same.

The compounds of the present invention are selective inhibitors of phosphodiesterase IV (PDE IV) activity and leukotriene B₄ (LTB₄) and C₄ (LTC₄) synthesis without having any significant effect on phosphodiesterase III (PDE III) activity.

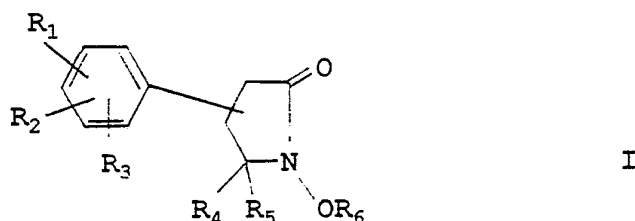
The combinatory effect due to the parallel inhibition of PDE IV activity and LTB₄ and LTC₄ synthesis makes the compounds of the invention especially valuable in the treatment of hypersensitivity and inflammatory diseases such as allergic rhinitis, atopic dermatitis, rheumatoid arthritis, psoriasis and especially asthma.

Conventionally, acute asthma has been treated using compounds that aid tracheal relaxation. Because these compounds only treat the acute symptom, other medicaments have to be given that treat pathogenic factors of the disease. These medicaments are, for example, compounds having antiinflammatory effect.

It has been surprisingly found that the compounds of the invention provide in one and the same compound three valuable characteristics. Inhibition of PDE IV activation and increase of cyclic AMP concentration leads to the tracheal relaxation, and is effective in acute asthma. On the other hand, the inhibition of the synthesis of LTC₄ diminishes bronchoconstriction in asthmatic subjects. At the same time,

the inhibition of LTB_4 synthesis has a potent antiinflammatory effect and is therefore believed to be effective in chronic asthma.

The compounds according to the present invention are substituted cyclic hydroxamic acids of general formula I



in which R_1 , R_2 and R_3 are independently hydrogen, halogen, lower alkyl, lower alkoxy, cycloalkoxy, aryloxy which is optionally substituted by 1 to 3 halogen, or aralkoxy, which is optionally substituted by 1 to 3 halogen, or R_1 and R_2 together form a $-\text{O}-\text{CH}_2-\text{O}-$ group; with the proviso that R_3 is not hydrogen when R_1 and R_2 are both hydrogen; R_4 and R_5 are independently hydrogen or lower alkyl, R_6 is hydrogen or lower alkyl, and physiologically acceptable salts and esters thereof.

The term "lower alkyl" as employed herein itself or as a part of another group refers to a straight or branched alkyl group having preferably 1 to 4 carbon atoms.

The term "lower alkoxy" as employed herein refers to an alkyl residue as defined above linked to an oxygen atom.

The term "cycloalkoxy" as employed herein refers to a saturated cyclic hydrocarbon group, preferably of 3 to 7 carbon atoms linked to an oxygen atom.

The term "aryloxy" as employed herein refers to an aromatic ring, preferably phenyl, linked to an oxygen atom.

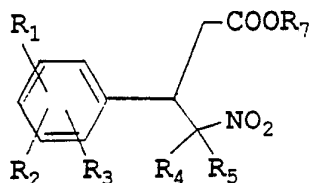
The term "aralkyloxy" as employed herein refers to a lower alkoxy group having aryl, preferably phenyl, as the substituent.

The term "halogen" as employed herein refers to chlorine, bromine, fluorine or iodine, chlorine and bromine being preferred.

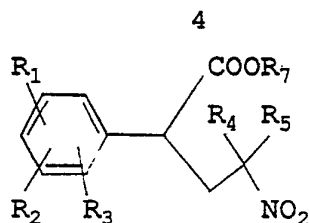
Particularly preferred groups of compounds include those in which R_1 is cycloalkyloxy, e.g. cyclopentyloxy, R_2 is lower alkoxy, e.g. methoxy or ethoxy, and R_6 is hydrogen. The phenyl group in Formula I may be in the 3- or 4-position of the pyrrolidone ring. The 4-position is preferred.

US 4,012,495 describes 4-polyalkoxyphenyl-2-pyrrolidones, such as 4-[3-(cyclopentyloxy)-4-methoxyphenyl]-2-pyrrolidone (rolipram). These compounds are stated to be useful in the treatment of various neurological and psychic disorders. The hydroxamic acids of the invention are chemically different from the compounds of US 4,012,495. Furthermore, the specific compound of US 4,012,495 (rolipram) is not selective PDE IV inhibitor but also inhibits PDE III. PDE III inhibitors are known to be used as inotropic agents in the treatment of heart failure. Therefore, the selective inhibition of only PDE IV in the trachea would be preferred to eliminate cardiac side effects such as arrhythmia the presence of which, it is suggested, is involved in the use of PDE III inhibitors.

The compounds of the formula I may be prepared in accordance with the present invention by selective reduction of the compounds of the formula IIa or IIb



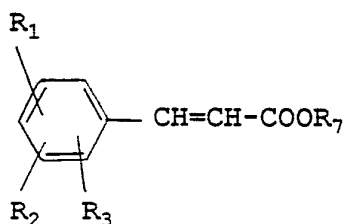
IIa



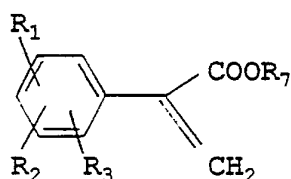
IIb

in which R_1 , R_2 , R_3 , R_4 and R_5 are the same as defined above and R_7 represents a lower alkyl group, with zinc dust, aluminium amalgam or sodium borohydride in the presence of platinum or palladium catalyst in a suitable buffer solution or in an inert solvent. Also electrochemical reduction applying the method described by Cariou M., Hazard R., Jubault M., and Tallec A. in *J. Electroanal. Chem.* 182 (1985), pp. 345-354 is possible.

The compounds of formula IIa and IIb may be prepared by the known methods (Pollini G.P., Barco A., DeGuili G., *Synthesis*, (1972), p. 44) from the corresponding cinnamic or 2-phenyl acrylic acid derivatives of formula IIIa and IIIb, respectively



IIIa



IIIb

in which R_1 , R_2 , R_3 and R_7 are the same as defined above, by Michael addition reaction of nitroalkane in the presence of a basic catalyst such as 1,1,3,3-tetramethylguanidine by using nitroalkane as the solvent at ambient or elevated temperature.

The compounds of formula I wherein R_6 is lower alkyl may be prepared by O-alkylation of the compounds of formula I in

which R₆ is hydrogen, using lower alkylhalide in basic conditions in an inert solvent such as acetone, N,N-dimethylformamide, tetrahydrofuran or N-methylpyrrolidone.

Salts of the compounds of the present invention may be prepared by known methods. Most commonly used physiologically acceptable salts are sodium, potassium, ammonium, calcium and magnesium salts.

The above compounds may be formulated to dosage forms using the principles which are known to those having average skill in the art. The compounds according to this invention are given to a patient as such or in combination with suitable pharmaceutical material in the form of tablets, dragees, capsules, suppositories, emulsions, suspensions or solutions whereby the contents of the active compounds is in the formulation from 1 to 100 weight-%.

Choosing the auxiliary ingredients for the formulation is routine for those of ordinary skill in the art. It is evident that suitable solvents, gel forming ingredients, dispersion forming ingredients, antioxidants, colours etc. are used in a normal way.

It is preferred way to give the compositions enterally. When they are given orally, they may be in the form of tablets, granules, capsules, emulsions, suspensions or solutions.

The effective dose varies considerably depending on location, degree and severity of the disease being treated as well as the age and the general conditions of the patient. The effective dose is generally from about 0,1 to about 10 mg/kg per day, preferably from 0,5 to 5 mg/kg per day for an adult, once a day or divided into two to five doses.

The preparation of the compounds according to the invention are described in detail in the following examples.

Example 1

1-Hydroxy-4-(3-cyclopentyloxy-4-methoxyphenyl)-2-pyrrolidone.

To a solution containing 10.9 g (0.039 mol) methyl 3-cyclopentyloxy-4-methoxycinnamate in 100 ml of nitromethane 5.5 ml 1,1,3,3-tetramethylguanidine was added gradually at ambient temperature. The solution was stirred overnight after which 400 ml of 2 N hydrochloric acid and 100 ml dichloromethane were added. The organic phase was separated and evaporated in vacuo. Yield 13.0 g (100 %), a yellowish oil which crystallized on standing.

A solution containing 13.0 g (0.039 mol) methyl 3-(3-cyclopentyloxy-4-methoxyphenyl)-4-nitrobutanoate prepared above in 400 ml tetrahydrofuran containing 4 ml water was gradually added to 3.8 g aluminium foil treated before with a solution of mercuric chloride (1 g) in water. The temperature was held at 15-20 °C by cooling. The mixture was stirred overnight at ambient temperature after which toluene and 200 ml 6 N hydrochloric acid were added. The organic phase was separated and washed with 0.8 M sodium hydrogen carbonate solution and evaporated to dryness in vacuo. The residue was crystallized from a mixture of dichloromethane-ether. Yield 1.7 g (15 %), mp 126-130°C.

Example 2

4-(4-Benzyloxyphenyl)-1-hydroxy-2-pyrrolidone

The starting material methyl 3-(4-benzyloxyphenyl)-4-nitrobutanoate was obtained by condensation of methyl 4-benzyloxy-cinnamate with nitromethane, yield about 100 % or a yellowish oil.

5.0 g of methyl 3-(4-benzyloxyphenyl)-4-nitrobutanoate was reduced in a similar manner as described in Example 1 to yield 0.3 g 4-(4-Benzyloxyphenyl)-1-hydroxy-2-pyrrolidone, mp 150-155 °C.

Example 3

4-(4-Benzyloxyphenyl)-1-methoxy-2-pyrrolidone.

A mixture containing 0.7 g 4-(4-benzyloxyphenyl)-1-hydroxy-2-pyrrolidone (Example 2), 5.0 ml methyl iodide and 2.0 g potassium carbonate in 5.0 ml N-methylpyrrolidone was stirred for 2 h at 50 °C. 20 ml 1 N sodium hydroxide solution was then added and the solution was extracted with a mixture of 20 ml cyclohexane and 10 ml of ether. The extract was washed with water and concentrated in vacuo whereupon the product crystallized. yield 0.31 g (41 %), mp 92-97 °C.

Example 4

4-(2,3-Dimethoxyphenyl)-1-hydroxy-2-pyrrolidone potassium salt.

The starting material methyl 3-(2,3-dimethoxyphenyl)-4-nitrobutanoate was obtained by condensation of methyl 2,3-dimethoxycinnamate with nitromethane, yield about 100 % of a yellowish oil.

16.0 g methyl 3-(2,3-dimethoxyphenyl)-4-nitrobutanoate was reduced in a similar manner as described in Example 1. The crude product was dissolved in 50 ml of anhydrous ethanol and 45 ml of 0.5 N potassium hydroxide in ethanol, after which 100 ml ether was added. The potassium salt precipitated was filtered. Yield 3.66 g (25 %), mp 138-143 °C.

Example 5

4-[3-(2,6-Dichlorobenzyloxy)-4-methoxyphenyl]-1-hydroxy-2-pyrrolidone

The starting material methyl 3-[3-(2,6-dichlorobenzyloxy)-4-methoxyphenyl]-4-nitrobutanoate was obtained in a similar way as described in foregoing Examples. Yield about 100 % of a yellowish oil.

21.5 g of methyl 3-[3-(2,6-dichlorobenzyloxy)-4-methoxyphenyl]-4-nitrobutanoate was reduced as described in Example 1. Yield 7.4 g (39 %), mp 134-140 °C.

Example 6

1-Hydroxy-4-(3,4-methylenedioxyphenyl)-2-pyrrolidone

The starting material methyl 3-(3,4-methylenedioxyphenyl)-4-nitro butanoate was obtained by condensation of methyl 3,4-methylenedioxy-cinnamate with nitromethane, yield about 100 % of a yellowish oil.

12.0 g of methyl 3,4-methylenedioxy-4-nitrobutanoate was reduced in a similar manner as described in Example 1. The crude product was crystallized from methanol-water. Yield 0.9 g, mp 119-123°C.

Example 7

1-Hydroxy-4-(3,5-di-tert.butyl-4-methoxyphenyl)-2-pyrrolidone

The starting material methyl 3-(3,5-di-tert.-butyl-4-methoxyphenyl)-4-nitrobutanoate was obtained by condensation of methyl 3,5-di-tert.-butyl-4-methoxycinnamate with nitromethane, yield about 100 % of a yellowish oil.

8.3 g of methyl 3-(3,5-di-tert.-butyl-4-methoxyphenyl)-4-nitrobutanoate was reduced in a similar manner as described in Example 1. The crude product was crystallized from methanol-water, yield 0.35 g, mp 196-200°C.

Example 8

1-Hydroxy-4-(2,4-dichlorophenyl)-2-pyrrolidone

The starting material methyl 3-(2,4-dichlorophenyl)-4-nitrobutanoate was prepared in the usual way from methyl 2,4-dichlorocinnamate and nitromethane in about theoretical yield.

16.0 g of methyl 3-(2,4-dichlorophenyl)-4-nitrobutanoate was reduced with aluminium amalgam as described in Example 1. The crude product was crystallized from toluene, yield 2.78 g, mp 153-156°C.

Example 9

1-Hydroxy-4-(2,4-dichlorophenyl)-5-methyl-2-pyrrolidone

The starting material methyl 3-(2,4-dichlorophenyl)-4-nitropentanoate was prepared in the usual way from methyl 2,4-dichlorocinnamate and nitroethane in about theoretical yield.

16.0 g of methyl 3-(2,4-dichlorophenyl)-4-nitropentanoate was reduced with aluminium amalgam as described in Example 1. The crude product was crystallized from dioxanecyclohexane. Yield 1.7 g of a mixture of diastereomers, mp 140-144°C.

Example 10

1-hydroxy-4-(2,4-dichlorophenyl)-5,5-dimethyl-2-pyrrolidone

The starting material methyl 3-(2,4-dichlorophenyl)-5-methyl-4-nitropentanoate was prepared in the usual way from methyl 2,4-dichlorocinnamate and 2-nitropropane in about theoretical yield.

16.0 g of methyl 3-(2,4-dichlorophenyl)-5-methyl-4-nitropentanoate was reduced with aluminium amalgam as described in Example 1. The crude product was crystallized from methanol, yield 4.9 g, mp 234-237°C.

Example 11

1-Hydroxy-5,5-dimethyl-4-(3,4-methylenedioxyphenyl)-2-pyrrolidone

The starting material methyl 3-(3,4-methylenedioxyphenyl)-5-methyl-4-nitropentanoate was prepared in the usual way from methyl 3,4-methylenedioxy cinnamate and 2-nitropropane in about theoretical yield.

16.0 g methyl 3-(3,4-methylenedioxyphenyl)-5-methyl-4-nitropentanoate was reduced with aluminium amalgam as described in Example 1. The crude product was crystallized from toluene, yield 3.8 g, mp 185-189°C.

Example 12

1-Hydroxy-5,5-dimethyl-3-(3-chlorophenyl)-2-pyrrolidone

The starting material methyl 2-(3-chlorophenyl)-4-methyl-4-nitropentanoate was obtained by condensation of methyl 2-(3-chlorophenyl)acrylate with 2-nitropropane, yield about 100 % of yellow oil.

18.95 g of methyl 2-(3-chlorophenyl)-4-methyl-4-nitropentanoate was reduced with aluminium amalgam as described in Example 1. The crude product was crystallized from toluene-ether, yield 2.5 g, mp 160-162°C.

Inhibition of PDE IV and PDE III

PDE isoenzymes were isolated using DEAE-Sepharose chromatography as described by Reeves et al. in *Biochem. J.*, 241 (1987), pp. 535-541. PDE IV and PDE III activities were determined by the method of Alajoutsijärvi and Nissinen as described in *Anal. Biochem.* 165 (1987), pp. 128-132.

Table 1

The selectivity of the inhibition of PDE IV and PDE III of the test compound.

Compound of Example	IC ₅₀	PDE IV μM	PDE III μM
1		0,9	205

Test compound

1-hydroxy-4-(3-cyclopentyloxy-4-methoxyphenyl)-
2-pyrrolidone

Inhibition of LTB₄ synthesis and LTC₄ synthesis

The inhibition of arachidonic acid induced LTB₄ and LTC₄ synthesis in human basophilic leucocytes was determined with liquid chromatography and UV detection. LTB₄ and LTC₄ were separated first by HPLC with a Spherisorb ODS column (5 μm, 150 x 4.6 mm) and Spectroflow 400 Kratos Analytical pump. The

flow rate was 1 ml/min and the solvents were methanol/water/acetic acid (68/32/0.1), pH 5.0 for LTB₄ and methanol/water/acetic acid/phosphoric acid (65/35/0.07/0.03), pH 5.5 for LTC₄. The peaks were analyzed further with Spektroflow 773 Kratos Analytical UV absorbance detector and leukotrienes were detected at the wavelength of 271 nm and 280 nm for LTB₄ and LTC₄, respectively.

The results are given in Table 2

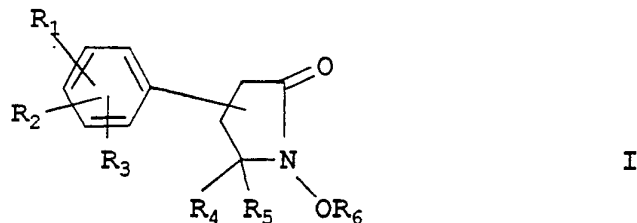
Table 2

The LTB₄ and LTC₄ synthesis inhibition

The compound of the Example	IC ₅₀ LTB ₄ μM	IC50 LTC ₄ μM
1	3.7	3.2

Claims

1. A compound according to the general formula I

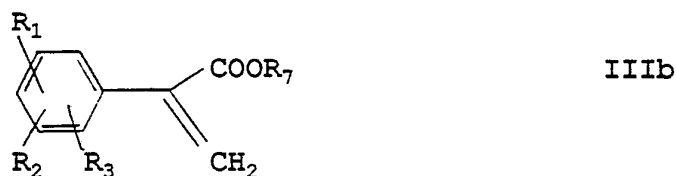
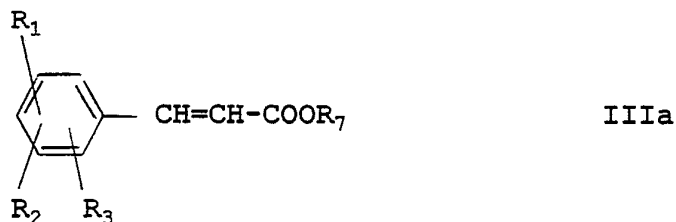


in which R_1 , R_2 and R_3 are independently hydrogen, halogen, lower alkyl, lower alkoxy, cycloalkoxy, aryloxy which is optionally substituted by 1 to 3 halogen, or aralkyloxy, which is optionally substituted by 1 to 3 halogen, or R_1 and R_2 together form a $-O-CH_2-O-$ group, with the proviso that R_3 is not hydrogen when R_1 and R_2 are both hydrogen; R_4 and R_5 are independently hydrogen or lower alkyl, R_6 is hydrogen or lower alkyl, or a physiologically acceptable salt or ester thereof.

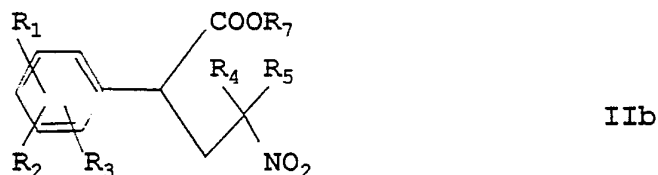
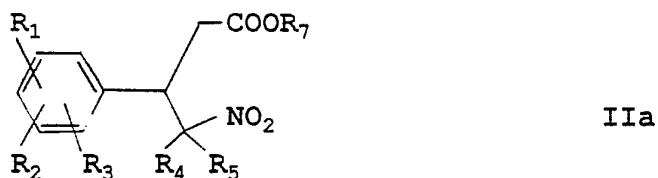
2. A compound according to claim 1 in which R_1 is cycloalkyloxy, R_2 is lower alkoxy and R_6 is hydrogen.
3. 1-Hydroxy-4-(3-cyclopentyloxy-4-methoxyphenyl)-2-pyrrolidone.
4. A pharmaceutical composition comprising a compound according to any one of claims 1 to 3 and a pharmaceutically acceptable carrier or diluent.
5. Use of a compound as defined in any one of claims 1 to 3 in the treatment of hypersensitivity or an inflammatory disease.
6. Use as defined in claim 5 wherein the disease is asthma.
7. The compound according to any one of claims 1 to 3 for use

in a method of treatment of hypersensitivity or an inflammatory disease.

8. A method of the preparation of a compound of any of the claims 1 to 3 comprising carrying out a Michael addition reaction of a nitroalkane and the compound of formula IIIa or IIIb



in which R_1 , R_2 , R_3 are as defined in claim 1 or R_7 is lower alkyl, to give the compound of formula IIa or IIb;



in which R_1 , R_2 , R_3 , R_4 and R_5 are the same as defined in claim 1 and R_7 represents a lower alkyl, whereafter the compound of formula IIa or IIb is selectively reduced to give the compound of formula I.

10. A method of preparation of a compound of formula I as defined in claim 1 in which R₆ is lower alkyl, comprising the o-alkylation of the corresponding compound of formula I in which R₆ is hydrogen.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/FI 9100123

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

C 07 D 207/46 A 61 K 31/40

II. FIELDS SEARCHED

Minimum Documentation Searched⁷

Classification System

Classification Symbols

Int. Cl. 5

C 07 D 207/00

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched⁸

III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

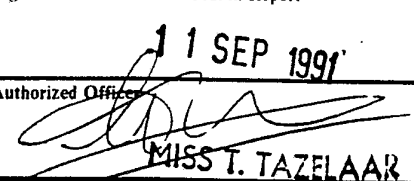
Category ^o	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	US-A-4 012 495 (SCHMIECHEN et al.) 15 March 1977, see the whole document (cited in the application) ---	1
X	LU-A- 85 404 (CONTINENTAL PHARMA) 24 January 1986, see the whole document; table 1 ---	1,4-10
A	EP-A-0 196 184 (WELLCOME) 1 October 1986, see claim 1; examples 70-75 -----	1,4-7

^o Special categories of cited documents : ¹⁰

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
30-07-1991	11 SEP 1991
International Searching Authority	Signature of Authorized Officer
EUROPEAN PATENT OFFICE	 MISS T. TAZELAAR

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.

FI 9100123
SA 47311

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 06/09/91. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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