

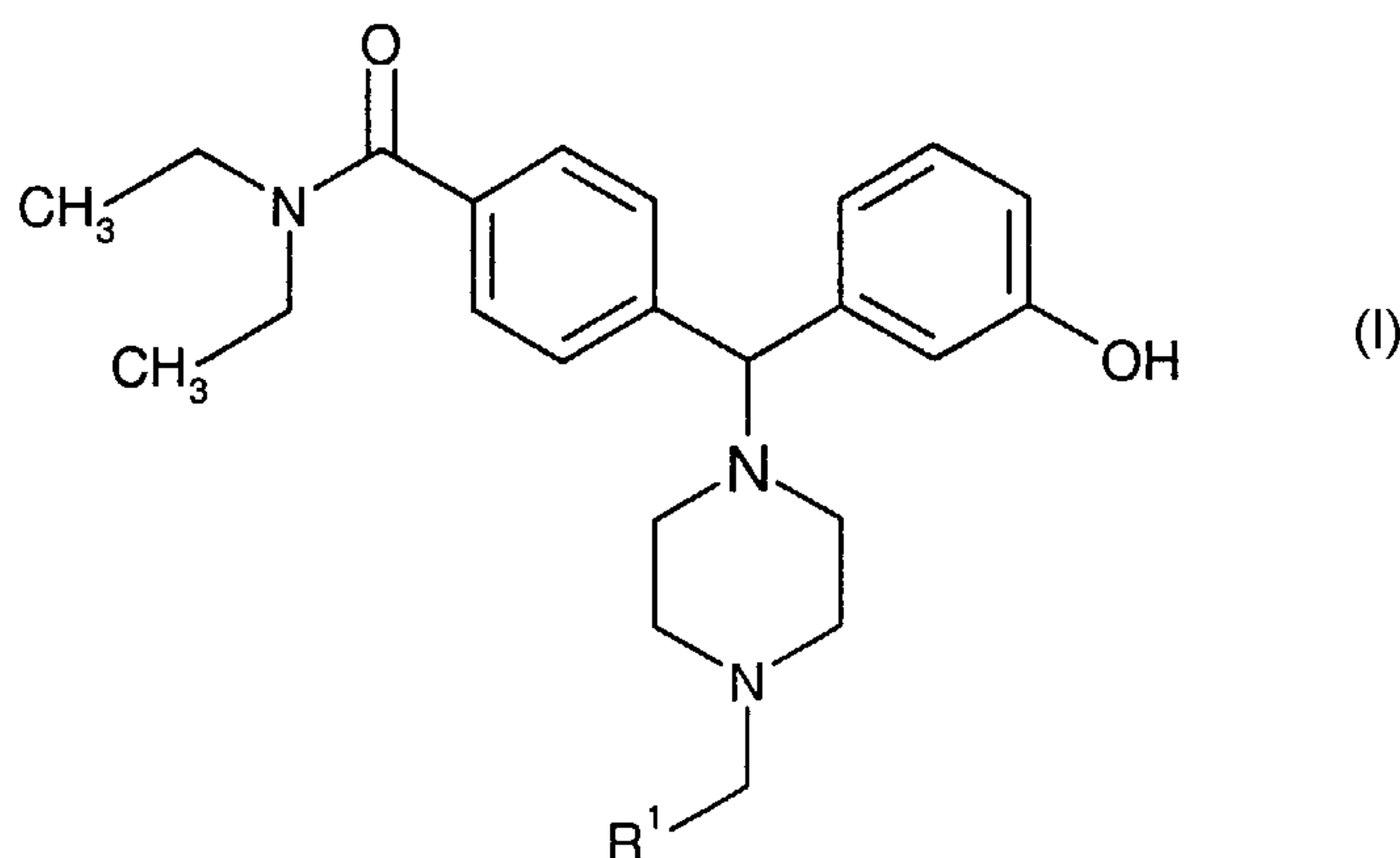


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(54) Titre : DERIVES D'HYDROXYPHENYL-PIPERAZINYL-METHYL-BENZAMIDE DESTINES AU TRAITEMENT DE LA DOULEUR

(54) Title: HYDROXYPHENYL-PIPERAZINYL-METHYL-BENZAMIDE DERIVATIVES FOR THE TREATMENT OF PAIN



(57) **Abrégé/Abstract:**

Compounds of general formula (I), where R<sup>1</sup> is selected from any one of pyridinyl, thienyl, furanyl, imidazolyl, and triazolyl; where each R<sup>1</sup> heteroaromatic ring may optionally and independently be further substituted by 1, 2 or 3 substituents selected from straight and branched C<sub>1</sub>-C<sub>6</sub> alkyl, NO<sub>2</sub>, CF<sub>3</sub>, C<sub>1</sub>-C<sub>6</sub> alkoxy, chloro, fluoro, bromo, and iodo. The substitutions on the heteroaromatic ring may take place in any position on said ring systems; are disclosed and claimed in the present application, as well as separate enantiomers of the compounds and salts and pharmaceutical compositions comprising the novel compounds and their use in therapy, in particular in the management of pain.

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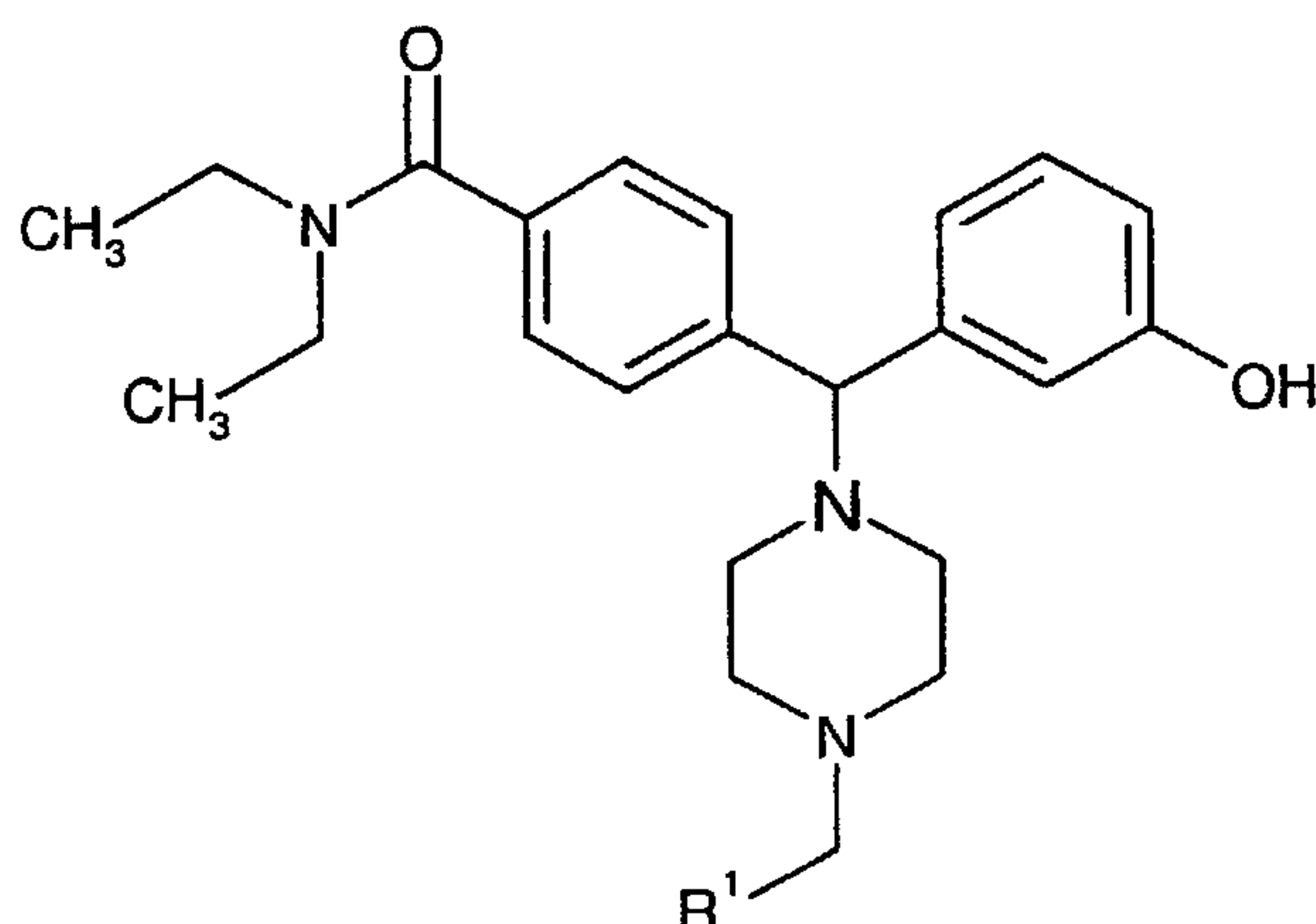
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(54) Title: HYDROXYPHENYL-PIPERAZINYL-METHYL-BENZAMIDE DERIVATIVES FOR THE TREATMENT OF PAIN



(I)

(57) Abstract: Compounds of general formula (I), where R<sup>1</sup> is selected from any one of pyridinyl, thienyl, furanyl, imidazolyl, and triazolyl; where each R<sup>1</sup> heteroaromatic ring may optionally and independently be further substituted by 1, 2 or 3 substituents selected from straight and branched C<sub>1</sub>-C<sub>6</sub> alkyl, NO<sub>2</sub>, CF<sub>3</sub>, C<sub>1</sub>-C<sub>6</sub> alkoxy, chloro, fluoro, bromo, and iodo. The substitutions on the heteroaromatic ring may take place in any position on said ring systems; are disclosed and claimed in the present application, as well as separate enantiomers of the compounds and salts and pharmaceutical compositions comprising the novel compounds and their use in therapy, in particular in the management of pain.

WO 01/74805 A1

# HYDROXYPHENYL-PIPERAZINYL-METHYL-BENZAMIDE DERIVATIVES FOR THE TREATMENT OF PAIN

## Field of the invention

The present invention is directed to novel compounds, to a process for their preparation, their use and pharmaceutical compositions comprising the novel compounds. The novel compounds are useful in therapy, and in particular for the treatment of pain.

## Background and prior art

The  $\delta$  receptor has been identified as having a role in many bodily functions such as circulatory and pain systems. Ligands for the  $\delta$  receptor may therefore find potential use as analgesics, and/or as antihypertensive agents. Ligands for the  $\delta$  receptor have also been shown to possess immunomodulatory activities.

The identification of at least three different populations of opioid receptors ( $\mu$ ,  $\delta$  and  $\kappa$ ) is now well established and all three are apparent in both central and peripheral nervous systems of many species including man. Analgesia has been observed in various animal models when one or more of these receptors has been activated.

With few exceptions, currently available selective opioid  $\delta$  ligands are peptidic in nature and are unsuitable for administration by systemic routes. One example of a non-peptidic  $\delta$ -agonist is SNC80 (*Bilsky E.J. et al., Journal of Pharmacology and Experimental Therapeutics*, 273(1), pp. 359-366 (1995)). There is however still a need for selective  $\delta$ -agonists having not only improved selectivity, but also an improved side-effect profile.

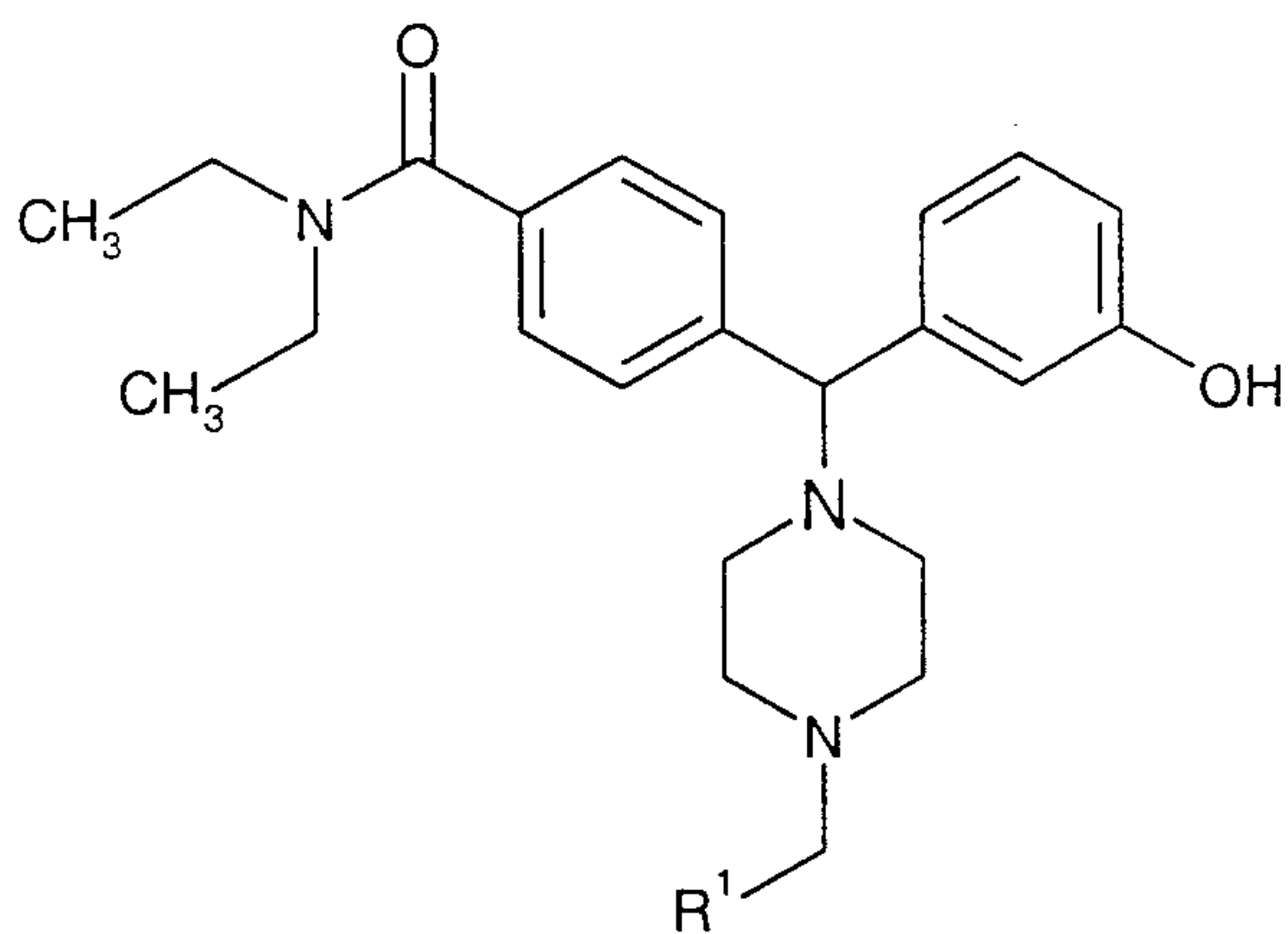
Thus, the problem underlying the present invention was to find new analgesics having improved analgesic effects, but also with an improved side-effect profile over current  $\mu$  agonists, as well as having improved systemic efficacy.

Analgesics that have been identified and are existing in the prior art have many disadvantages in that they suffer from poor pharmacokinetics and are not analgesic when administered by systemic routes. Also, it has been documented that preferred  $\delta$  agonist compounds, described within the prior art, show significant convulsive effects when administered systemically.

We have now found that certain compounds not specifically disclosed by, but included within the scope of WO 97/23466, exhibit surprisingly improved  $\delta$ -agonist properties and in vivo potency.

#### Outline of the invention

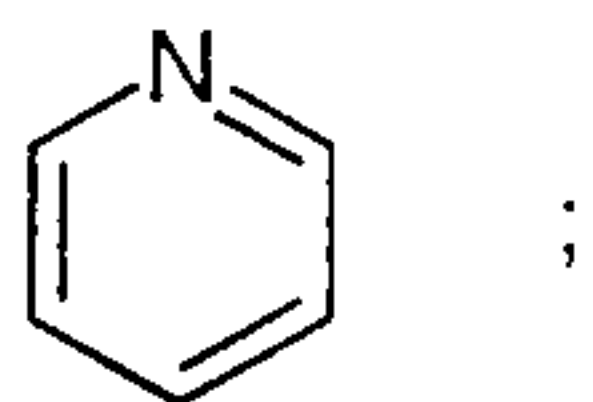
The novel compounds according to the present invention are defined by the formula I



wherein

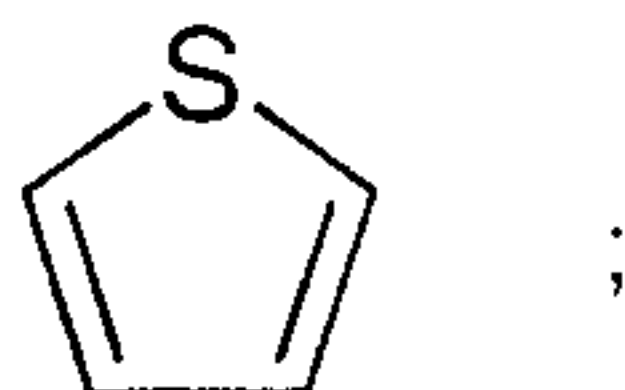
R<sup>1</sup> is selected from any one of

(ii) pyridinyl

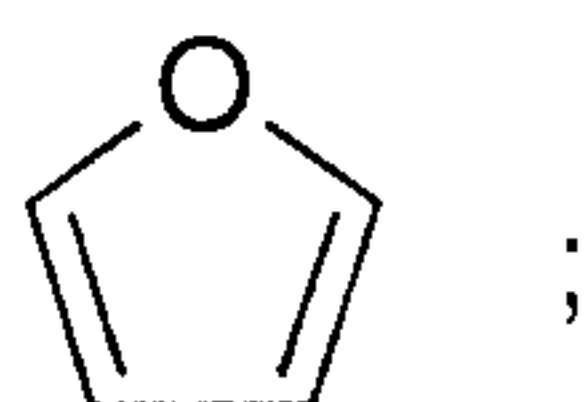


(iii) thienyl

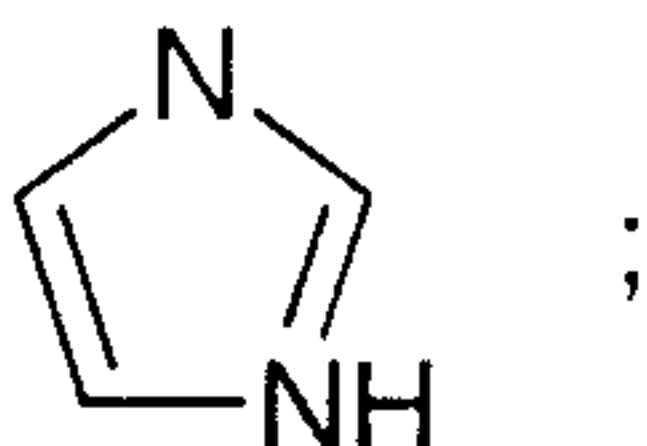
5



(iv) furanyl

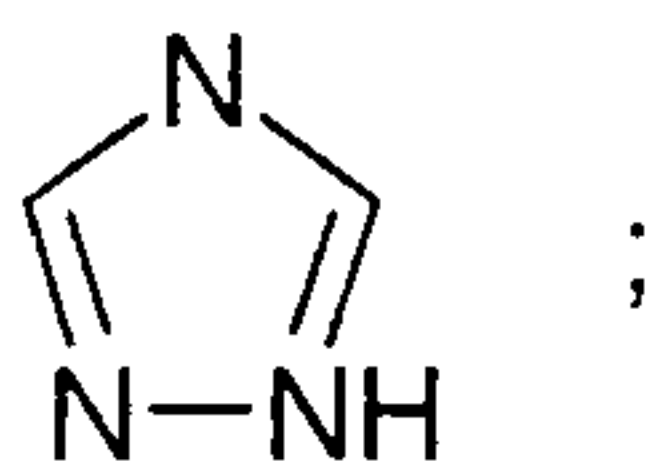


10 (v) imidazolyl



(vi) triazolyl

15



where each  $R^1$  heteroaromatic ring may optionally and independently be further substituted by 1, 2 or 3 substituents selected from straight and branched  $C_1$ - $C_6$  alkyl,  $NO_2$ ,  $CF_3$ ,  $C_1$ - $C_6$  alkoxy, chloro, fluoro, bromo, and iodo. The substitutions on the heteroaromatic ring may take place in any position on said ring systems;

20

A preferred embodiment of the present invention is a compound according to figure I wherein  $R^1$  is as defined above and each  $R^1$  phenyl ring and  $R^1$  heteroaromatic ring may independently be further substituted by a methyl group.

25

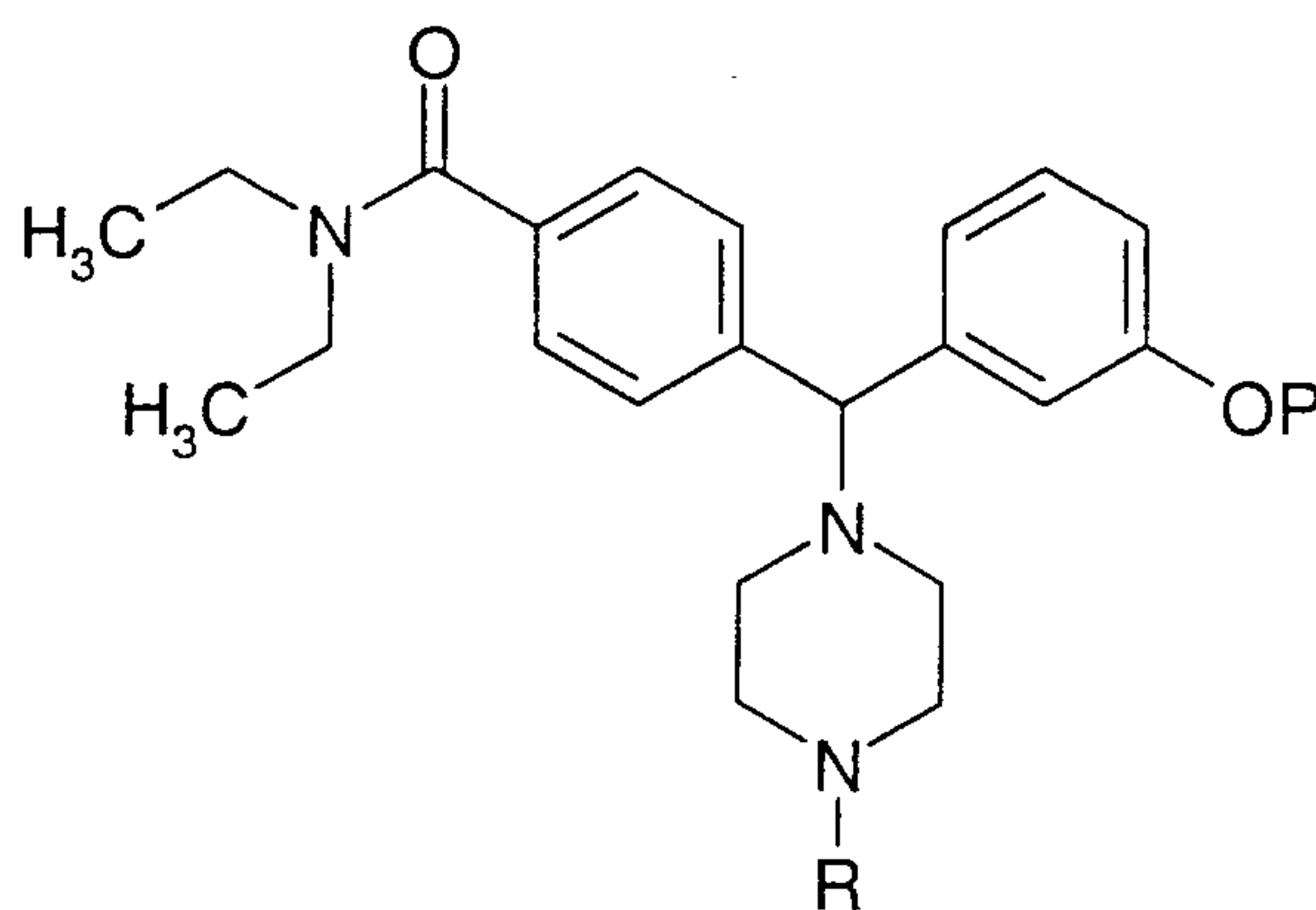
A more preferred embodiment of the present invention is a compound according to figure I wherein  $R^1$  is pyridinyl, thienyl or furanyl.

Within the scope of the invention are also separate enantiomers and salts of the compounds of the formula I, including salts of enantiomers.

Separation of racemic mixtures into separate enantiomers is well known in the art and may be accomplished for example by separation on a suitable chiral chromatography column. Preparation of salts is well known in the art, and may be accomplished for example by  
5 mixing a compound of formula I in a suitable solvent with the desired protic acid and isolation by means standard in the art. Salts of compounds of formula I include pharmaceutically acceptable salts and also pharmaceutically unacceptable salts.

When the heteroaromatic ring(s) are substituted, the preferred substituents are selected  
10 from anyone of CF<sub>3</sub>, methyl, iodo, bromo, fluoro and chloro.

Key reaction step Scheme 1, *vide infra*, is performed by reacting an intermediate compound of the general formula II



II

wherein R is an N-protecting group such as Boc or CBz, and P is a O-protecting group such as TBS or Me, which is first N-deprotected and then alkylated using either,

- i) a compound of the general formula R<sup>1</sup>-CH<sub>2</sub>-X, wherein R<sup>1</sup> is as defined above and X is  
20 halogen, preferably bromide, and a suitable base, or
- ii) a compound of the general formula R<sup>1</sup>-CHO, wherein R<sup>1</sup> is as defined above, and a suitable reducing agent

to give the compounds of general formula I, after O-deprotection.

Suitable bases to be used in the standard alkylation step *i*) above includes, but is not limited to, triethylamine and potassium carbonate.

5 Suitable reducing agents to be used in the standard reduction step *ii*) includes, but is not limited to, sodium cyanoborohydride and sodium triacetoxyborohydride.

The novel compounds of the present invention are useful in therapy, especially for the treatment of various pain conditions such as chronic pain, neuropathic pain, acute pain,  
10 cancer pain, pain caused by rheumatoid arthritis, migraine, visceral pain etc. This list should however not be interpreted as exhaustive.

Compounds of the invention are useful as immunomodulators, especially for autoimmune diseases, such as arthritis, for skin grafts, organ transplants and similar surgical needs, for  
15 collagen diseases, various allergies, for use as anti-tumour agents and anti viral agents.

Compounds of the invention are useful in disease states where degeneration or dysfunction of opioid receptors is present or implicated in that paradigm. This may involve the use of isotopically labelled versions of the compounds of the invention in diagnostic techniques  
20 and imaging applications such as positron emission tomography (PET).

Compounds of the invention are useful for the treatment of diarrhoea, depression, anxiety, urinary incontinence, various mental illnesses, cough, lung oedema, various gastro-intestinal disorders, spinal injury and drug addiction, including the treatment of alcohol,  
25 nicotine, opioid and other drug abuse and for disorders of the sympathetic nervous system for example hypertension.

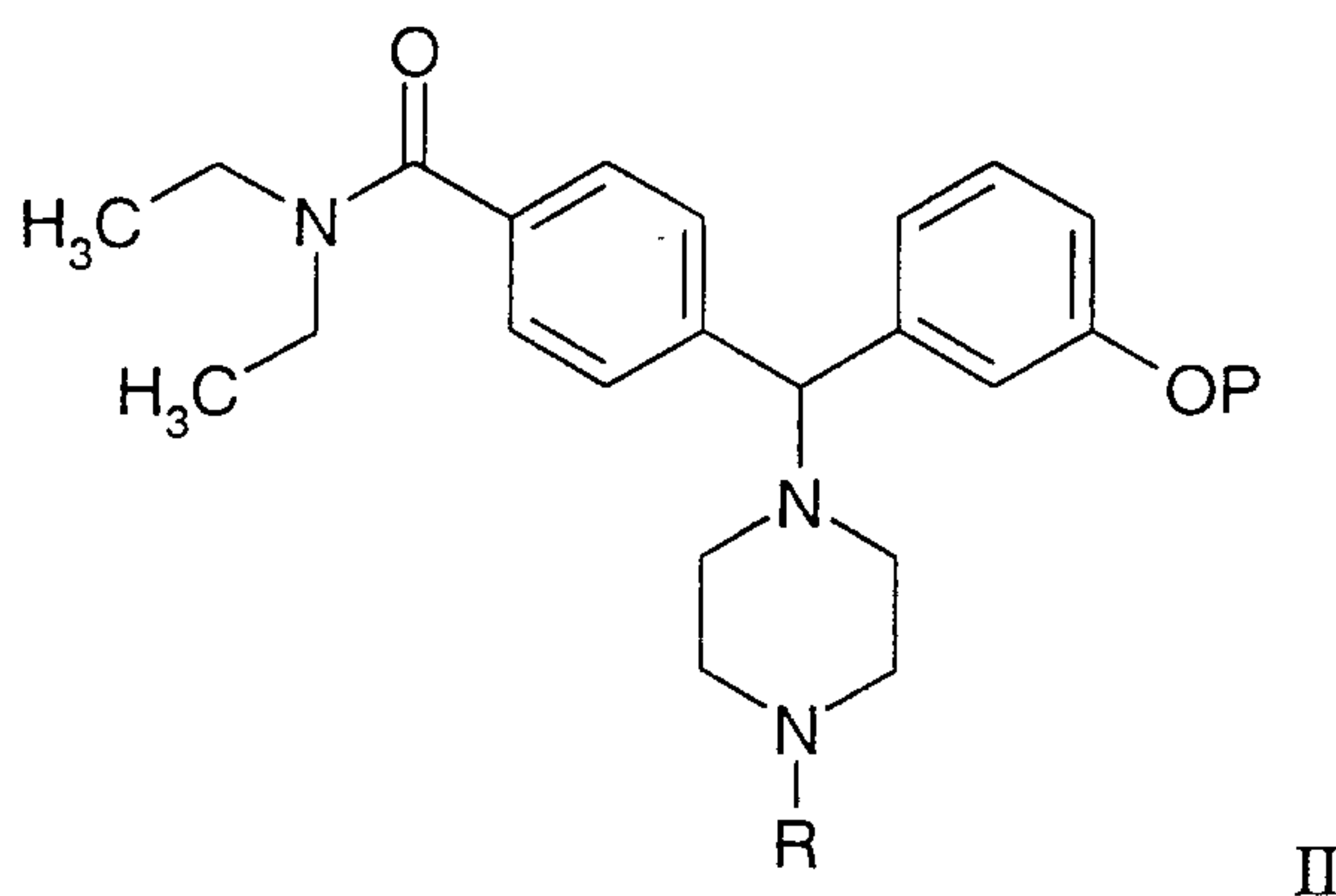
Compounds of the invention are useful as an analgesic agent for use during general anaesthesia and monitored anaesthesia care. Combinations of agents with different  
30 properties are often used to achieve a balance of effects needed to maintain the anaesthetic

state (eg. amnesia, analgesia, muscle relaxation and sedation). Included in this combination are inhaled anaesthetics, hypnotics, anxiolytics, neuromuscular blockers and opioids.

Also within the scope of the invention is the use of any of the compounds according to the formula I above, for the manufacture of a medicament for the treatment of any of the conditions discussed above.

A further aspect of the invention is a method for the treatment of a subject suffering from any of the conditions discussed above, whereby an effective amount of a compound according to the formula I above, is administered to a patient in need of such treatment.

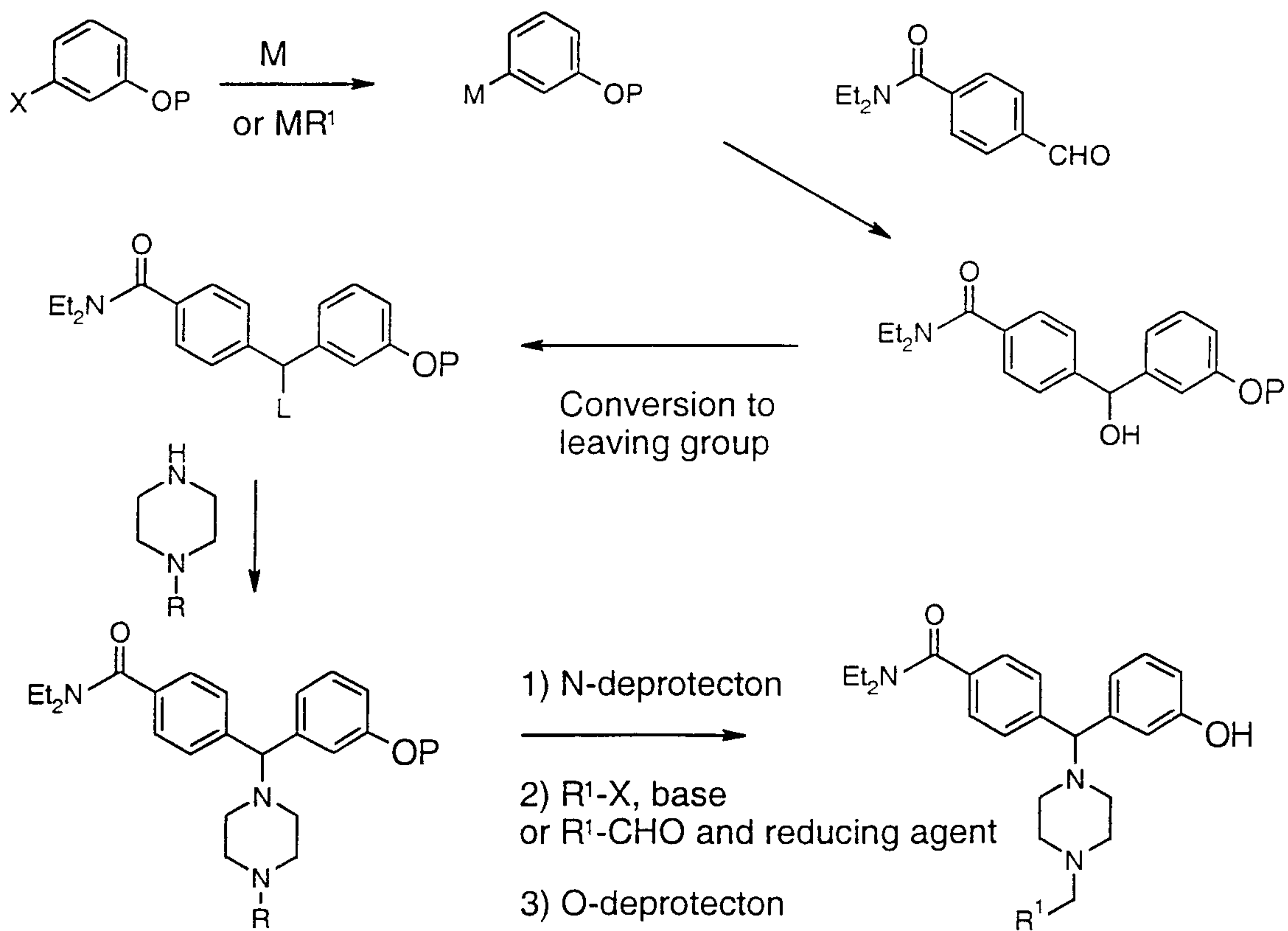
A further aspect of the present invention is intermediates of the general formula II,



wherein R is an N-protecting group such as Boc or CBz, and P is a O-protecting group such as TBS or Me.

#### Methods of preparation

The compounds according to the present invention may be prepared by following any one of the procedures described in Schemes I, II, III and IV below. Similar procedures are described in *J. March, Advanced Organic Chemistry, 4<sup>th</sup> Edition, John Wiley and sons (1992)*; *Katritsky, A.R., Lan, X. Chem. Soc. Rev., pp. 363-373 (1994)*, which are hereby incorporated by reference.

**SCHEME I**

R=a protecting group such as Boc, CBz

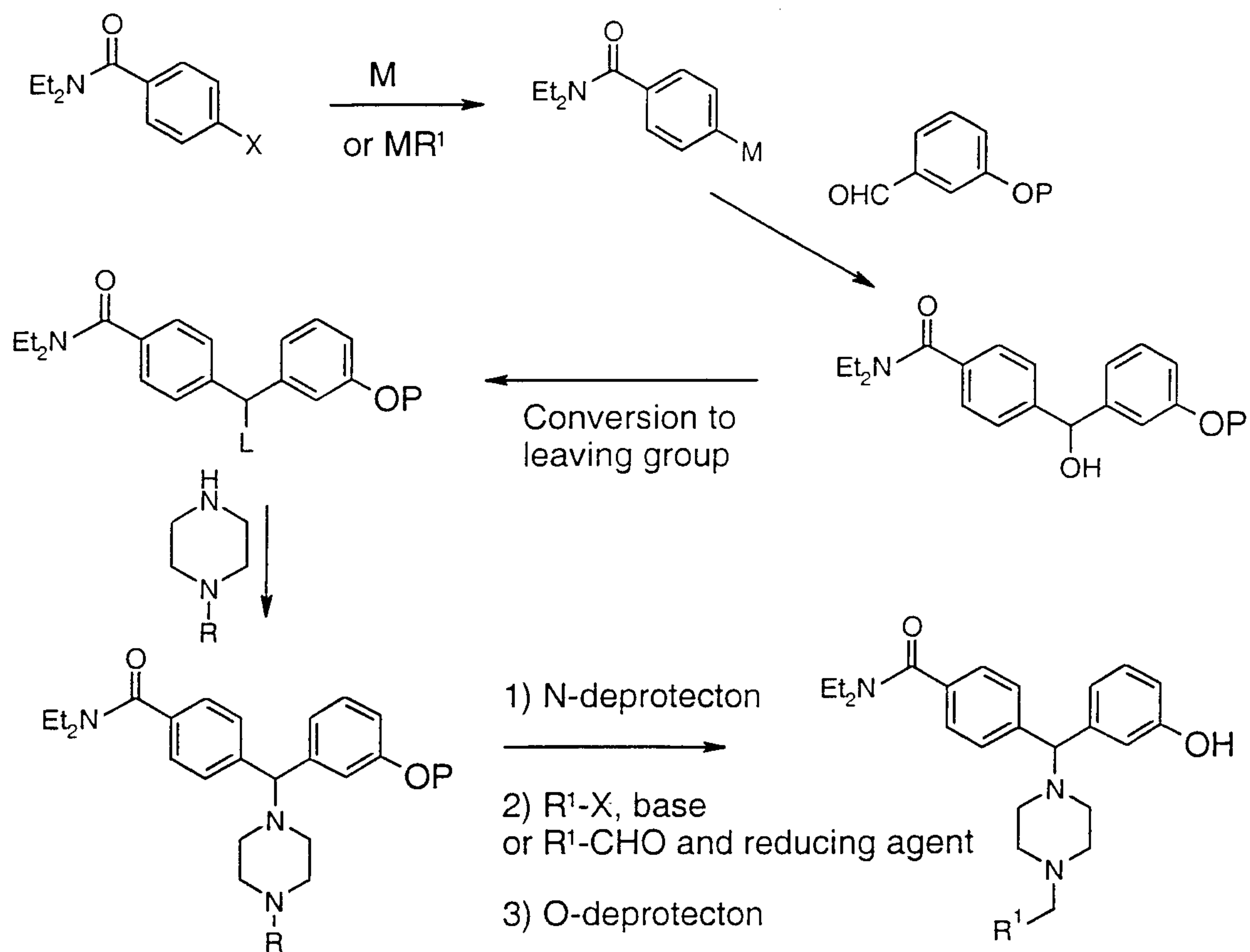
P=a protecting group such as TBS or Me

M= Li, Mg, Zn

X=Br, I

L=Cl, Br, OMs, OTs, I

R<sup>1</sup>= as defined in formula (I) above

**Scheme II**

R=a protecting group such as Boc, CBz

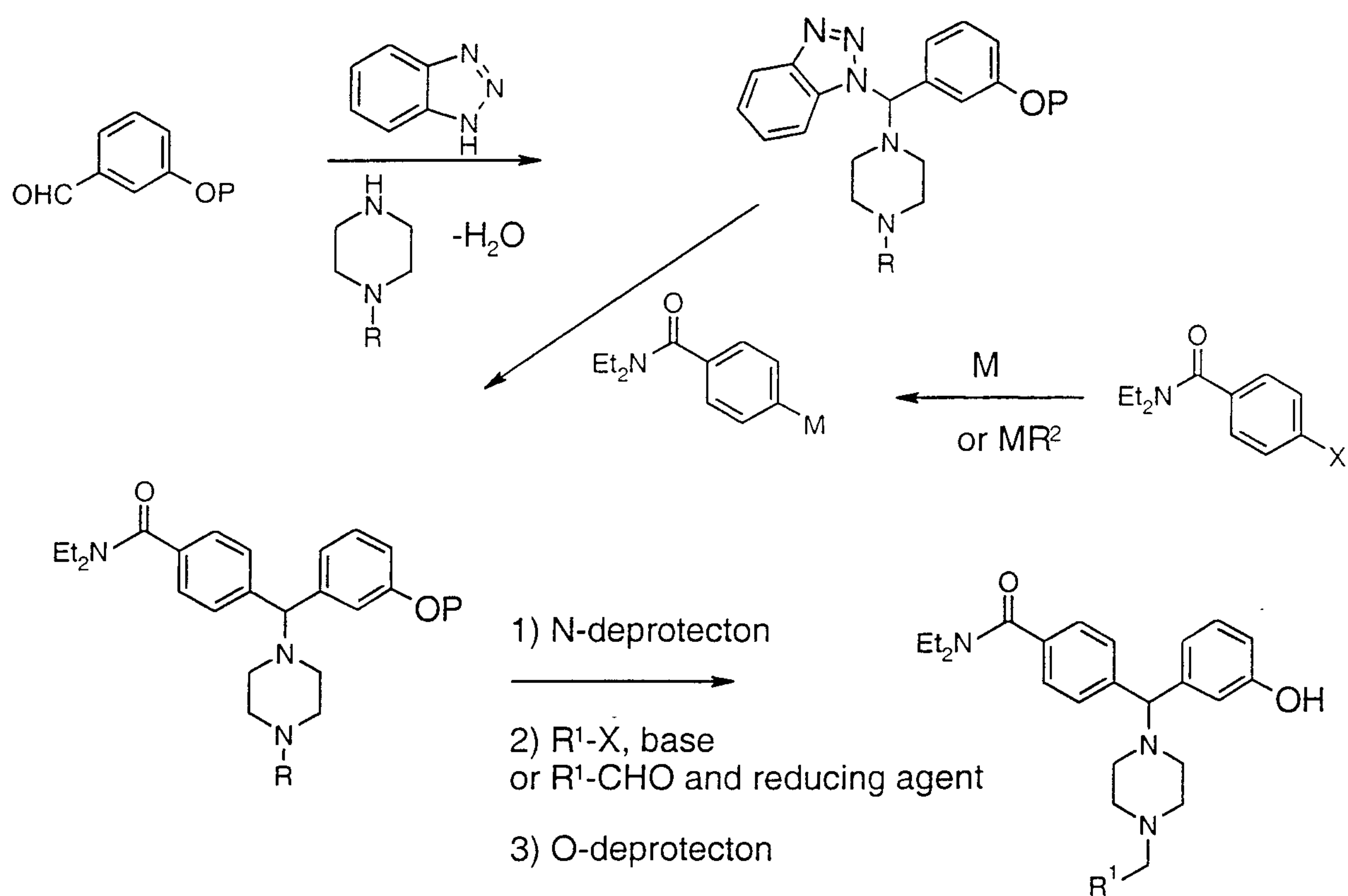
P=a protecting group such as TBs or Me

M= Li, Mg, Zn

X=Br, I

L=Cl, Br, OMs, OTs, I

R<sup>1</sup>= as defined in formula (I) above

**SCHEME III**

R=a protecting group such as Boc, CBz

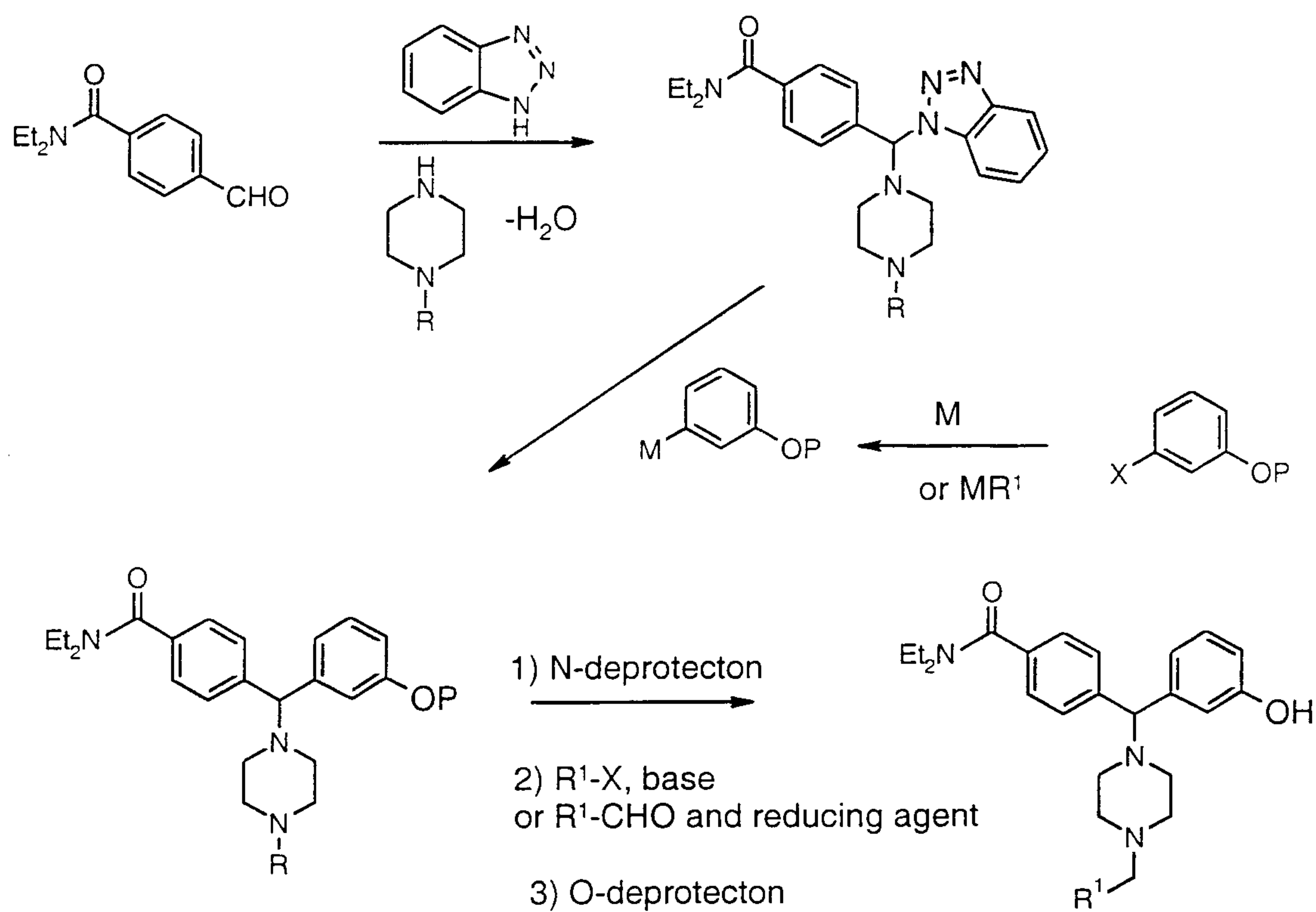
P=a protecting group such as TBS or Me

M= Li, Mg, Zn

X=Br, I

L=Cl, Br, OMs, OTs, I

R<sup>1</sup>= as defined in formula (I) above

**SCHEME IV**

R=a protecting group such as Boc, CBz

P=a protecting group such as TBS or Me

M= Li, Mg, Zn

X=Br, I

L=Cl, Br, OMs, OTs, I

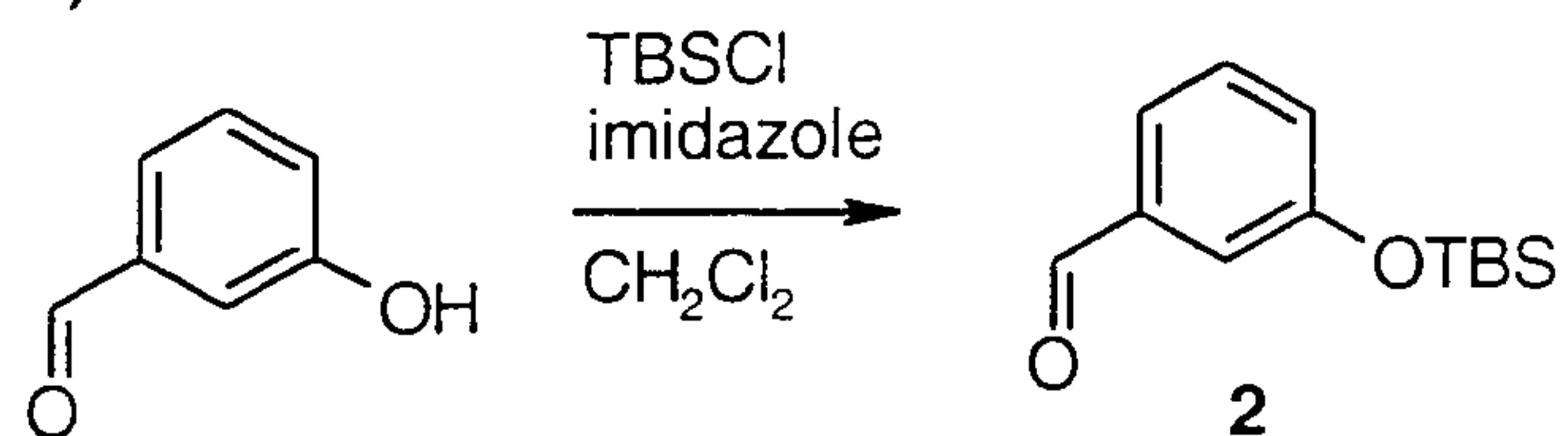
R<sup>1</sup>= as defined in formula (I) above

**EXAMPLES**

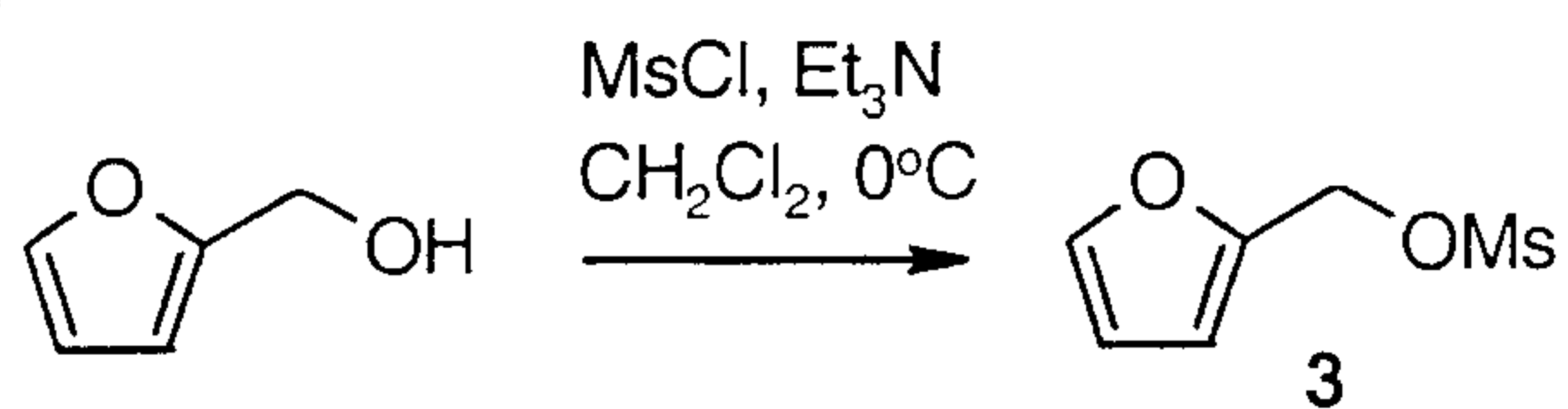
- 5 The invention will now be described in more detail by the following Examples, which are not to be construed as limiting the invention.

**Scheme 1**

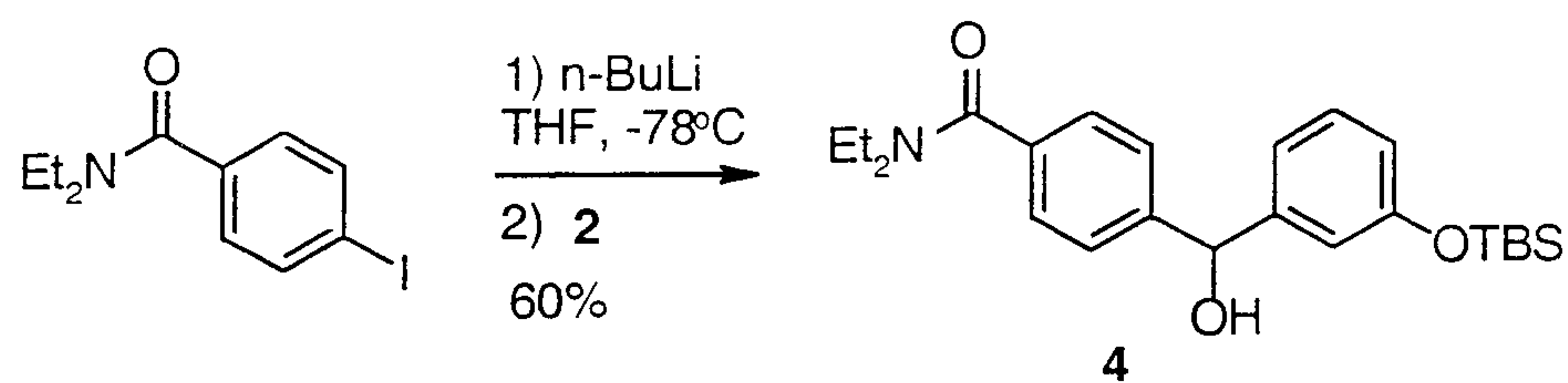
i)



ii)

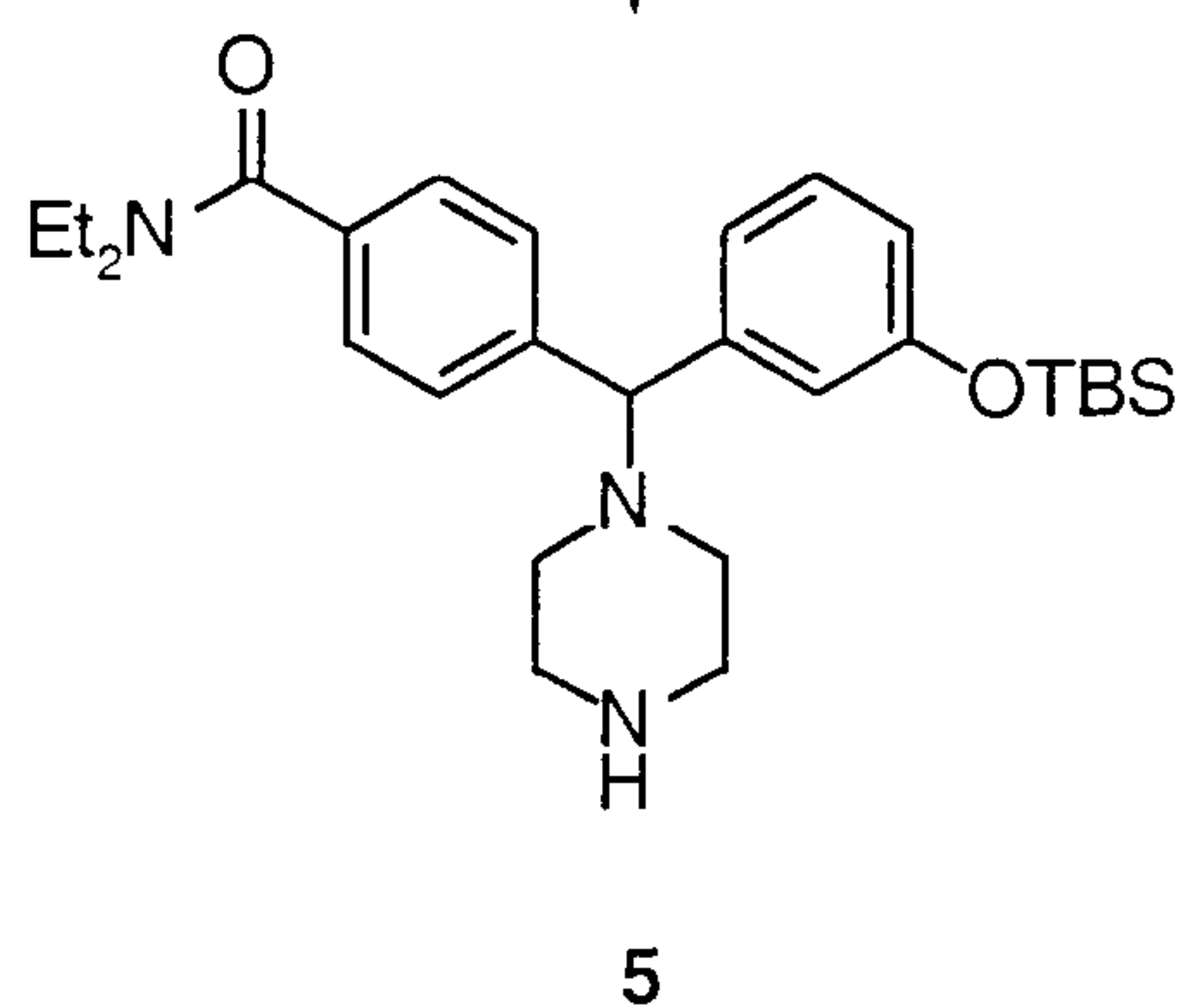


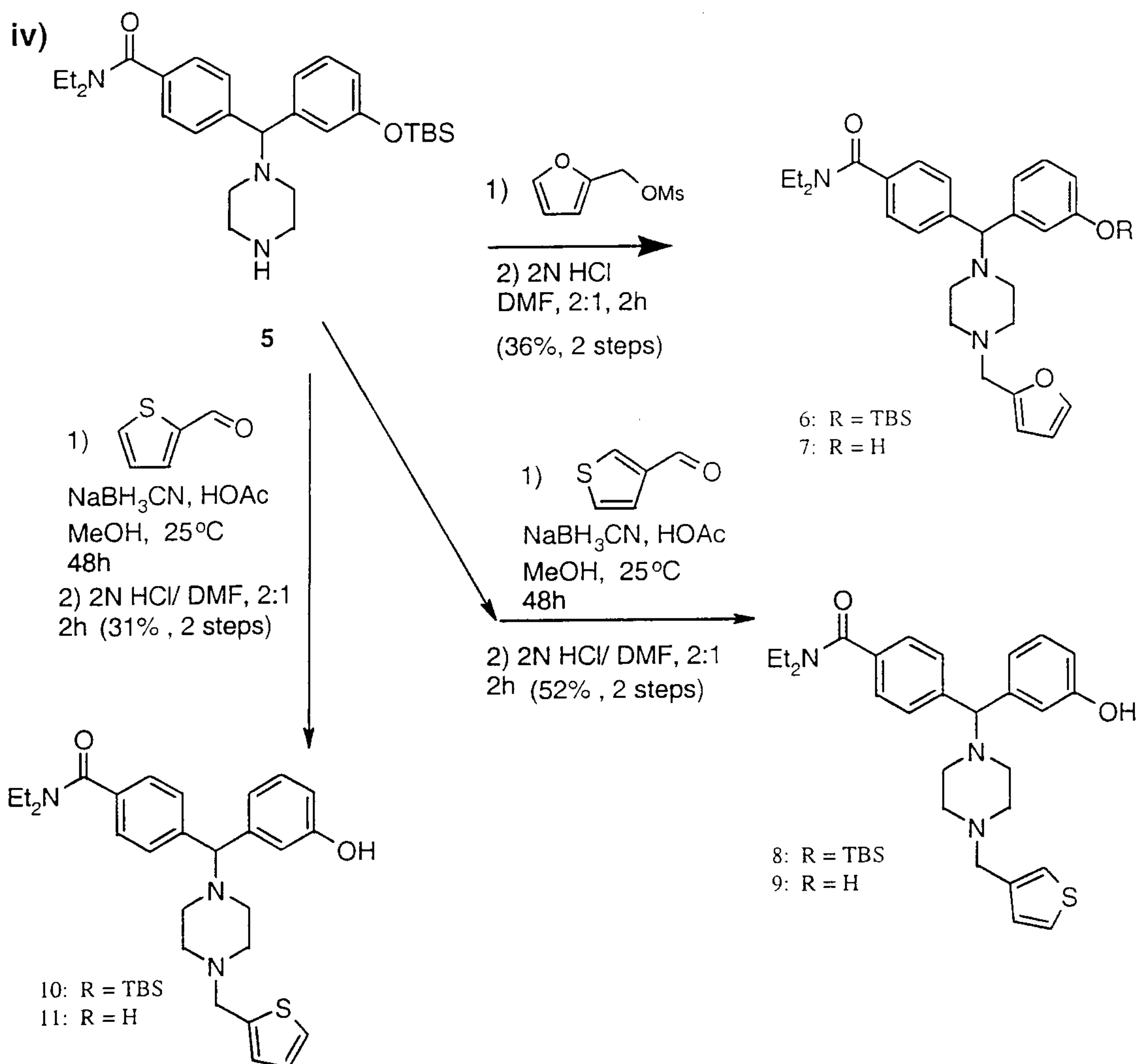
iii)



1)  $\text{SOCl}_2$   
 $\text{CH}_2\text{Cl}_2$

2) piperazine  
 $\text{MeCN}$ ,  $80^\circ\text{C}$   
52%



**Scheme 1 (continued)**

### Example 1

#### Preparation of *N,N*-diethyl-4-[[4-(2-furvlmethvl)-1-piperazinvl](3-hydroxyphenvl)methvl]benzamide (compound 7)

##### (i) Preparation of 3-{{*tert*-butyl(dimethyl)silyl}oxy}benzaldehyde (compound 2)

3-Hydroxybenzaldehyde (10 g, 82 mmol) was dissolved in DMF (50 mL) with imidazole (12 g, 180 mmol) and *t*-butyldimethylsilyl chloride (13 g, 90 mmol) and stirred at 25 °C for 12 h. Aqueous workup and chromatography on silica gave **compound 2** (18 g, 93%).

MS (EI) *m/e* 236, 179, 151.

##### (ii) Preparation of 4-[(3-{{*tert*-butyl(dimethyl)silyl}oxy}phenyl)(hydroxy)methvl]-*N,N*-diethylbenzamide (compound 4)

*N,N*-Diethyl-4-iodobenzamide (3.0 g, 10 mmol) was dissolved in THF (100 mL) and cooled to -78 °C under nitrogen atmosphere. *n*-BuLi (7.7 mL, 1.3 M solution in hexane, 10 mmol) was added dropwise during 10 min at -65 to -78 °C. **Compound 2** prepared in the previous step (1.9 g, 8.0 mmol) was added dropwise dissolved in THF (2 mL). NH<sub>4</sub>Cl (aq.) was added after 30 min. After concentration *in vacuo*, extraction with EtOAc / water, drying (MgSO<sub>4</sub>) and evaporation of the organic phase, the residue was purified by chromatography on silica to give **compound 4** (2.0 g, 60%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 0 (s, 6H), 0.80 (s, 9H), 0.9-1.2 (m, 6H), 2.6 (s, 1H), 3.0-3.5 (m, 4H), 5.59 (s, 1H), 6.55-7.25 (m, 8H).

##### (iii) Preparation of 4-[(3-{{*tert*-butyl(dimethyl)silyl}oxy}phenyl)(1-piperazinvl)methvl]-*N,N*-diethylbenzamide (compound 5)

**Compound 4** prepared in the previous step (2.0 g, 4.8 mmol) was dissolved in dry CH<sub>2</sub>Cl<sub>2</sub> (50 mL) and treated with SOCl<sub>2</sub> (0.38 mL, 5.2 mmol) in at 0 to 25 °C for 30 min, the solvent was evaporated *in vacuo*. The residue was dissolved in MeCN (50 mL) and reacted with piperazine (1.6 g, 19 mmol) at 80 °C for 12 h. Concentration *in vacuo* and chromatography on silica gave **compound 5** (1.2 g, 52%).

<sup>1</sup>H NMR (amine, CDCl<sub>3</sub>) δ = 1.0, 1.1 (2m, 6H), 2.2-2.4 (m, 4H), 2.80 (m, 4H), 3.15, 3.45 (2m, 4H), 4.10 (s, 1H), 6.58 –7.38 (m, 8H).

(iv) 4-((3-((*tert*-butyl(dimethyl)silyl)oxy)phenyl)[4-(2-furvlmethyl)-1-piperazinyl]methyl)-*N,N*-diethylbenzamide (compound 6)

2-furvlmethanol (compound 3 prepared as shown in Scheme 1 above) (0.29 mL, 3.3 mmol) was dissolved in CH<sub>2</sub>Cl<sub>2</sub> (5 mL) with triethylamine (1.0 mL, 7.4 mmol).

Methanesulfonylchloride (0.26 mL, 3.4 mmol) was added at 0 °C and the solution stirred 15 min at 0 °C before **compound 5** prepared in the previous step (0.81 g, 1.7 mmol) was added. The reaction was stirred 48 h at 25 °C before concentration *in vacuo* and chromatography on silica gave **compound 6** (0.40 g, 42%).

(v) Preparation of *N,N*-diethyl-4-[[4-(2-furvlmethyl)-1-piperazinyl](3-hydroxyphenyl)methyl]benzamide (compound 7)

**Compound 6** prepared in the previous step was treated with DMF/ 2N HCl, 1:2 for 1 h at 25 °C. Concentration and reverse phase chromatography gave **the title compound 7** (0.26 g, 54%) as the ditrifluoroacetate salt.

MS (ES) 448.24 (MH<sup>+</sup> monoisot.).

IR (2x TFA, NaCl) : 3232, 1674, 1599, 1457, 1288, 1199, 1134 (cm<sup>-1</sup>).

<sup>1</sup>H NMR (2x TFA, CDCl<sub>3</sub>) δ = 1.1, 1.2 (2m, 6H), 2.5-3.6 (m, 13H), 4.21 (s, 2H), 4.28 (s, 1H), 6.44 –7.50 (m, 11H).

**Example 2****Preparation of *N,N*-diethyl-4-[(3-hydroxyphenyl)[4-(2-thienylmethyl)-1-piperazinyl]methyl]benzamide ditrifluoroacetate (compound 11)**

5 Prepared as in Example Iiv and Iv from compound 5 as prepared in Example Iiii above, to give the **title compound 11**, after purification by reverse phase chromatography and extraction (CH<sub>2</sub>Cl<sub>2</sub> /K<sub>2</sub>CO<sub>3</sub>(aq)), as base(28 mg, 31 %).

MS (ES) 464.10 (MH<sup>+</sup> monoisot.).

IR (2x TFA, NaCl) : 3393, 3180, 1672, 1607, 1457, 1289, 1199, 1133 (cm<sup>-1</sup>).

10 <sup>1</sup>H NMR (2x HCl, CDCl<sub>3</sub>) δ = 1.1, 1.3 (m, 6H), 2.4-3.6 (m, 13H), 4.27 (s, 1H), 4.35 (s, 2H), 6.64 –7.45 (m, 11H).

**Example 3**

15 **Preparation of *N,N*-diethyl-4-[(3-hydroxyphenyl)[4-(3-thienylmethyl)-1-piperazinyl]methyl]benzamide dihydrochloride (compound 9)**

Prepared as in Example Iiv and Iv from compound 5 as prepared in Example Iiii above, to give the **title compound 8**, after purification by reverse phase chromatography and extraction (CH<sub>2</sub>Cl<sub>2</sub> /K<sub>2</sub>CO<sub>3</sub>(aq)), as base (29 mg, 52 %). Treatment with HCl (aq.)  
20 gave dihydrochloride. MS (ES) 464.08 (MH<sup>+</sup> monoisot.).

IR (2x HCl, NaCl) : 3393, 3180, 1607, 1457, 1289 (cm<sup>-1</sup>).

<sup>1</sup>H NMR (2x HCl, CDCl<sub>3</sub>) δ = 1.1, 1.2 (m, 6H), 1.6-2.2 (m, 8H), 3.1-4.4 (m, 5H), 4.30 (s, 2H), 5.0 (s, 1H), 6.8 –7.9 (m, 11H).

Pharmaceutical compositions

The novel compounds according to the present invention may be administered orally,  
5 intramuscularly, subcutaneously, topically, intranasally, intraperitoneally, intrathoracically,  
intravenously, epidurally, intrathecally, intracerebroventricularly and by injection into the  
joints.

A preferred route of administration is orally, intravenously or intramuscularly.

10 The dosage will depend on the route of administration, the severity of the disease, age and  
weight of the patient and other factors normally considered by the attending physician,  
when determining the individual regimen and dosage level as the most appropriate for a  
particular patient.

15 For preparing pharmaceutical compositions from the compounds of this invention, inert,  
pharmaceutically acceptable carriers can be either solid or liquid. Solid form preparations  
include powders, tablets, dispersible granules, capsules, cachets, and suppositories.

20 A solid carrier can be one or more substances which may also act as diluents, flavoring  
agents, solubilizers, lubricants, suspending agents, binders, or tablet disintegrating agents;  
it can also be an encapsulating material.

In powders, the carrier is a finely divided solid which is in a mixture with the finely divided  
25 active component. In tablets, the active component is mixed with the carrier having the  
necessary binding properties in suitable proportions and compacted in the shape and size  
desired.

For preparing suppository compositions, a low-melting wax such as a mixture of fatty acid  
30 glycerides and cocoa butter is first melted and the active ingredient is dispersed therein by,

for example, stirring. The molten homogeneous mixture is then poured into convenient sized molds and allowed to cool and solidify.

Suitable carriers are magnesium carbonate, magnesium stearate, talc, lactose, sugar, pectin, dextrin, starch, tragacanth, methyl cellulose, sodium carboxymethyl cellulose, a low-melting wax, cocoa butter, and the like.

Salts include, but are not limited to pharmaceutically acceptable salts. Examples of pharmaceutically acceptable salts within the scope of the present invention include: acetate, benzenesulfonate, benzoate, bicarbonate, bitartrate, bromide, calcium acetate, camsylate, carbonate, chloride, citrate, dihydrochloride, edetate, edisylate, estolate, esylate, fumarate, glucaptate, gluconate, glutamate, glycolylarsanilate, hexylresorcinate, hydrabamine, hydrobromide, hydrochloride, hydroxynaphthoate, isethionate, lactate, lactobionate, malate, maleate, mandelate, mesylate, methylbromide, methylnitrate, methylsulfate, mucate, napsylate, nitrate, pamoate (embonate), pantothenate, phosphate/diphosphate, polygalacturonate, salicylate, stearate, subacetate, succinate, sulfate, tannate, tartrate, teoclate, triethiodide, benzathine, chlorprocaine, choline, diethanolamine, ethylenediamine, meglumine, procaine, aluminium, calcium, lithium, magnesium, potassium, sodium, and zinc. Examples of pharmaceutically unacceptable salts within the scope of the present invention include: hydroiodide, perchlorate, and tetrafluoroborate. Preferred pharmaceutically acceptable salts are the hydrochlorides, sulfates and bitartrates. The hydrochloride and sulfate salts are particularly preferred.

The term composition is intended to include the formulation of the active component with encapsulating material as a carrier providing a capsule in which the active component (with or without other carriers) is surrounded by a carrier which is thus in association with it. Similarly, cachets are included.

Tablets, powders, cachets, and capsules can be used as solid dosage forms suitable for oral administration.

Liquid from compositions include solutions, suspensions, and emulsions. Sterile water or water-propylene glycol solutions of the active compounds may be mentioned as an example of liquid preparations suitable for parenteral administration. Liquid compositions can also be formulated in solution in aqueous polyethylene glycol solution.

5

Aqueous solutions for oral administration can be prepared by dissolving the active component in water and adding suitable colorants, flavoring agents, stabilizers, and thickening agents as desired. Aqueous suspensions for oral use can be made by dispersing the finely divided active component in water together with a viscous material such as  
10 natural synthetic gums, resins, methyl cellulose, sodium carboxymethyl cellulose, and other suspending agents known to the pharmaceutical formulation art.

Preferably the pharmaceutical compositions is in unit dosage form. In such form, the composition is divided into unit doses containing appropriate quantities of the active  
15 component. The unit dosage form can be a packaged preparation, the package containing discrete quantities of the preparations, for example, packeted tablets, capsules, and powders in vials or ampoules. The unit dosage form can also be a capsule, cachet, or tablet itself, or it can be the appropriate number of any of these packaged forms.

## BIOLOGICAL EVALUATION

### In vitro model

#### Cell culture

- 5 A. Human 293S cells expressing cloned human  $\mu$ ,  $\delta$ , and  $\kappa$  receptors and neomycin resistance were grown in suspension at 37°C and 5% CO<sub>2</sub> in shaker flasks containing calcium-free DMEM10% FBS, 5% BCS, 0.1% Pluronic F-68, and 600  $\mu$ g/ml geneticin.
- B. Mouse and rat brains were weighed and rinsed in ice-cold PBS (containing 2.5mM EDTA, pH 7.4). The brains were homogenized with a polytron for 15 sec (mouse) or  
10 30 sec (rat) in ice-cold lysis buffer (50mM Tris, pH 7.0, 2.5mM EDTA, with phenylmethylsulfonyl fluoride added just prior use to 0.5mM from a 0.5M stock in DMSO:ethanol).

#### Membrane preparation

- 15 Cells were pelleted and resuspended in lysis buffer (50 mM Tris, pH 7.0, 2.5 mM EDTA, with PMSF added just prior to use to 0.1 mM from a 0.1 M stock in ethanol), incubated on ice for 15 min, then homogenized with a polytron for 30 sec. The suspension was spun at 1000g (max) for 10 min at 4°C. The supernatant was saved on ice and the pellets  
20 resuspended and spun as before. The supernatants from both spins were combined and spun at 46,000 g(max) for 30 min. The pellets were resuspended in cold Tris buffer (50 mM Tris/Cl, pH 7.0) and spun again. The final pellets were resuspended in membrane buffer (50 mM Tris, 0.32 M sucrose, pH 7.0). Aliquots (1 ml) in polypropylene tubes were frozen in dry ice/ethanol and stored at -70°C until use. The protein concentrations were  
25 determined by a modified Lowry assay with sodium dodecyl sulfate.

#### Binding assays

- Membranes were thawed at 37°C, cooled on ice, passed 3 times through a 25-gauge  
30 needle, and diluted into binding buffer (50 mM Tris, 3 mM MgCl<sub>2</sub>, 1 mg/ml BSA (Sigma A-7888), pH 7.4, which was stored at 4°C after filtration through a 0.22  $\mu$ m filter, and to

which had been freshly added 5  $\mu\text{g/ml}$  aprotinin, 10  $\mu\text{M}$  bestatin, 10  $\mu\text{M}$  diproton A, no DTT). Aliquots of 100  $\mu\text{l}$  were added to iced 12x75 mm polypropylene tubes containing 100  $\mu\text{l}$  of the appropriate radioligand and 100  $\mu\text{l}$  of test compound at various concentrations. Total (TB) and nonspecific (NS) binding were determined in the absence and presence of 10  $\mu\text{M}$  naloxone respectively. The tubes were vortexed and incubated at 25°C for 60-75 min, after which time the contents are rapidly vacuum-filtered and washed with about 12 ml/tube iced wash buffer (50 mM Tris, pH 7.0, 3 mM  $\text{MgCl}_2$ ) through GF/B filters (Whatman) presoaked for at least 2h in 0.1% polyethyleneimine. The radioactivity (dpm) retained on the filters was measured with a beta counter after soaking the filters for at least 12h in minivials containing 6-7 ml scintillation fluid. If the assay is set up in 96-place deep well plates, the filtration is over 96-place PEI-soaked unifilters, which were washed with 3 x 1 ml wash buffer, and dried in an oven at 55°C for 2h. The filter plates were counted in a TopCount (Packard) after adding 50  $\mu\text{l}$  MS-20 scintillation fluid/well.

### Functional Assays

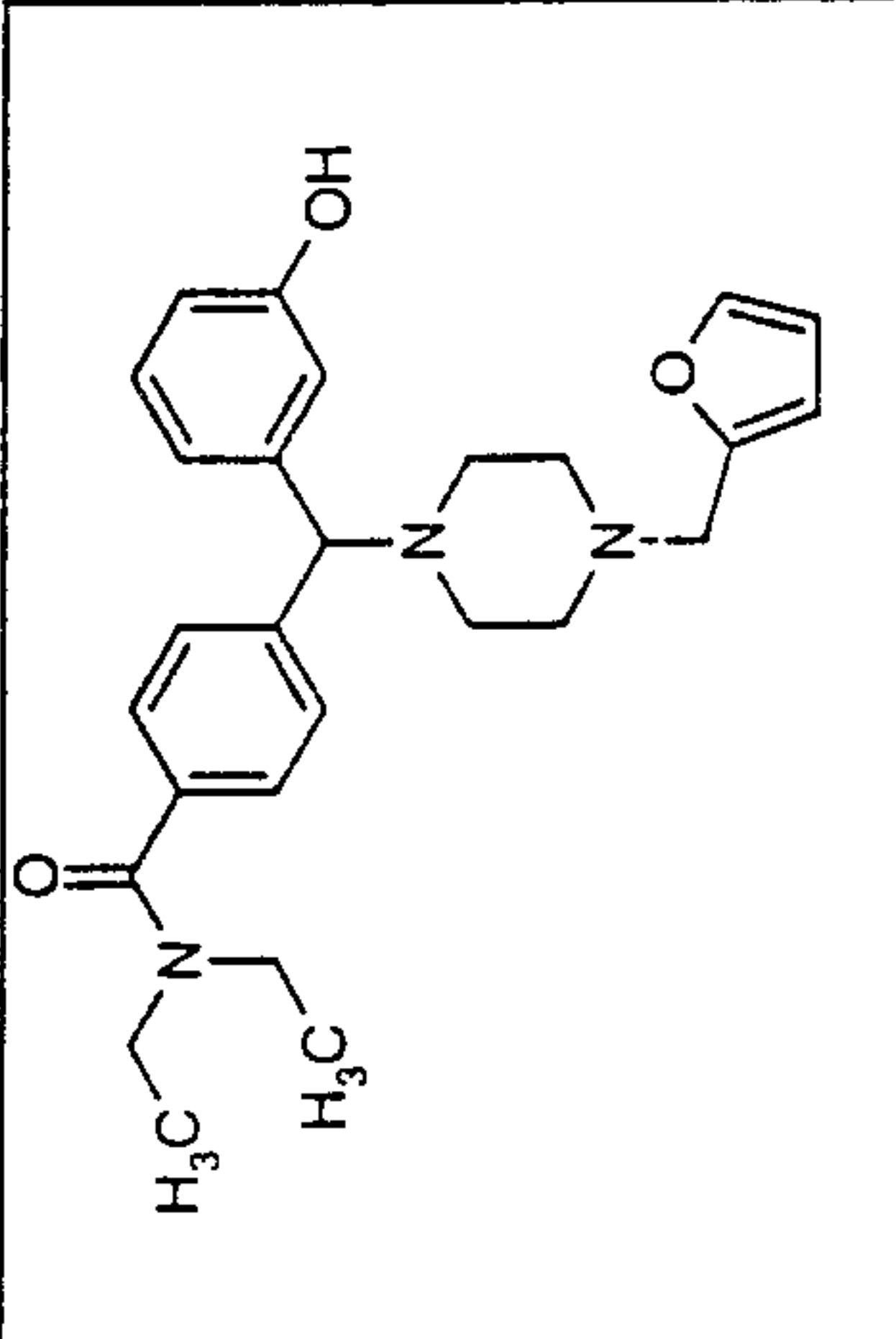
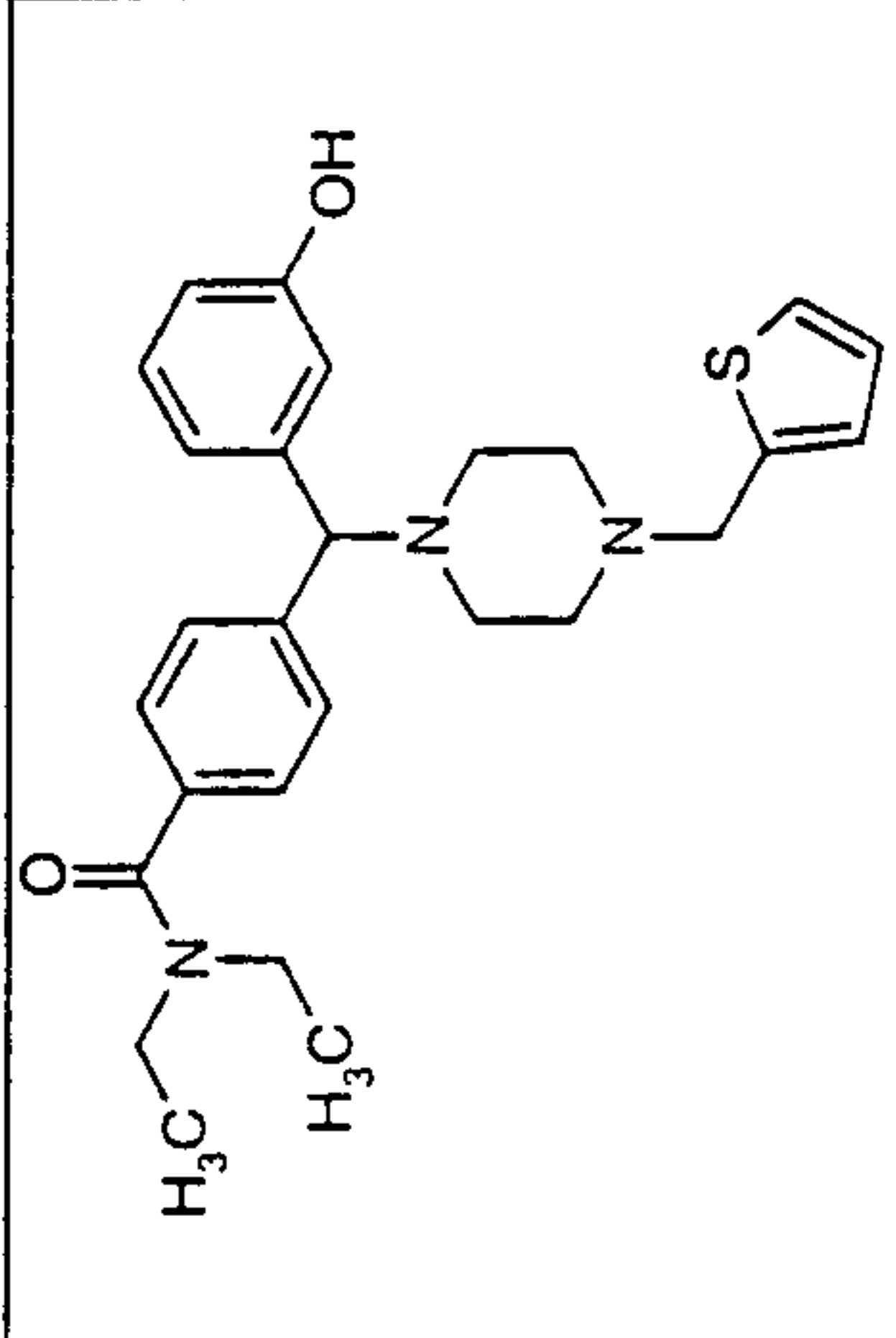
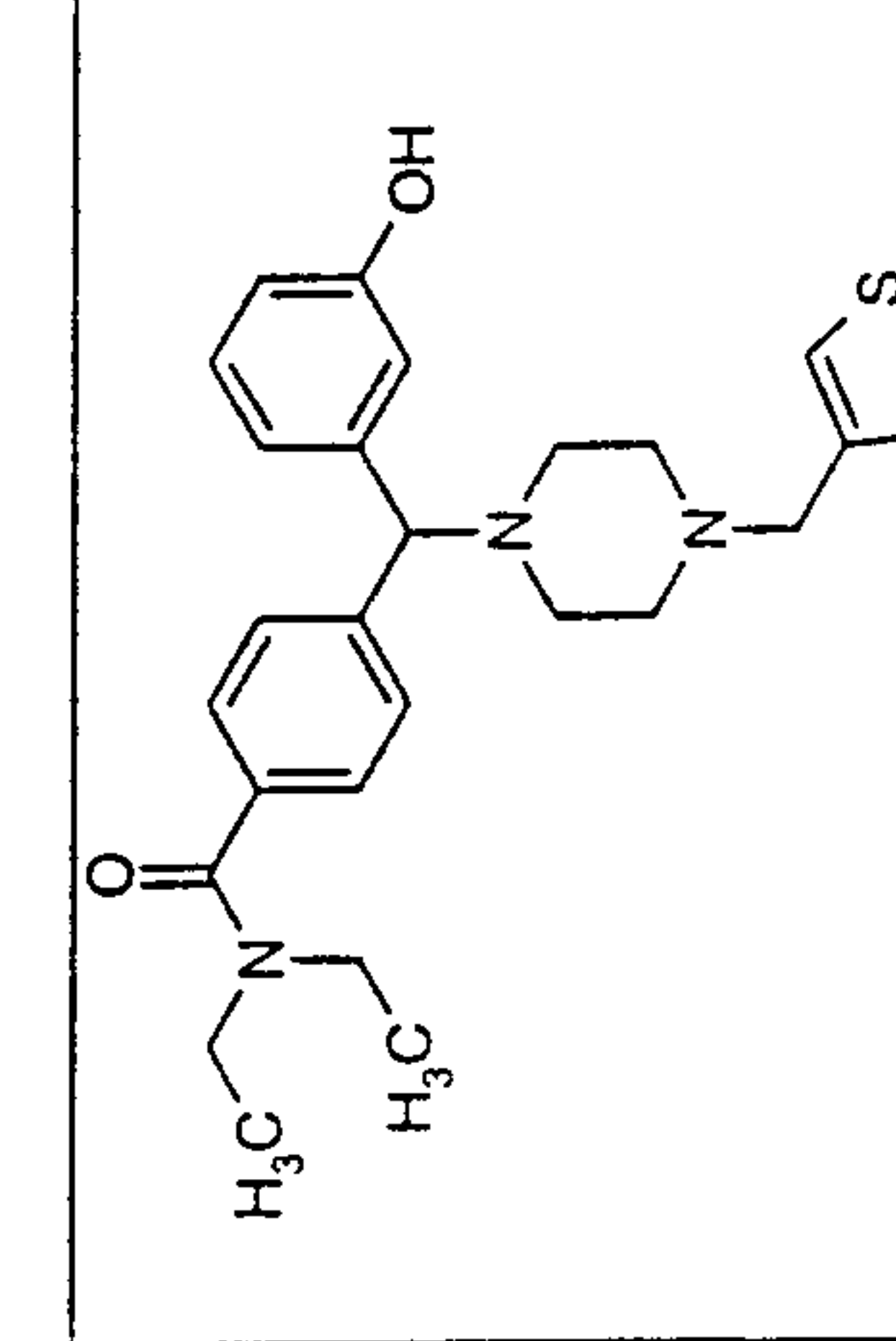
The agonist activity of the compounds is measured by determining the degree to which the compounds receptor complex activates the binding of GTP to G-proteins to which the receptors are coupled. In the GTP binding assay,  $\text{GTP}[\gamma]^{35}\text{S}$  is combined with test compounds and membranes from HEK-293S cells expressing the cloned human opioid receptors or from homogenised rat and mouse brain. Agonists stimulate  $\text{GTP}[\gamma]^{35}\text{S}$  binding in these membranes. The  $\text{EC}_{50}$  and  $\text{E}_{\text{max}}$  values of compounds are determined from dose-response curves. Right shifts of the dose response curve by the delta antagonist naltrindole are performed to verify that agonist activity is mediated through delta receptors.

### Data analysis

The specific binding (SB) was calculated as  $\text{TB} - \text{NS}$ , and the SB in the presence of various test compounds was expressed as percentage of control SB. Values of  $\text{IC}_{50}$  and Hill coefficient ( $n_H$ ) for ligands in displacing specifically bound radioligand were calculated

from logit plots or curve fitting programs such as Ligand, GraphPad Prism, SigmaPlot, or ReceptorFit. Values of  $K_i$  were calculated from the Cheng-Prusoff equation. Mean  $\pm$  S.E.M. values of  $IC_{50}$ ,  $K_i$  and  $n_H$  were reported for ligands tested in at least three displacement curves. Biological data are tabulated on the following page in Table 1.

Table 1: Biological data.

Ex. #	MOLECULAR STRUCTURE	HDELTA	HDELTA		RAT BRAIN		MOUSE BRAIN	
			EC50	% Emax	EC50	% EMax	EC50	% Emax
1		0.381	0.21	94.84	1.25	130.09	2.6	112.93
2		0.357	0.24	104.62	0.79	120.37	1.16	117.56
3		0.338	0.15	114.45	0.93	128.08	1	122.03

### Receptor saturation experiments

Radioligand  $K_D$  values were determined by performing the binding assays on cell membranes  
5 with the appropriate radioligands at concentrations ranging from 0.2 to 5 times the estimated  
 $K_D$  (up to 10 times if amounts of radioligand required are feasible). The specific radioligand  
binding was expressed as pmole/mg membrane protein. Values of  $K_D$  and  $B_{max}$  from  
individual experiments were obtained from nonlinear fits of specifically bound (B) vs. nM  
free (F) radioligand from individual according to a one-site model.

10

### DETERMINATION OF MECHANO-ALLODYNIA USING VON FREY TESTING

Testing was performed between 08:00 and 16:00h using the method described by Chaplan et  
al. (1994). Rats were placed in Plexiglas cages on top of a wire mesh bottom which allowed  
15 access to the paw, and were left to habituate for 10-15 min. The area tested was the mid-  
plantar left hind paw, avoiding the less sensitive foot pads. The paw was touched with a  
series of 8 Von Frey hairs with logarithmically incremental stiffness (0.41, 0.69, 1.20, 2.04,  
3.63, 5.50, 8.51, and 15.14 grams; Stoelting, Ill, USA). The von Frey hair was applied from  
underneath the mesh floor perpendicular to the plantar surface with sufficient force to cause a  
20 slight buckling against the paw, and held for approximately 6-8 seconds. A positive response  
was noted if the paw was sharply withdrawn. Flinching immediately upon removal of the  
hair was also considered a positive response. Ambulation was considered an ambiguous  
response, and in such cases the stimulus was repeated.

### TESTING PROTOCOL

The animals were tested on postoperative day 1 for the FCA-treated group. The 50% withdrawal threshold was determined using the up-down method of Dixon (1980). Testing was started with the 2.04 g hair, in the middle of the series. Stimuli were always presented in a consecutive way, whether ascending or descending. In the absence of a paw withdrawal response to the initially selected hair, a stronger stimulus was presented; in the event of paw withdrawal, the next weaker stimulus was chosen. Optimal threshold calculation by this method requires 6 responses in the immediate vicinity of the 50% threshold, and counting of these 6 responses began when the first change in response occurred, e.g. the threshold was first crossed. In cases where thresholds fell outside the range of stimuli, values of 15.14 (normal sensitivity) or 0.41 (maximally allodynic) were respectively assigned. The resulting pattern of positive and negative responses was tabulated using the convention, X = no withdrawal; O = withdrawal, and the 50% withdrawal threshold was interpolated using the formula:

$$50\% \text{ g threshold} = 10^{(X_f + k_\delta)} / 10,000$$

where  $X_f$  = value of the last von Frey hair used (log units);  $k$  = tabular value (from Chaplan et al. (1994)) for the pattern of positive / negative responses; and  $\delta$  = mean difference between stimuli (log units). Here  $\delta = 0.224$ .

Von Frey thresholds were converted to percent of maximum possible effect (% MPE), according to Chaplan et al. 1994. The following equation was used to compute % MPE:

$$\% \text{ MPE} = \frac{\text{Drug treated threshold (g)} - \text{allodynia threshold (g)}}{\text{Control threshold (g)} - \text{allodynia threshold (g)}} \times 100$$

### ADMINISTRATION OF TEST SUBSTANCE

Rats were injected (subcutaneously, intraperitoneally, intravenously or orally) with a test substance prior to von Frey testing, the time between administration of test compound and the von Frey test varied depending upon the nature of the test compound.

5

### WRITHING TEST

Acetic acid will bring abdominal contractions when administered intraperitoneally in mice. These will then extend their body in a typical pattern. When analgesic drugs are administered, this described movement is less frequently observed and the drug selected as a potential good candidate.

10

A complete and typical Writhing reflex is considered only when the following elements are present: the animal is not in movement; the lower back is slightly depressed; the plantar aspect of *both* paws is observable. In this assay, compounds of the present invention demonstrate significant inhibition of writhing responses after oral dosing of 1-100 $\mu$ mol/kg.

15

#### **(i) Solutions preparation**

Acetic acid (AcOH): 120  $\mu$ L of Acetic Acid is added to 19.88 ml of distilled water in order to obtain a final volume of 20 ml with a final concentration of 0.6% AcOH. The solution is then mixed (vortex) and ready for injection.

20

Compound (drug): Each compound is prepared and dissolved in the most suitable vehicle according to standard procedures.

25

#### **(ii) Solutions administration**

The compound (drug) is administered orally, intraperitoneally (i.p.) , subcutaneously (s.c.) or intravenously (i.v.) at 10 ml/kg (considering the average mice body weight) 20, 30 or 40 minutes (according to the class of compound and its characteristics) prior to testing. When the compound is delivered centrally: Intraventricularly (i.c.v.) or intrathecally (i.t.) a volume of 5  $\mu$ L is administered.

30

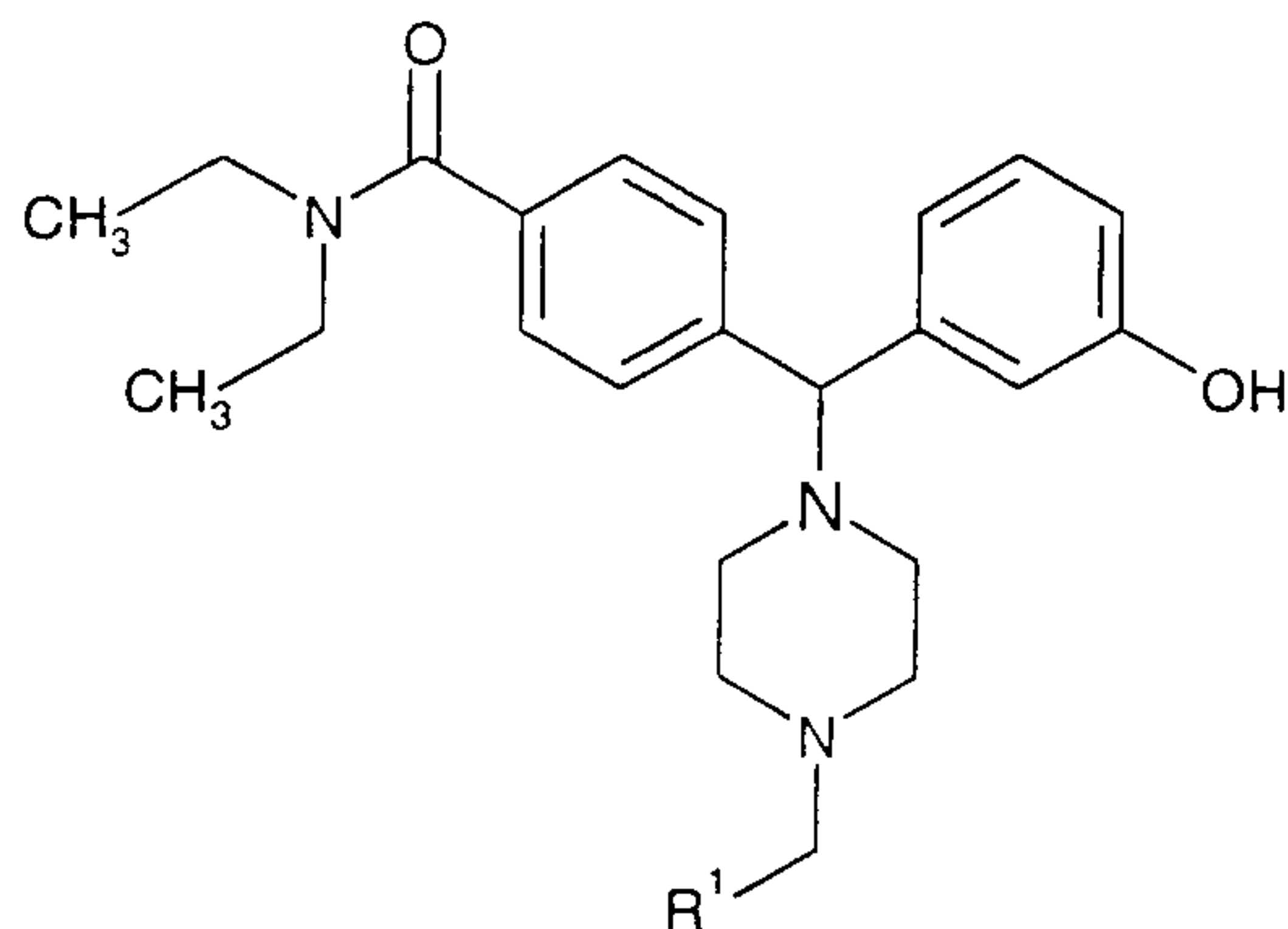
The AcOH is administered intraperitoneally (i.p.) in two sites at 10 ml/kg (considering the average mice body weight) immediately prior to testing.

5 **(iii) Testing**

The animal (mouse) is observed for a period of 20 minutes and the number of occasions (Writhing reflex) noted and compiled at the end of the experiment. Mice are kept in individual “shoe box” cages with contact bedding. A total of 4 mice are usually observed at the same time: one control and three doses of drug.

**Claims**

1. A compound of the formula I

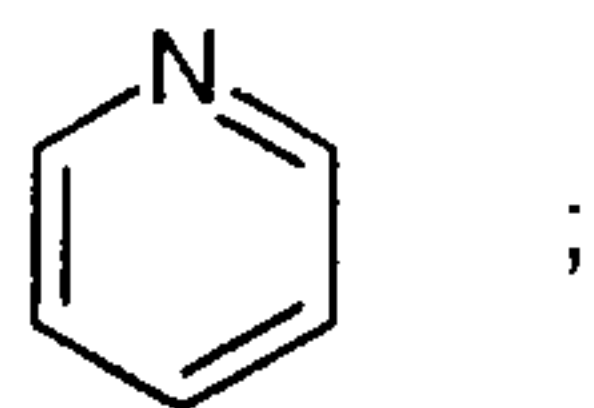


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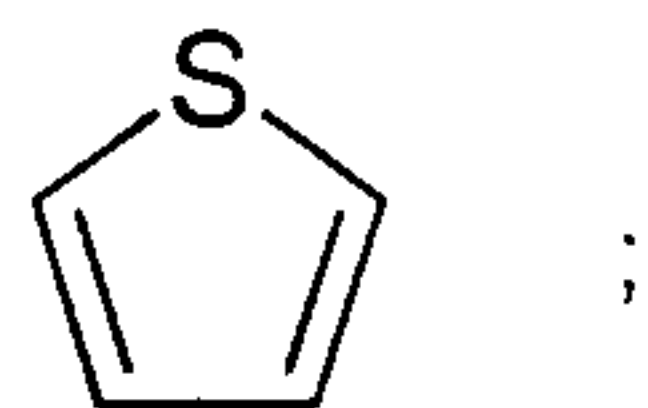
wherein

$R^1$  is selected from any one of

10 (ii) pyridinyl

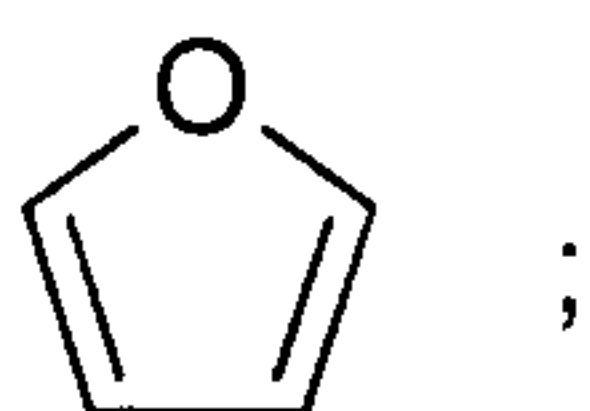


(iii) thienyl

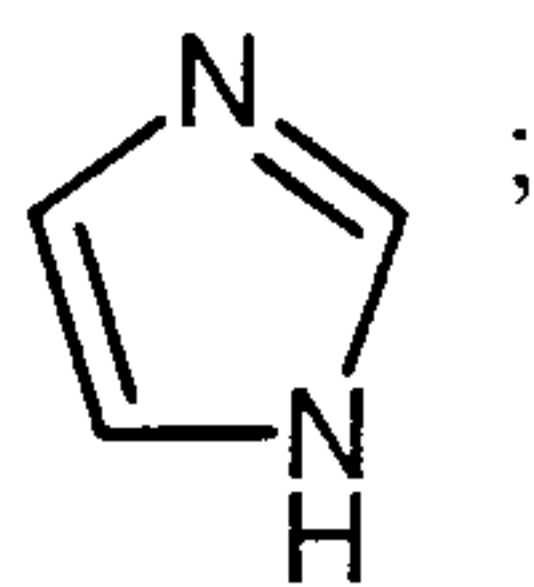


15

(iv) furanyl

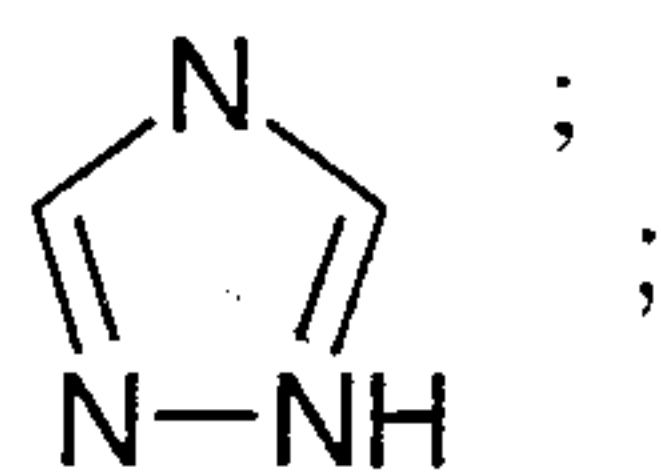


(v) imidazolyl



20

(vi) triazolyl



where each R<sup>1</sup> heteroaromatic ring may independently be further substituted by 1, 2 or 3 substituents selected from straight and branched C<sub>1</sub>-C<sub>6</sub> alkyl, NO<sub>2</sub>, CF<sub>3</sub>, C<sub>1</sub>-C<sub>6</sub> alkoxy, chloro, fluoro, bromo, and iodo, as well as enantiomer and salts and thereof.

5

2. A compound according to claim 1, wherein each R<sup>1</sup> heteroaromatic ring may independently be further substituted by 1, 2 or 3 substituents selected from methyl, CF<sub>3</sub>, chloro, fluoro, bromo, and iodo.

10 3. A compound according to claim 1, wherein each R<sup>1</sup> phenyl ring and R<sup>1</sup> heteroaromatic ring may independently be further substituted by a methyl group.

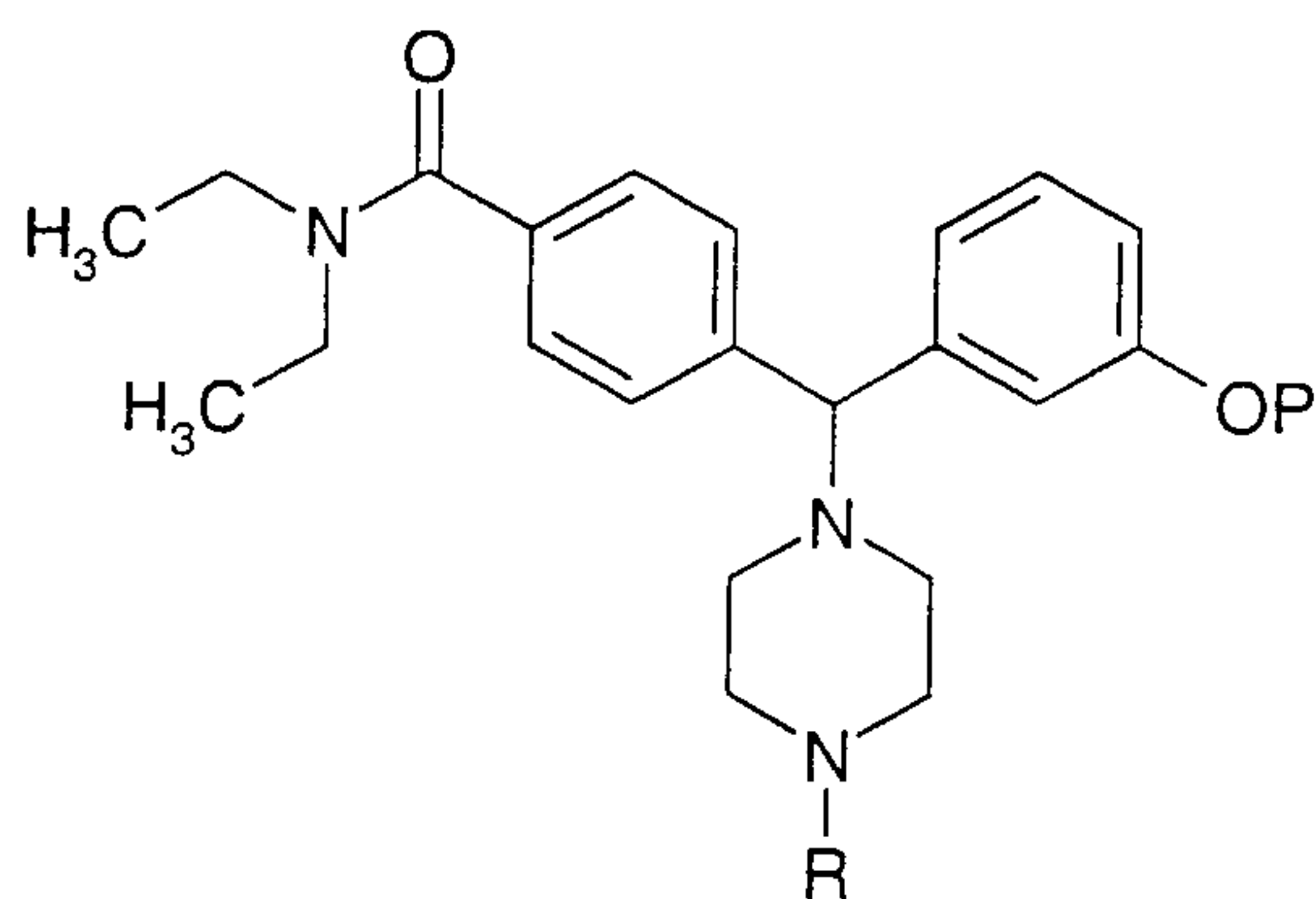
4. A compound according to claim 1, wherein R<sup>1</sup> is pyridinyl, thienyl or furanyl.

15 5. A compound according to claim 1 or 2, selected from any one of  
*N,N*-diethyl-4-[[4-(2-furylmethyl)-1-piperazinyl](3-hydroxyphenyl)methyl]benzamide;  
*N,N*-diethyl-4-{(3-hydroxyphenyl)[4-(2-thienylmethyl)-1-piperazinyl]methyl}benzamide ;  
and *N,N*-diethyl-4-{(3-hydroxyphenyl)[4-(3-thienylmethyl)-1-piperazinyl]methyl}  
benzamide .

20

6. A compound according to any of the preceding claims, in form of its hydrochloride, dihydrochloride, sulfate, tartrate, ditrifluoroacetate or citrate salts.

7. A process for preparing a compound of formula I, comprising the reaction of,  
25 reacting a compound of the general formula II



II

wherein R is an N-protecting group, and P is a O-protecting group such as TBS or Me, which is first N-deprotected and then alkylated using either,

- i) a compound of the general formula  $R^1-CH_2-X$ , wherein  $R^1$  is as defined in claim 1 and X is halogen, and a suitable base, or
- ii) a compound of the general formula  $R^1-CHO$ , wherein  $R^1$  is as defined in claim 1, and a suitable reducing agent to give the compounds of general formula I, after O-deprotection.

8. A compound according claim 1 for use in therapy.

9. A compound according to claim 8, wherein the therapy is pain management.

10. A compound according to claim 8, wherein the therapy is directed towards gastrointestinal disorders.

11. A compound according to claim 8, wherein the therapy is directed towards spinal injuries.

12. A compound according to claim 8, wherein the therapy is directed to disorders of the sympathetic nervous system.

13. Use of a compound according to formula I of claim 1 for the manufacture of a medicament for use in the treatment of pain, gastrointestinal disorders or spinal injuries.

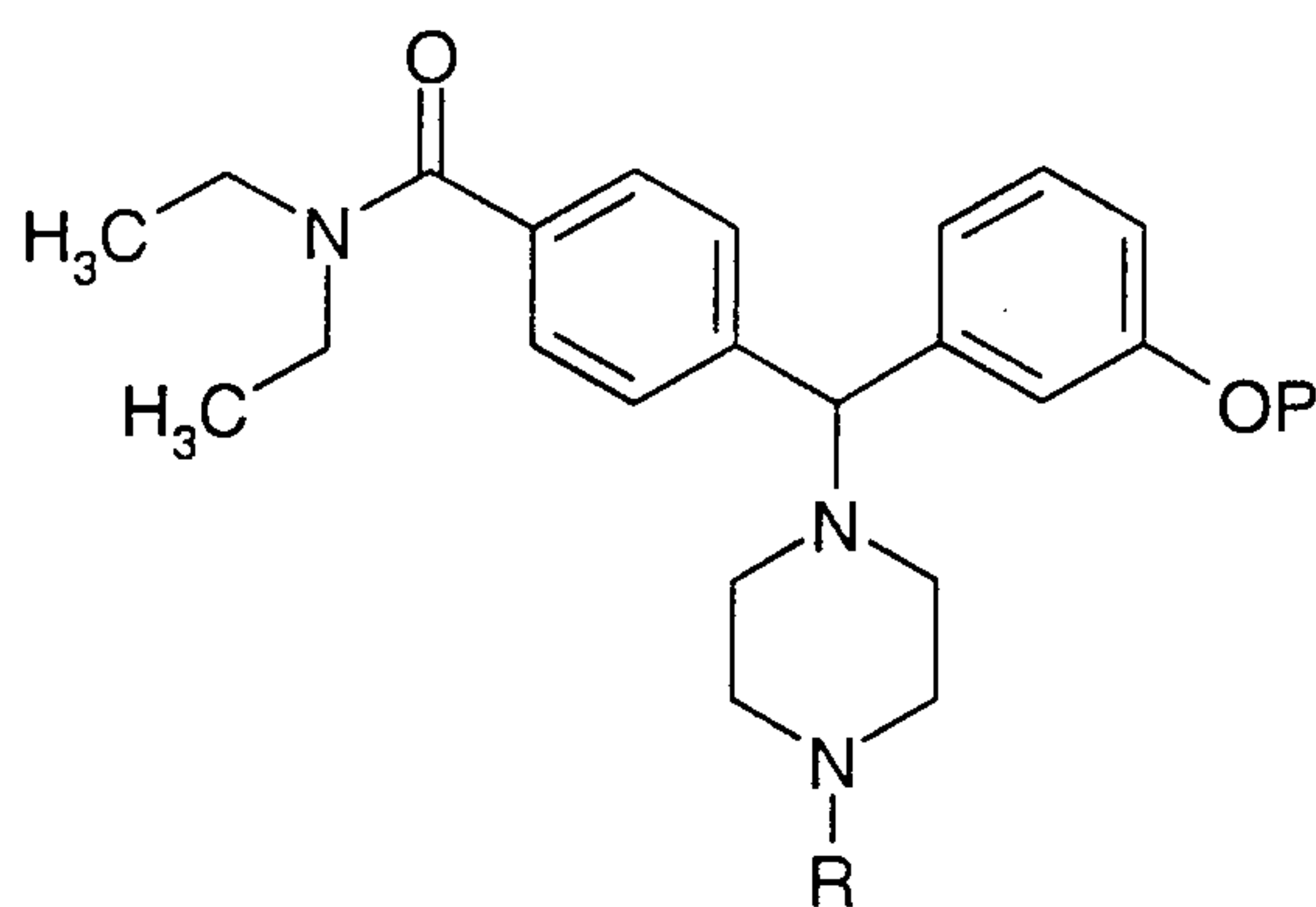
14. A pharmaceutical composition comprising a compound of the formula I according to claim 1 as an active ingredient, together with a pharmacologically and pharmaceutically acceptable carrier.

15. A method for the treatment of pain, whereby an effective amount of a compound of the formula I according to claim 1 is administered to a subject in need of pain management.

16. A method for the treatment of gastrointestinal disorders, whereby an effective amount of a compound of the formula I according to claim 1, is administered to a subject suffering from said gastrointestinal disorder.

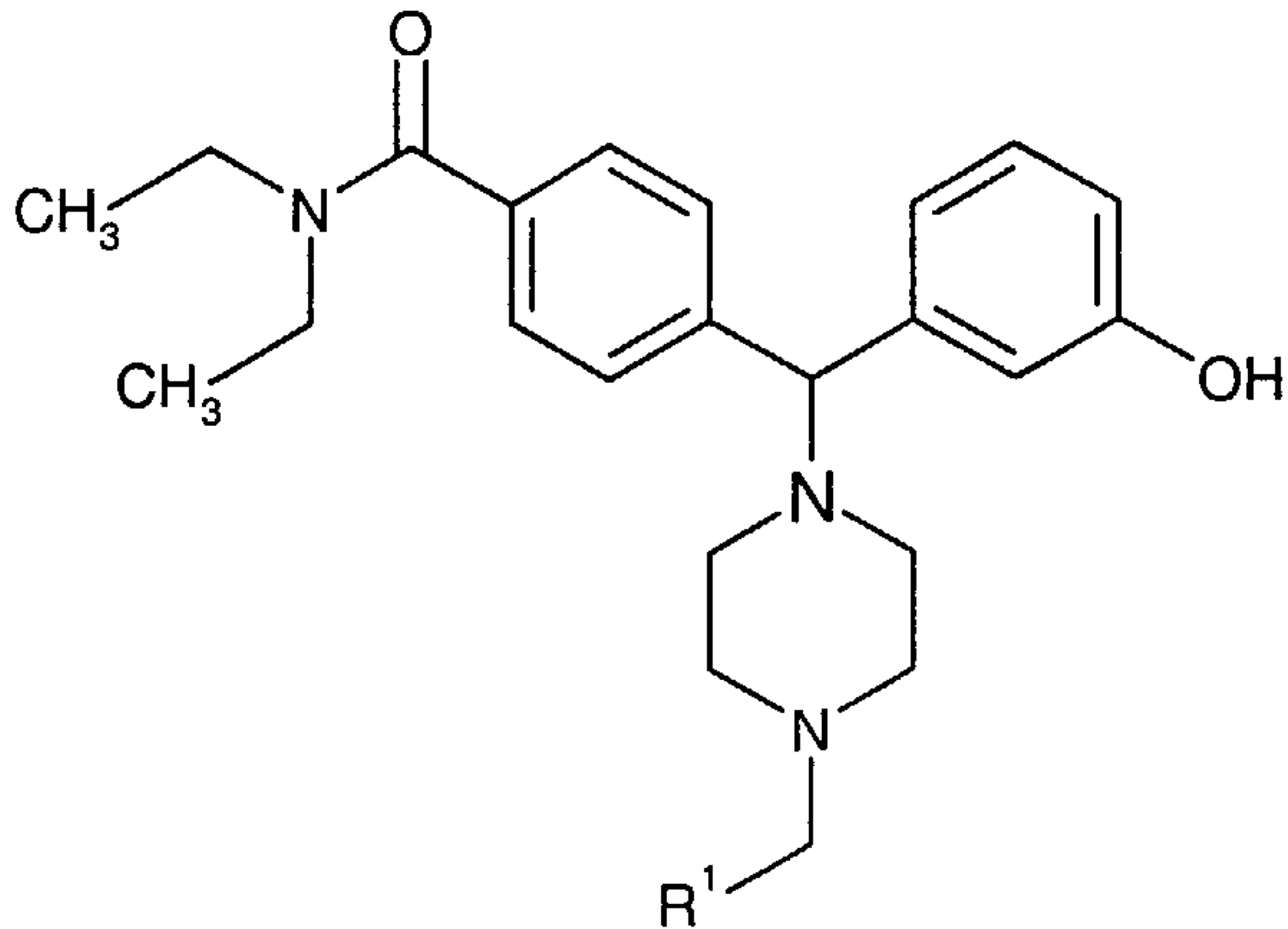
17. A method for the treatment of spinal injuries, whereby an effective amount of a compound of the formula I according to claim 1, is administered to a subject suffering from said spinal injury.

18. A compound of the general formula II



II

wherein R is an N-protecting group such as Boc or CBz, and P is a O-protecting group such as TBS or Me.



(I)