

Piperazinyl derivatives for the treatment of cancer

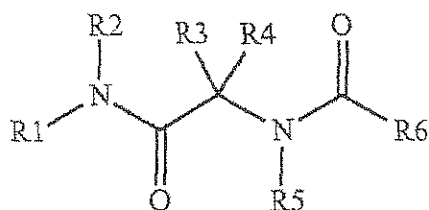
The present invention concerns piperazinyl compounds particularly useful in the treatment of cancer, compositions containing the same and their method of preparation.

With lengthening lifetimes cancer, one of the leading causes of mortality in the world, affects an increasingly greater number of persons and remains difficult to treat.

The developing resistance to anticancer agents is a serious problem which considerably curbs the treatment of numerous types of cancer. Lowered tolerance to an agent is often accompanied by cross-resistance to a variety of other agents. This multiple resistance to anticancer agents known as Multidrug Resistance, MDR, is caused by numerous mechanisms of which only a very small number have been well characterized. These mechanisms include an increase in drug efflux, an increase in cell detoxifying capability, alteration of molecular targets affected by these anticancer agents, modification of the DNA repair system and modification of apoptotic routes (Baguley, *Mol. Biotechnol.*, 2010, 46, 308–316; Gatti *et al.*, *Methods Mol. Med.* 2005, 111, 127–148; Longley *et al.*, *J. Pathol.* 2005, 205, 275–292; Kohno *et al.*, *Eur. J. Cancer* 2005, 41, 2577–2586).

The development of anticancer treatments able to avoid these resistance mechanisms is a major challenge and up until the present time the initiated trials have given few results.

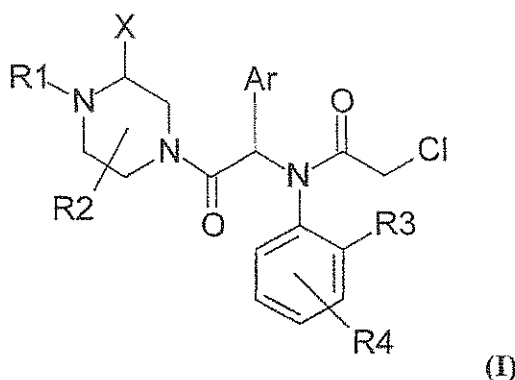
Anticancer agents more particularly intended for the treatment of chemotherapy-resistant cancer are described in WO 2009/150248. They meet the following general formula:



where R1 and R2, together with the nitrogen atom which carries them, may form a heterocycle such as a piperazinyl group optionally substituted, the only exemplified compounds being optionally substituted on the nitrogen atom of the piperazine.

The inventors of this patent application have surprisingly discovered that the insertion of a substituent X at alpha position of the second nitrogen atom of piperazine (see formula (I) below) allows an improvement in the physicochemical properties of the compounds, in particular their solubility, their pharmacokinetic properties and biological activities.

The subject of the present patent application is therefore more particularly a substituted piperaziny compound of following general formula (I):



and the pharmaceutically acceptable salts thereof, its stereoisomers or mixtures of stereoisomers in any proportion, in particular an enantiomer mixture and notably a racemic mixture,

where:

- X is a (C₁–C₆) alkyl, phenyl, benzyl, C(O)OR₅ or C(O)NHR₅ group;
 - R₁ is a hydrogen atom or a C(O)H, C(O)R₆ or C(O)OR₆ group;
 - R₂ is a hydrogen atom or a (C₁–C₆)alkyl group;
- or R₂ together with R₁ or X forms a saturated hydrocarbon chain to form a 5 or 6-membered ring, in particular a 5-membered ring;
- R₃ is a hydrogen or halogen atom or a (C₁–C₆)alkyl or (C₁–C₆)alkoxy group;
 - R₄ is a hydrogen or halogen atom, CN, NO₂, or a (C₁–C₆)alkyl, (C₁–C₆)alkoxy, aryloxy, benzyloxy or heteroaryloxy group, the said group optionally being substituted by one or more halogen atoms;
 - Ar is a thiophenyl group or a phenyl group optionally substituted by one or more halogen atoms; and

- R5 and R6 independently of one another are a (C₁–C₆)alkyl, aryl–(C₁–C₆)alkyl or aryl group, the said group optionally being substituted by one or more halogen atoms.

In another aspect, there is provided a compound of general formula (I) as disclosed herein for use as a drug.

In another aspect, there is provided a compound of general formula (I) as disclosed herein for use in the treatment or prevention of chemotherapy-resistant cancer.

In another aspect, there is provided a pharmaceutical composition comprising at least one compound of general formula (I) as disclosed herein, in association with one or more pharmaceutically acceptable excipients.

In another aspect, there is provided a pharmaceutical composition comprising:

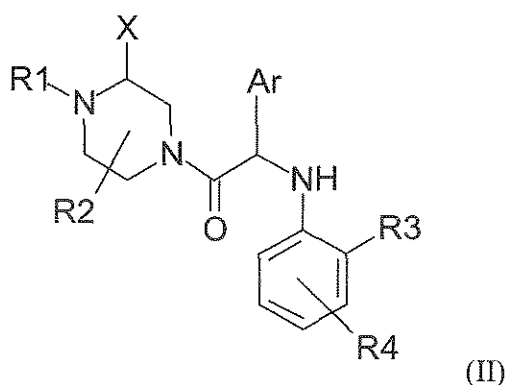
- (i) at least one formula (I) compound as disclosed herein; and
- (ii) at least one other active ingredient such as an anticancer agent,

as combination products for simultaneous, separate or time-staggered use thereof.

In another aspect, there is provided a pharmaceutical composition as disclosed herein for use as a drug intended to treat or prevent a chemotherapy-resistant cancer.

In another aspect, there is provided a method for preparing a compound of formula (I) as disclosed herein, the method comprising the following successive steps:

- a) reacting an amine of following formula (II):



where X, R1, R2, R3, R4 and Ar are as defined above, R1 not representing a hydrogen atom,

with chloroacetyl chloride in the presence of a base to give a formula (I) compound where $R1 \neq H$; and

- b) optionally deprotecting the nitrogen atom carrying the $R1 \neq H$ group to give a formula (I) compound where $R1 = H$.

By « halogen » in the meaning of the present invention is meant a fluorine, bromine, chlorine or iodine atom. Advantageously it is a fluorine, bromine or chlorine atom.

By « alkyl » group in the meaning of the present invention is meant any saturated, straight-chain or branched hydrocarbon group, advantageously having 1 to 6, preferably 1 to 4 carbon atoms. These may particularly be methyl, ethyl, n-propyl, isopropyl, n-butyl, iso-butyl, sec-butyl, tert-butyl, n-pentyl, neopentyl or n-hexyl groups. Advantageously it is a methyl, ethyl, isopropyl, tert-butyl or isobutyl group.

In some cases, the alkyl group may optionally be substituted by one or more halogen atoms, in particular bromine, chlorine and fluorine and advantageously fluorine. In this case the group will particularly be the $-CF_3$ group.

By « alkoxy » group in the meaning of the present invention is meant an alkyl group such as defined above linked to the remainder of the molecule via an oxygen atom. Examples of alkoxy group are the methoxy, ethoxy, isopropoxy or tert-butoxy groups. Advantageously it is the methoxy or tert-butoxy group, and further advantageously the methoxy group.

In some cases, the alkoxy group can be substituted by one or more fluorine atoms. In this case, it is advantageously the $-OCHF_2$ or $-OCF_3$ group, in particular $-OCF_3$.

By « aryl » group in the meaning of the present invention is meant an aromatic group preferably having 5 to 10 carbon atoms and comprising one or more fused rings. Advantageously it is the phenyl group.

By « heteroaryl » group in the meaning of the present invention is meant any aryl group such as defined above in which one or more carbon atoms have been replaced by one or more heteroatoms, advantageously 1 to 4 and more advantageously 1 to 2, such as sulfur, nitrogen or oxygen atoms for example. Advantageously it is a furyl, thiophenyl, pyridinyl, pyrimidyl, quinolinyl, 1,2,3-thiadiazolyl benzoimidazolyl, indazolyl or 1,2,3-benzotriazolyl group.

By « aryloxy » group in the meaning of the present invention is meant an aryl group such as defined above linked to the remainder of the molecule via an oxygen atom. It is advantageously a phenyloxy group.

By « heteroaryloxy » group in the meaning of the present invention is meant a heteroaryl group such as defined above linked to the remainder of the molecule via an oxygen atom. It is advantageously a pyridinyloxy group.

By « aryl-(C₁-C₆)alkyl » group in the meaning of the present invention is meant an aryl group such as defined above linked to the remainder of the molecule via an alkyl group such as defined above comprising 1 to 6 carbon atoms. Advantageously it is a benzyl or 1-phenethyl group, and more advantageously benzyl.

In the present invention by « pharmaceutically acceptable » is meant that which is useful for the preparation of a pharmaceutical composition that is generally safe, non-toxic and neither biologically nor otherwise undesirable and is acceptable for veterinary use and human pharmacopeia use.

By « pharmaceutically acceptable salts » of a compound in the present invention is meant salts which are pharmaceutically acceptable as defined herein and which have the desired pharmacological activity of the parent compound. Such salts comprise:

- (1) hydrates and solvates;
- (2) acid addition salts formed with inorganic acids such as hydrochloric acid, hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid and similar; or formed with organic acids such as acetic acid, benzenesulfonic acid, benzoic acid, camphorsulfonic acid, citric acid, ethane-sulfonic acid, fumaric acid, glucoheptonic acid, gluconic acid, glutamic acid, glycolic acid, hydroxynaphthoic acid, 2-hydroxyethanesulfonic acid, lactic acid, maleic acid, malic acid, mandelic acid, methanesulfonic acid, muconic acid, 2-naphtalenesulfonic acid, propionic acid, salicylic acid, succinic acid, dibenzoyl-L-tartaric acid, tartaric acid, p-toluenesulfonic acid, trimethylacetic acid, trifluoroacetic acid and similar, advantageously it is hydrochloric acid; and
- (3) the salts formed when an acid proton present in the parent compound is either replaced by a metal ion e.g. an alkaline metal ion (Na⁺, K⁺ or Li⁺ for example), an alkaline-earth metal ion (such as Ca²⁺ or Mg²⁺) or an aluminium ion; or it is coordinated with an organic or inorganic base. Acceptable organic bases comprise diethanolamine, ethanolamine, N-methylglucamine, triethanolamine, tromethamine and

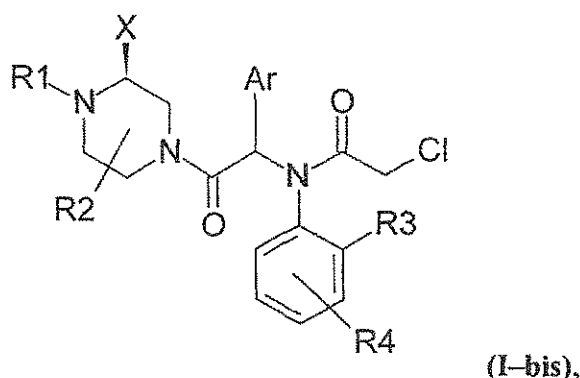
similar. Acceptable inorganic bases comprise aluminium hydroxide, calcium hydroxide, potassium hydroxide, sodium carbonate and sodium hydroxide.

In the present invention by « stereoisomers » it is meant to designate diastereoisomers or enantiomers. They are therefore optical isomers. The stereoisomers which are not images of one another in a mirror are therefore designated as « diastereoisomers », and the stereoisomers which are non-superimposable images in a mirror are designated as « enantiomers ».

A carbon atom linked to four non-identical substituents is called a chiral centre.

An equimolar mixture of two enantiomers is called a racemic mixture.

The compounds of the present invention can in particular meet the following formula (I-bis):



the nitrogen atom carrying the X group then being of (S) configuration.

Advantageously X is a (C₁-C₆)alkyl, in particular (C₁-C₄)alkyl, phenyl or benzyl group.

Advantageously R₁ is a hydrogen atom or a C(O)R₆ or C(O)OR₆ group, in particular a hydrogen atom.

Advantageously R₂ is a hydrogen atom or a (C₁-C₆)alkyl group e.g. methyl.

Advantageously R₃ is a hydrogen atom or a (C₁-C₆)alkyl group e.g. methyl.

Advantageously R₄ is a hydrogen or halogen atom, or a (C₁-C₆)alkyl, (C₁-C₆)alkoxy or aryloxy group, the said group optionally being substituted by one or more halogen atoms, fluorine in particular.

Advantageously Ar is a thiophenyl group or a phenyl group substituted by one or more fluorine atoms such as 4-fluoro-phenyl.

According to one particular embodiment of the invention, X is a (C₁–C₆)alkyl, phenyl, benzyl, C(O)OR₅, C(O)NHR₅ group; R₁ is a hydrogen atom; R₂ is a hydrogen atom or a (C₁–C₆)alkyl group, advantageously (C₁–C₄)alkyl or together with R₁ or X forms a saturated hydrocarbon chain to form a 5–membered ring; R₃ is a hydrogen or halogen atom or a (C₁–C₆)alkyl group, in particular (C₁–C₃)alkyl, or a (C₁–C₆)alkoxy e.g. methoxy; R₄ is a halogen atom, CN, NO₂ or a (C₁–C₆)alkyl, (C₁–C₆)alkoxy, aryloxy, benzyloxy or heteroaryloxy group, the said group optionally being substituted by one or more halogen atoms; Ar is a thiophenyl group or a phenyl group optionally substituted by a halogen; and R₅ and R₆ independently of one another are a (C₁–C₆)alkyl, aryl–(C₁–C₆)alkyl or aryl group, the said group optionally being substituted by one or more halogen atoms.

More advantageously, X is a (C₁–C₆)alkyl, phenyl, benzyl, C(O)OR₅, C(O)NHR₅ group; R₁ is a hydrogen atom; R₂ is a hydrogen atom or a C₁–C₆)alkyl group, advantageously (C₁–C₄)alkyl; R₃ is a hydrogen or halogen atom or a (C₁–C₆)alkyl group, in particular (C₁–C₃)alkyl, or a (C₁–C₆)alkoxy, e.g. methoxy; R₄ is a halogen atom or a (C₁–C₆)alkyl, (C₁–C₆)alkoxy, aryloxy, benzyloxy or heteroaryloxy group, the said group optionally being substituted by one or more halogen atoms; Ar is a thiophenyl group or phenyl group optionally substituted by a halogen; and R₅ and R₆ independently of one another are a (C₁–C₆)alkyl, aryl–(C₁–C₆)alkyl or aryl group, the said group optionally being substituted by one or more halogen atoms.

Further advantageously, X is a (C₁–C₆)alkyl, phenyl or benzyl group; R₁ and R₂ are a hydrogen atom; R₃ is a hydrogen or halogen atom or a (C₁–C₆)alkyl group, in particular (C₁–C₃)alkyl; R₄ is a halogen atom or a (C₁–C₆)alkyl, (C₁–C₆)alkoxy, aryloxy or benzyloxy group, the said group optionally being substituted by one or more halogen atoms; Ar is a thiophenyl group or a phenyl group optionally substituted by a halogen; and R₅ and R₆ independently of one another are a (C₁–C₆)alkyl, aryl–(C₁–C₆)alkyl or aryl group, the said group optionally being substituted by one or halogen atoms.

Preferably X is a (C₁–C₆)alkyl, phenyl or benzyl group; R₁ and R₂ are a hydrogen atom; R₃ is a hydrogen atom or a (C₁–C₆)alkyl group, in particular (C₁–C₃)alkyl; R₄ is a halogen atom or a (C₁–C₆)alkyl, (C₁–C₆)alkoxy, aryloxy or benzyloxy group, the said group optionally being substituted by one or more halogen atoms; Ar

represents a thiophenyl group or a phenyl group optionally substituted by a fluorine atom such as 4-fluoro-phenyl; and R5 and R6 independently of one another are a (C₁–C₆)alkyl, aryl–(C₁–C₆)alkyl or aryl group, the said group optionally being substituted by one or more fluorine atoms.

In particular it is one of the compounds in Examples I–1a to I–63 described in the experimental part below, or one of the pharmaceutically acceptable salts thereof, their stereoisomers or mixtures of stereoisomers in any proportion, in particular an enantiomer mixture and especially a racemic mixture.

The present invention also concerns a compound of formula (I) such as defined above for use thereof as drug intended in particular for the treatment or prevention of cancer, and particularly to treat chemotherapy-resistant cancer.

The present invention also concerns the use of a compound of formula (I) such as defined above to produce a drug particularly intended to treat or prevent cancer, in particular to treat chemotherapy-resistant cancer.

The present invention also concerns a method for treating or preventing cancer, in particular chemotherapy-resistant cancer, comprising the administration of a sufficient amount of formula (I) compound such as defined above to a patient in need thereof.

A further subject of the invention is a pharmaceutical composition comprising at least one formula (I) compound such as defined above in association with one or more pharmaceutically acceptable excipients.

In one particular embodiment, this composition may comprise at least one other active ingredient.

In particular this or these active ingredient(s) may be anticancer agents conventionally used to treat cancer. These anticancer agents can be selected in particular from among cisplatin and the derivatives thereof such as carboplatin and oxalyplatin; taxanes such as taxol, taxotere, paclitaxel and docetaxel; vinca alkaloids such as vinblastine, vincristine and vinorelbine; purine analogues such as mercaptopurine, thioguanine, pentostatin and 2-chlorodeoxyadenosine; topoisomerase I inhibitors such as camptothecin compounds e.g. irinotecan and topotecan; topoisomerase II inhibitors

such as epipodophyllotoxin, podophyllotoxin and the derivatives thereof e.g. etoposide and teniposide; anti-tumour nucleoside derivatives such as 5-fluorouracil, leucovorin, gemcitabine or capecitabine; alkylating agents such as nitrogen mustards e.g. cyclophosphamide, mechlorethamine, chlorambucil and melphalan, nitroso-ureas such as carmustin, lomustin and streptozocin, alkylsulfonates such as busulfan, ethylenimines and methylmelamines such as thiotepa and hexamethylmelamine, and tetrazines such as dacarbazine; derivatives of anti-tumour anthracyclines such as daunorubicin, adriamycin, doxil, idarubicin and mitoxantrone; molecules targeting the IGF-I receptor such as picropodophyllin; derivatives of tetracarcin such as tetrocarcin A; corticosteroids such as prednisone; antibodies such as trastuzumab (anti-HER2 antibody), rituximab (anti-CD20 antibody), gemtuzamab, cetuximab, pertuzumab and bevacizumab; antagonists or selective modulators of oestrogen receptors such as tamoxifen, fulvestrant, toremifene, droloxifene, faslodex and raloxifene; aromatase inhibitors such as exemestane, anastrozole, letrozole and vorozole; differentiating agents such as retinoids e.g. retinoic acid and vitamin D and agents blocking the metabolism of retinoic acid such as accutane; DNA methyl-transferase inhibitors such as azacytidine and decitabine; antifolates such as perimetrexed disodium; antibiotics such as antinomycin D, bleomycin, mitomycin C, actinomycin D, carminomycin, daunomycin and plicamycin; antimetabolites such as chlofarabine, aminopterin, cytosine arabinoside, floxuridine and methotrexate; apoptosis-inducing agents and anti-angiogenic Bcl-2 inhibitors such as YC 137, BH 312, ABT 737, gossypol, HA 14-1, TW 37 and decanoic acid; agents binding to tubulin such as combrestatin, derivatives of colchicine and nocodazole; kinase inhibitors such as flavoperidol, imatinib mesylate, erlotinib and gefitinib; farnesyl transferase inhibitors such as tipifarnib; inhibitors of histone-deacetylases such as sodium butyrate, suberoylanilide hydroxamic acid, depsipeptide, NVP- LAQ824, R306465, JNJ-26481585 and trichostatin A; inhibitors of the ubiquitin-proteasome system such as MLN .41, bortezomib and yondelis; and telomerase inhibitors such as telomestatin.

The compounds of the invention can be given via oral, sublingual, parenteral, sub-cutaneous, intramuscular, intravenous, transdermal, local or rectal route.

In the pharmaceutical compositions of the present invention for oral, sublingual, parenteral, sub-cutaneous, intramuscular, intravenous, transdermal, local or rectal route,

the active ingredient can be administered in unit administration forms, in a mixture with conventional pharmaceutical carriers, to animals or to human beings. Suitable unit administration forms include forms via oral route such as tablets, capsules, powders, granules and oral solutions or suspensions, sublingual and buccal administration forms, parenteral, sub-cutaneous, intramuscular, intravenous, intranasal or intraocular administration forms, and rectal administration forms.

When a solid composition is prepared in tablet form, the main active ingredient is mixed with a pharmaceutical carrier such as gelatin, starch, lactose, magnesium stearate, talc, gum arabic or analogues. It is possible to coat the tablets with sucrose or other suitable materials, or they can be treated so that they have sustained or delayed release and continuously release a predetermined amount of active ingredient.

A capsule preparation is obtained by mixing the active ingredient with a diluent and pouring the mixture obtained into soft or hard capsules.

A preparation in syrup or elixir form can contain the active ingredient together with a sweetener, an antiseptic and taste enhancer and suitable colouring agent.

Water-dispersible powders or granules can contain the active ingredient in a mixture with dispersing agents or wetting agents, or suspending agents, and also with taste enhancers or sweeteners.

For rectal administration, recourse is made to suppositories prepared with binders which melt at rectal temperature e.g. cocoa butter or polyethylene glycols.

For parenteral, intranasal or intraocular administration use is made of aqueous suspensions, of saline isotonic solutions or sterile, injectable solutions which contain pharmacologically compatible dispersing agents and/or wetting agents.

The active ingredient can also be formulated in microcapsule form optionally with one or more additive carriers.

The compounds of the invention can be used at doses of between 0.01 mg and 1000 mg per day, given in a single daily dose or in several doses throughout the day e.g. twice daily in equal doses. The daily administered dose is advantageously between 5 mg and 500 mg, more advantageously between 10 mg and 200 mg. It may be necessary to use doses outside these ranges which persons skilled in the art will know how to determine.

A further subject of the invention is a pharmaceutical composition comprising:

- (i) at least one formula (I) compound such as defined above; and
- (ii) at least one other active ingredient

as combination products for simultaneous, separate or time-staggered use.

It is effectively frequent for cancer to be treated with bi- or tri-therapy. It may be useful in particular to associate the molecules of the invention with one or more anticancer compounds first allowing treatment of the cancer and secondly preventing the onset of resistant cancer cells.

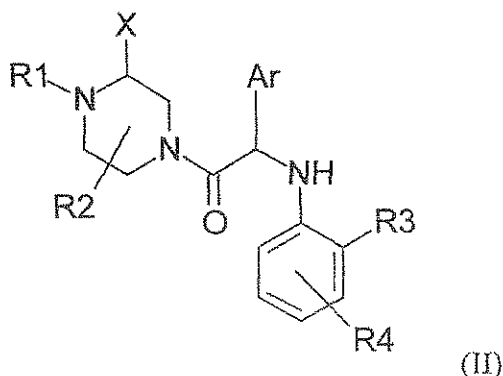
In particular, this or these active ingredient(s) may be anticancer agents usually used to treat cancer. These anticancer agents can be selected in particular from among cisplatin and its derivatives such as carboplatin and oxalyplatin; taxanes such as taxol, taxotere, paclitaxel and docetaxel; vinca alkaloids such as vinblastine, vincristine and vinorelbine; purine analogues such as mercaptopurine, thioguanine, pentostatin and 2-chlorodeoxyadenosine; topoisomerase I inhibitors such as camptothecin compounds e.g. irinotecan and topotecan; topoisomerase II inhibitors such as epipodophyllotoxin, podophyllotoxin and the derivatives thereof such as etoposide and teniposide; anti-tumour nucleoside derivatives such as 5-fluorouracil, leucovorin, gemcitabine or capecitabine; alkylating agents such as nitrogen mustards e.g. cyclophosphamide, mechlorethamine, chlorambucil and melphalan, nitroso-ureas such as carmustin, lomustin and streptozocin, alkylsulfonates such as busulfan, ethylenimines and methylmelamines such as thiotepa and hexamethylmelamine, and tetrazines such as dacarbazine; anti-tumour anthracycline derivatives such as daunorubicin, adriamycin, doxil, idarubicin and mitoxantrone; molecules targeting the IGF-I receptor such as picropodophyllin; tetracarcin derivatives such as tetrocarcin A; corticosteroids such as prednisone; antibodies such as trastuzumab (anti-HER2 antibody), rituximab (anti-CD20 antibody), gemtuzamab, cetuximab, pertuzumab and bevacizumab; antagonists or selective modulators of oestrogen receptors such as tamoxifen, fulvestrant, toremifene, droloxifene, faslodex and raloxifene; aromatase inhibitors such as exemestane, anastrozole, letrozole and vorozole; differentiating agents such as retinoids e.g. retinoic acid and vitamin D and agents blocking the metabolism of retinoic acid such as accutane; DNA methyl-transferase inhibitors such as azacytidine and decitabine; antifolates such as perimetrex disodium; antibiotics such as antinomycin D,

bleomycin, mitomycin C, actinomycin D, carminomycin, daunomycin and plicamycin; antimetabolites such as chlofarabine, aminopterin, cytosine arabinoside, floxuridine and methotrexate; apoptosis-inducing agents and anti-angiogenic agents of Bcl-2 inhibitors such as YC 137, BH 312, ABT 737, gossypol, HA 14-1, TW 37 and decanoic acid; agents binding to tubulin such as combrestatin, derivatives of colchicine and nocodazole; kinase inhibitors such as flavoperidol, imatinib mesylate, erlotinib and gefitinib; farnesyl transferase inhibitors such as tipifarnib; inhibitors of histone-deacetylases such as sodium butyrate, suberoylanilide hydroxamic acid, depsipeptide, NVP- LAQ824, R306465, JNJ-26481585 and trichostatin A; inhibitors of the ubiquitin-proteasome system such as MLN .41, bortezomib and yondelis; and telomerase inhibitors such as telomestatin.

A further subject of the invention is a pharmaceutical composition such as defined above, for use thereof as drug to treat or prevent cancer in particular, and particularly chemotherapy-resistant cancer.

The present invention also concerns a method for preparing a formula (I) compound such as defined above comprising the following successive steps:

- a) reacting an amine of following formula (II):



where X, R1, R2, R3, R4 and Ar are such as previously defined, R1 not representing a hydrogen atom;

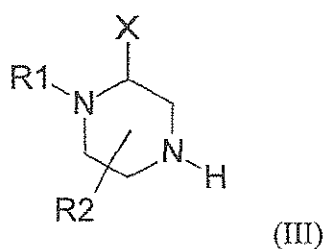
with chloroacetyl chloride in the presence of a base to give a formula (I) compound where R1 ≠ H; and

- b) optionally deprotecting the nitrogen atom carrying the R1 ≠ H group to give a formula (I) compound where R1 = H.

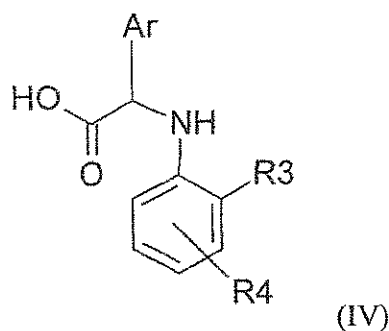
Step a) :

The base used for this step is preferably a weak base such as NaHCO_3 .

The amine of formula (II) can be obtained by reaction of a piperazine of following formula (III):



where X, R1 and R2 are as previously defined, R1 not representing a hydrogen atom, with an acid of following formula (IV):



where R3, R4 and Ar are as previously defined.

This reaction can be conducted under peptide coupling conditions well known to skilled persons.

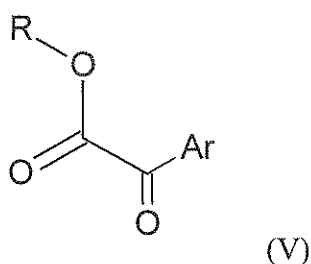
Coupling is therefore preferably performed in the presence of a coupling agent such as diisopropylcarbodiimide (DIC), dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (EDC), carbonyldiimidazole (CDI), 2-(1H-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate (HBTU), 2-(1H-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium tetrafluoroborate (TBTU) or O-(7-azabenzotriazol-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate (HATU), optionally associated with a coupling auxiliary such as N-hydroxy succinimide (NHS), N-hydroxy benzotriazole (HOBt), 3,4-dihydro-3-hydroxy-4-oxo-1,2,3-benzotriazole (HOObt), 1-hydroxy-7-azabenzotriazole (HAt) or N-hydroxysulfosuccinimide (sulfo NHS). Preferably it is HBTU.

A base such as diisopropyl-ethylamine (DIPEA) may also be present.

The piperazine of formula (III) is either obtained commercially or prepared following methods well known to persons skilled in the art.

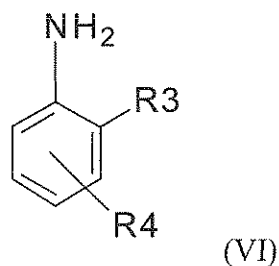
The acid of formula (IV) can be prepared using the following successive steps:

- i) reacting a ketoester of following formula (V):

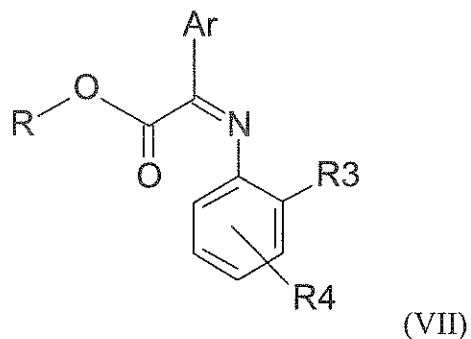


where Ar is as previously defined and R represents a (C₁-C₆)alkyl group e.g. ethyl,

with an aniline of following formula (VI):

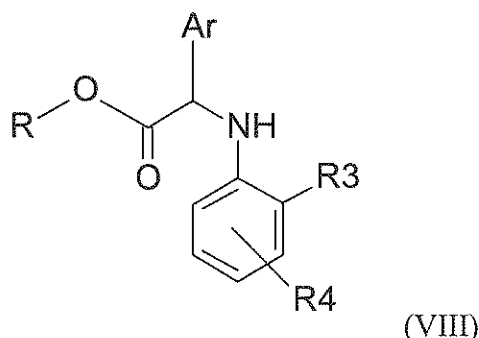


where R3 and R4 are as previously defined,
to give an imine of following formula (VII):



where R, R3, R4 and Ar are as previously defined;

- ii) reducing the imine of formula (VII) obtained at the preceding step to give an amine of following formula (VIII) :



where R, R3, R4 and Ar are as previously defined; and

- iii) saponifying the ester function of the formula (VIII) compound obtained at the preceding step to give the acid of formula (IV).

Step i) can be conducted in the presence of an acid such as paratoluene sulfonic acid (PTSA). The reaction can be performed in a polar solvent such as toluene. Preferably the reaction medium is heated under reflux using Dean–Stark apparatus to remove the water as and when it is formed during the reaction.

The ketoester (V) used for this reaction is either obtained commercially or prepared via Friedel–Crafts reaction using ethyl oxalyl chloride and the corresponding aromatic in the presence of a Lewis acid such as aluminium chloride AlCl_3 .

The aniline (VI) used for this reaction is either obtained commercially or prepared using methods well known to skilled persons.

Reducing step ii) can be performed in the presence of a reducing agent well known to skilled persons such as sodium cyanoborohydride.

Saponification step iii) can be performed under conditions well known to skilled persons, in particular in the presence of a base such as NaOH, KOH or LiOH.

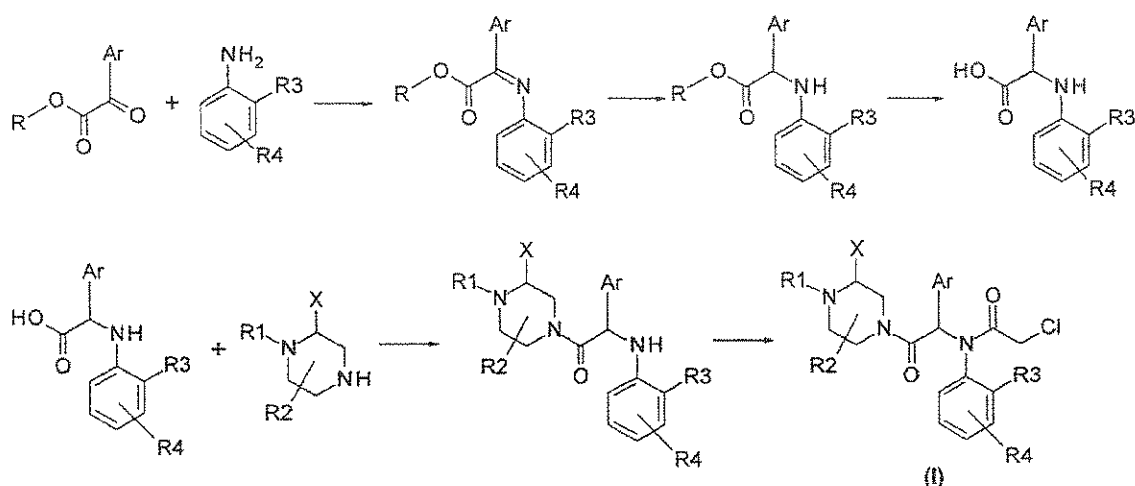
Step b):

This step is preferably conducted with a formula (I) compound in which $\text{R1} = \text{CO}_2\text{R6}$, such as CO_2tBu , via treatment with an acid such as HCl.

The compound thus obtained can be separated from the reaction medium using methods well known to skilled persons, e.g. by extraction, evaporation of the solvent or by precipitation and filtration.

The compound may also be purified if necessary using techniques well known to skilled persons, e.g. by recrystallization if the compound is crystalline, by distillation, by silica gel chromatography or high performance liquid chromatography (HPLC).

The method of the present invention to prepare compounds of the present invention where $R1 \neq H$ is shown in the following reaction scheme:



The following examples illustrate the invention but are not limiting thereof.

FIGURE:

Figure 1 gives the time-plasma concentration curves for a mouse given compound I-43 dia2 administered via intravenous route (IV) at a dose of 10 mg/kg or via oral route (PO) at a dose of 30 mg/kg.

EXAMPLES:

I - Synthesis of compounds of the invention

In the following section two different nomenclatures were adopted when the two diastereoisomers of a compound of the invention were separated:

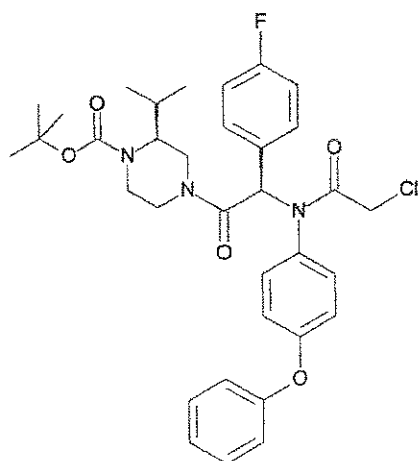
- a / b each designating the particular structure of a single diastereoisomer;
- dia1 / dia2 respectively designating the least polar and most polar diastereoisomer in the chromatographic system used.

The particular stereochemistry of each of the diastereoisomers was not determined. Therefore, it was impossible to allocate the particular structure a and b to each isolated diastereoisomer dia1 and dia2. This is why a double nomenclature is used.

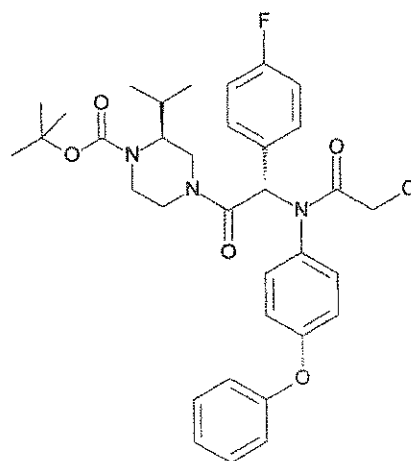
The following abbreviations are used in this section:

TLC	Thin Layer Chromatography
DCM	Dichloromethane
DIEA	Diisopropylethylamine
HBTU	2-(1H-Benzotriazole-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate
LCMS	Liquid Chromatography coupled with Mass Spectrometer
NMR	Nuclear Magnetic Resonance
RT	Room temperature

Examples I-1a and I-1b : Diastereoisomers of the *tert*-butyl ester of 4-[2-[(2-chloro-acetyl)-(4-phenoxy-phenyl)-amino]-2-(4-fluoro-phenyl)-acetyl]-(S)-2-isopropyl-piperazine-1-carboxylic acid.



I-1a



I-1b

Stage 1: Ethyl ester of (4-fluoro-phenyl)-oxo-acetic acid (1):

To a solution of aluminium chloride (21.13 g; 160 mmol) in DCM (200 mL) at 0°C under argon, ethyl oxalyl chloride (17.9 mL; 160 mmol) was added dropwise for 10 min. The medium was left under agitation for 10 minutes. Fluorobenzene (14.7 mL; 160 mmol) diluted in 30 mL of DCM, was added dropwise at 0°C. The medium was left

under agitation at room temperature for 12 hours. The medium was washed with water and the organic phase dried over MgSO_4 . After evaporation, the recovered oil was purified by flash chromatography on silica gel eluting with cyclohexane–ethyl acetate 90:10.

A yellow oil was recovered (17.08 g; 54 %).

^1H NMR (300 MHz, CDCl_3): δ 8.04–8.14 (m; 1.8 H); 7.15–7.24 (m; 1.9 H); 4.46 (q; J = 7.2 Hz; 2.0 H); 1.44 (t; J = 7.2 Hz; 3.0 H).

Stage 2: Ethyl ester of (4-fluoro-phenyl)-[(Z)-4-phenoxy-phenylimino]-acetic acid (2):

To a solution of **1** (3.92 g; 20 mmol) in toluene (25 mL) were successively added para-toluene sulfonic acid (200 mg; 1 mmol) and 4-phenoxyphenyl-aniline (3.70 g; 20 mmol) in the presence of a molecular sieve. The medium was placed under reflux in DeanStark apparatus for 20 hours. The medium was washed in water and the organic phase dried over MgSO_4 . After evaporation, the recovered oil was purified by flash silica gel chromatography eluting with cyclohexane–ethyl acetate 90:10.

Recovery of a yellow oil (6.27 g; 86 %).

LCMS $[\text{M}+\text{H}] = 364$ ($\text{C}_{22}\text{H}_{18}\text{FNO}_3$)

Stage 3: Ethyl ester of (4-fluoro-phenyl)-(4-phenoxy-phenylamino)-acetic acid (3):

To a solution of **2** (6.27 g; 17.26 mmol) in methanol (75 mL) and acetic acid (7.5 mL), sodium cyanoborohydride (1.63 g; 26 mmol) was added. The medium was left under agitation for 1 hour at RT. The methanol was partly evaporated, the solution neutralized with Na_2CO_3 with the addition of water if necessary. The medium was extracted with DCM and the organic phase dried over MgSO_4 . After evaporation, the recovered oil was purified by flash chromatography on silica gel eluting with cyclohexane–ethyl acetate 95:5.

Recovery of a yellow oil (5.91 g; 93 %).

LCMS $[\text{M}+\text{H}] = 366$ ($\text{C}_{22}\text{H}_{20}\text{FNO}_3$)

^1H NMR (300 MHz, CDCl_3): δ 7.45–7.54 (m; 1.9 H); 7.23–7.31 (m; 1.9 H); 6.97–7.11 (m; 2.9 H); 6.81–6.94 (m; 3.9 H); 6.54 (d; J = 9.0 Hz; 2.0 H); 5.01 (br; 1.0 H); 4.90 (br; 0.9 H); 4.10–4.32 (m; 2.0 H); 1.23 (t; J = 7.0 Hz; 3.0 H).

Stage 4: (4-fluoro-phenyl)-(4-phenoxy-phenylamino)-acetic acid (4) :

To a solution of **3** (8.04 g; 22 mmol) in 130 mL of acetonitrile was added 66 mL of a 1 M solution of LiOH (3 eq). The reaction medium was left under agitation for 2 to 3 hours, completion of the reaction being controlled by TLC (cyclohexane–ethyl acetate 60:40). The acetonitrile was partly evaporated, the medium acidified with a 1 M solution of HCl with the addition of 200 mL of water. The medium was filtered and the recovered solid washed three times in water and dried *in vacuo* in a drying oven in the presence of P₂O₅.

Recovery of a white powder (7.17 g; 97 %).

LCMS [M+H] = 338 (C₂₀H₁₆FN₃O₃)

¹H NMR (300 MHz, DMSO): δ 7.55 (dd; *J* = 8.5 Hz; *J* = 5.6 Hz; 2.1 H); 7.28 (t; *J* = 7.9 Hz; 2.1 H); 7.20 (t; *J* = 8.5 Hz; 2.1 H); 6.99 (t; *J* = 7.0 Hz; 1.1 H); 6.74–6.90 (m; 4.0 H; 6.62–6.70 (m; 2.0 H); 5.10 (s 1.0 H).

Stage 5: Tert-butyl ester of 4-[2-(4-fluoro-phenyl)-2-(4-phenoxy-phenylamino)-acetyl]-(S)-2-isopropyl-piperazine-1-carboxylic acid (**5**):

To a solution of **4** (7.17 g; 21.2 mmol) in DCM (150 mL) in the presence of one equivalent of DIEA (3.7 mL) was added a solution of Boc-α-(S)-isopropyl-piperazine hydrochloride (5.63 g; 21.26 mmol) in the presence of 1 eq of DIEA (3.7 mL) in 50 mL of DCM, followed by HBTU (8.06 g; 21.2 mmol). The medium was left under agitation for 12 hours. The medium was washed with water and the organic phase dried over MgSO₄. After evaporation the recovered oil was purified by flash chromatography on silica gel eluting with cyclohexane–ethyl acetate 80:20.

Recovery of a white foam (11.90 g; 100 %).

LCMS [M+H] = 548 (C₃₂H₃₈FN₃O₄)

Stage 6 Tert-butyl ester of 4-[2-[(2-chloro-acetyl)-(4-phenoxy-phenyl)-amino]-2-(4-fluoro-phenyl)-acetyl]-(S)-2-isopropyl-piperazine-1-carboxylic acid

To a solution of **5** (11.86 g; 22.66 mmol) in 250 mL of DCM in the presence of NaHCO₃ (7.30 g; 87.0 mmol) the chloroacetyl chloride (3.45 mL; 43.3 mmol) was added. The medium was left under agitation for 12 hours. The medium was washed with water and the organic phase dried over MgSO₄. After evaporation the recovered oil was purified by flash chromatography on silica gel with cyclohexane–ethyl acetate gradient of 95–5' to 50–50 to obtain two diastereoisomers separately in the form of colourless foam:

Least polar diastereoisomer (I-1 dia1)

(3.80 g; 28 %)

LCMS [M+H] = 625 (C₃₄H₃₉ClFN₃O₅)

¹H NMR (300 MHz, CDCl₃): δ 7.92–8.01 (m; 1.0 H); 7.30–7.40 (m; 2.0 H); 7.10–7.18 (m; 1.1 H); 7.01–7.09 (m; 1.1 H); 6.84–7.00 (m; 6.1 H); 6.55–6.65 (m; 1.1 H); 6.32–6.48 (m; 2.1 H); 4.72 (d; *J* = 13.5 Hz; 0.5 H) 4.63 (d; *J* = 13.5 Hz; 0.4 H); 3.52–3.96 (m; 4.0 H); 3.10–3.27 (m; 0.5 H); 2.85–3.07 (m; 0.4 H); 2.23–2.85 (m; 0.5 H + 0.7 H + 0.4 H); 1.87–2.14 (m; 0.6 H); 1.42 (s; 8.7 H); 1.17 (d; *J* = 6.6 Hz; 1.0 H); 1.03 (d; *J* = 6.6 Hz; 1.3 H); 0.88 (d; *J* = 6.6 Hz; 1.1 H); 0.69 (d; *J* = 6.6 Hz; 1.3 H).

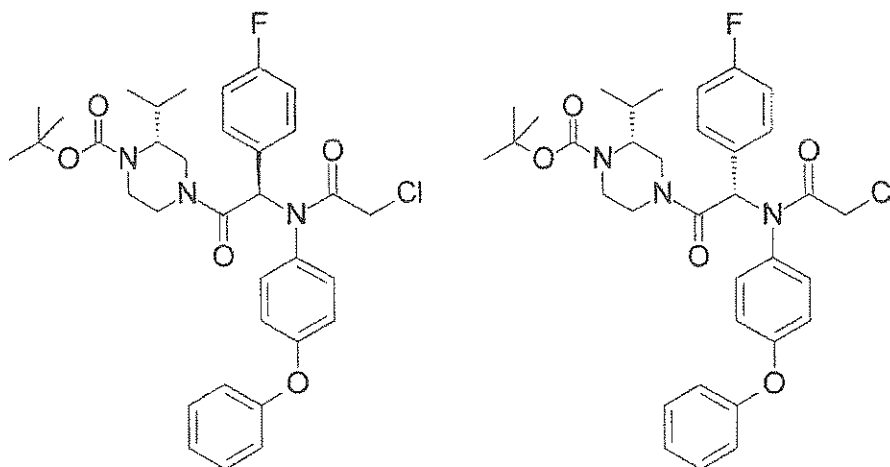
Most polar diastereoisomer (I-1 dia2)

(3.29 g; 24 %)

LCMS [M+H] = 625 (C₃₄H₃₉ClFN₃O₅)

¹H NMR (300 MHz, CD₂Cl₂): δ 7.85–8.00 (m; 1.0 H); 7.36 (t; *J* = 7.6 Hz; 2.1 H); 6.99–7.21 (m; 3.2 H); 6.81–6.98 (m; 5.2 H); 6.63 (br; 1.1 H); 6.35–6.55 (m; 2.1 H); 4.65 (d; *J* = 13.1 Hz; 0.6 H) 4.42 (d; *J* = 13.1 Hz; 0.3 H); 3.50–4.16 (m; 4.9 H); 3.00–3.43 (m; 0.9 H); 2.57–2.90 (m; 1.9 H); 1.98–2.18 (m; 0.7 H); 1.36–1.49 (m; 10.0 H); 1.73 (d; *J* = 6.5 Hz; 2.1 H); 0.90 (d; *J* = 6.5 Hz; 2.1 H); 0.63 (d; *J* = 6.5 Hz; 1.0 H); 0.20 (d; *J* = 6.5 Hz; 0.9 H).

Examples I-2a and I-2b: Diastereoisomers of the tert-butyl ester of 4-[2-[(2-chloro-acetyl)-(4-phenoxy-phenyl)-amino]-2-(4-fluoro-phenyl)-acetyl]-(R)-2-isopropyl-piperazine-1-carboxylic acid.



I-2a

I-2b

Stage 1: Tert-butyl ester of 4-[2-(4-fluoro-phenyl)-2-(4-phenoxy-phenylamino)-acetyl]-(R)-2-isopropyl-piperazine-1-carboxylic acid (6):

To a solution of (4-fluoro-phenyl)-(4-phenoxy-phenylamino)-acetic acid 4 (253 mg; 0.75 mmol) in DCM (10 mL) in the presence of one equivalent of DIEA (131 μ L) was added a solution of Boc-alpha-(R)-isopropyl-piperazine (171 mg; 0.75 mmol) in the presence of 1 eq of DIEA (131 μ L) in 5 mL of DCM, followed by HBTU (285 mg; 0.75 mmol). The medium was left under agitation for 12 hours. The medium was washed with water and the organic phase dried over MgSO_4 . After evaporation the recovered oil was purified by flash chromatography on silica gel eluting with cyclohexane-ethyl acetate 80:20.

Recovery of a white foam (369 mg; 90 %).

LCMS $[\text{M}+\text{H}] = 548$ ($\text{C}_{32}\text{H}_{38}\text{FN}_3\text{O}_4$)

Stage 2: Ter-butyl ester of 4-[2-[(2-chloro-acetyl)-(4-phenoxy-phenyl)-amino]-2-(4-fluoro-phenyl)-acetyl]-(R)-2-isopropyl-piperazine-1-carboxylic acid:

Both diastereoisomers were prepared from 6 following the same operating mode as for the preparation in Example 1 (stage 6).

Separate recovery of the two diastereoisomers in the form of a colourless foam.

Least polar diastereoisomer (I-2 dia1) (195 mg; 42 %)

LCMS $[\text{M}+\text{H}] = 625$ ($\text{C}_{34}\text{H}_{39}\text{ClFN}_3\text{O}_5$)

^1H NMR (300 MHz, CD_2Cl_2): δ 7.85–8.00 (m; 1.0 H); 7.36 (t; $J = 7.6$ Hz; 2.0 H); 6.99–7.21 (m; 3.1 H); 6.81–6.98 (m; 4.9 H); 6.63 (br; 1.0 H); 6.35–6.55 (m; 2.1 H); 4.65 (d; $J = 13.0$ Hz; 0.7 H) 4.42 (d; $J = 13.0$ Hz; 0.2 H); 3.50–4.16 (m; 4.9 H); 3.00–3.43 (m; 0.8 H); 2.57–3.90 (m; 2.0 H); 1.98–2.18 (m; 0.8 H); 1.36–1.49 (m; 10.5 H); 1.73 (d; $J = 6.5$ Hz; 2.0 H); 0.90 (d; $J = 6.5$ Hz; 2.0 H); 0.63 (d; $J = 6.5$ Hz; 0.8 H); 0.20 (d; $J = 6.5$ Hz; 0.8 H).

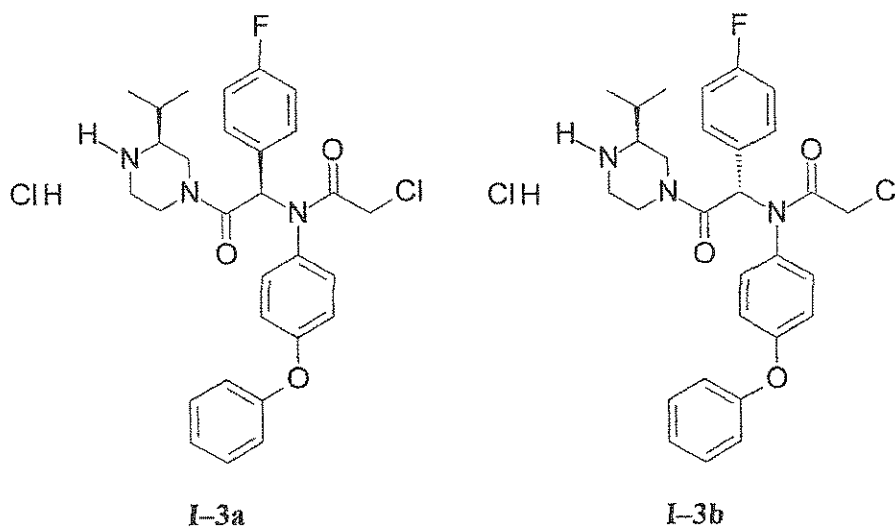
Most polar diastereoisomer (I-2 dia2) (122 mg; 26 %)

LCMS $[\text{M}+\text{H}] = 625$ ($\text{C}_{34}\text{H}_{39}\text{ClFN}_3\text{O}_5$)

^1H NMR (300 MHz, CDCl_3): δ 7.92–8.01 (m; 1.0 H); 7.30–7.40 (m; 2.0 H); 7.10–7.18 (m; 1.0 H); 7.01–7.09 (m; 1.1 H); 6.84–7.00 (m; 6.0 H); 6.55–6.65 (m; 1.1 H); 6.32–6.48 (m; 2.1 H); 4.72 (d; $J = 13.5$ Hz; 0.4 H) 4.63 (d; $J = 13.5$ Hz; 0.3 H); 3.52–3.96 (m; 4.7 H); 3.10–3.27 (m; 0.7 H); 2.85–3.07 (m; 0.5 H); 2.23–2.85 (m; 0.5 H + 0.6 H + 0.8

H); 1.87–2.14 (m; 0.9 H); 1.42 (s; 8.6 H); 1.17 (d; $J = 6.6$ Hz; 1.4 H); 1.03 (d; $J = 6.6$ Hz; 2.1 H); 0.88 (d; $J = 6.6$ Hz; 2.1 H); 0.69 (d; $J = 6.6$ Hz; 1.6 H).

Examples I-3a and I-3b : Hydrochloride of the diastereoisomers of 2-chloro-N-[1-(4-fluoro-phenyl)-2-((S)-3-isopropyl-piperazin-1-yl)-2-oxo-ethyl]-N-(4-phenoxy-phenyl)-acetamide.



To a solution of the I-1dia2 diastereoisomer (3.24 g; 5.2 mmol) in 50 mL of DCM the HCl gas was added by bubbling. The reaction medium was left under agitation for 12 hours at RT. The DCM was evaporated and the residual oil precipitated in ether.

The example I-3 dia2 was obtained in the form of a white power after filtration: (2.53 g; 87 %).

LCMS $[M+H] = 524$ ($C_{29}H_{32}Cl_2FN_3O_3$)

^1H NMR (300 MHz, DMSO): δ 8.60–9.35 (m; 1.6 H); 7.77 (br; 0.8 H); 7.30–7.40 (m; 2.0 H); 7.00–7.23 (m; 5.1 H); 6.80–7.00 (m; 3.1 H); 6.54–6.76 (m; 3.0 H); 4.56 (d; $J = 13.3$ Hz; 1.0 H); 3.88–4.16 (m; 3.0 H); 3.00–3.30 (m; 3.1 H); 2.65–2.96 (m; 1.7 H); 1.52–2.00 (m; 1.6 H); 1.00 (t; $J = 7.4$ Hz; 2.4 H); 0.59 (dd; $J = 15.6$ Hz; $J = 6.7$ Hz; 3.5 H)

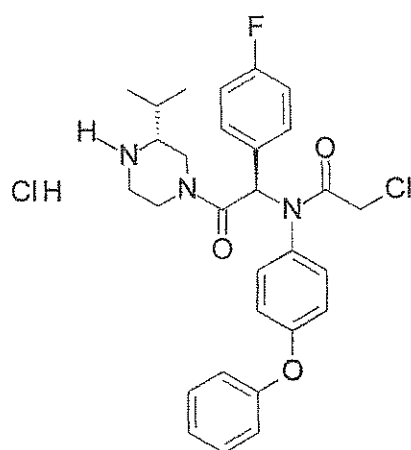
Applying the same procedure starting from example I-1dia1, example I-3 dia1 was obtained in the form of a white powder after filtration: (63 mg).

LCMS $[M+H] = 524$ ($C_{29}H_{32}Cl_2FN_3O_3$)

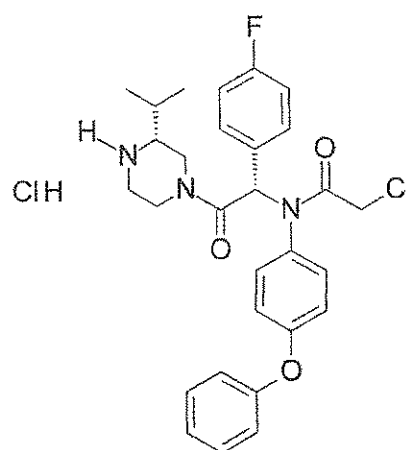
^1H NMR (300 MHz, DMSO): δ 8.65–9.6 (br; 1.2 H); 7.77 (br.; 0.8 H); 7.30–7.40 (m; 2.0 H); 6.36–7.25 (m; 11.7 H); 4.40–4.60 (m; 0.8 H); 4.00–4.12 (m; 2.0 H); 3.76–3.98

(m; 0.9 H); 3.37–3.63 (m; 0.9 H); 2.65–3.30 (m; 4.0 H); 1.77–2.06 (m; 1.6 H); 0.89–1.06 (m; 6.1 H).

Examples I-4a and I-4b : Hydrochloride of the diastereoisomers of 2-Chloro-N-[1-(4-fluoro-phenyl)-2-((R)-3-isopropyl-piperazin-1-yl)-2-oxo-ethyl]-N-(4-phenoxy-phenyl)-acetamide.



I-4a



I-4b

The same protocol was followed as for Examples I-3a and I-3b starting from each of the diastereoisomers I-2a and I-2b.

Starting from the first diastereoisomer of Example I-2 (I-4 dia1):

Recovery of a white powder after filtration: (95 mg)

LCMS [M+H] = 524 (C₂₉H₃₂Cl₂FN₃O₃)

¹H NMR (300 MHz, DMSO): δ 8.65–9.6 (br; 1.3 H); 7.77 (br; 0.4 H); 7.30–7.40 (m; 2.0 H); 6.36–7.25 (m; 11.8 H); 4.40–4.60 (m; 0.9 H); 4.00–4.12 (m; 2.0 H); 3.76–3.98 (m; 1.0 H); 3.37–3.63 (m; 1.0 H); 2.65–3.30 (m; 3.8 H); 1.77–2.06 (m; 1.8 H); 0.89–1.06 (m; 6.1 H).

Starting from the second diastereoisomer of Example I-2 (I-4 dia2):

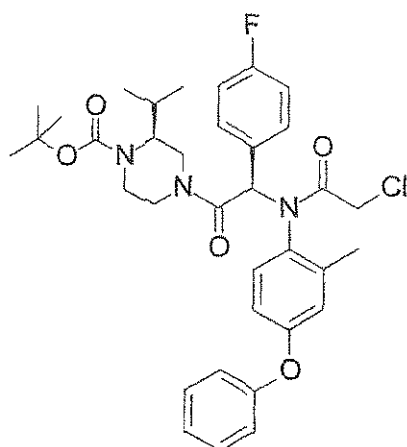
Recovery of a white powder after filtration: (95 mg)

LCMS [M+H] = 524 (C₂₉H₃₂Cl₂FN₃O₃)

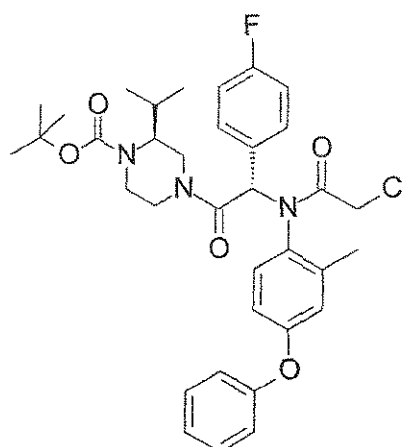
¹H NMR (300 MHz, DMSO): δ 8.60–9.35 (m; 1.7 H); 7.77 (br; 0.9 H); 7.30–7.40 (m; 2.0 H); 7.00–7.23 (m; 5.0 H); 6.80–7.00 (m; 3.0 H); 6.54–6.76 (m; 2.9 H); 4.56 (d; J = 13.3 Hz; 1.0 H); 3.88–4.16 (m; 3.0 H); 3.00–3.30 (m; 3.1 H); 2.65–2.96 (m; 1.7 H);

1.52–2.06 (m; 1.9 H); 1.00 (t; $J = 7.2$ Hz; 2.4 H); 0.59 (dd; $J = 15.4$ Hz; $J = 6.7$ Hz; 3.3 H).

Examples I-5a and I-5b: Diastereoisomers of the tert-butyl ester of 4-[2-[(2-chloro-acetyl)-(2-methyl-4-phenoxy-phenyl)-amino]-2-(4-fluoro-phenyl)-acetyl]-(S)-2-isopropyl-piperazine-1-carboxylic acid.



I-5a



I-5b

Stage 1: Tert-butyl ester of 4-[2-(4-fluoro-phenyl)-2-(2-methyl-4-phenoxy-phenylamino)-acetyl]-(S)-2-isopropyl-piperazine-1-carboxylic acid (8):

To a solution of (4-fluoro-phenyl)-(2-methyl-4-phenoxy-phenylamino)-acetic acid (9.29 g; 26.4 mmol) in DCM (150 mL) in the presence of one equivalent of DIEA (4.6 mL) was added a solution of Boc-alpha-(S)-isopropyl-piperazine hydrochloride (7.00 g; 26.4 mmol) in the presence of 1 eq of DIEA (4.6 mL) in 50 mL of DCM, followed by HBTU (10.00 g; 26.4 mmol). The medium was left under agitation for 12 hours. The medium was washed with water and the organic phase dried over MgSO_4 . After evaporation the recovered oil was purified by flash chromatography on silica gel eluting with cyclohexane-ethyl acetate 80:20.

Recovery of a white foam (14.13 g; 95 %).

LCMS $[\text{M}+\text{H}] = 562$ ($\text{C}_{33}\text{H}_{40}\text{FN}_3\text{O}_4$)

Stage 2: Tert-butyl ester of 4-[2-[(2-chloro-acetyl)-(2-methyl-4-phenoxy-phenyl)-amino]-2-(4-fluoro-phenyl)-acetyl]-(S)-2-isopropyl-piperazine-1-carboxylic acid

To a solution of **8** (14.13 g; 25.1 mmol) in 250 mL of DCM in the presence of NaHCO_3 (8.40 g; 100.0 mmol) was added chloroacetyl chloride (4.00 mL; 50.0 mmol). The

medium was left under agitation for 12 hours. The medium was washed with water and the organic phase dried over MgSO_4 . After evaporation the recovered oil was purified by flash chromatography on silica gel eluting with cyclohexane–ethyl acetate 90:10 gradually up to 50:50.

Recovery of both diastereoisomers in the form of a colourless foam:

Least polar diastereoisomer (I-5 dia1) (3.83 g; 24 %)

LCMS $[\text{M}+\text{H}] = 639$ ($\text{C}_{35}\text{H}_{41}\text{ClFN}_3\text{O}_5$)

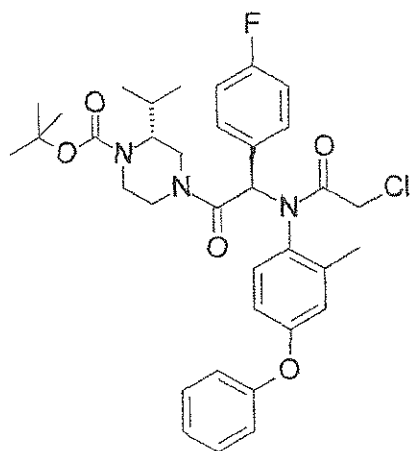
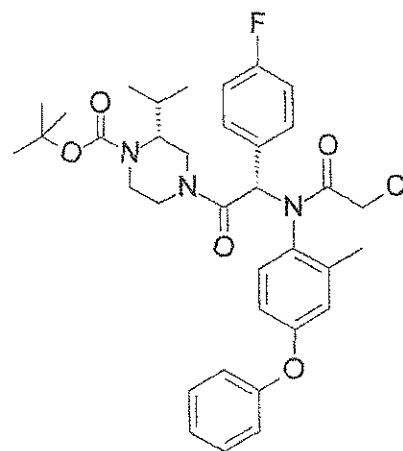
^1H NMR (300 MHz, CD_2Cl_2): δ 7.94–8.57 (m; 1.0 H); 7.35 (t; $J = 7.9$ Hz; 2.0 H); 7.07–7.27 (m; 3.0 H); 6.74–6.95 (m; 5.0 H); 6.58 (br d; $J = 2.6$ Hz; 1.1 H); 6.51 (br s; 0.2 H); 6.41 (s; 0.8 H); 6.31 (br s; 0.3 H); 4.62 (d; $J = 13.5$ Hz; 0.7 H) 4.39 (d; $J = 13.5$ Hz; 0.3 H); 3.53–4.05 (m; 4.8 H); 3.04–3.46 (m; 0.8 H); 2.41–2.96 (m; 2.1 H); 2.04–2.23 (m; 0.8 H); 1.82–1.95 (m; 2.2 H); 1.43 (br s; 10.1 H); 1.07 (d; $J = 6.5$ Hz; 2.1 H); 0.90 (d; $J = 6.5$ Hz; 2.3 H); 0.63 (d; $J = 6.5$ Hz; 1.0 H); 0.29 (d; $J = 6.5$ Hz; 0.8 H).

Most polar diastereoisomer (I-5 dia2) (4.40 g; 27 %)

LCMS $[\text{M}+\text{H}] = 639$ ($\text{C}_{35}\text{H}_{41}\text{ClFN}_3\text{O}_5$)

^1H NMR (300 MHz, CDCl_3): δ 8.00–8.10 (m; 1.0 H); 7.30–7.40 (m; 2.1 H); 6.98–7.18 (m; 3.2 H); 6.73–6.90 (m; 5.3 H); 6.52–6.58 (m; 1.0 H); 6.34–6.39 (m; 1.0 H); 4.71 (d; $J = 13.5$ Hz; 0.7 H); 4.49 (d; $J = 13.5$ Hz; 0.4 H); 3.50–4.00 (m; 4.7 H); 3.10–3.30 (m; 0.7 H); 2.86–3.07 (m; 0.4 H); 2.54–2.85 (m; 1.5 H); 2.30–2.47 (m; 0.4 H); 1.80–1.87 (m; 2.8 H); 1.54–1.60 (m; 2.5 H); 1.42 (br s; 8.8 H); 1.19 (d; $J = 6.6$ Hz; 1.1 H); 1.00 (d; $J = 6.6$ Hz; 1.5 H); 0.88 (d; $J = 6.6$ Hz; 1.2 H); 0.64 (d; $J = 6.6$ Hz; 1.5 H).

Examples I-6a and I-6b : Diastereoisomers of the tert-butyl ester of 4-[2-(2-chloro-acetyl)-(4-phenoxy-phenyl)-amino]-2-(4-fluoro-phenyl)-acetyl-(R)-2-isopropyl-piperazine-1-carboxylic acid

**I-6a****I-6b**

These two diastereoisomers were prepared in the same manner as in the preceding example in the form of colourless foam:

Least polar diastereoisomer (I-6 dia1) (97 mg; 30 %)

LCMS [M+H] = 639 (C₃₅H₄₁ClFN₃O₅)

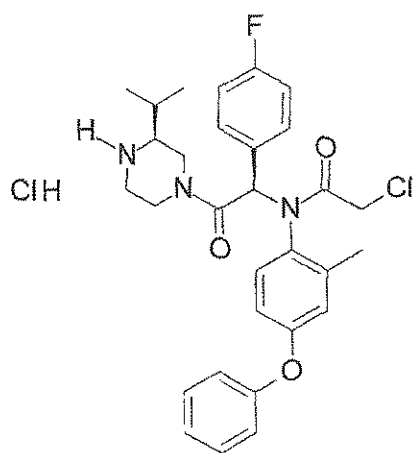
¹H NMR (300 MHz, CD₂Cl₂): δ 7.94–8.57 (m; 0.9 H); 7.35 (t; *J* = 7.9 Hz; 1.9 H); 7.05–7.25 (m; 3.1 H); 6.72–6.93 (m; 5.0 H); 6.58 (br d; *J* = 2.6 Hz; 1.1 H); 6.41 (s; 0.8 H); 6.31 (br s; 0.3 H); 4.63 (d; *J* = 13.5 Hz; 0.8 H) 4.40 (d; *J* = 13.5 Hz; 0.3 H); 3.51–4.06 (m; 4.8 H); 3.03–3.45 (m; 1.0 H); 2.41–2.96 (m; 1.6 H); 2.02–2.21 (m; 0.8 H); 1.82–1.95 (m; 2.1 H); 1.43 (br s; 10.1 H); 1.07 (d; *J* = 6.5 Hz; 2.1 H); 0.90 (d; *J* = 6.5 Hz; 2.3 H); 0.63 (d; *J* = 6.5 Hz; 1.0 H); 0.29 (d; *J* = 6.5 Hz; 0.8 H).

Most polar diastereoisomer (I-6 dia2) (90 mg; 28 %)

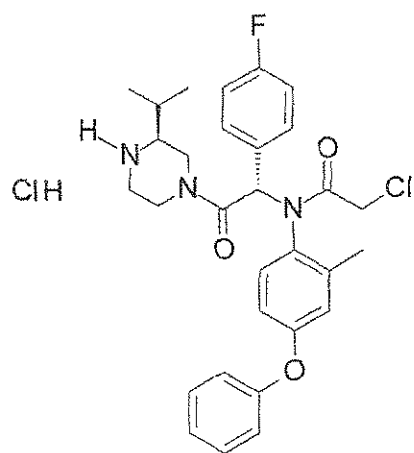
LCMS [M+H] = 639 (C₃₅H₄₁ClFN₃O₅)

¹H NMR (300 MHz, CDCl₃): δ 8.00–8.10 (m; 1.0 H); 7.30–7.40 (m; 2.1 H); 6.98–7.18 (m; 3.1 H); 6.73–6.90 (m; 5.1 H); 6.52–6.58 (m; 1.0 H); 6.34–6.39 (m; 1.0 H); 4.70 (d; *J* = 13.5 Hz; 0.7 H); 4.49 (d; *J* = 13.5 Hz; 0.4 H); 3.50–4.00 (m; 4.8 H); 3.10–3.30 (m; 0.7 H); 2.86–3.07 (m; 0.4 H); 2.54–2.85 (m; 1.5 H); 2.30–2.47 (m; 0.4 H); 1.80–1.87 (m; 2.8 H); 1.54–1.60 (m; 2.6 H); 1.42 (br s; 8.6 H); 1.20 (d; *J* = 6.6 Hz; 1.1 H); 1.01 (d; *J* = 6.6 Hz; 1.5 H); 0.89 (d; *J* = 6.6 Hz; 1.2 H); 0.64 (d; *J* = 6.6 Hz; 1.5 H).

Examples I-7a and I-7b: Hydrochloride of the diastereoisomers of 2-chloro-*N*-[1-(4-fluoro-phenyl)-2-((*S*)-3-isopropyl-piperazin-1-yl)-2-oxo-ethyl]-*N*-(2-methyl-4-phenoxy-phenyl)-acetamide



I-7a



I-7b

To a solution of one of the diastereoisomers I-5a and I-5b in 50 mL of DCM the HCl gas was added by bubbling. The reaction medium was left under agitation for 12 hours at RT. The DCM was evaporated and the residual oil precipitated in ethyl ether.

Starting from the first diastereoisomer of Example I-5 (I-7 dia1):

Recovery of a white powder after filtration: (26 mg)

LCMS [M+H] = 538 (C₃₀H₃₄Cl₂FN₃O₃)

¹H NMR (300 MHz, DMSO): δ 8.79–9.33 (m; 1.3 H); 7.83 (t; *J* = 9.0 Hz; 1.0 H); 7.24–7.40 (m; 4.0 H); 6.97–7.15 (m; 3.1 H); 6.73–6.89 (m; 3.2 H); 6.64 (d; *J* = 2.7 Hz; 0.9 H); 6.51–6.59 (m; 1.0 H); 4.40–4.55 (br m; 1.1 H); 3.86–4.09 (m; 3.6 H); 3.45–3.60 (m; 0.7 H); 2.78–3.05 (m; 2.8 H); 1.79–2.00 (m; 4.5 H); 1.61–1.77 (m; 0.7 H); 0.97 (d; *J* = 6.7 Hz; 6.0 H).

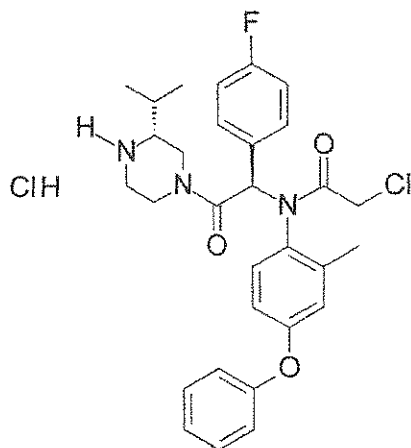
Starting from the second diastereoisomer of Example I-5 (I-7 dia2):

Recovery of a white powder after filtration: (2.62 g)

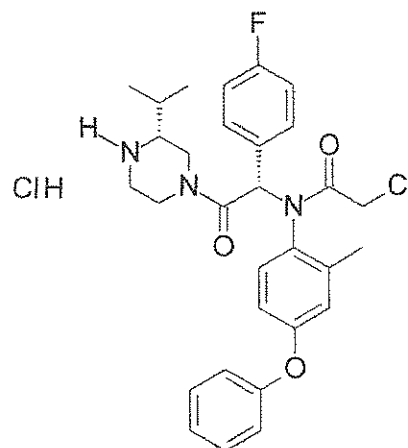
LCMS [M+H] = 538 (C₃₀H₃₄Cl₂FN₃O₃)

¹H NMR (300 MHz, DMSO) : δ 8.78–9.51 (m; 1.9 H); 7.82 (t; *J* = 8.9 Hz; 0.9 H); 7.20–7.41 (m; 4.0 H); 6.97–7.16 (m; 3.1 H); 6.71–6.90 (m; 3.1 H); 6.61–6.70 (m; 1.9 H); 4.46–4.60 (br m; 1.0 H); 3.85–4.15 (m; 3.1 H); 3.00–3.30 (m; 3.0 H); 2.57–2.96 (m; 1.8 H); 1.43–1.98 (m; 4.3 H); 1.00 (dd; *J* = 8.8 Hz; *J* = 7.0 Hz; 2.7 H); 0.71 (d; *J* = 6.8 Hz; 1.6 H); 0.65 (d; *J* = 6.8 Hz; 1.5 H).

Example I-8: Hydrochloride of 2-chloro-*N*-[1-(4-fluoro-phenyl)-2-((*R*)-3-isopropyl-piperazin-1-yl)-2-oxo-ethyl]-*N*-(2-methyl-4-phenoxy-phenyl)-acetamide



I-8a



I-8b

The same protocol as in the preceding example was followed starting from each of the diastereoisomers of Example I-6.

Starting from the first diastereoisomer of Example I-6 (I-8 dia1) :

Recovery of a white powder after filtration: (34 mg; 56 %)

LCMS [M+H] = 538 (C₃₀H₃₄Cl₂FN₃O₃)

¹H NMR (300 MHz, DMSO): δ 8.79–9.33 (m; 1.3 H); 7.83 (t; *J* = 9.0 Hz; 0.9 H); 7.24–7.40 (m; 4.0 H); 6.97–7.15 (m; 3.1 H); 6.73–6.89 (m; 3.1 H); 6.64 (d; *J* = 2.7 Hz; 1.0 H); 6.51–6.59 (m; 1.0 H); 4.41–4.56 (br m; 1.1 H); 3.86–4.09 (m; 3.4 H); 3.45–3.60 (m; 0.7 H); 2.78–3.05 (m; 2.8 H); 1.79–2.00 (m; 4.4 H); 1.61–1.77 (m; 0.8 H); 0.97 (d; *J* = 6.7 Hz; 6.0 H).

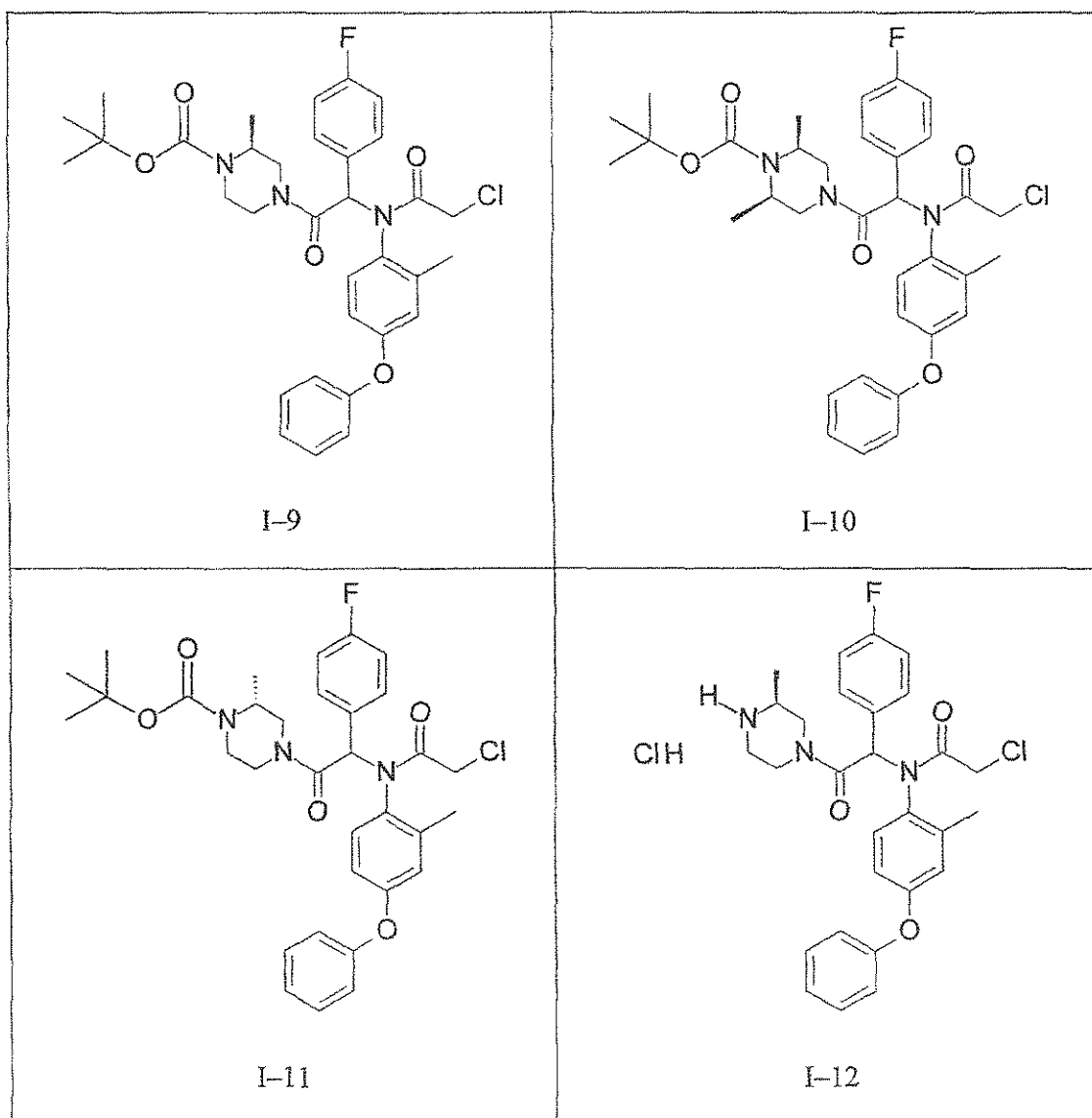
Starting from the second diastereoisomer of Example I-6 (I-8 dia2):

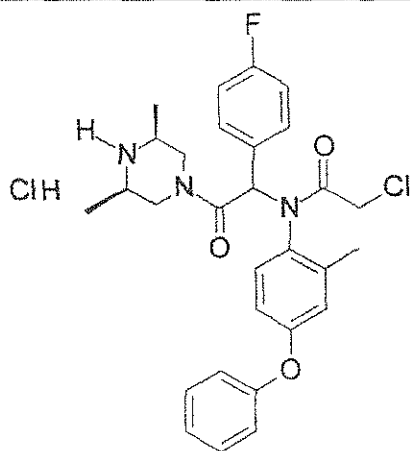
Recovery of a white powder after filtration: (30 mg; 54 %)

LCMS [M+H] = 538 (C₃₀H₃₄Cl₂FN₃O₃)

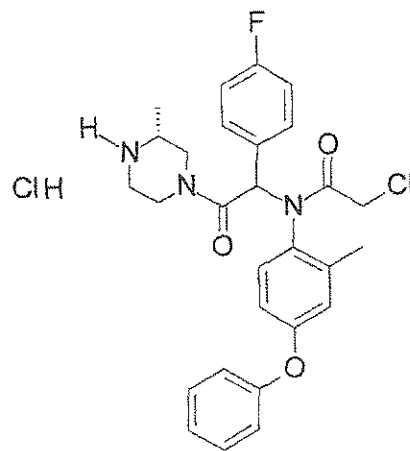
¹H NMR (300 MHz, DMSO): δ 8.78–9.51 (m; 1.5 H); 7.82 (t; *J* = 8.9 Hz; 1.0 H); 7.20–7.41 (m; 4.0 H); 6.97–7.16 (m; 3.1 H); 6.71–6.90 (m; 3.2 H); 6.61–6.70 (m; 1.9 H); 4.46–4.60 (br m; 1.0 H); 3.85–4.15 (m; 3.1 H); 3.00–3.30 (m; 2.9 H); 2.57–2.96 (m; 1.8 H); 1.43–1.98 (m; 4.3 H); 1.00 (dd; *J* = 8.8 Hz; *J* = 7.0 Hz; 2.7 H); 0.71 (d; *J* = 6.8 Hz; 1.6 H); 0.65 (d; *J* = 6.8 Hz; 1.5 H).

Using the same operating modes and the same separation modes by silica chromatography as above, the following examples were prepared from diversely substituted anilines and piperazines. They were isolated either in the form of a mixture of two or four diastereoisomers (one example number for the same chemical structure) or in the form of separate diastereoisomers. In this latter case the nomenclature a / b was used to designate each of the diastereoisomers.

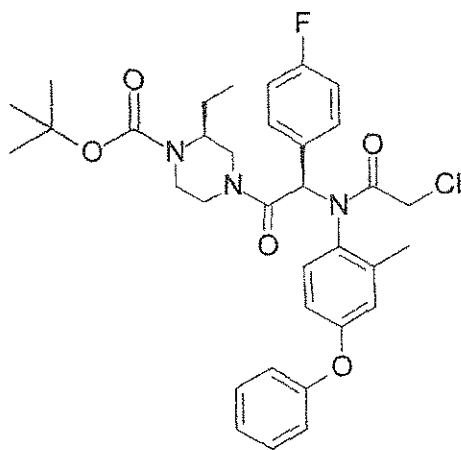




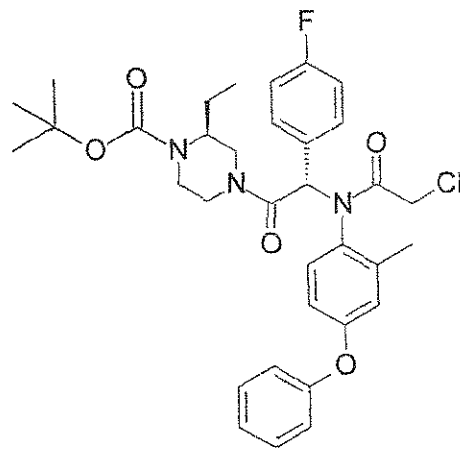
I-13



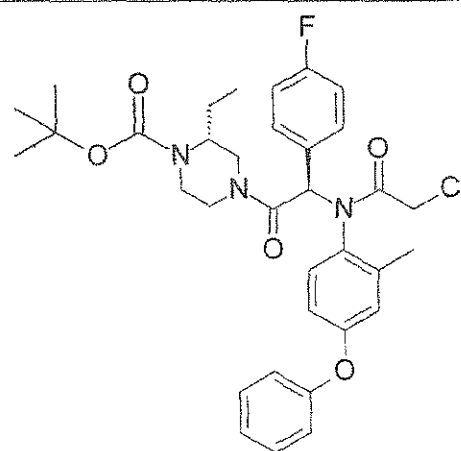
I-14



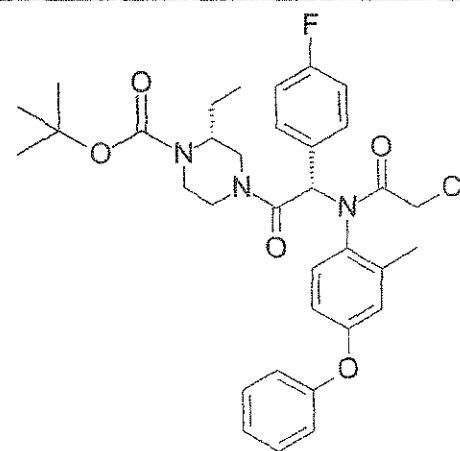
I-15a



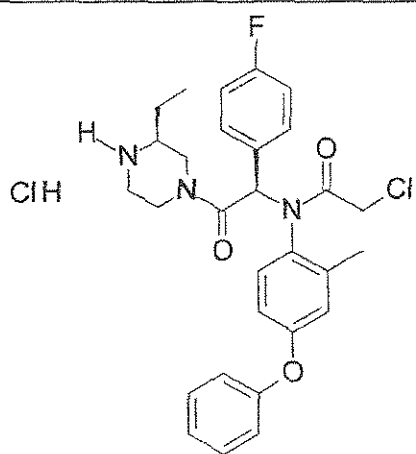
I-15b



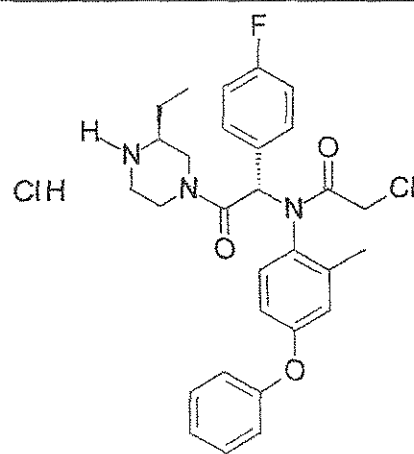
I-16a



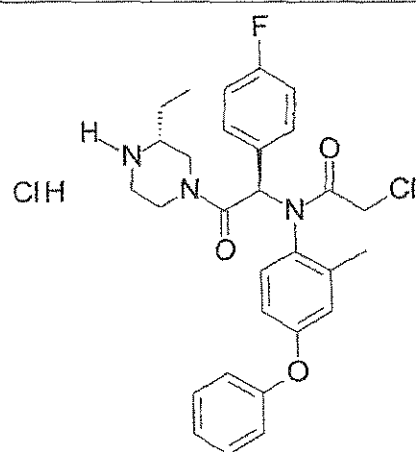
I-16b



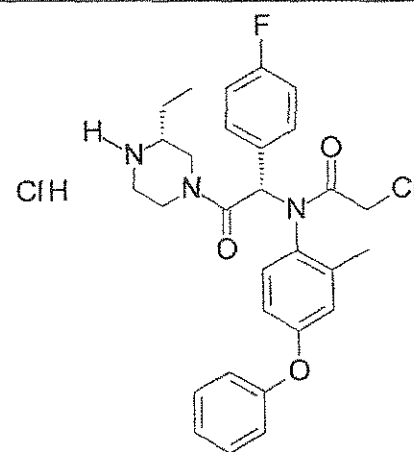
I-17a



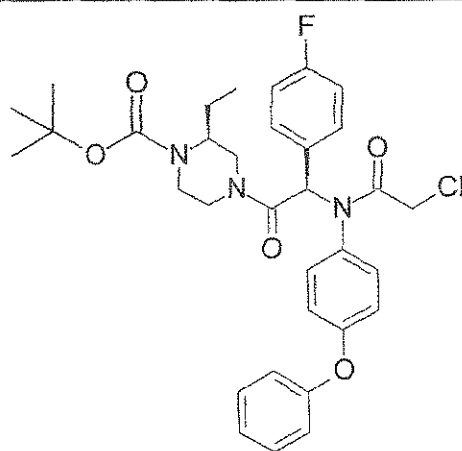
I-17b



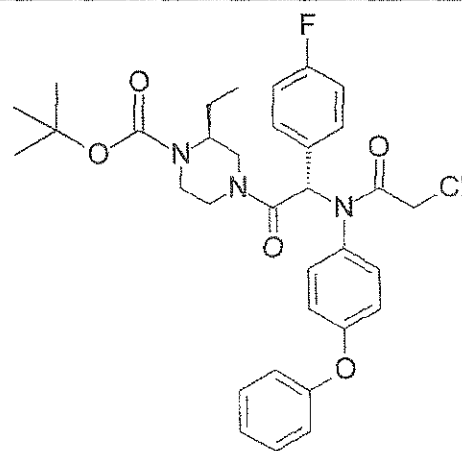
I-18a



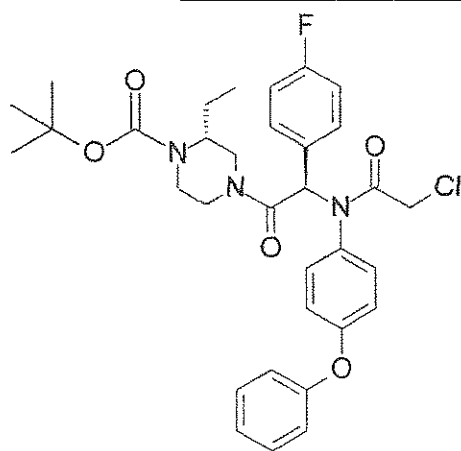
I-18b



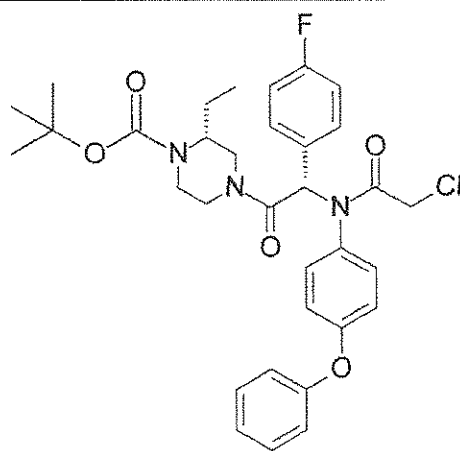
I-19a



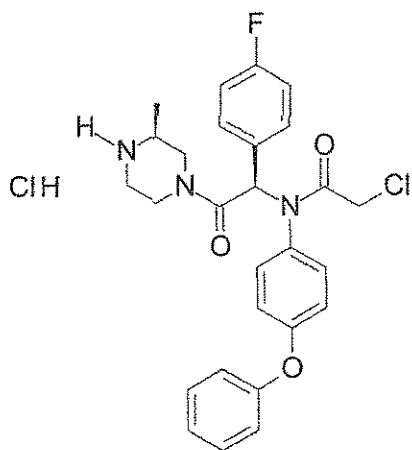
I-19b



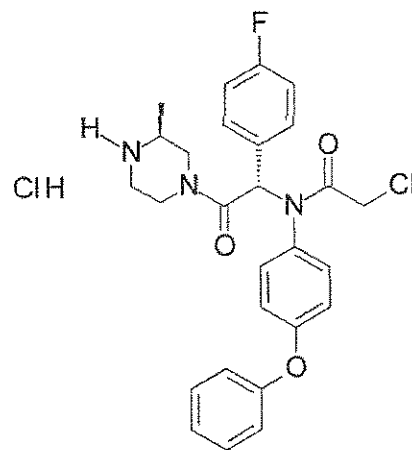
I-20a



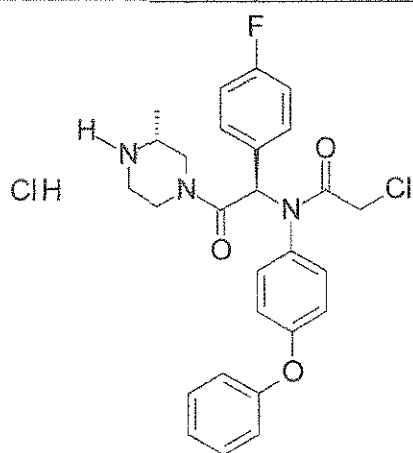
I-20b



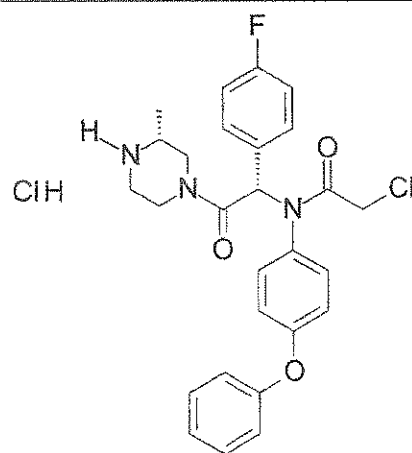
I-21a



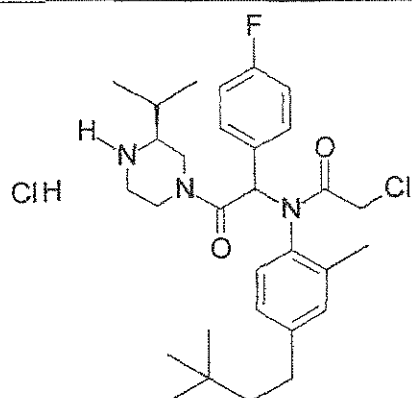
I-21b



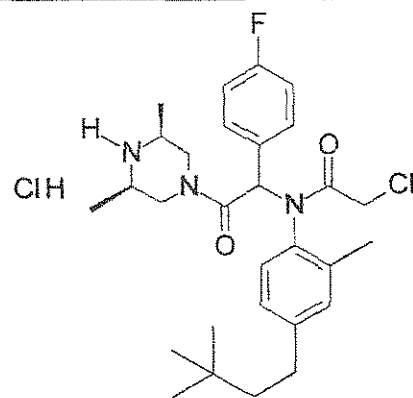
I-22a



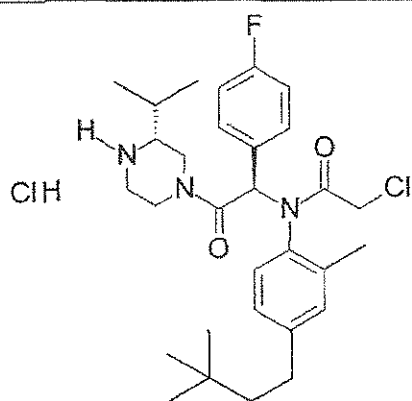
I-22b



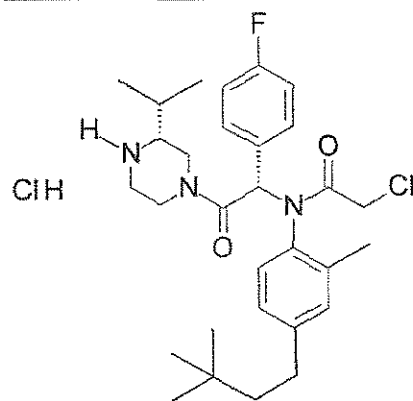
I-23



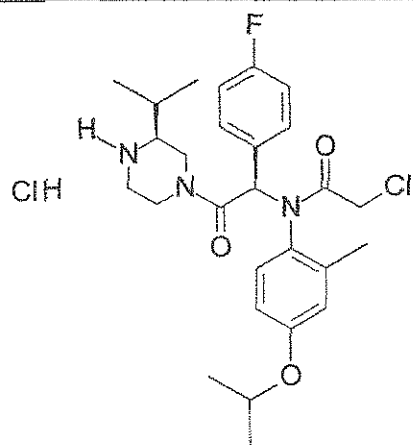
I-24



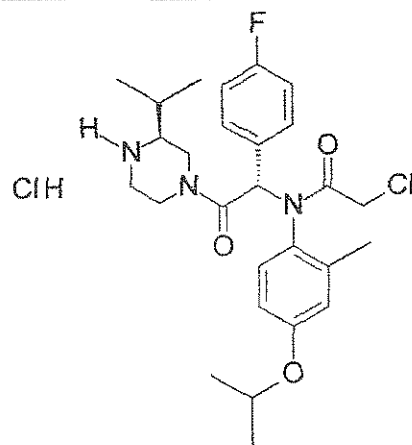
I-25a



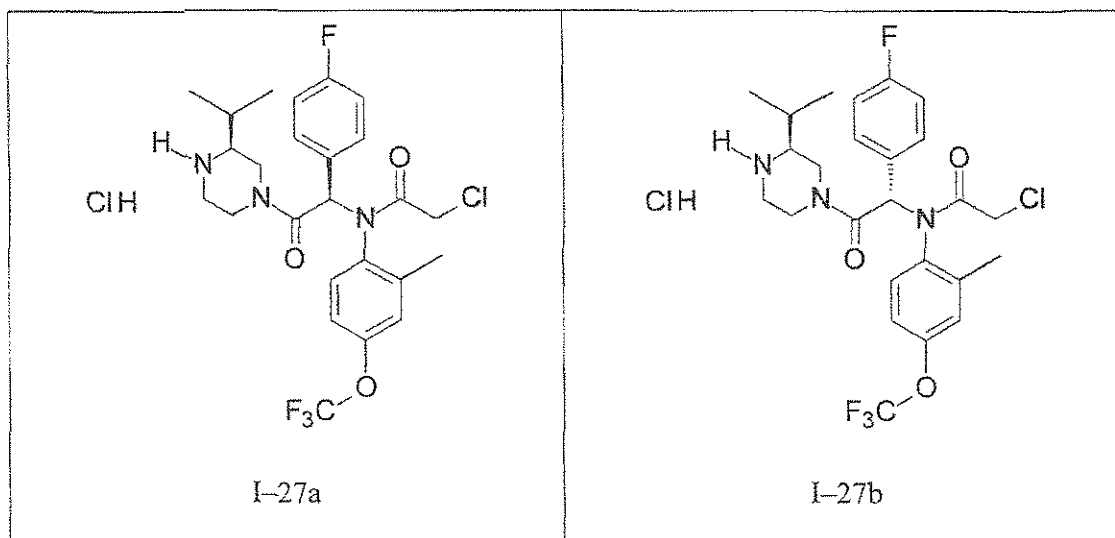
I-25b



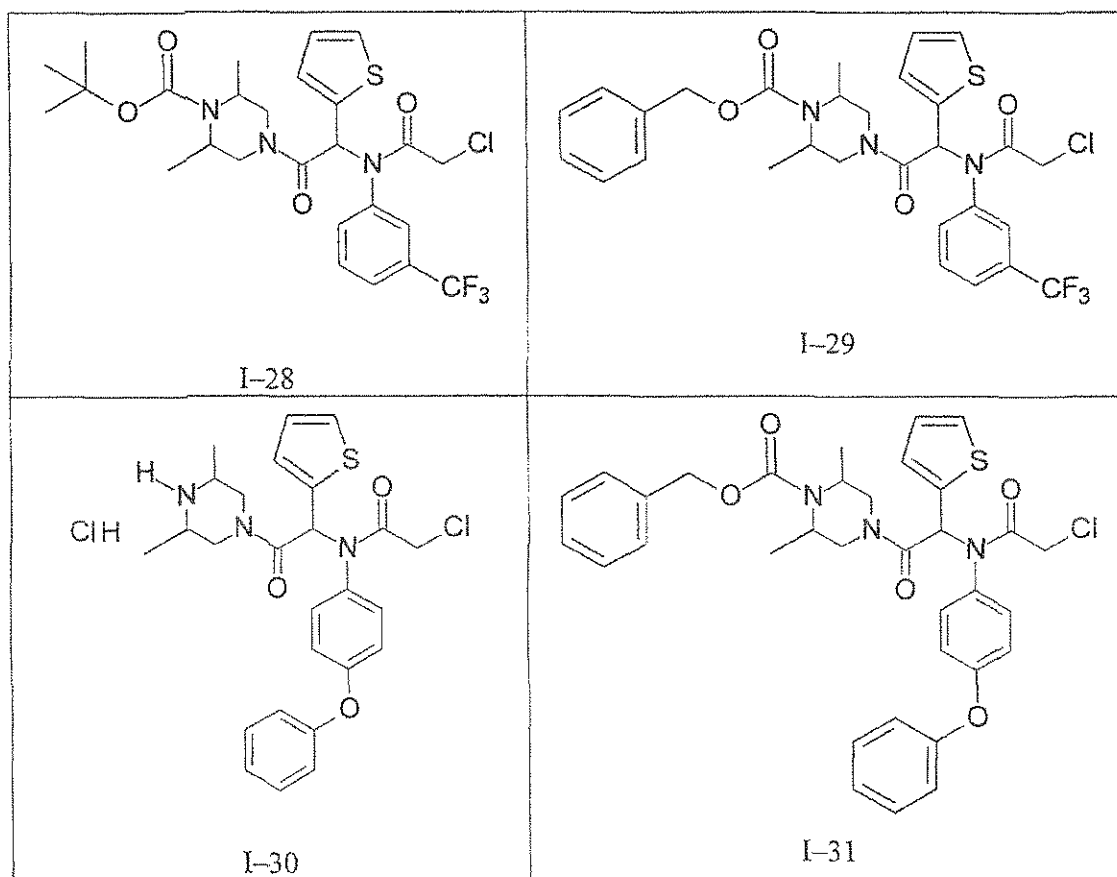
I-26a

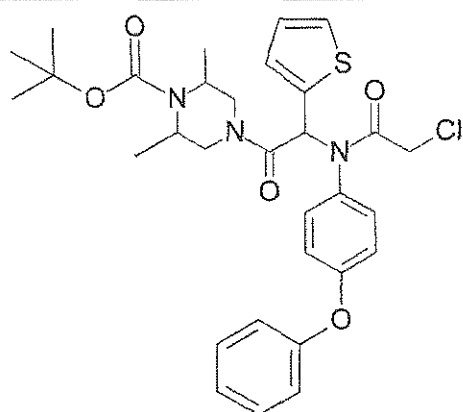


I-26b

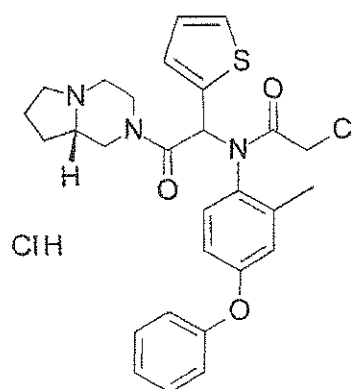


The following examples were obtained by replacing the ethyl ester of (4-fluorophenyl)-oxo-acetic acid by ethyl thiophene-2-glyoxylate and following the same operating modes as previously.

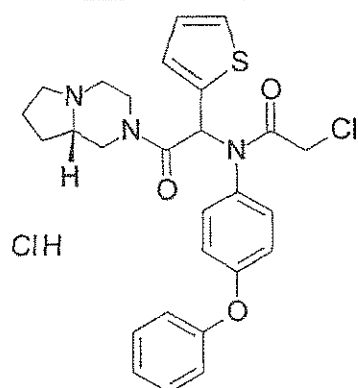




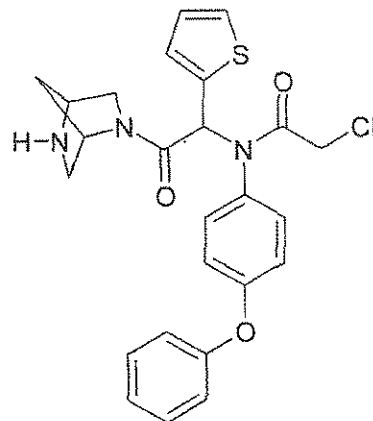
I-32



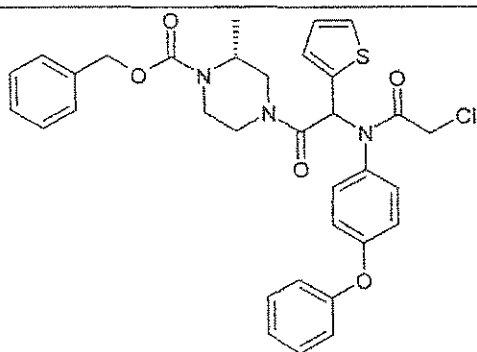
I-33



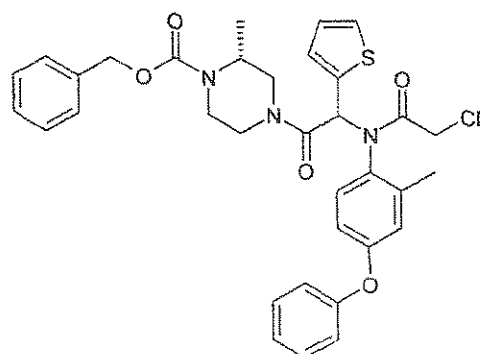
I-34



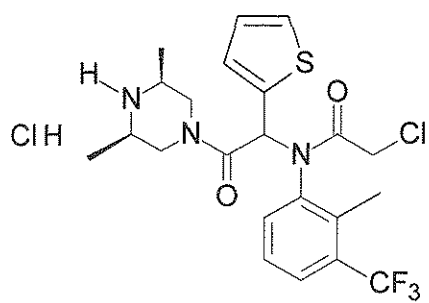
I-35



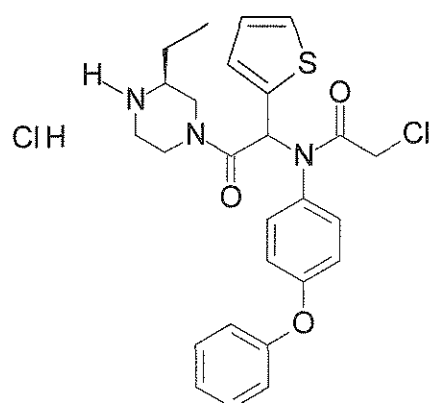
I-36



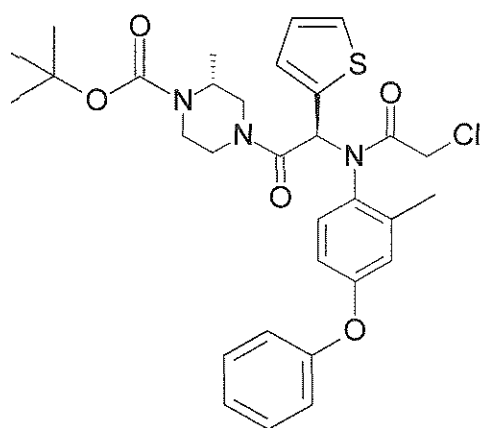
I-37



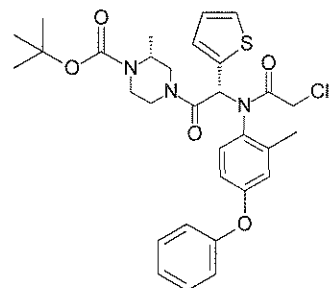
I-38



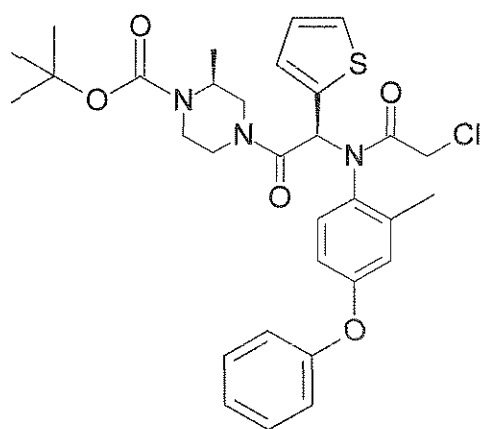
I-39



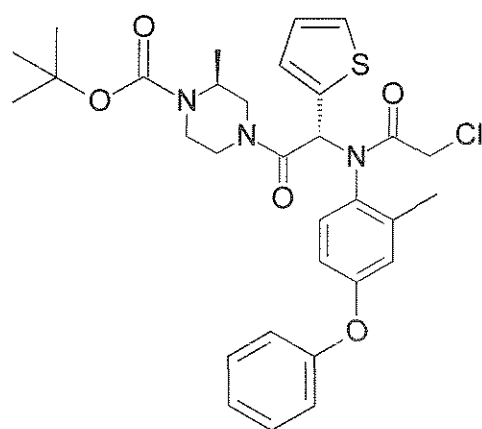
I-40a



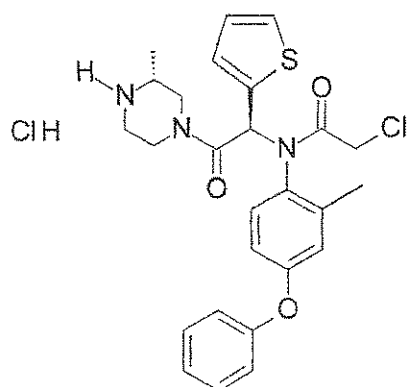
I-40b



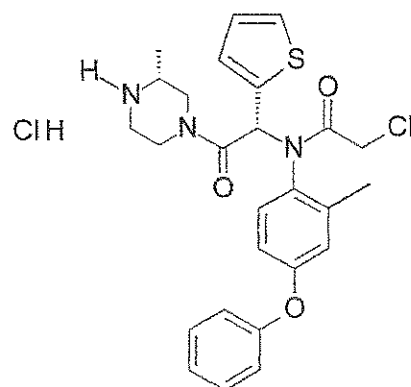
I-41a



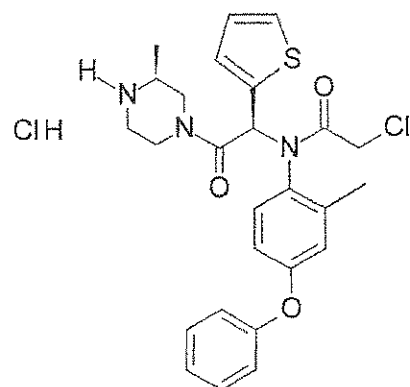
I-41b



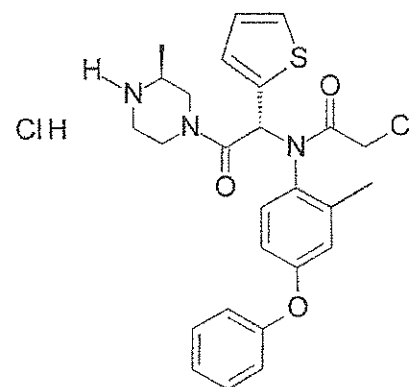
I-42a



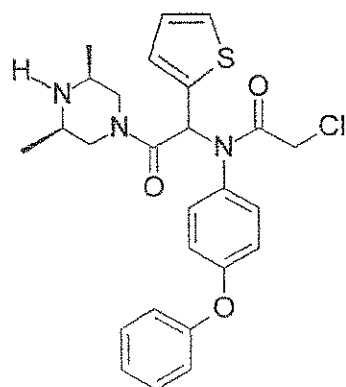
I-42b



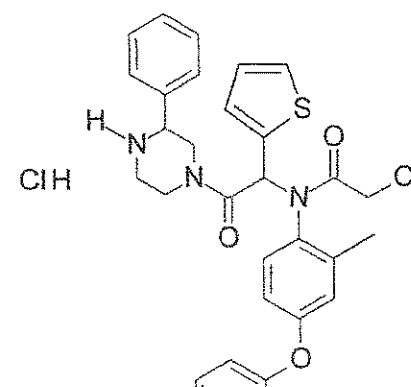
I-43a



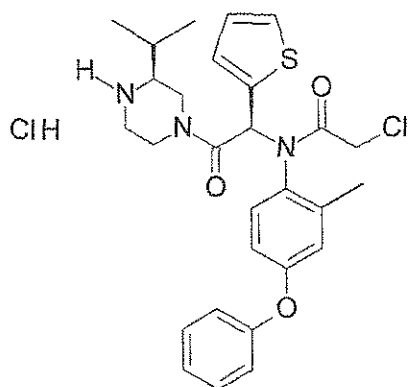
I-43b



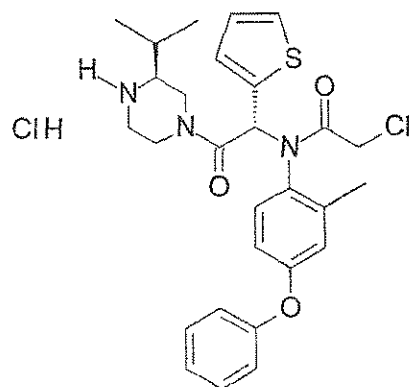
I-44



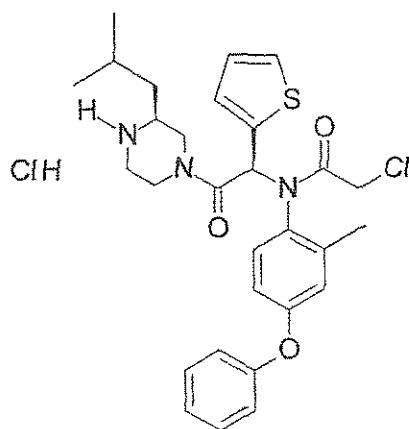
I-45



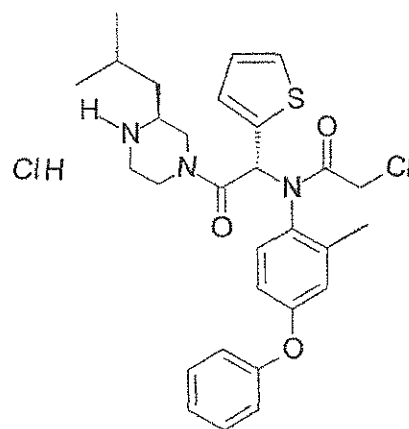
I-46a



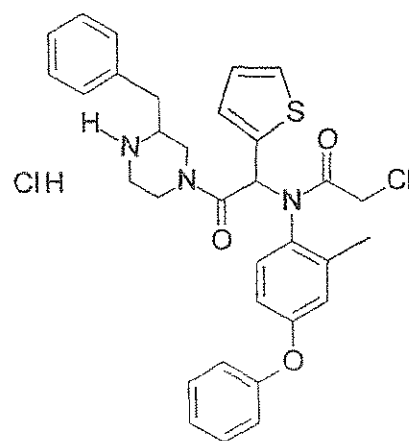
I-46b



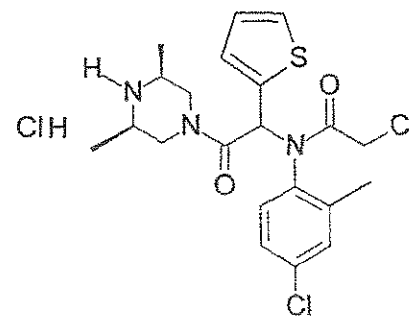
I-47a



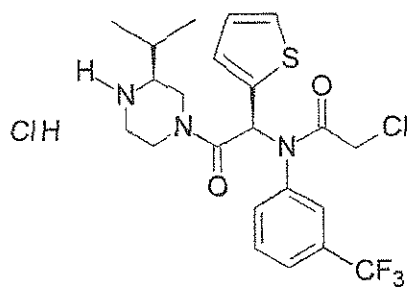
I-47b



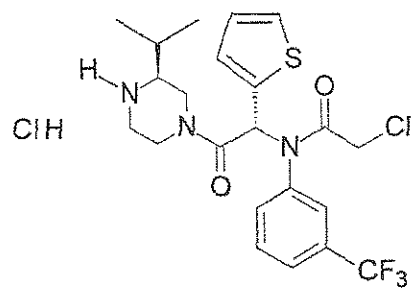
I-48



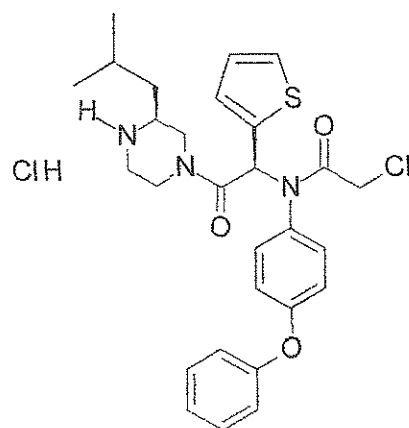
I-49



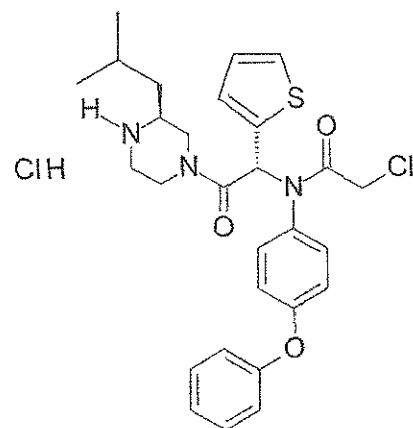
I-50a



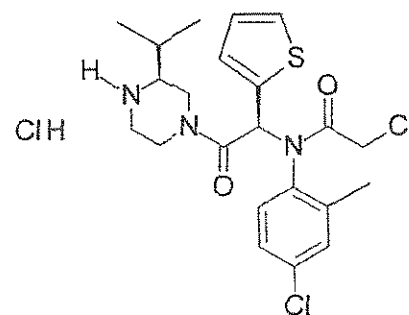
I-50b



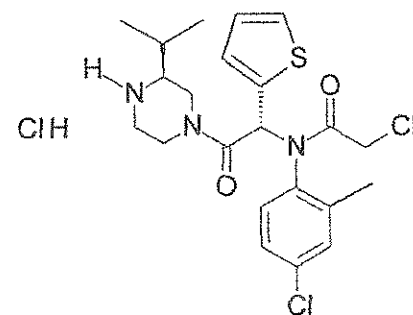
I-51a



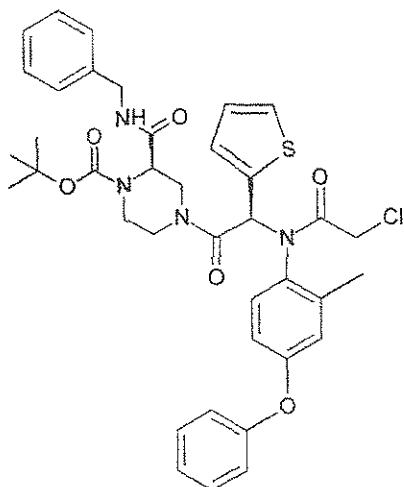
I-51b



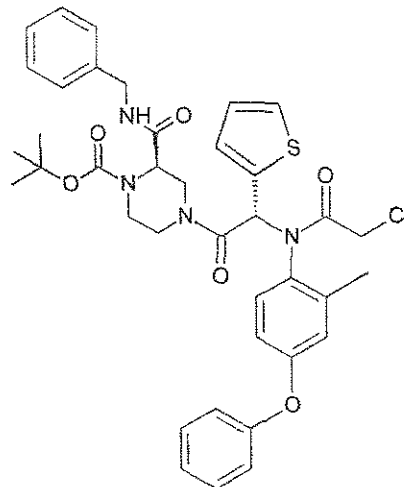
I-52a



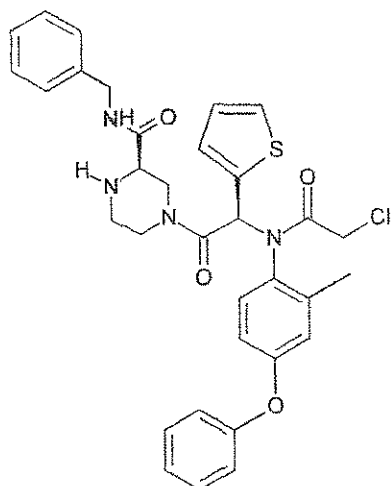
I-52b



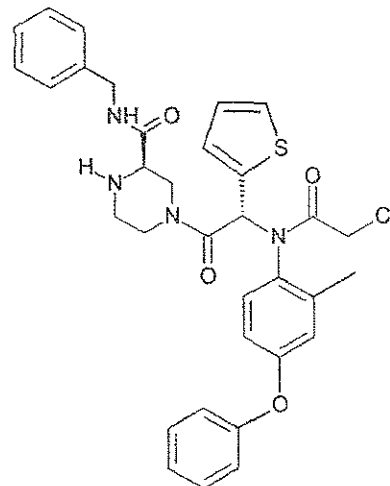
I-53a



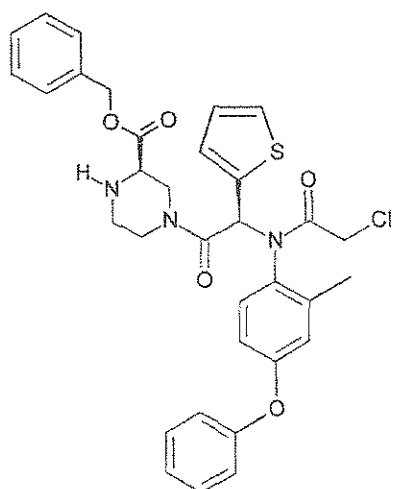
I-53b



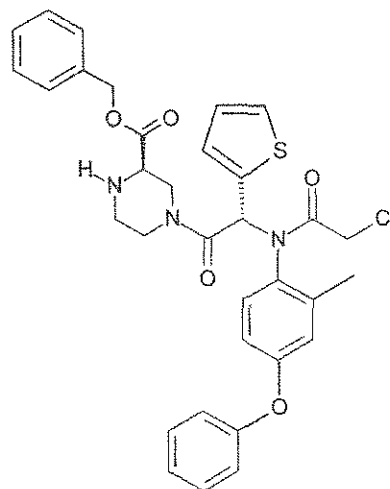
I-54a



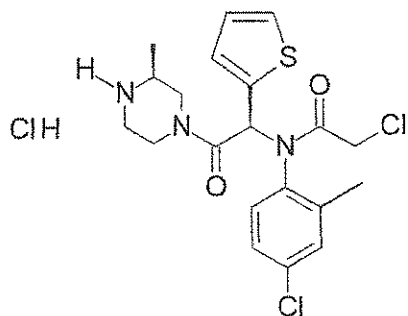
I-54b



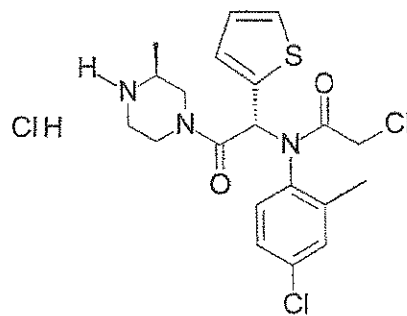
I-55a



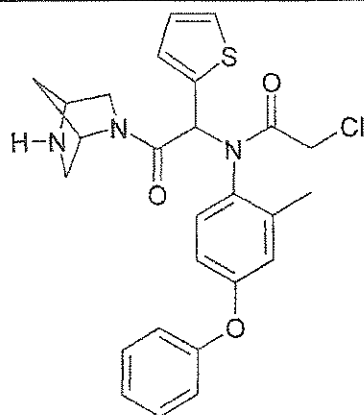
I-55b



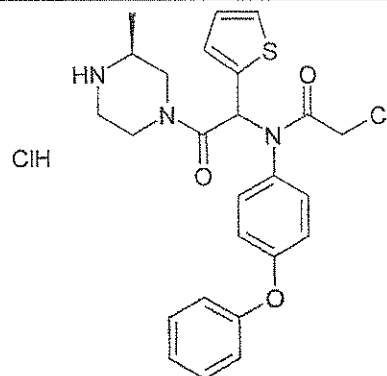
I-56a



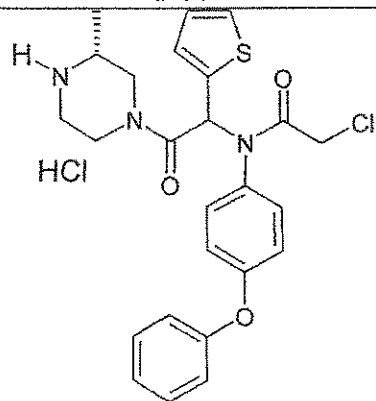
I-56b



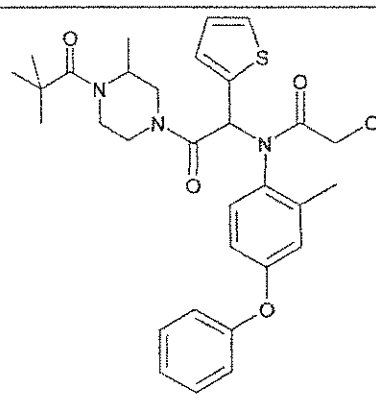
I-57



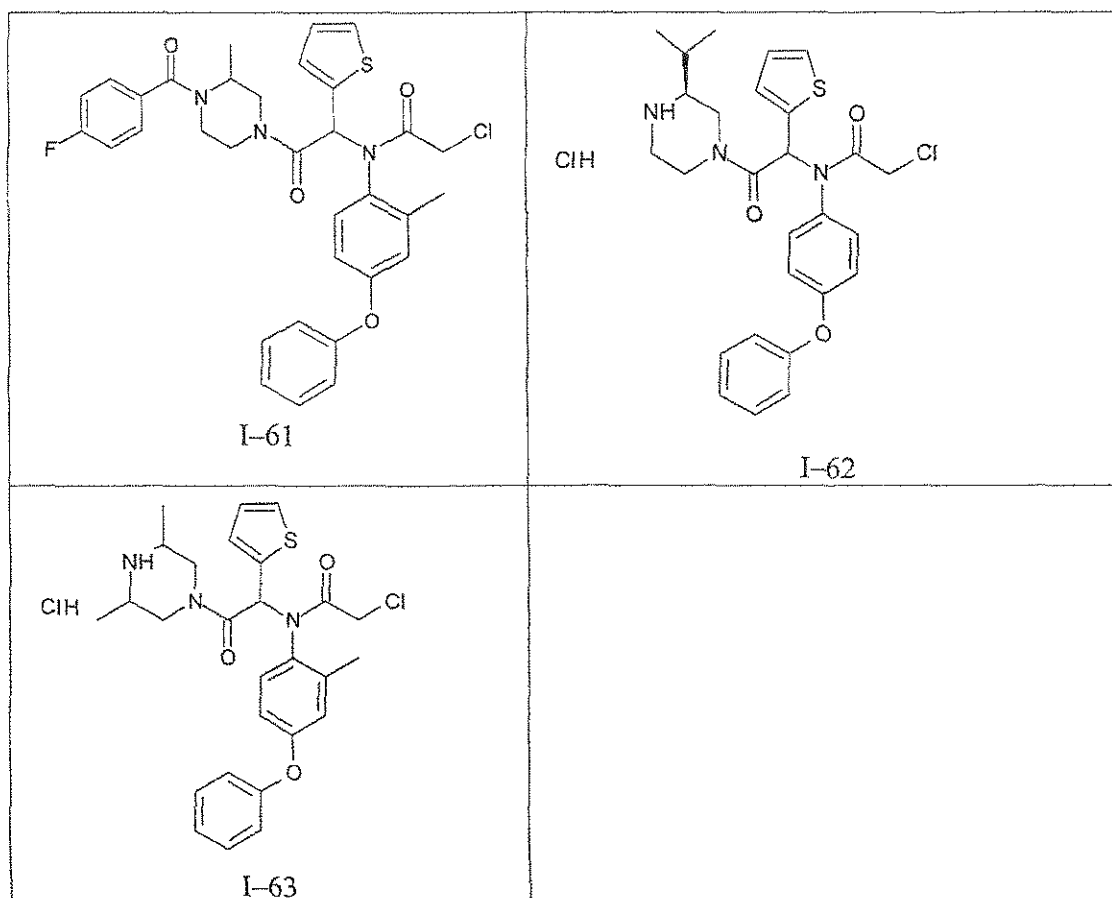
I-58



I-59



I-60



II - Pharmacological study of the compounds of the present invention

I) Cytotoxicity tests

The effects of the compounds of the invention on the proliferation of cancer cells were studied on different human cancer cell lines of different tissue origin (MCF-7: breast cancer, MCF-7/adr adriamycin-resistant breast cancer, HL-60: acute promyelocytic leukaemia, HL-60/R10: doxorubicin-resistant acute promyelocytic leukaemia, HT29 : colon adenocarcinoma, Mia Paca2: pancreatic tumour, Panc-1: pancreatic exocrine tumour, SK-OV-3: cisplatin- and adriamycin resistant ovarian cancer). The cancer cells used for this study were incubated at 37°C in the presence of one of the compounds of the invention added to the culture medium at different concentrations.

The cancer cell lines were obtained from ATCC (American Type Culture Collection) for MCF-7, from Hôpital de la Pitié Salpêtrière for MCF-7/adr and from Oncodesign (Dijon, France) for HL-60, HL-60/R10, HT29, MiaPaCa2, Panc-1 and SK-OV-3. They were cultured in RPMI 1640 medium containing 2 mM L-Glutamine

supplemented with 10 % foetal calf serum (Lonza; Verviers, Belgium). All the cell lines were held in culture at 37°C in a humid atmosphere containing 5 % CO₂. Cell proliferation was assessed using the ViaLight® Plus Assay Kit (Lonza; Verviers, Belgium) following the manufacturer's instructions. The cells were seeded in 96-well culture plates compatible with luminescence read-off (white plates with transparent bottom) in a proportion of 5 000 to 10 000 cells per well in 100 µl of culture medium. After a pre-incubation time of 24 hours at 37°C, the compounds of the invention dissolved in dimethylsulfoxide (DMSO) were individually added to each well in a proportion of 0.5 µl per well. After 72 hours' incubation at 37°C in a humid atmosphere containing 5 % CO₂, 50 µl of lysis buffer were added to each well and 15 minutes later 100 µl of ATP measuring agent were added. The plates were read under a luminometer to evaluate cell viability. The data obtained was processed by computer to obtain the EC₅₀ value i.e. the concentration value of each of the compounds which induces 50 % cell viability compared with a control value (0.5 % DMSO alone).

The results obtained are given in following Tables 1 and 2.

Table 1: Results obtained with cell lines HL-60, HL60/R10, MCF-7 and MCF-7/adr (EC₅₀ expressed in nM)

Example N°	EC ₅₀ (nM)			
	HL-60	HL60/R10	MCF-7	MCF-7 /adr
I-1 dia1	1799	-219	-2500	338
I-1 dia2	824	23	1304	39
I-2 dia1	728	40	2091	49
I-2 dia2	2061	472	2500	645
I-3 dia1	1311	15	927	55
I-3 dia2	504	2	301	9
I-4 dia1	648	4	315	13
I-4 dia2	1321	62	863	166
I-7 dia1	2500	604	2500	618
I-7 dia2	1938	26	1954	98
I-8 dia1	2029	54	1740	148
I-8 dia2	1737	312	2410	477
I-9	771	99	2500	108
I-10	641	131	2500	151

Example N°	EC ₅₀ (nM)			
	HL-60	HL60/R10	MCF-7	MCF-7 /adr
I-11	939	68	2500	102
I-12	2321	82	1787	421
I-13	1989	88	2500	532
I-14	1848	95	2500	232
I-16 dial	1478	450	2500	527
I-16 dia2	1913	317	2500	443
I-17 dial	2313	353	2500	898
I-17 dia2	1604	49	1994	152
I-18 dial	1596	140	2500	485
I-18 dia2	352	44	591	152
I-19 dial	516	97	2500	128
I-19 dia2	453	24	2500	35
I-20 dial	196	80	1571	73
I-20 dia2	1478	139	2500	165
I-21 dial	2447	13	1950	93
I-21 dia2	630	8	869	10
I-22 dial	1995	17	569	131
I-22 dia2	1149	18	430	34
I-23	559	12	nd	nd
I-24	626	15	nd	nd
I-25 dial	1122	43	nd	nd
I-25 dia2	819	103	nd	nd
I-26 dial	2447	13	1950	93
I-26 dia2	630	8	869	10
I-27 dial	1995	17	569	131
I-27 dia2	1149	18	430	34
I-28	623	206	nd	nd
I-29	939	38	1032	54
I-30	202	10	1006	44
I-31	766	64	2500	89
I-32	175	78	2500	58
I-33	2500	157	2500	394
I-34	1123	30	1775	100
I-35	300	249	632	863
I-36	372	28	2500	24
I-37	967	154	2500	156
I-38	2500	189	2500	851
I-39	1814	9	776	52

Example N°	EC ₅₀ (nM)			
	HL-60	HL60/R10	MCF-7	MCF-7 /adr
I-40 dia1	2129	248	2500	371
I-40 dia2	2500	487	2500	827
I-43 dia2	1886	20	1424	126
I-44	215	7	nd	nd
I-45	2136	17	nd	nd
I-46 dia1	2500	318	2500	544
I-46 dia2	449	10	1184	58
I-47 dia1	936	54	nd	nd
I-47 dia2	849	8	nd	nd
I-48	1991	10	nd	nd
I-49	1166	321	nd	nd
I-50 dia1	2102	259	nd	Nd
I-50 dia2	841	8	nd	nd
I-51 dia1	145	96	nd	nd
I-51 dia2	3	1	nd	nd
I-52 dia1	2500	194	nd	nd
I-52 dia2	223	24	nd	nd
I-53 dia1	1981	645	2064	462
I-53 dia2	547	305	nd	nd
I-58	1058	11	870	88
I-59	956	16	745	106

nd = non-determined

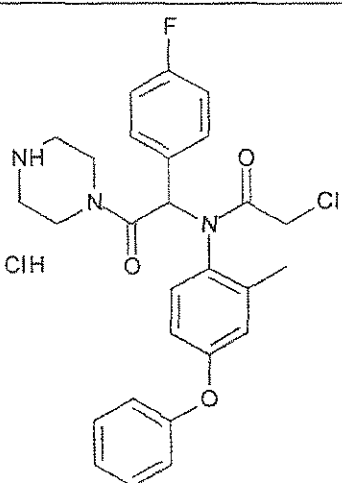
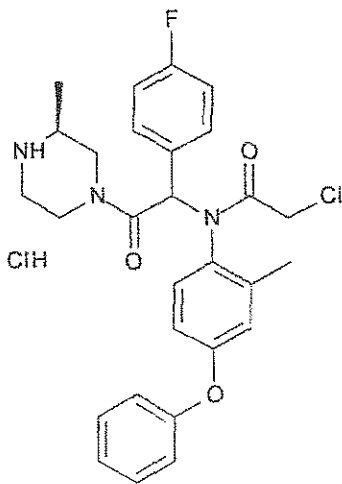
Table 2: Results obtained with other cell lines (EC₅₀ expressed in nM)

Example N°	EC ₅₀ (nM)			
	HT29	Mia PaCa2	Panc-1	SK-OV-3
I-3 dia2	1	2	1	1
I-7 dia2	8	13	5	7
I-43 dia2	10	18	7	9
I-46 dia2	6	10	4	6
I-50 dia2	9	2200	9	11

Following Tables 3 and 4 illustrate the gain in cytotoxic activity on the resistant HL60/R10 line, obtained with the compounds having a piperazine substituted at alpha position of nitrogen 4 of the piperazine compared with a non-substituted piperazine

and/or substituted at another position of the piperazine. The best cytotoxic activity is obtained with the absolute configuration (S) of this substitution.

Table 3: Results obtained with different substitutions of piperazine

Example	EC ₅₀ (nM)	
	HL-60	HL-60/R10
 <p>Comparative example</p>	1627	226
 <p>I-12</p>	2321	82

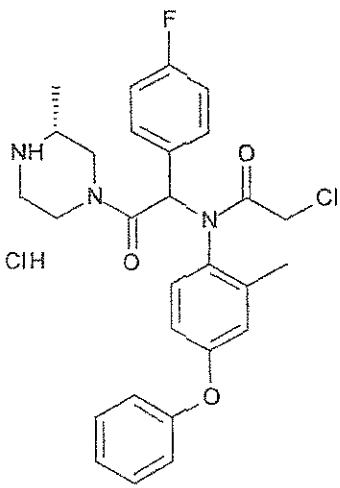
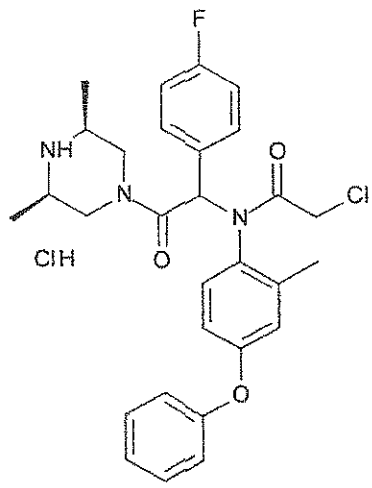
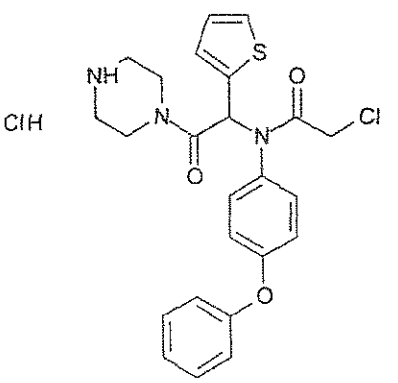
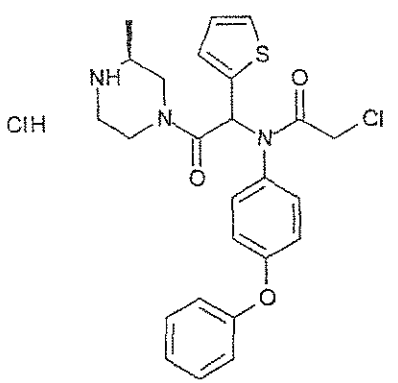
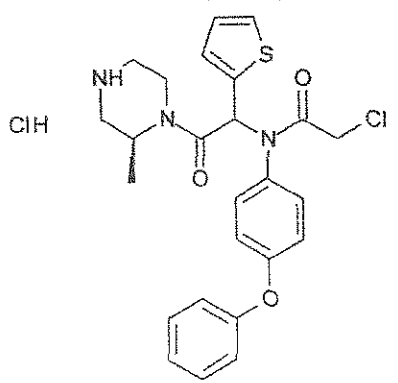
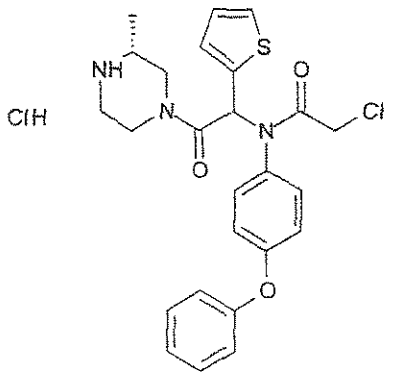
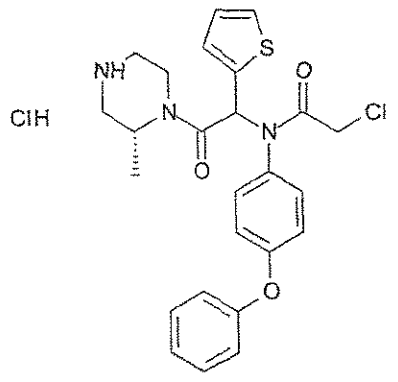
Example	EC ₅₀ (nM)	
	HL-60	HL-60/R10
<div><p>Chemical structure of compound I-14: A piperidine ring with a methyl group at the 2-position and a carbonyl group at the 1-position. The carbonyl group is part of an amide linkage to a central carbon atom. This central carbon atom is also bonded to a 4-fluorophenyl group, a 4-(benzyloxy)-2-methylphenyl group, and a carbonyl group. The carbonyl group is part of an amide linkage to a 2-chloroethyl group. The piperidine ring is shown in a chair conformation with the methyl group at the 2-position and the carbonyl group at the 1-position. The amide linkage is at the 1-position of the piperidine ring.</p></div> <p>I-14</p>	1989	88
<div><p>Chemical structure of compound I-13: A piperidine ring with a methyl group at the 2-position and a carbonyl group at the 1-position. The carbonyl group is part of an amide linkage to a central carbon atom. This central carbon atom is also bonded to a 4-fluorophenyl group, a 4-(benzyloxy)-2-methylphenyl group, and a carbonyl group. The carbonyl group is part of an amide linkage to a 2-chloroethyl group. The piperidine ring is shown in a chair conformation with the methyl group at the 2-position and the carbonyl group at the 1-position. The amide linkage is at the 1-position of the piperidine ring.</p></div> <p>I-13</p>	1848	95

Table 4: Results obtained with different substitutions of piperazine

Example	EC ₅₀ (nM)	
	HL-60	HL-60/R10
<p>ClH</p> 	579	21
Comparative example		
<p>ClH</p> 	1058	11
I-58		
<p>ClH</p> 	662	65
Comparative example		

Example	EC ₅₀ (nM)	
	HL-60	HL-60/R10
 I-59	966	16
 Comparative example	311	38

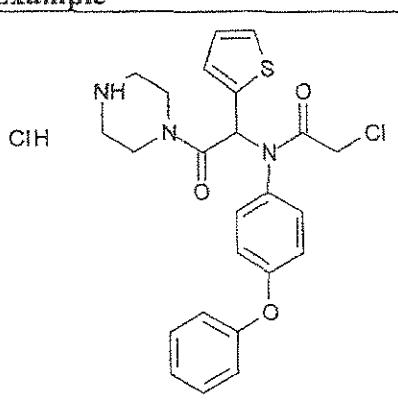
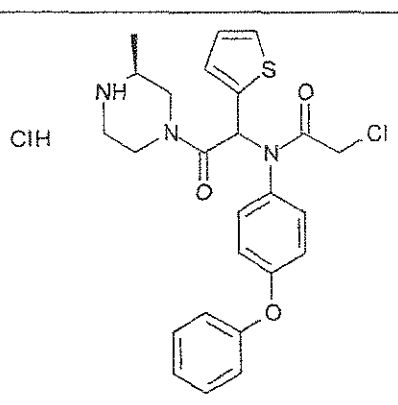
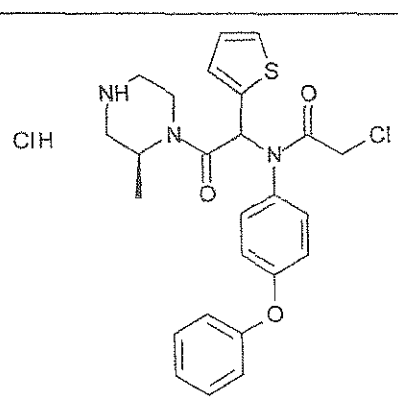
2) Determination of aqueous solubility

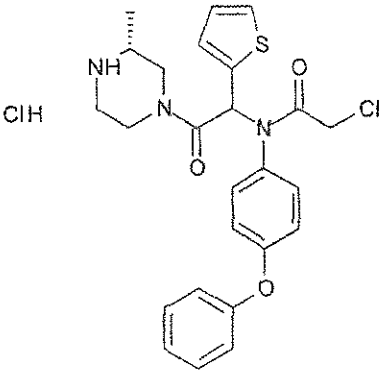
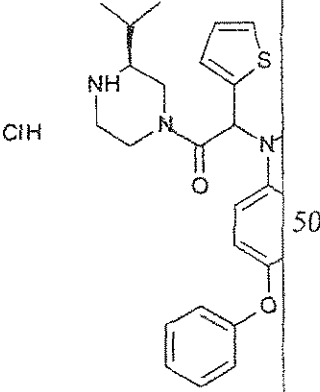
Aqueous solubility is a major physicochemical parameter for improving the ADME properties (Absorption, Distribution, Metabolism and Excretion) in a molecule (Drug-like properties: concepts, structure design and methods, Edward Harvel Kerns, Li Di; Academic Press, 2008).

The aqueous solubility of each compound was measured at pH 7.4. It was measured using HPLC on the supernatants obtained by centrifugation after saturation of the media with excess compound after an agitation time of 24 h and at a temperature of 20°C. The preparation and treatment of the samples was robotized.

Table 5 shows the gain in aqueous solubility obtained for a compound of the invention I-58 compared with a non-substituted piperazine or substituted at another position.

Table 5: Aqueous solubility obtained with different piperazine substitutions.

Example	Solubility ($\mu\text{g/mL}$)
<p>ClH</p>  <p>68</p>	
<p>Comparative example</p>	
<p>ClH</p>  <p>203</p>	
<p>I-58</p>	
<p>ClH</p>  <p>105</p>	
<p>Comparative example</p>	

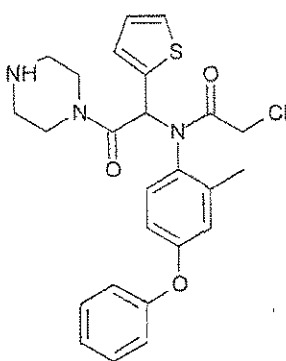
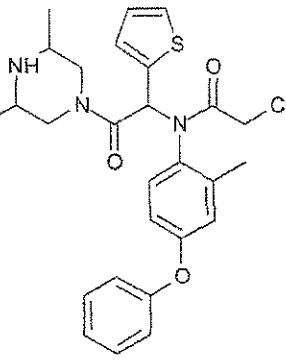
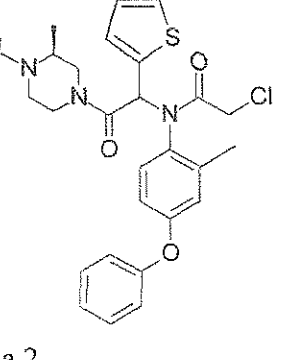
Example	Solubility (µg/mL)
<div data-bbox="323 360 703 730">  </div> <div data-bbox="304 763 363 797">I-59</div>	<div data-bbox="1190 555 1238 589">152</div>
<div data-bbox="1086 833 1407 1223">  </div> <div data-bbox="1070 1256 1129 1290">I-62</div>	<div data-bbox="1374 1037 1407 1070">50</div>

3) Pharmacokinetic parameters in mice

The pharmacokinetic behaviour of compounds is a pre-requisite for reasonable use thereof in *in vivo* experimentation. The compounds were given in DMSO solution via intravenous route (IV) or oral route (PO) to balb/c mice. Blood samples were taken at times ranging from 5 minutes to 6 hours, the plasmas were collected and the concentration of the compounds in each sample was assayed by LC/MS/MS. The data obtained allowed the plotting of time-concentration curves and determination of fundamental parameters such as plasma half-life of the compound ($T_{1/2}$), area under curve at a given time (AUCt) and the maximum concentration obtained (C_{max}). Table 6 shows the gain contributed by piperazine substitution on the pharmacokinetic parameters of the compounds administered via intravenous route at a dose of 10 mg/kg.

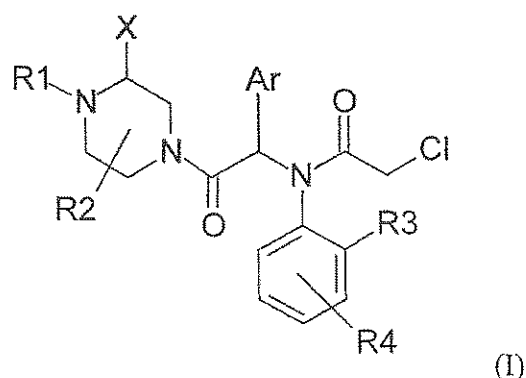
Figure 1 gives the time - plasma concentration curves in a mouse after administration of I-43 dia2 via IV and PO route. Compound I-43 dia2 therefore shows good bioavailability in a mouse, in particular via oral route.

Table 6: Pharmacokinetic parameters obtained with various piperazine substitutions.

Example	C _{max} (ng/mL)	AUC _t (ng/mL*h)	AUC _{inf} (ng/mL*h)	t _{1/2} (h)
ClH 	1469.50	1278.25	1321.68	1.38
Comparative example				
ClH 	3797.6	3287.08	3837.61	2.64
I-63				
ClH 	1424.37	1677.94	2057.38	2.47
I-43 dia 2				

CLAIMS

1. A compound of following general formula (I):

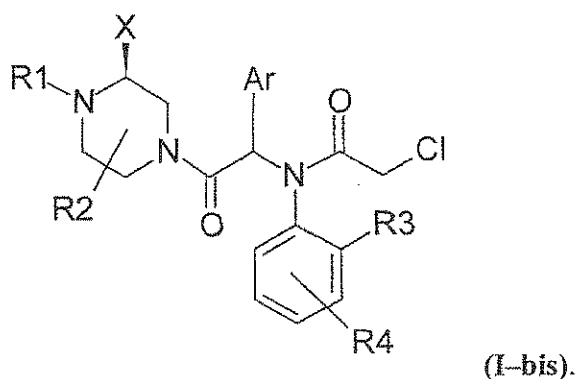


and the pharmaceutically acceptable salts thereof, its stereoisomers or mixtures of stereoisomers in any proportion, in particular an enantiomer mixture, and particularly a *racemic mixture*,

where:

- X is a (C₁-C₆)alkyl, phenyl, benzyl, C(O)OR₅ or C(O)NHR₅ group;
- R₁ is a hydrogen atom or a C(O)H, C(O)R₆ or C(O)OR₆ group;
- R₂ is a hydrogen atom or a (C₁-C₆)alkyl group;
or R₂ together with R₁ or X forms a saturated hydrocarbon chain to form a 5- or 6-membered ring, in particular a 5-membered ring;
- R₃ is a hydrogen or halogen atom or a (C₁-C₆)alkyl or (C₁-C₆)alkoxy group;
- R₄ is a hydrogen or halogen atom, CN, NO₂, or a (C₁-C₆)alkyl, (C₁-C₆)alkoxy, aryloxy, benzyloxy or heteroaryloxy group, the said group optionally being substituted by one or more halogen atoms;
- Ar is a thiophenyl group or a phenyl group optionally substituted by one or more halogen atoms; and
- R₅ and R₆ independently of one another are a (C₁-C₆)alkyl, aryl-(C₁-C₆)alkyl or aryl group, the said group optionally being substituted by one or more halogen atoms.

2. The compound according to claim 1, characterized in that it meets the following formula (I-bis):



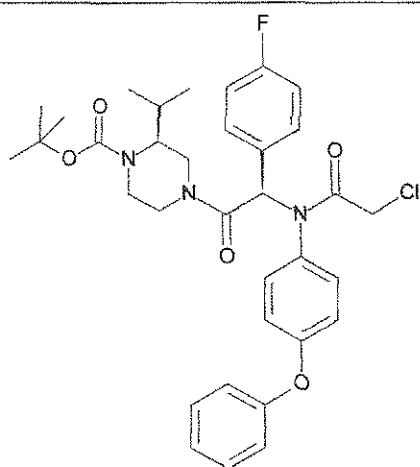
3. The compound according to any one of claims 1 and 2, characterized in that Ar is a thiophenyl group or a phenyl group substituted by one or more fluorine atoms such as 4-fluoro-phenyl.

4. The compound according to any one of claims 1 to 3, characterized in that R4 is a hydrogen or halogen atom or a (C₁-C₆)alkyl, (C₁-C₆)alkoxy or aryloxy group, the said group optionally being substituted by one or more halogen atoms, fluorine in particular.

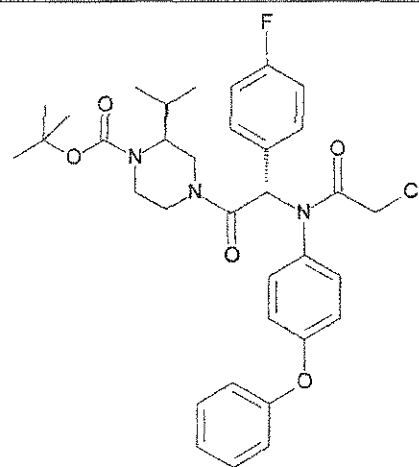
5. The compound according to any one of claims 1 to 4, characterized in that R3 is a hydrogen atom or a (C₁-C₆)alkyl group e.g. methyl.

6. The compound according to any one of claims 1 to 5, characterized in that X is a (C₁-C₆)alkyl, phenyl or benzyl group; R1 and R2 are a hydrogen atom; R3 is a hydrogen atom or a (C₁-C₆)alkyl group, in particular (C₁-C₃)alkyl; R4 is a halogen atom or a (C₁-C₆)alkyl, (C₁-C₆)alkoxy, aryloxy or benzyloxy group, the said group optionally being substituted by one or more halogen atoms; Ar is a thiophenyl group or a phenyl group optionally substituted by a fluorine atom such as 4-fluoro-phenyl; and R5 and R6 independently of one another are a (C₁-C₆)alkyl, aryl-(C₁-C₆)alkyl or aryl group, the said group optionally being substituted by one or more fluorine atoms.

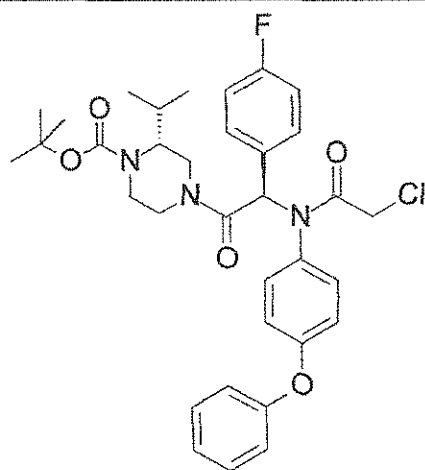
7. The compound according to claim 1, characterized in that the compound is selected from among:



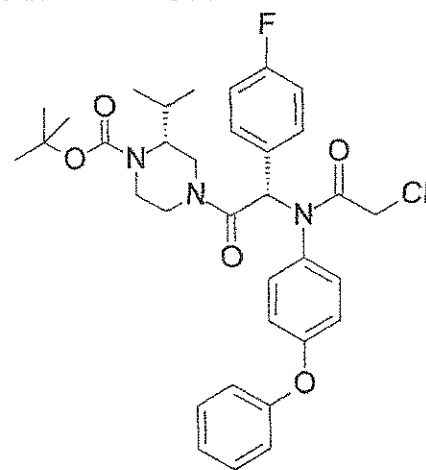
I-1a



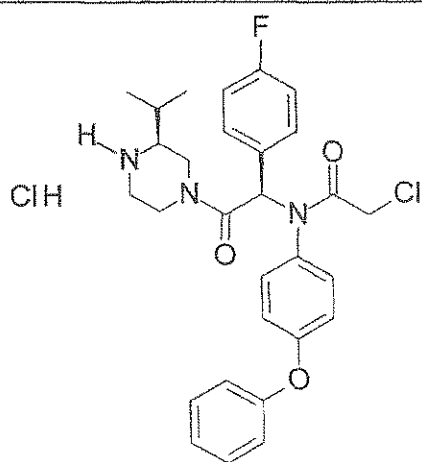
I-1b



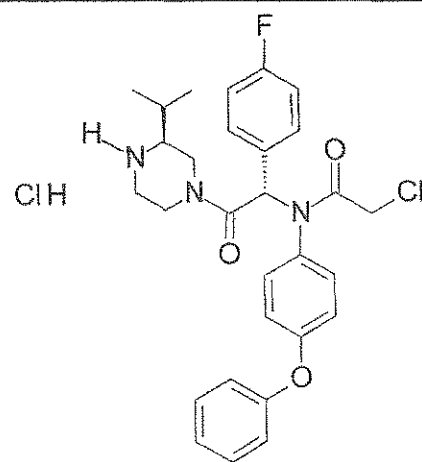
I-2a



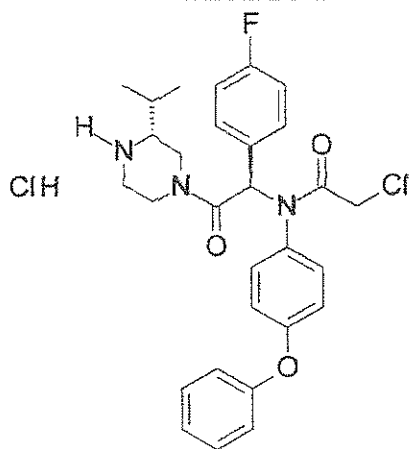
I-2b



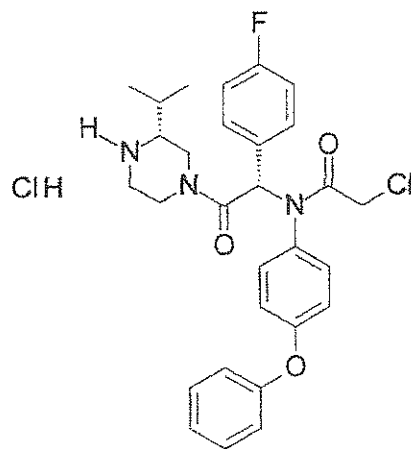
I-3a



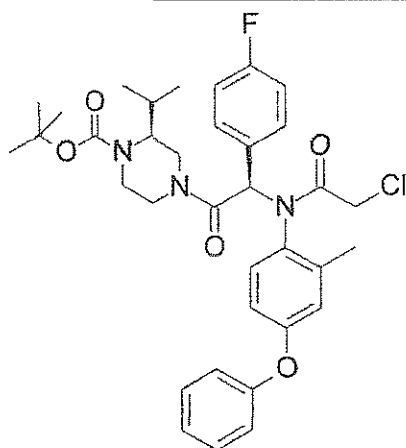
I-3b



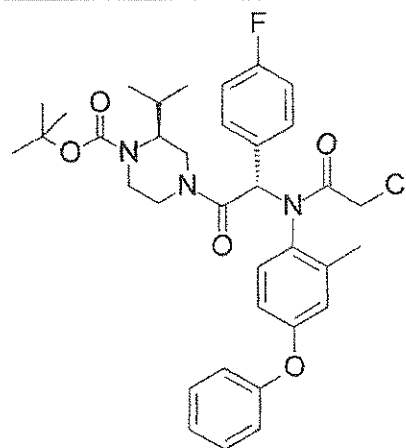
I-4a



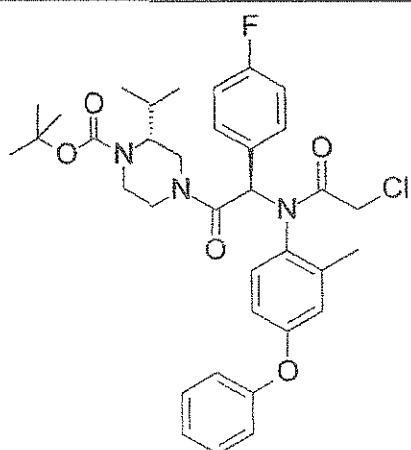
I-4b



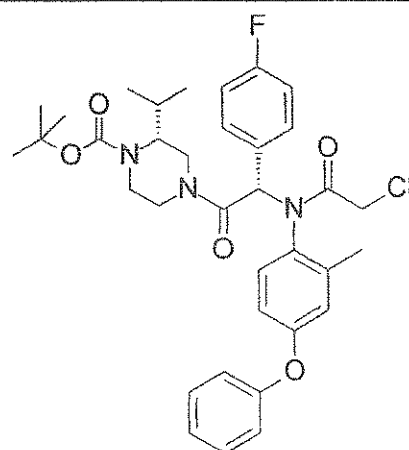
I-5a



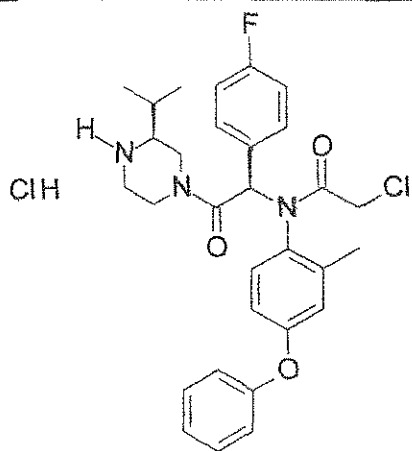
I-5b



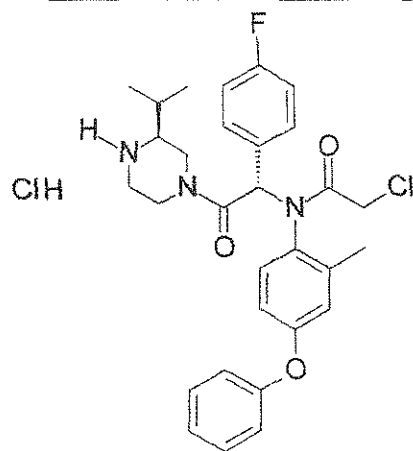
I-6a



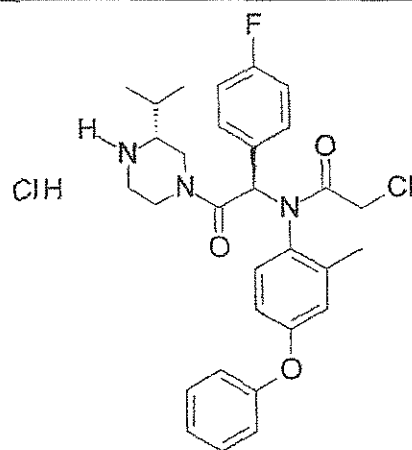
I-6b



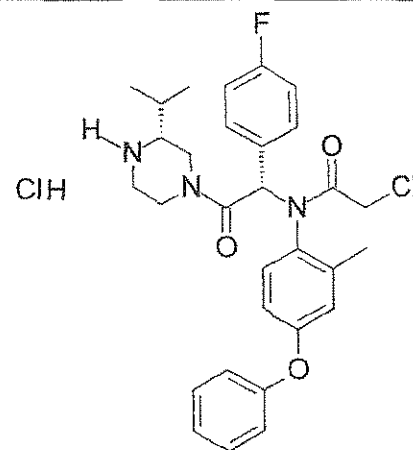
I-7a



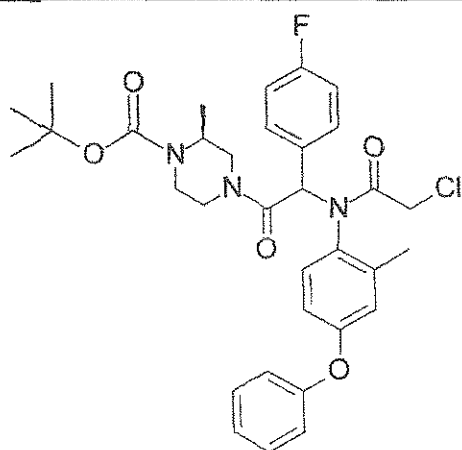
I-7b



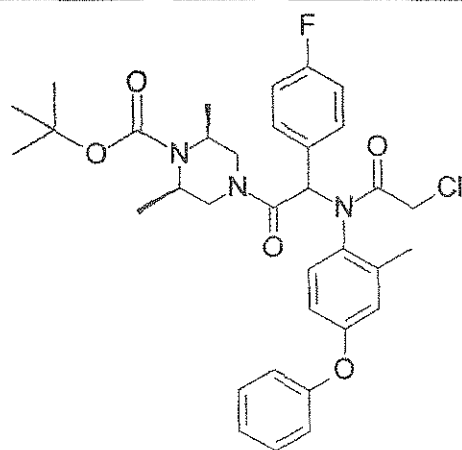
I-8a



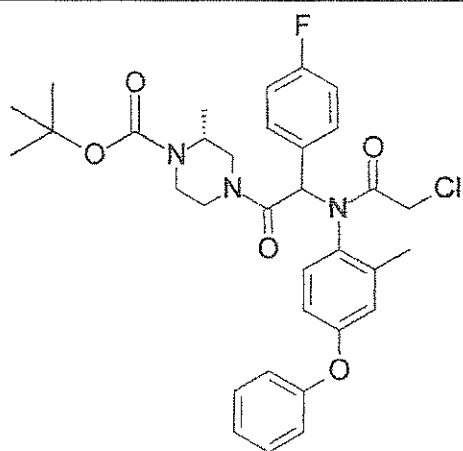
I-8b



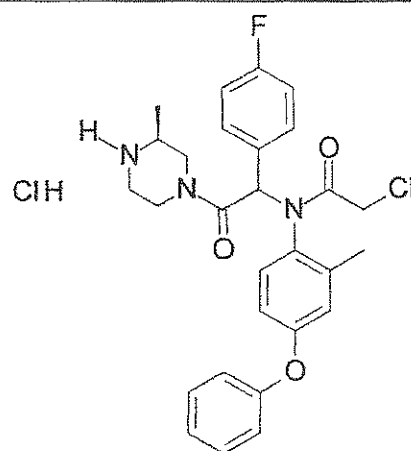
I-9



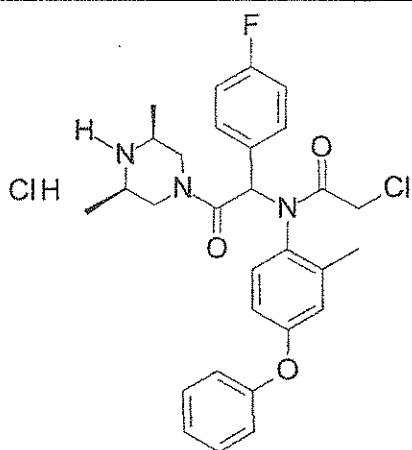
I-10



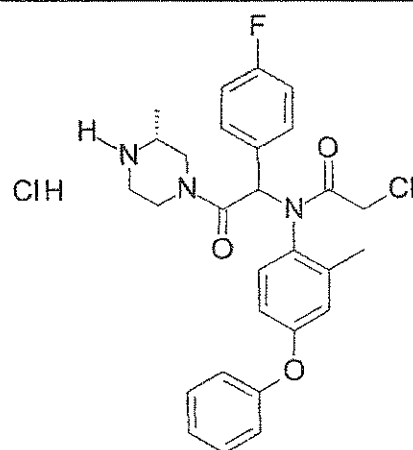
I-11



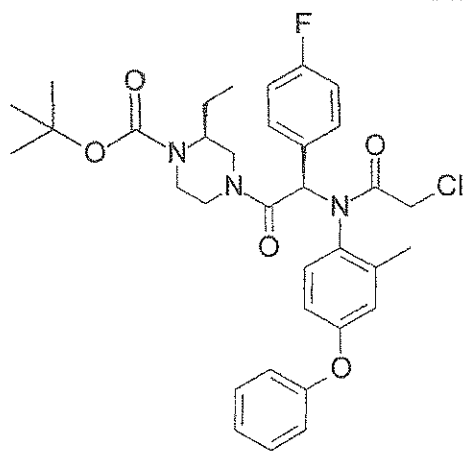
I-12



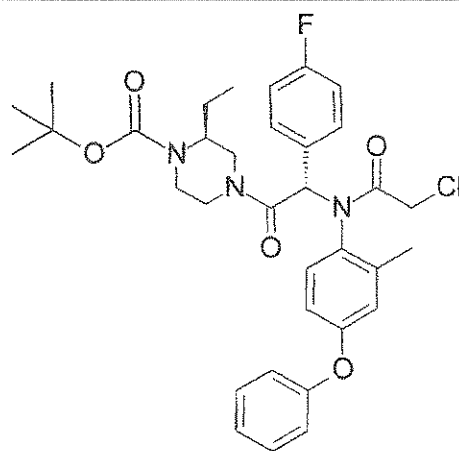
I-13



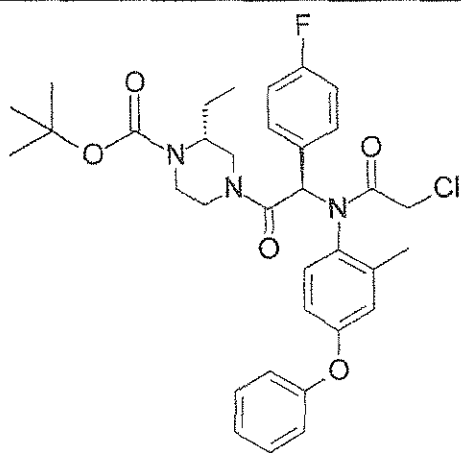
I-14



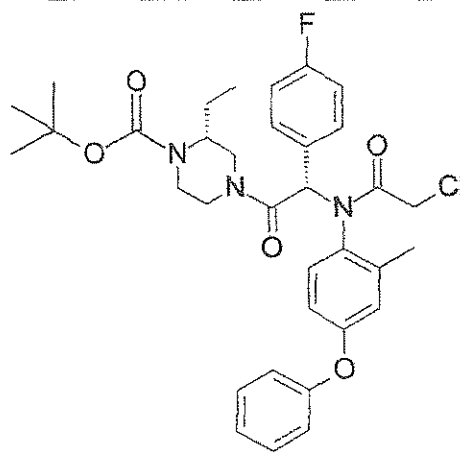
I-15a



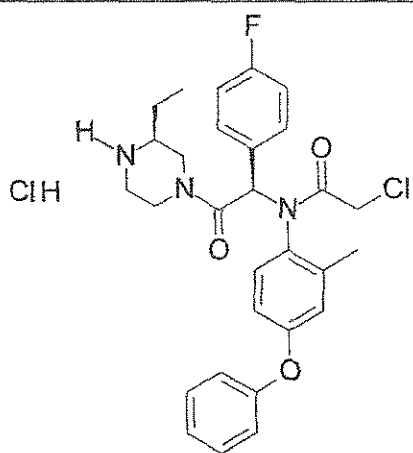
I-15b



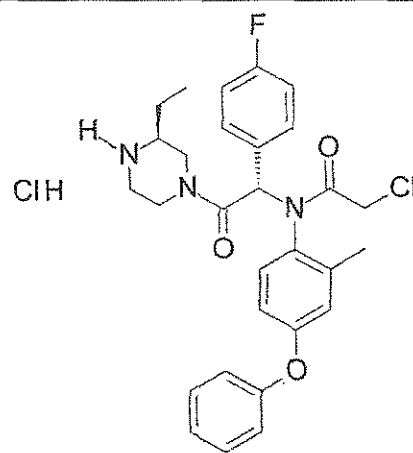
I-16a



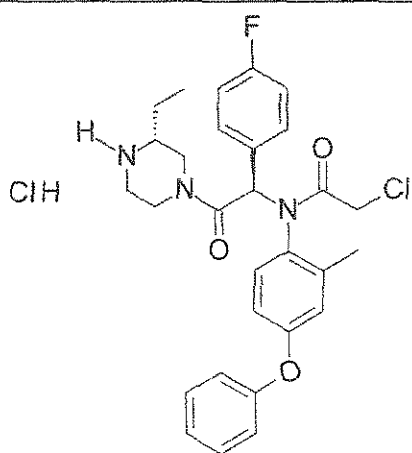
I-16b



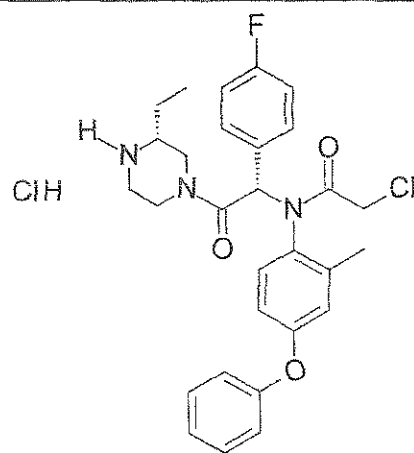
I-17a



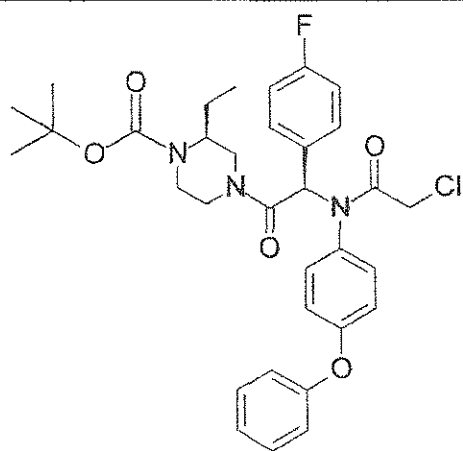
I-17b



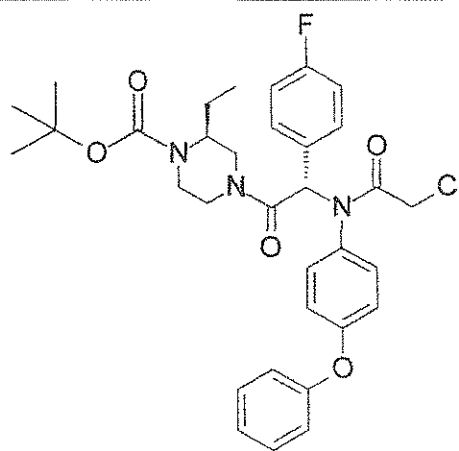
I-18a



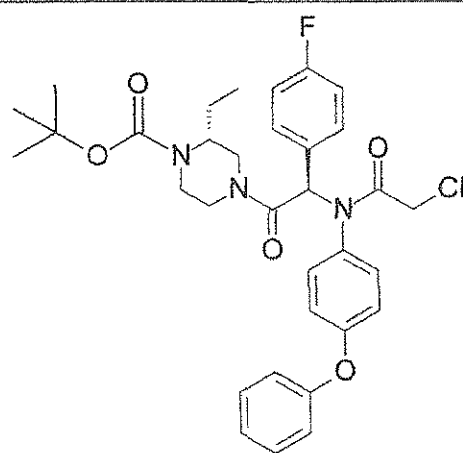
I-18b



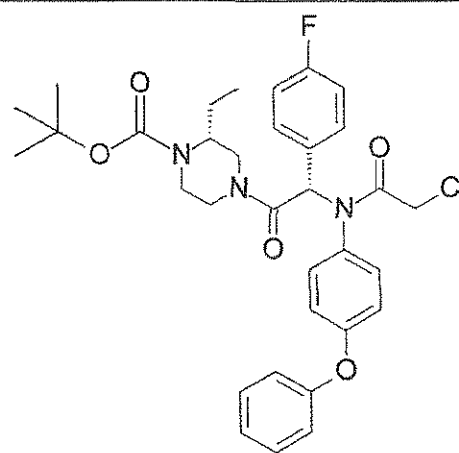
I-19a



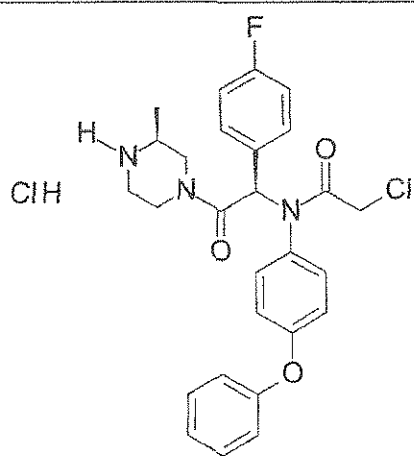
I-19b



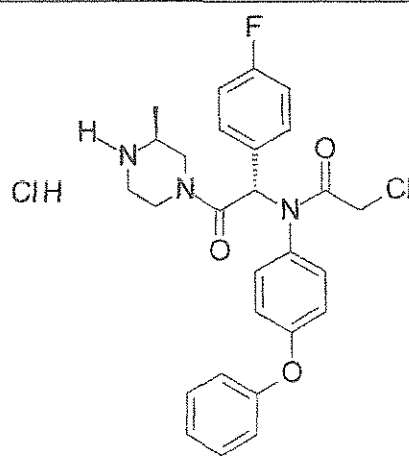
I-20a



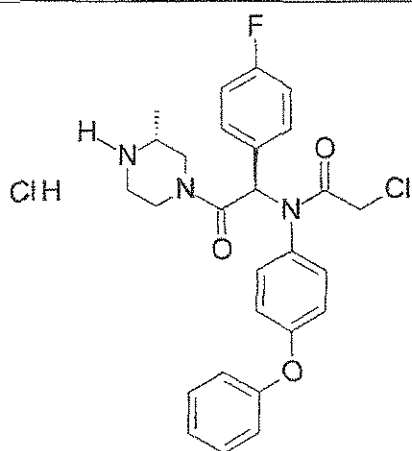
I-20b



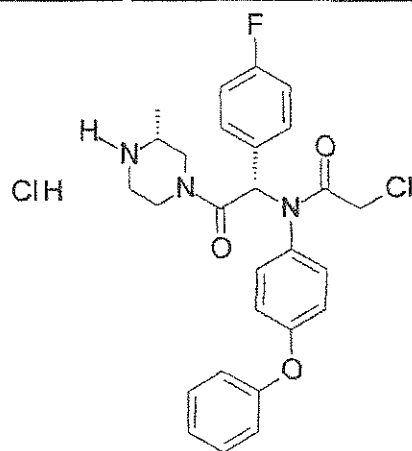
I-21a



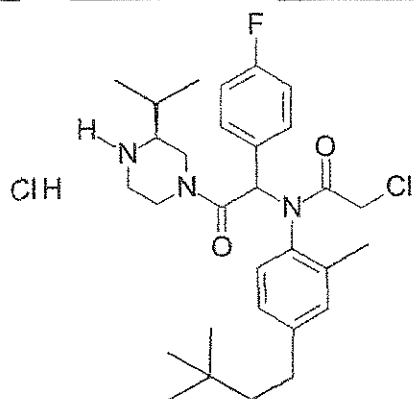
I-21b



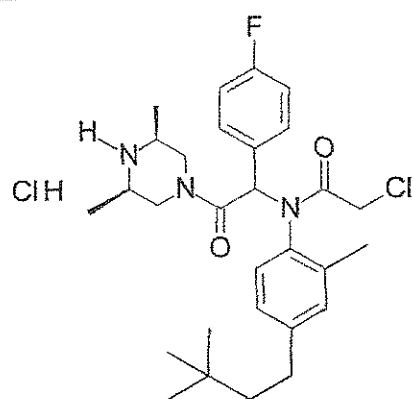
I-22a



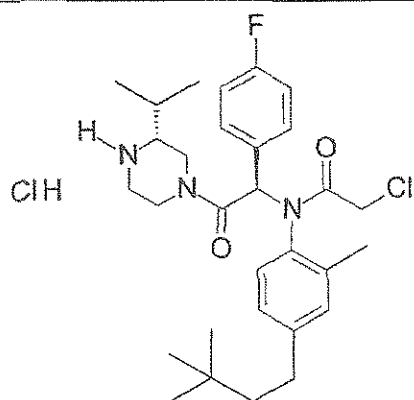
I-22b



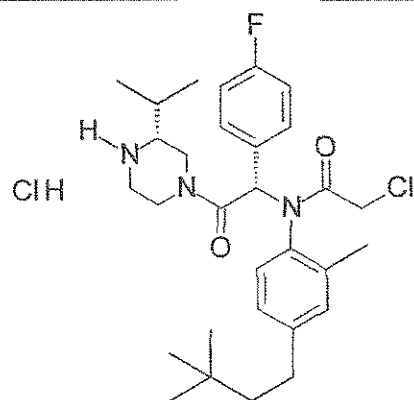
I-23



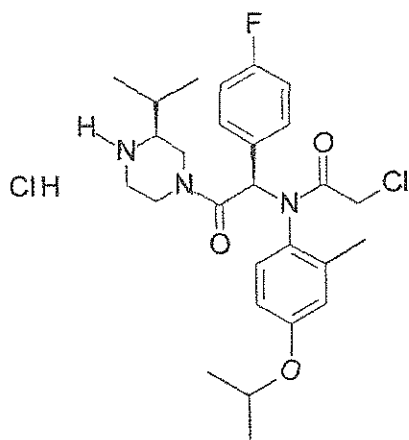
I-24



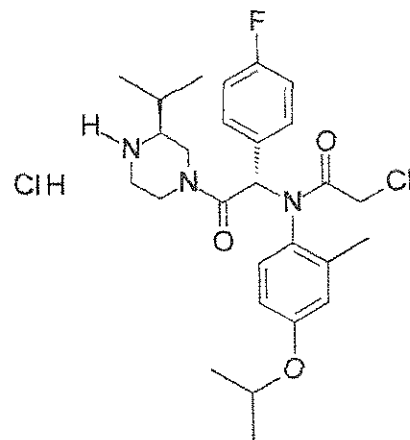
I-25a



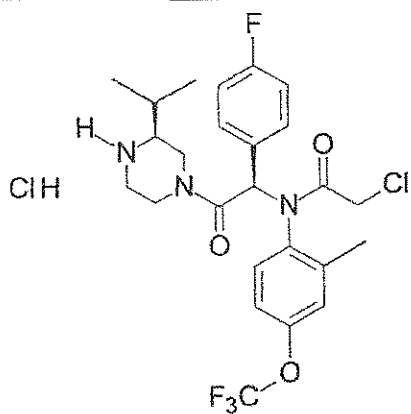
I-25b



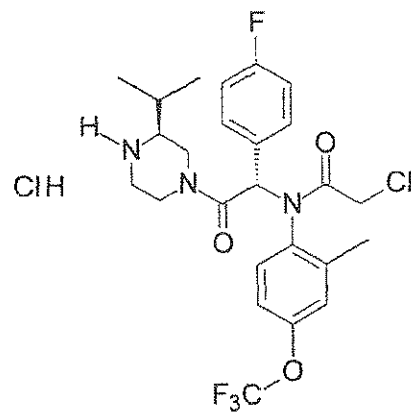
I-26a



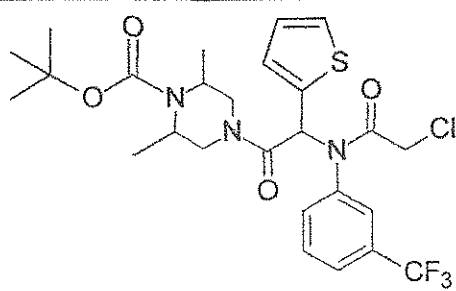
I-26b



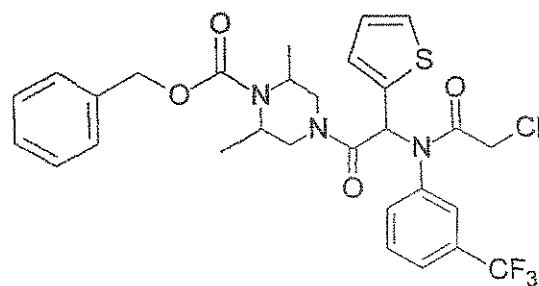
I-27a



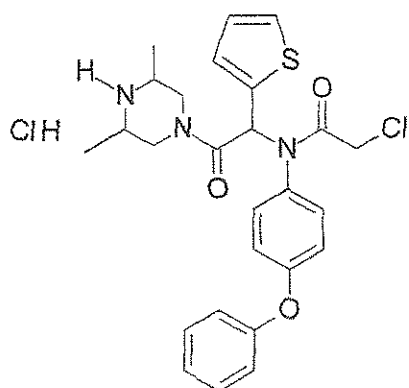
I-27b



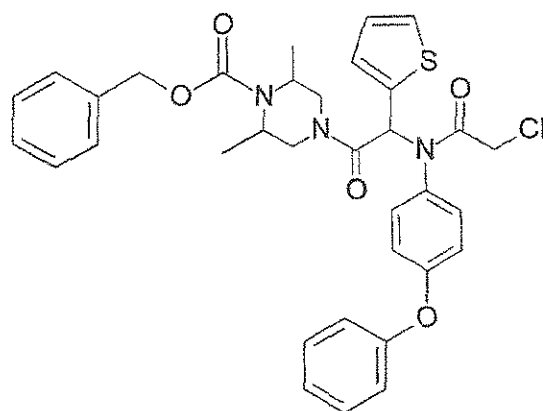
I-28



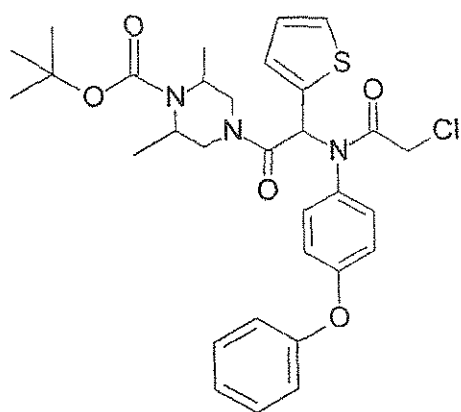
I-29



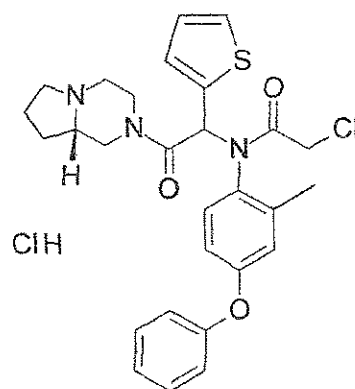
I-30



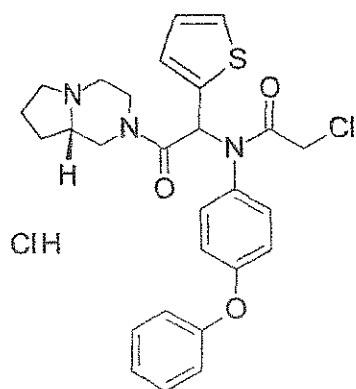
I-31



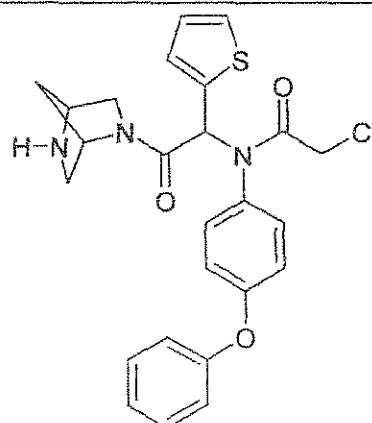
I-32



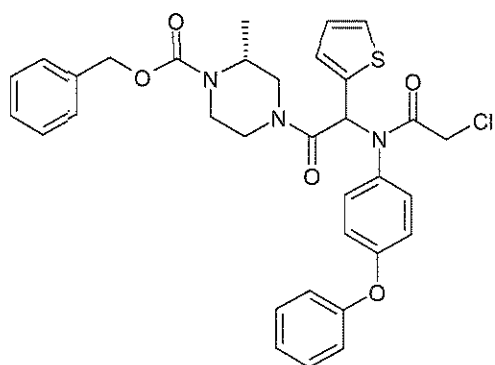
I-33



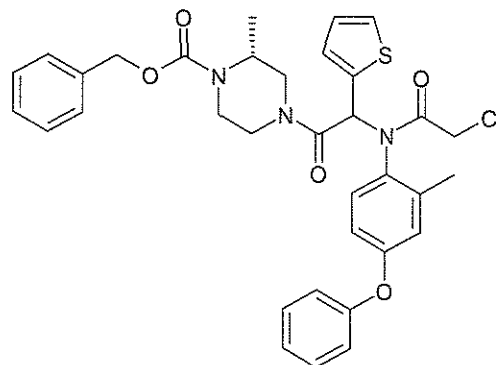
I-34



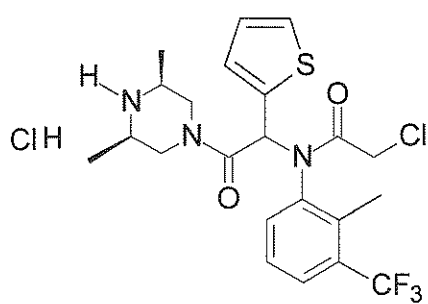
I-35



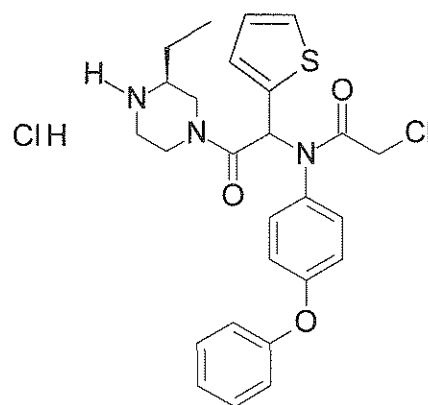
I-36



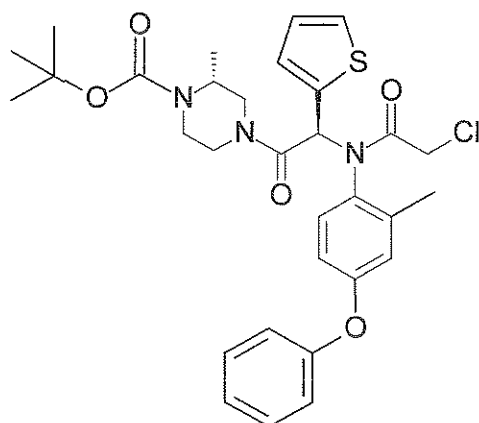
I-37



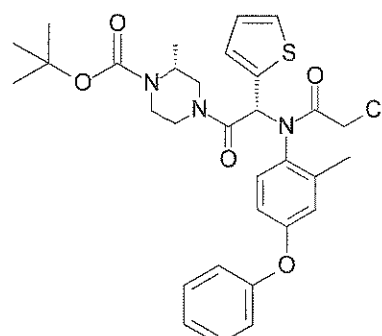
I-38



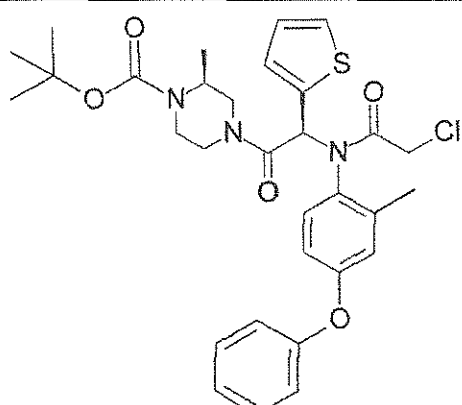
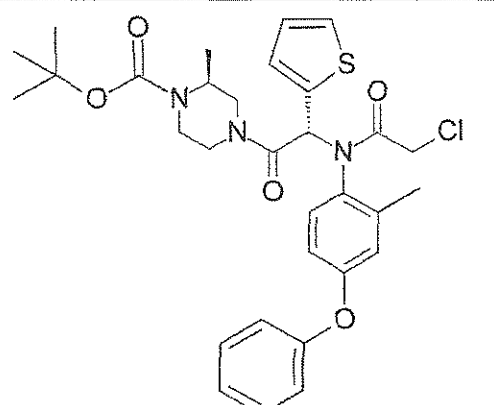
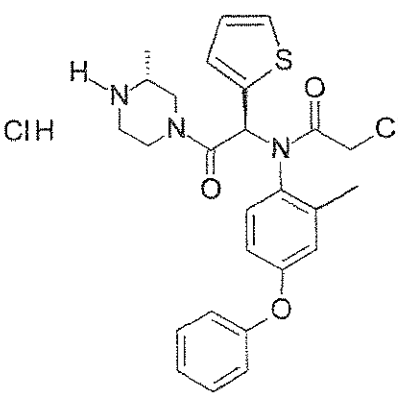
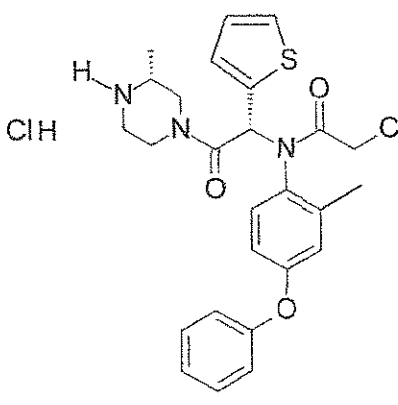
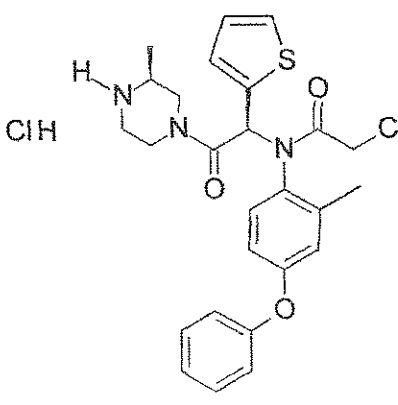
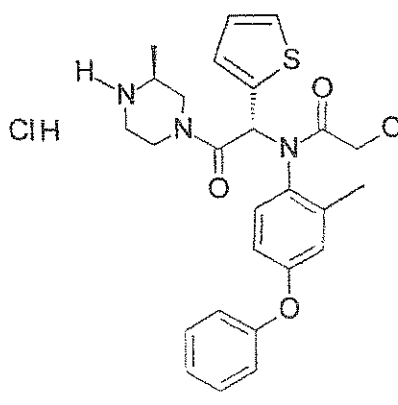
I-39

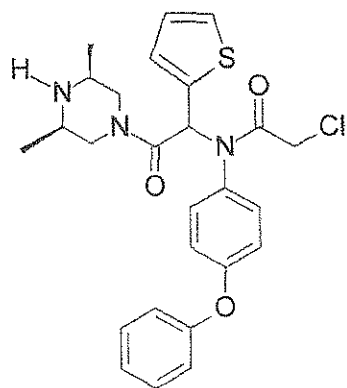


I-40a

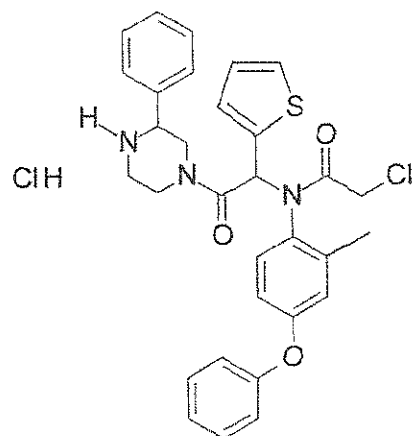


I-40b

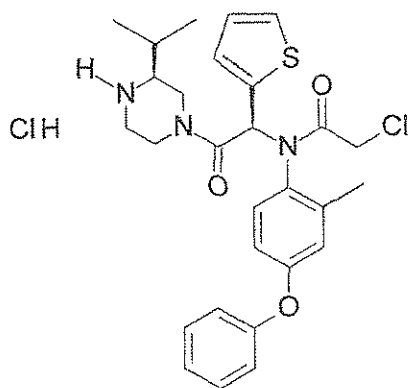
 <p>I-41a</p>	 <p>I-41b</p>
 <p>I-42a</p>	 <p>I-42b</p>
 <p>I-43a</p>	 <p>I-43b</p>



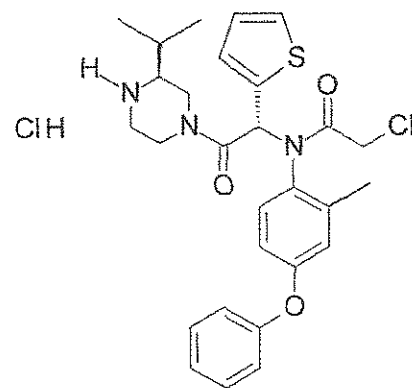
I-44



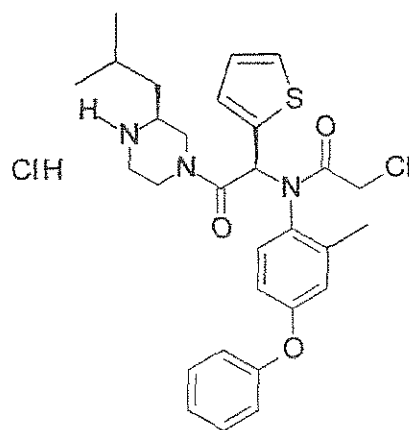
I-45



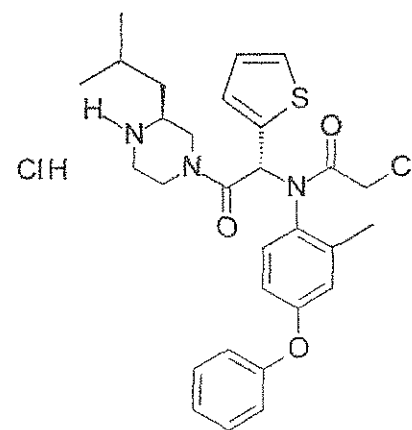
I-46a



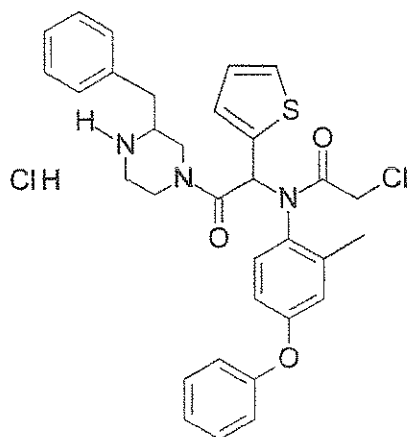
I-46b



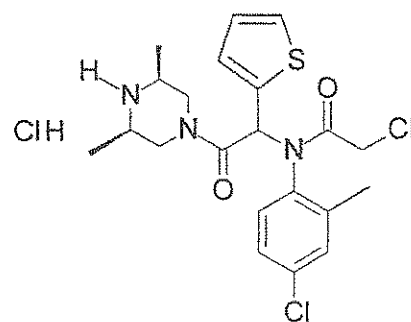
I-47a



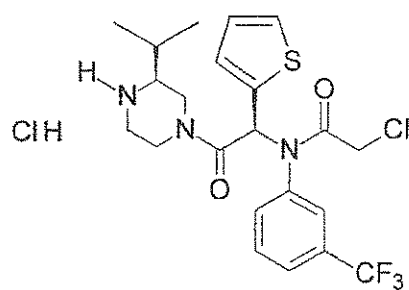
I-47b



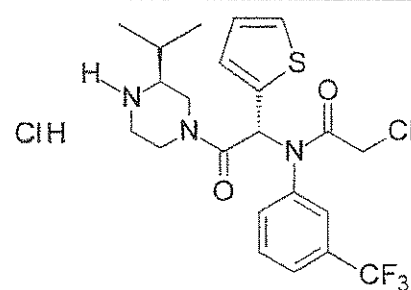
I-48



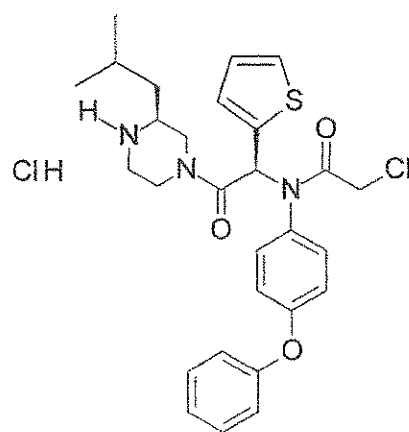
I-49



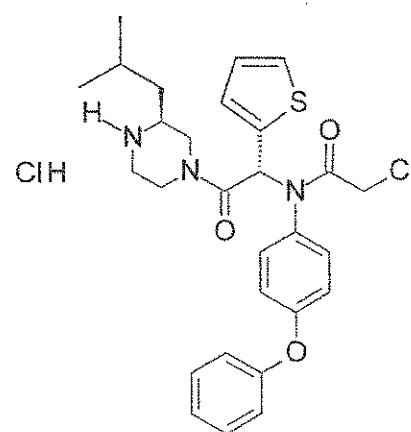
I-50a



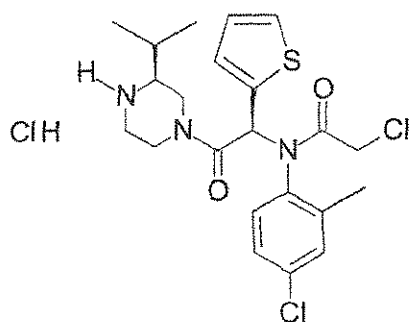
I-50b



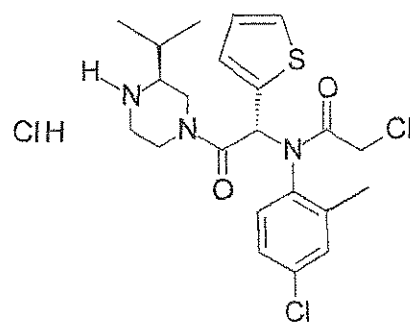
I-51a



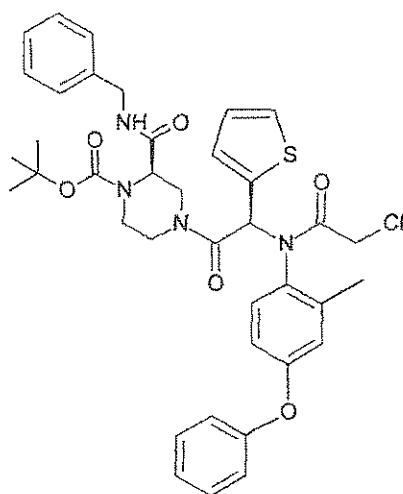
I-51b



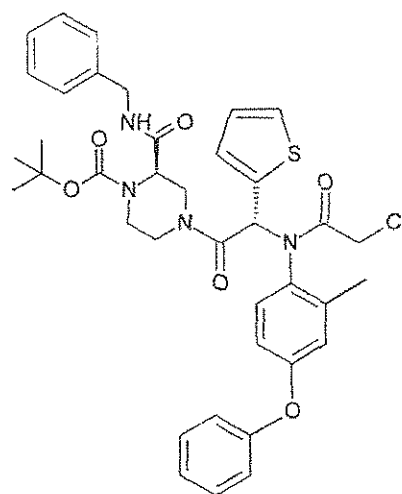
I-52a



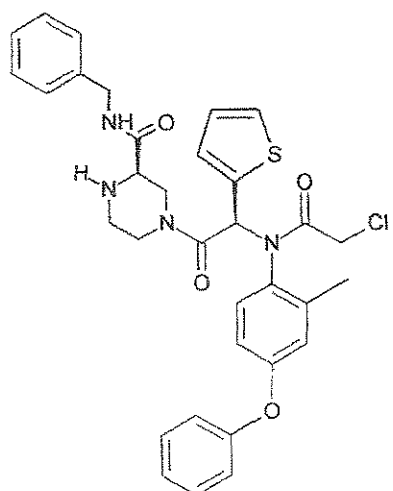
I-52b



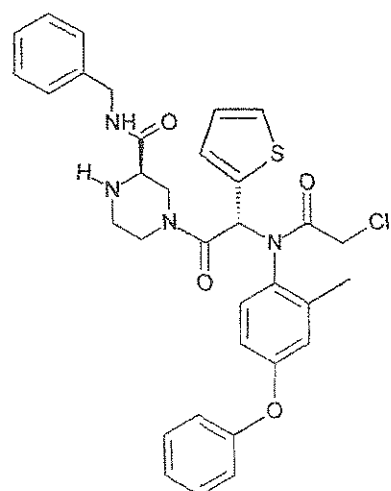
I-53a



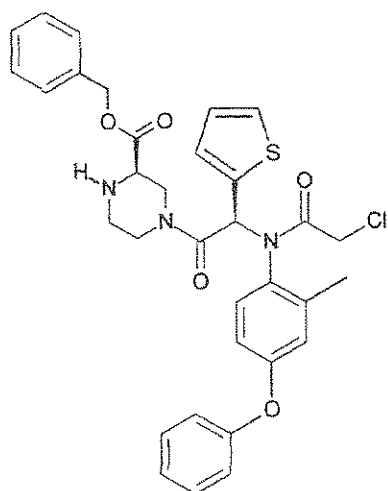
I-53b



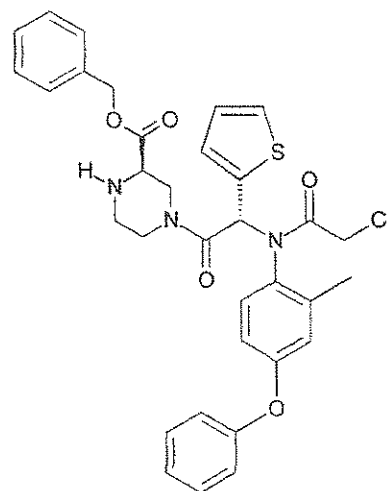
I-54a



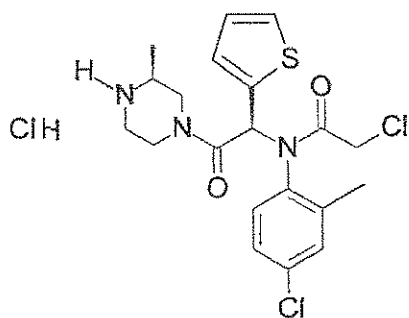
I-54b



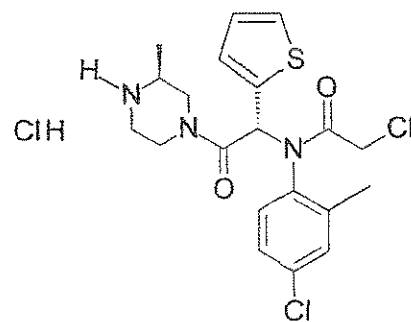
I-55a



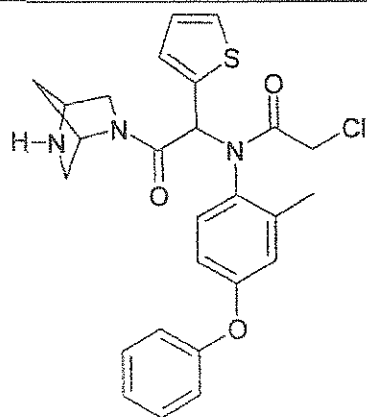
I-55b



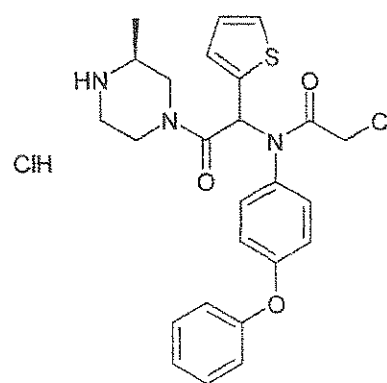
I-56a



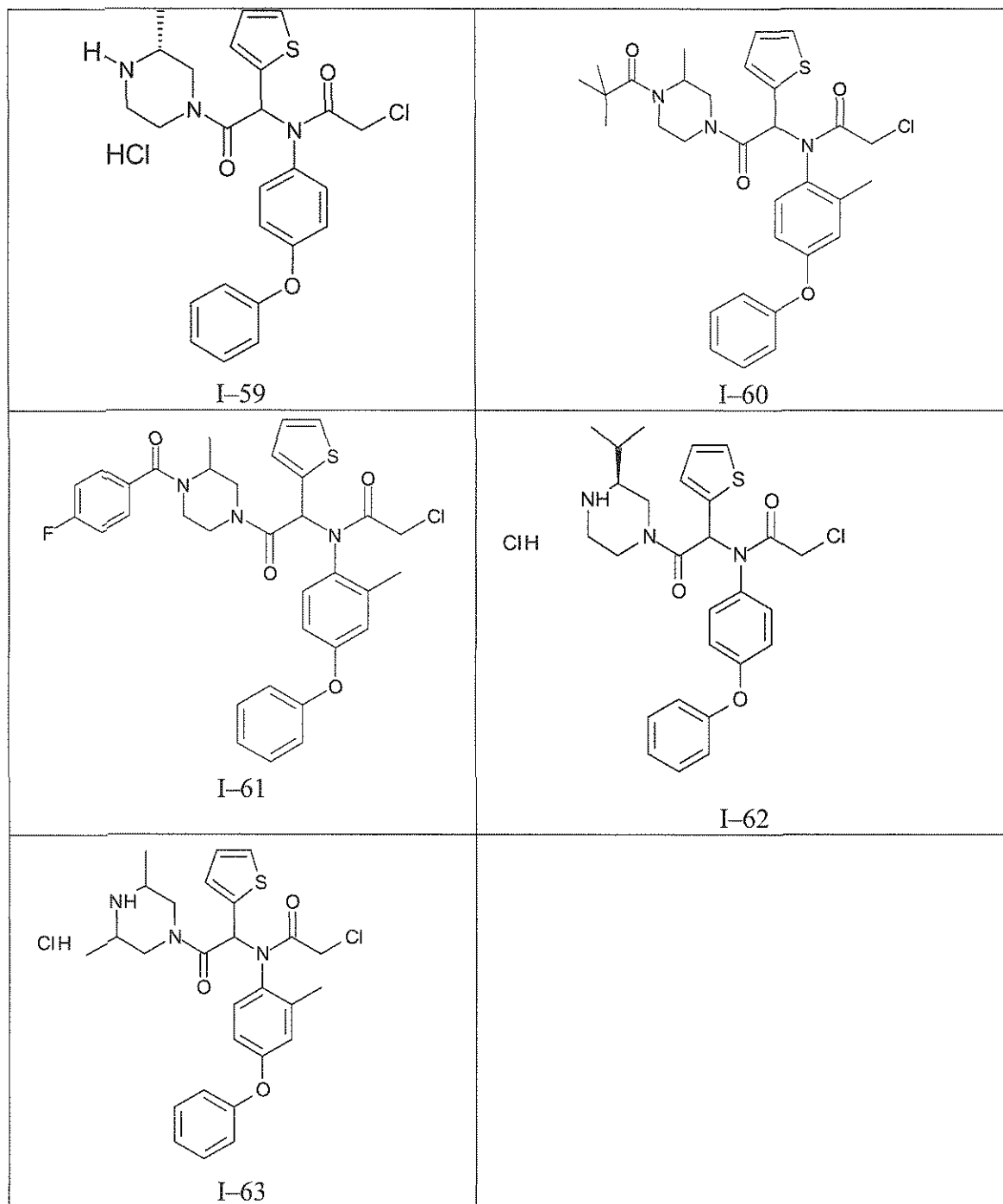
I-56b



I-57



I-58



8. A compound of general formula (I) according to any one of claims 1 to 7 for use as a drug.

9. Use of a compound of general formula (I) according to any one of claims 1 to 7 in the manufacture of a medicament for the treatment or prevention of chemotherapy-resistant cancer.

10. A pharmaceutical composition comprising at least one compound of general formula (I) according to any one of claims 1 to 7, in association with one or more pharmaceutically acceptable excipients.

11. The pharmaceutical composition according to claim 10, characterized in that it comprises at least one other active ingredient such as an anticancer agent.

12. The pharmaceutical composition according to claim 11, characterized in that the active ingredient(s) are chosen from among cisplatin and its derivatives such as carboplatin and oxalyplatin; taxanes such as taxol, taxotere, paclitaxel and docetaxel; vinca alkaloids such as vinblastine, vincristine and vinorelbine; purine analogues such as mercaptopurine, thioguanine, pentostatin and 2-chlorodeoxyadenosine; topoisomerase I inhibitors such as camptothecin compounds e.g. irinotecan and topotecan; topoisomerase II inhibitors such as epipodophyllotoxin, podophyllotoxin and the derivatives thereof such as etoposide and teniposide; anti-tumour nucleoside derivatives such as 5-fluorouracil, leucovorin, gemcitabine or capecitabine; alkylating agents such as nitrogen mustards e.g. cyclophosphamide, mechlorethamine, chlorambucil and melphalan, nitroso-ureas such as carmustin, lomustin and streptozocin, alkylsulfonates such as busulfan, ethylenimines and methylmelamines such as thiotepa and hexamethylmelamine, and tetrazines such as dacarbazine; derivatives of anti-tumour anthracyclines such as daunorubicin, adriamycin, doxil, idarubicin and mitoxantrone; molecules targeting the IGF-I receptor such as picropodophyllin; tetracarcin derivatives such as tetrocarcin A; corticosteroids such as prednisone; antibodies such as trastuzumab (anti-HER2 antibody), rituximab (anti-CD20 antibody), gemtuzumab, cetuximab, pertuzumab and bevacizumab; antagonists or selective modulators of oestrogen receptors such as tamoxifen, fulvestrant, toremifene, droloxifene, faslodex and raloxifene, aromatase inhibitors such as exemestane, anastrozole, letrozole and vorozole; differentiating agents such as retinoids e.g. retinoic acid and vitamin D and agents blocking the metabolism of retinoic acid such as accutane; DNA methyl-transferase inhibitors such as azacytidine and decitabine; antifolates such as perimetrexed disodium; antibiotics such as antinomycin D, bleomycin, mitomycin C, actinomycin D, carminomycin, daunomycin and plicamycin;

antimetabolites such as chlofarabine, aminopterin, cytosine arabinoside, floxuridine and methotrexate; apoptosis-inducing agents and anti-angiogenic agents of Bcl-2 inhibitors such as YC 137, BH 312, ABT 737, gossypol, HA 14-1, TW 37 and decanoic acid; agents binding to tubulin such as combrestatin, colchicine derivatives and nocodazole; kinase inhibitors such as flavoperidol, imatinib mesylate, erlotinib and gefitinib; farnesyl transferase inhibitors such as tipifarnib; histone-deacetylase inhibitors such as sodium butyrate, suberoylanilide hydroxamic acid, depsipeptide, NVP- LAQ824, R306465, JNJ-26481585 and trichostatin A; inhibitors of the ubiquitin-proteasome system such as MLN .41, bortezomib and yondelis; and telomerase inhibitors such as telomestatin.

13. A pharmaceutical composition comprising:

- (i) at least one formula (I) compound according to any one of claims 1 to 7; and
- (ii) at least one other active ingredient such as an anticancer agent,

as combination products for simultaneous, separate or time-staggered use thereof.

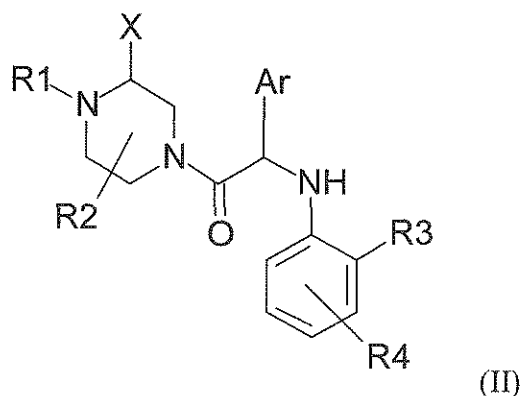
14. The pharmaceutical composition according to claim 13, characterized in that the active ingredient(s) are selected from among cisplatin and the derivatives thereof such as carboplatin and oxalyplatin; taxanes such as taxol, taxotere, paclitaxel and docetaxel; vinca alkaloids such as vinblastine, vincristine and vinorelbine; purine analogues such as mercaptopurine, thioguanine, pentostatin and 2-chlorodeoxyadenosine; topoisomerase I inhibitors such as camptothecin compounds e.g. irinotecan and topotecan; topoisomerase II inhibitors such as epipodophyllotoxin, podophyllotoxin and the derivatives thereof such as etoposide and teniposide; anti-tumour nucleoside derivatives such as 5-fluorouracil, leucovorin, gemcitabine or capecitabine; alkylating agents such as nitrogen mustards e.g. cyclophosphamide, mechlorethamine, chlorambucil and melphalan, nitroso-ureas such as carmustin, lomustin and streptozocin, alkylsulfonates such as busulfan, ethylenimines and methylmelamines such as thiotepa and hexamethylmelamine, and tetrazines such as dacarbazine; derivatives of anti-tumour anthracyclines such as daunorubicin, adriamycin, doxil, idarubicin and mitoxantrone; molecules targeting the IGF-I receptor

such as picropodophyllin; tetracarcin derivatives such as tetrocarcin A; corticosteroids such as prednisone; antibodies such as trastuzumab (anti-HER2 antibody), rituximab (anti-CD20 antibody), gemtuzamab, cetuximab, pertuzumab and bevacizumab; antagonists or selective modulators of oestrogen receptors such as tamoxifen, fulvestrant, toremifene, droloxifene, faslodex and raloxifene; aromatase inhibitors such as exemestane, anastrozole, letrozole and vorozole; differentiating agents such as retinoids e.g. retinoic acid and vitamin D and agents blocking the metabolism of retinoic acid such as accutane; DNA methyl-transferase inhibitors such as azacytidine and decitabine; antifolates such as perimetrex disodium; antibiotics such as actinomycin D, bleomycin, mitomycin C, actinomycin D, carminomycin, daunomycin and plicamycin; antimetabolites such as chlofarabine, aminopterin, cytosine arabinoside, floxuridine and methotrexate; apoptosis-inducing agents and anti-angiogenic agents of Bcl-2 inhibitors such as YC 137, BH 312, ABT 737, gossypol, HA 14-1, TW 37 and decanoic acid; agents binding to tubulin such as combrestatin, colchicine derivatives and nocodazole; kinase inhibitors such as flavoperidol, imatinib mesylate, erlotinib and gefitinib; farnesyl transferase inhibitors such as tipifarnib; histone-deacetylase inhibitors such as sodium butyrate, suberoylanilide hydroxamic acid, depsipeptide, NVP- LAQ824, R306465, JNJ-26481585 and trichostatin A; inhibitors of the ubiquitin-proteasome system such as MLN .41, bortezomib and yondelis; and telomerase inhibitors such as telomestatin.

15. Use of a pharmaceutical composition according to any one of claims 10 to 14 in the manufacture of a medicament for treating or preventing a chemotherapy-resistant cancer.

16. A method for preparing a formula (I) compound according to any one of claims 1 to 7 comprising the following successive steps:

a) reacting an amine of following formula (II):



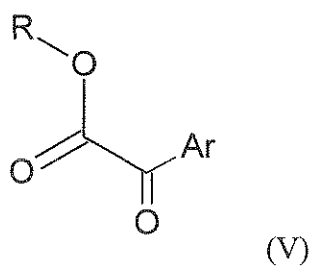
where X, R1, R2, R3, R4 and Ar are as defined in claim 1, R1 not representing a hydrogen atom,

with chloroacetyl chloride in the presence of a base to give a formula (I) compound where R1 $\neq$ H; and

- b) optionally deprotecting the nitrogen atom carrying the R1 $\neq$ H group to give a formula (I) compound where R1 = H.

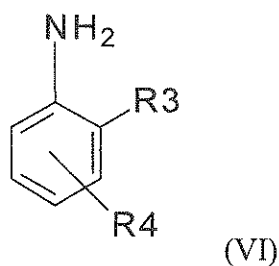
17. The method according to claim 16 comprising the following successive steps:

- i) reacting a ketoester of following formula (V):



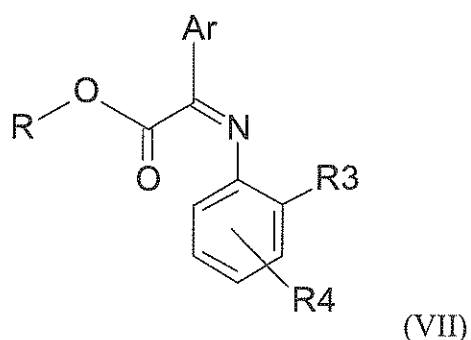
where Ar is as defined in claim 1 and R represents a (C₁–C₆)alkyl group, such as ethyl;

with an aniline of following formula (VI):



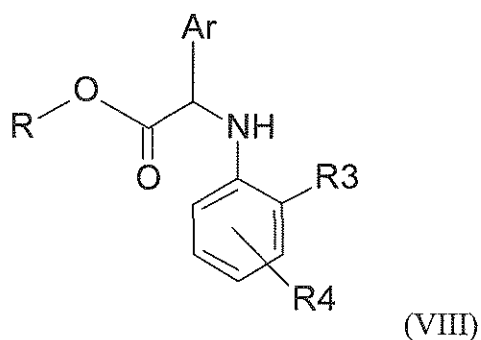
where R3 and R4 are as defined in claim 1,

to give an imine of following formula (VII):



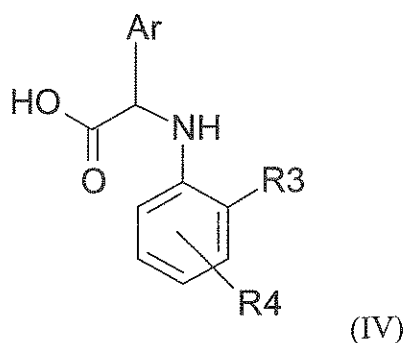
where R, R3, R4 and Ar are as defined in claim 1;

- ii) reducing the imine of formula (VII) obtained at the preceding step to give an amine of following formula (VIII):



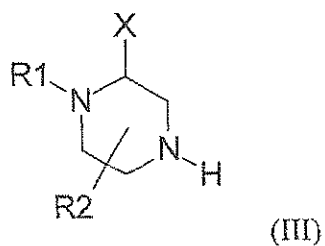
where R, R3, R4 and Ar are as defined in claim 1;

- iii) saponifying the ester function of the formula (VIII) compound obtained at the preceding step to give an acid of following formula (IV):



where R3, R4 and Ar are as defined in claim 1;

- iv) reacting the acid of formula (IV) obtained at the preceding step with a piperazine of following formula (III):



where X, R1 and R2 are as defined in claim 1, R1 not representing a hydrogen atom,

to give an amine of formula (II) according to claim 16;

- v) reacting the amine of formula (II) obtained at the preceding step with chloroacetyl chloride in the presence of a base to give a formula (I) compound where $R1 \neq H$; and
- vi) optionally deprotecting the nitrogen atom carrying the $R1 \neq H$ group to give a formula (I) compound where $R1 = H$.