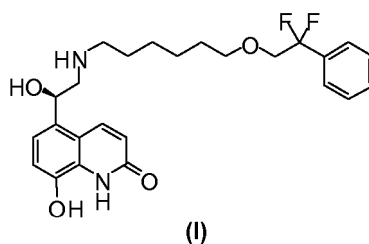


PROCESS FOR PREPARING

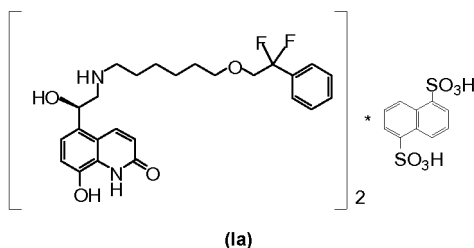
5 - (2 - { [6 - (2,2-DIFLUORO-2-PHENYLETHOXY) HEXYL] AMINO} - 1 (R) - HYDROXYETHYL) - 8 - HYDROXY QUINOLIN-2 (1H) - ONE VIA A NOVEL INTERMEDIATE

The present invention is directed to novel processes for preparing 5-(2-{[6-(2,2-difluoro-2-phenylethoxy)hexyl]amino}-1(*R*)-hydroxyethyl)-8-hydroxyquinolin-2(1*H*)-one (Compound (I)) and pharmaceutically acceptable salts thereof. The present invention is also directed to intermediate compounds and to processes for preparing said intermediate compounds.

- 10 5-(2-{[6-(2,2-difluoro-2-phenylethoxy)hexyl]amino}-1(*R*)-hydroxyethyl)-8-hydroxyquinolin-2(1*H*)-one (Compound (I)) as well as a process for its manufacture are described in WO 2006/122788 and WO 2010/102831.



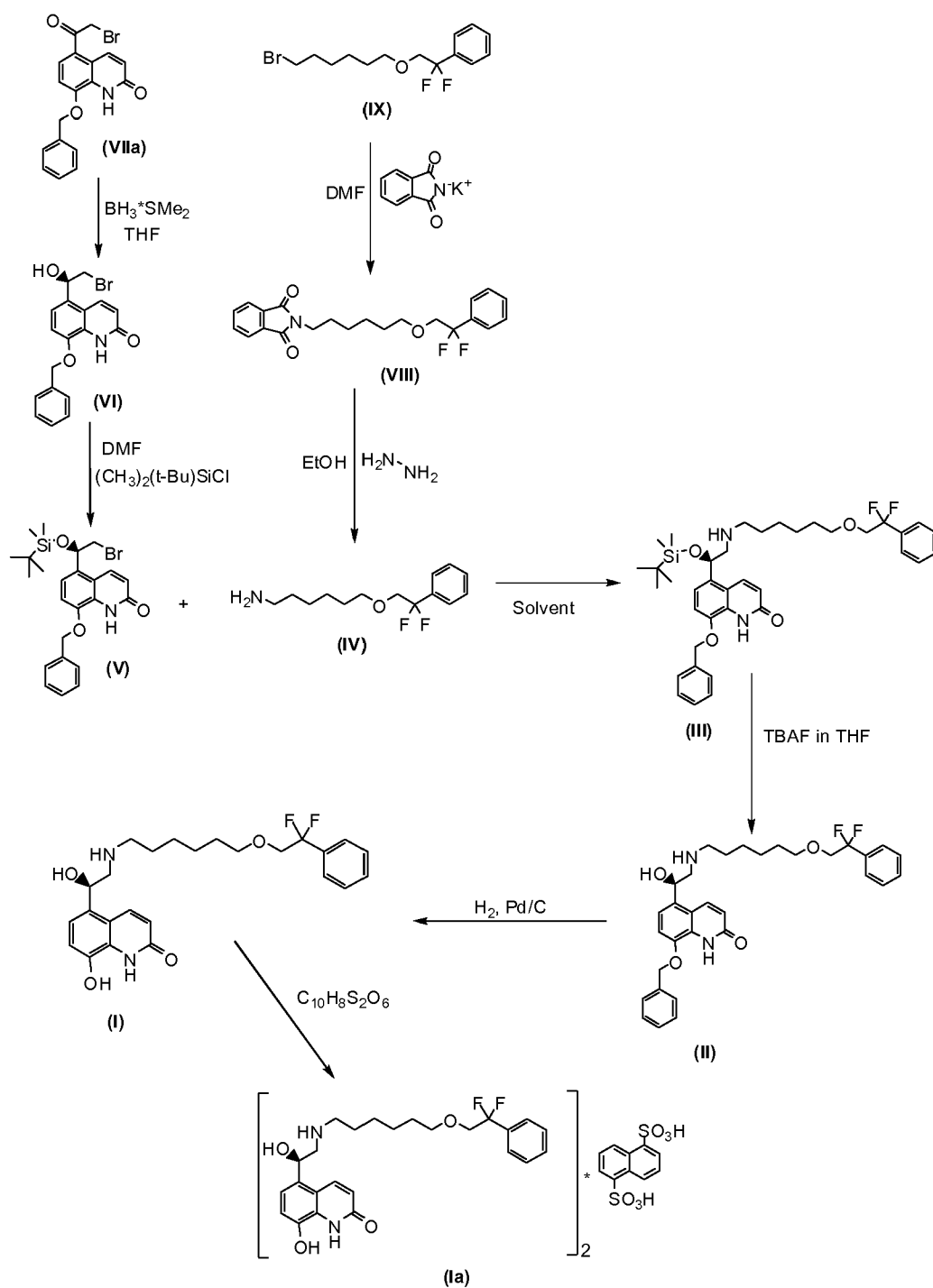
- 15 WO 2008/095720 discloses a method for preparing the napadisylate salt compound of formula (Ia).



- 20 WO 2010/102831 describes an improved process for preparing compounds of formula (Ia), by selecting specific solvents and also by modifying or removing some purification steps, thus reducing the reaction time while obtaining the final product within higher yields and minimizing the amounts of impurities.

The synthetic process described in the above patent applications can be summarized in Scheme 1.

Scheme 1



Therefore, in order to prepare compounds of formula (Ia), an alkylation reaction process of amine derivative of formula (IV) with the protected bromohydrin derivative of formula (V) is first carried out to give intermediates of formula (III), which are subsequently deprotected twice to give the compound of formula (I). The treatment of compound (I) with a pharmaceutically acceptable acid gives the corresponding salt compound of formula (Ia).

Intermediate of formula (IV) can be obtained by reacting intermediate of formula (VIII) with hydrazine, which is known to be a very toxic compound, in a solvent such as methanol, ethanol or tetrahydrofuran and at a temperature ranging from 50 to 90°C. Intermediate of formula (VIII) may be prepared reacting intermediate of formula (IX) with potassium phthalimide in a solvent such as dimethylformamide, dimethylsulfoxide or acetonitrile. These synthetic methods are already known and are described, for example, in WO 2006/122788 (Intermediates 8 and 9).

The protected bromohydrin derivative of formula (V) can be obtained by reducing the bromoketone derivative of formula (VIIa) using borane dimethylsulfide complex (BH₃-Me₂S), followed by protecting the hydroxyl moiety of intermediate (VI) using a suitable protecting group such as tert-butyldimethylsilyl chloride (TBS). These synthetic methods are already known and are described, for example, in US2004059116 (Example 9C), WO 2004/011416 (Example 2) and WO 2004/016578 (Example 1ii).

It is known that the borane dimethylsulfide complex gives rise to better enantiomeric purities contrary to other borane-based reagents which are known to yield poorer enantiomeric excess. However the borane dimethylsulfide complex, when used in this kind of the process, generates a high quantity of toxic and environmentally problematic by-products (dimethyl sulphide). Thus, it is highly recommended to avoid the use of this kind of reagents, especially at an industrial scale.

On the other hand, the deprotection process of intermediate (III) as depicted in Scheme 1 is carried out in two separate steps. The first deprotection step allows the formation of intermediates of formula (II) which are known to be very active compound due to their highly potent beta adrenergic activity and therefore should be handled using special equipments.

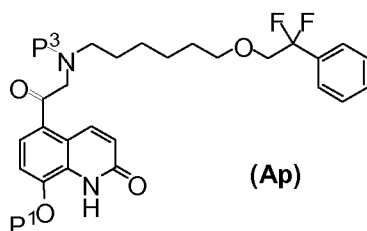
Furthermore, the above processes involve many steps of synthesis, including protection and deprotection reactions, and the need of many purification steps and/or separations of the intermediates between each steps and also the use of large quantities of solvents and catalyst thus rendering the whole process very complicated and not adequate at industrial scales.

Therefore there is still a need to improve the above-mentioned synthetic process in order to produce compound (I), or its pharmaceutically acceptable salt, on an acceptable industrial scale in a shorter and a simpler synthetic process. The attention

is especially drawn to intermediate (V), in particular to the reduction process of the bromoketone intermediate (VIIa) which reaction conditions are difficult to be effected and thus intermediate (VI) are difficult to obtain and to isolate with an adequate purity. In addition to this, it is convenient avoiding the manipulation of highly potent intermediates, such as intermediate (II), during the process, due to their active center which allow these intermediates to be highly active compounds.

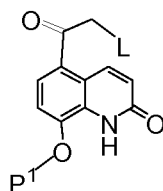
It is therefore an object of the present invention to provide new synthetic processes and intermediate products suitable for the production of a compound of formula (I) or its pharmaceutically acceptable salts, which can be easily produced in a simplest way using industrially readily obtainable starting materials and avoiding the use of substances which are not environmental friendly.

Accordingly, the present invention is directed to a compound of formula (Ap) or a pharmaceutically acceptable salt thereof,



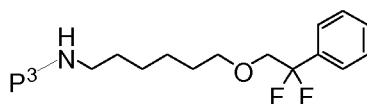
wherein P¹ represents a hydroxy protecting group and P³ represents an amino protecting group.

The present invention further provides a process for preparing a compound of formula (Ap) or a pharmaceutically acceptable salt thereof, which process comprises a) reacting an intermediate of formula (VII)



(VII)

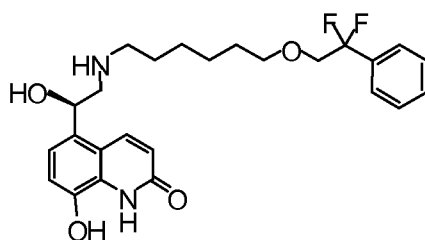
wherein L is a leaving group, with a 6-(2,2-difluoro-2-phenylethoxy)hexan-1-amine derivative of formula (X),



(X)

in the presence of a base, wherein P¹ and P³ are as defined herein.

The invention further provides a process for preparing a 5-(2-{{6-(2,2-difluoro-2-phenylethoxy) hexyl}amino}-1(R)-hydroxyethyl)-8-hydroxyquinolin-2(1H)-one compound of formula (I) or a pharmaceutically acceptable salt thereof,



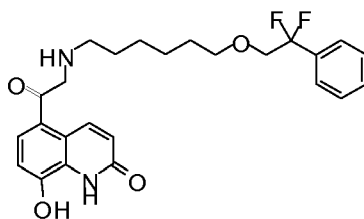
(I)

which process comprises reducing and deprotecting a compound of formula (Ap), or a pharmaceutically acceptable salt thereof, to give a compound of formula (I) or a pharmaceutically acceptable salt thereof.

The invention further provides:

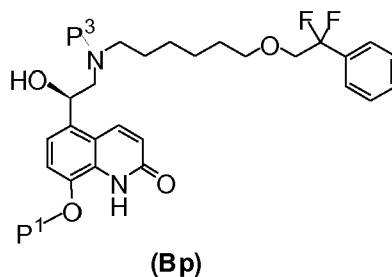
- a process for preparing a 5-(2-{{6-(2,2-difluoro-2-phenylethoxy) hexyl}amino}-1(R)-hydroxyethyl)-8-hydroxyquinolin-2(1H)-one compound of formula (I) or a pharmaceutically acceptable salt thereof, which comprises (i) preparing a compound of formula (Ap) or a pharmaceutically acceptable salt thereof by a process of the invention, and then (ii) reducing and deprotecting the compound of formula (Ap), or a pharmaceutically acceptable salt thereof, by a process of the invention, to give a compound of formula (I) or a pharmaceutically acceptable salt thereof;

- a compound of formula (A1) or a pharmaceutically acceptable salt thereof;



(A1)

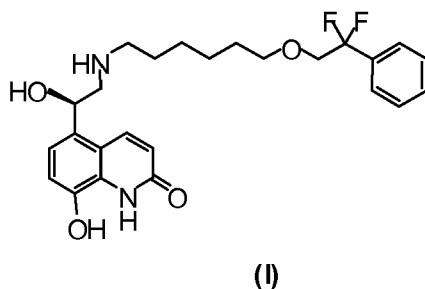
- a compound of formula (**Bp**) or a pharmaceutically acceptable salt thereof



wherein P¹ and P³ are as defined above;

5

- a process for preparing a 5-(2-[[6-(2,2-difluoro-2-phenylethoxy) hexyl]amino]-1(R)-hydroxyethyl)-8-hydroxyquinolin-2(1H)-one compound of formula (**I**) or a pharmaceutically acceptable salt thereof,



10

- which process comprises either
- b2) reduction of the aminoketone moiety of the compound of formula (**A1**) or a pharmaceutically acceptable salt thereof; or
- c1) removal of protecting groups P¹ and P³ from the compound of formula (**Bp**) or a pharmaceutically acceptable salt thereof;

15

- a process for preparing a compound of formula (**A1**) or a pharmaceutically acceptable salt thereof, which process comprises removal of protecting groups P¹ and P³ from a compound of formula (**Ap**) or pharmaceutically acceptable salt thereof; and

20

- a process for preparing a compound of formula (**Bp**) or a pharmaceutically acceptable salt thereof, which process comprises reduction of the aminoketone moiety of a compound of formula (**Ap**) or a pharmaceutically acceptable salt thereof.

25

Contrary to the previous methods, the process of the invention as described above enables production of compound (I) and the pharmaceutically acceptable salts thereof in a very short way thus significantly reducing the reaction time. Moreover, compound (I) and its salts can easily be prepared from the novel intermediate (Ap) through only two synthetic steps while maintaining the yield and the purity of the final compound at acceptable levels.

Within the novel synthetic process of the present invention, the reduction of the amino ketone is preferably carried out using a rhodium or ruthenium based catalyst described below, so that the use of the borane dimethylsulfide complex is therefore avoided and thus all the drawbacks generated within the use of this reagent are now prevented. Moreover the use of the highly toxic hydrazine as a reagent is also avoided.

Contrary to the previous process, the reduction process of the aminoketone moiety is effected at a later stage. This fact allows the whole process to be carried out in a simple way and thus the whole process is more effective.

The term "pharmaceutically-acceptable salt" typically refers to a salt prepared from an acid which is acceptable for administration to a patient, such as a mammal. Such salts can be derived from pharmaceutically-acceptable inorganic or organic acids.

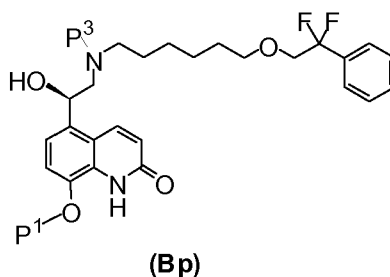
Salts derived from pharmaceutically-acceptable acids include acetic, benzenesulfonic, benzoic, camphosulfonic, citric, ethanesulfonic, formic, fumaric, gluconic, glutamic, hydrobromic, hydrochloric, hydrofluoric, lactic, maleic, malic, mandelic, methanesulfonic, trifluoroacetic, mucic, nitric, pantothenic, phosphoric, succinic, sulfuric, tartaric, p-toluenesulfonic, xinafoic (1-hydroxy-2-naphthoic acid), napadisilic (1,5-naphthalenedisulfonic acid), triphenyl acetic and the like. Particularly preferred are salts derived from formic, fumaric, hydrobromic, hydrochloric, hydrofluoric, acetic, sulfuric, methanesulfonic, trifluoroacetic, xinafoic, tartaric, maleic, succinic and napadisilic acids.

Examples of particularly preferred pharmaceutically acceptable salts are selected from hydrochloride, napadisylate, sulfate, hydrogensulfate, methanesulfonate and trifluoroacetate, with hydrochloride, napadisylate and methanesulfonate more preferred, and napadisylate most preferred.

As skilled chemist will appreciate, conversion of the compound of formula (**Ap**) or pharmaceutically acceptable salt thereof into a compound of formula (**I**) or a pharmaceutically acceptable salt, may typically involve either (i) reducing the aminoketone group and then removing protecting groups P^1 and P^3 , or (ii) removing

Thus, in a typical embodiment the process for preparing a 5-(2-([6-(2,2-difluoro-2-phenylethoxy) hexyl]amino)-1(R)-hydroxyethyl)-8-hydroxyquinolin-2(1*H*)-one compound of formula (**I**) or a pharmaceutically acceptable salt thereof comprises:

b1) reduction of the aminoketone moiety of the intermediate of formula (**Ap**) or a pharmaceutically acceptable salt thereof, to give an intermediate of formula (**Bp**) or a pharmaceutically acceptable salt thereof,

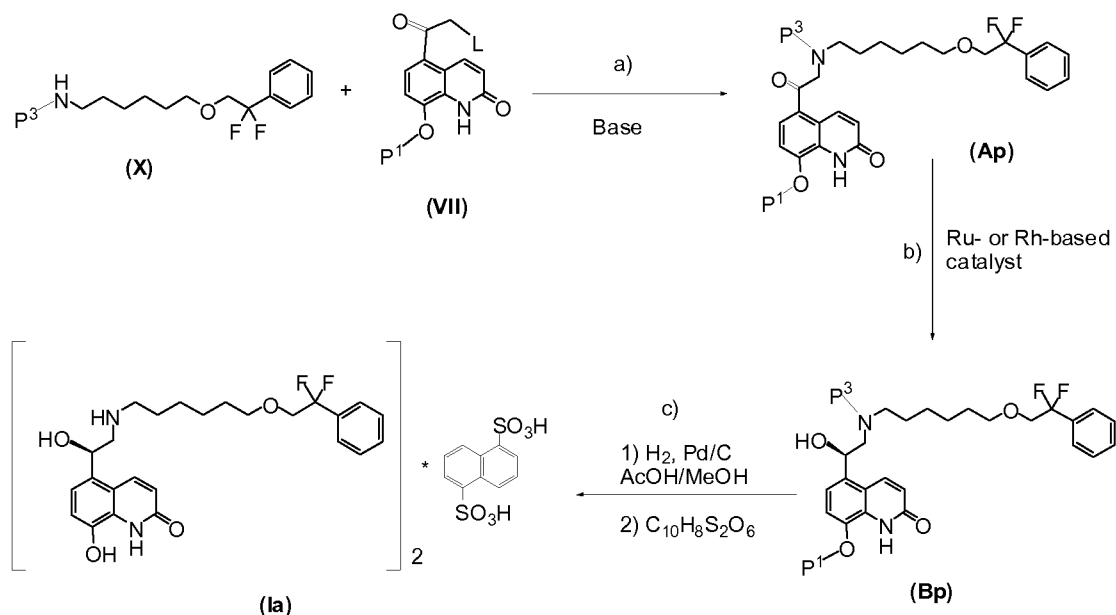


wherein P^1 and P^3 are as defined herein; and

c1) removal of protecting groups P^1 and P^3 from the intermediate of formula (**Bp**) or a pharmaceutically acceptable salt thereof.

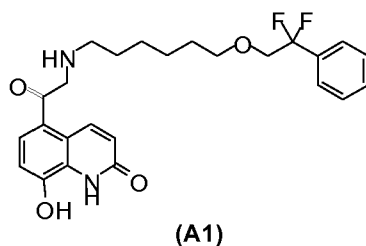
An example of such a process of the present invention can be summarised as depicted in Scheme 2.

Scheme 2



In an alternative typical embodiment, converting the process for preparing a 5-(2-((6-(2,2-difluoro-2-phenylethoxy) hexyl)amino)-1(R)-hydroxyethyl)-8-hydroxyquinolin-2(1H)-one compound of formula (I) or a pharmaceutically acceptable salt thereof comprises:

c2) removal of protecting groups P^1 and P^3 from the intermediate of formula (Ap) or a pharmaceutically acceptable salt thereof, to give an intermediate of formula (A1) or a pharmaceutically acceptable salt thereof:

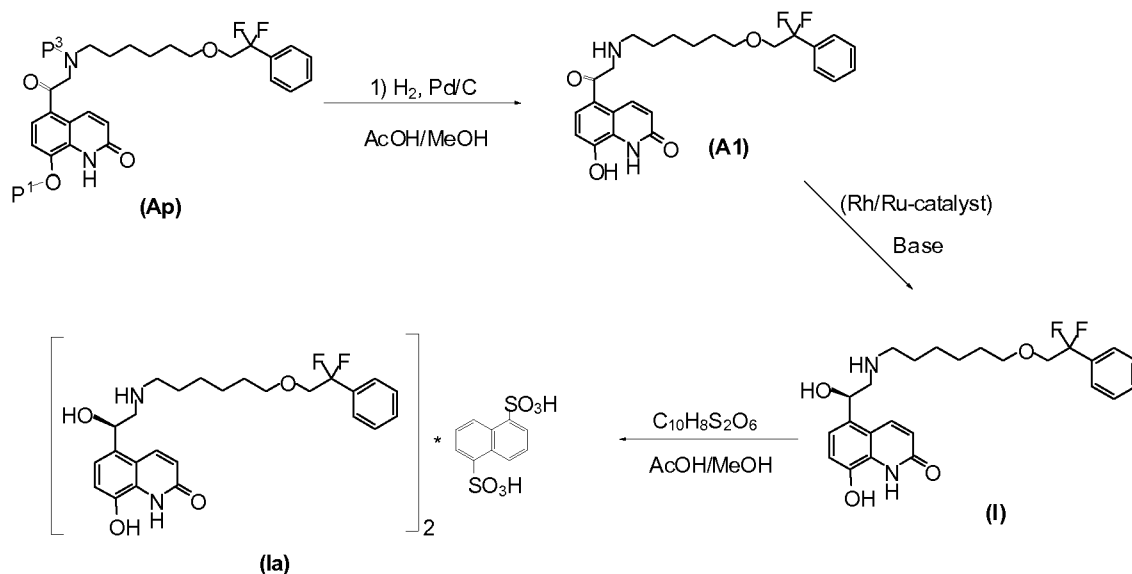


and

b2) reduction of the aminoketone moiety of the intermediate of formula (A1) or a pharmaceutically acceptable salt thereof.

An example of such a process of the present invention can be summarised as depicted in Scheme 3.

Scheme 3



Preferably, the compound of formula (I) or a pharmaceutically acceptable salt thereof is prepared from the intermediate of formula (Ap) or pharmaceutically acceptable salt via intermediate (Bp).

Preferably, compounds of formula (Ap) are used in the form of a free base, rather than a pharmaceutically acceptable salt. Preferably, compounds of formula (A1) are used in the form of a free base, rather than a pharmaceutically acceptable salt. Preferably, compounds of formula (Bp) are used in the form of a free base, rather than a pharmaceutically acceptable salt. More preferably all of (Ap), (Bp) and (A1) are used in the form of a free base, rather than as pharmaceutically acceptable salts.

L is a leaving group. A skilled chemist would easily be able to select appropriate leaving groups for the L position. Examples of suitable leaving groups include halogen atoms, mesylate groups (-O-S(O)₂-CH₃) and triflate (-OS(O)₂-CF₃) groups.

Preferably, L is a halogen atom. More preferably, L is a bromine atom.

P¹ and P³ are a hydroxy and an amino protecting group, respectively. A skilled chemist can easily select suitable protecting groups for the P¹ and P³ positions. For example, appropriate protecting groups are discussed in T.W. Greene and G.M. Wuts, Protective Groups in Organic Synthesis, Third Edition, Wiley, New York, 1999, and references cited therein. Suitable deprotection method for such protecting groups are well known in the art, for example following the synthetic processes described in T.W. Greene and

G.M. Wuts, Protective Groups in Organic Chemistry, Third Edition, Wiley, New York, 1999.

Examples of P¹ hydroxy-protecting groups include, but are not limited to, alkyl groups, such as methyl, ethyl and tert-butyl; acyl groups, for example alkanoyl groups, such as acetyl; arylmethyl groups, such as benzyl (Bn), p-methoxybenzyl (PMB), 9-fluorenylmethyl (Fm), and diphenylmethyl (benzhydryl, DPM); silyl groups, such as trimethylsilyl (TMS) and tert-butyldimethylsilyl (TBS); and the like. Preferably, P¹ is selected from a benzyl group and allyl group, more preferably a benzyl group.

Examples of P³ amino-protecting groups include, but are not limited to, formyl; acyl, allyl groups, for example alkanoyl groups, such as acetyl; alkoxycarbonyl groups, such as tert-butoxycarbonyl (Boc); arylmethoxycarbonyl groups, such as benzyloxycarbonyl (Cbz) and 9-fluorenylmethoxycarbonyl (Fmoc); arylmethyl groups, such as benzyl (Bn), trityl (Tr), and 1,1-di-(4'-methoxyphenyl)methyl; silyl groups, such as trimethylsilyl (TMS) and tert-butyldimethylsilyl (TBS); and the like. Preferably, P³ is a benzyl group, an allyl group or a tert-butyldimethylsilyl (TBS) group.

Preferably, P¹ and P³ are the same or different and each represent a benzyl group or an allyl group, preferably a benzyl group. More preferably P¹ and P³ represent the same protecting group.

Typically, the base used in step a) is selected from triethylamine, diisopropylethylamine or potassium carbonate, preferably triethylamine.

Typically, the aminoketone moiety is reduced in the presence of a rhodium or ruthenium-based catalyst.

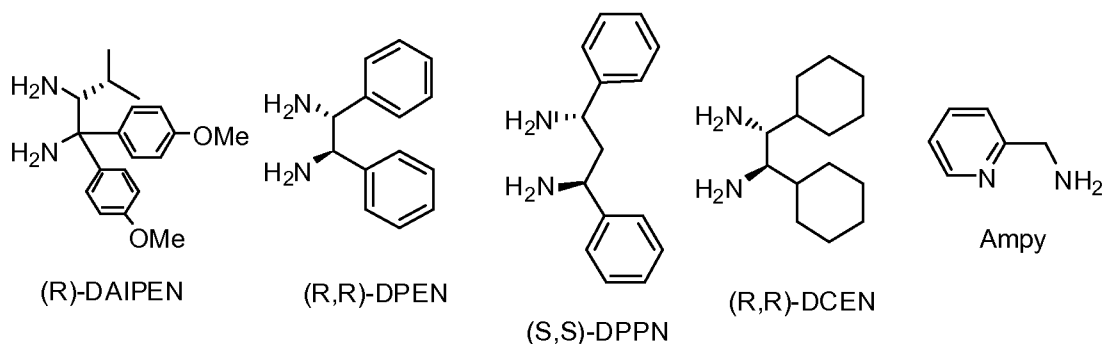
Preferably, the aminoketone moiety is reduced using a ruthenium based catalyst. It has been found that within this type of catalysts very excellent results have been obtained with a very high conversion (>95%, ee >99%)

Examples of such catalysts are Noyori-type ruthenium catalysts such as, [(R)-Tol-Binap RuCl₂ (R)-DAIPEN], [(R)-Binap RuCl₂ (R)-DAIPEN], [(R)-Binap RuCl₂ (R,R)-DPEN]], [(R)-Binap RuCl₂ (S,S)-DPPN], [(R)-Tol-Binap RuCl₂ (R,R)-DPEN], [(R)-Xyl-PPhos

RuCl₂ (S,S)-DPEN], [(R)-Xyl-PPhos RuCl₂ (S,S)-DPPN], [(S)-PPhos RuCl₂ (S)-DAIPEN], [(S)-PPhos RuCl₂ (S,S)-DPEN] and [(R)-PPhos RuCl₂ (R,R)-DCEN].

These catalysts are in the form of a ruthenium complex catalyst wherein RuCl₂ forms a complex compound with a diamine based chiral ligands from one side and with a diaryl-substituted phosphine derivative ligand on the other side. Examples of diamine-based chiral ligands are shown in the following Scheme 4.

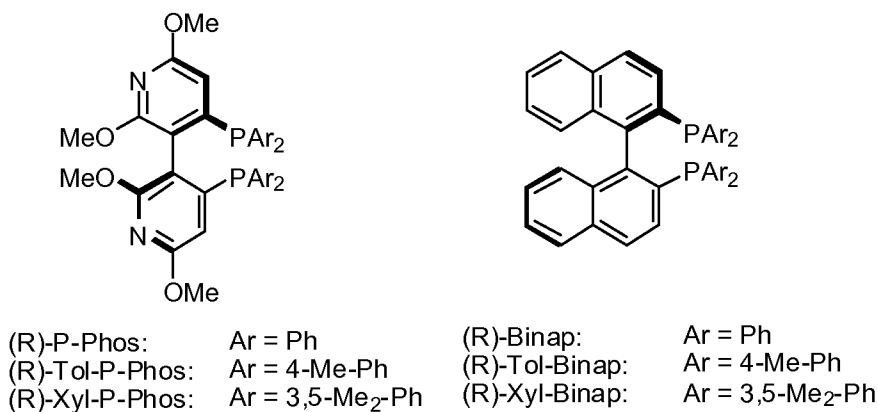
Scheme 4



Diamine-based chiral ligands

Examples of ligands based on diaryl-substituted phosphine are shown in the following Scheme 5.

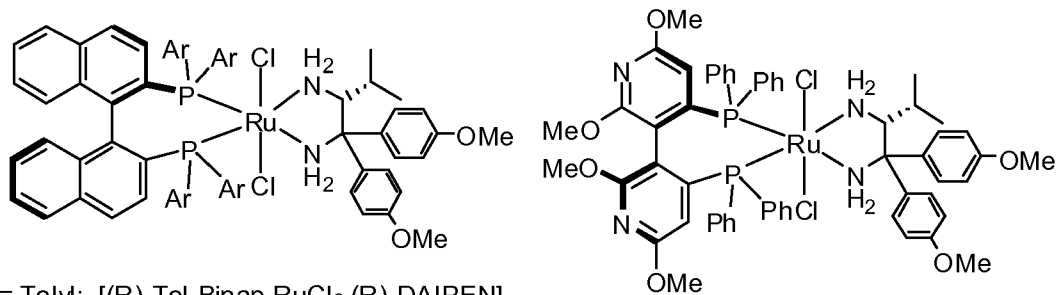
Scheme 5



Diaryl-substituted phosphine-based chiral ligands

Preferably, the Noyori-type ruthenium based catalyst are those complexes having PPhos, Binap or Tol-Binap as diaryl-substituted phosphine based chiral ligands and DAIPEN, DPEN or DCEN as diamine-based chiral ligands. More preferably, the Noyori-type ruthenium based catalysts are the ones depicted in the following scheme 6:

Scheme 6



Ar = Tolyl: [(R)-Tol-Binap RuCl₂ (R)-DAIPEN]

Ar = Ph: [(R)-Binap RuCl₂ (R)-DAIPEN]

[(R)-PPhos Ru Cl₂ (R)-DAIPEN]

5 Typically, the aminoketone moiety is reduced in the presence of a rhodium or ruthenium-based catalyst at a temperature ranging from room temperature to 75°C, preferably at a temperature ranging from 65-70°C. Within this latter range and using the catalysts described above, a full conversion and higher enantiomeric excess values are obtained (99%, ee>99%).

10

Typically, the aminoketone moiety is reduced in the presence of a rhodium or ruthenium-based catalyst under a pressure ranging from 3 to 30 bar, preferably at a pressure of 20-28 bar, more preferably at a pressure of about 25 bar, most preferably at 25 bar.

15

Typically, the aminoketone moiety is reduced in the presence of a rhodium or ruthenium-based catalyst in the presence of a base. The base is preferably potassium *tert*-butoxide (tBuOK). Preferably the base is present in an amount between 1.5 and 3 equivalents of intermediate (**Ap**) or (**A1**).

20

Typically, the aminoketone moiety is reduced in the presence of a rhodium or ruthenium-based catalyst in the presence of an alcohol based solvent, such as methanol, ethanol, isopropanol, t-butanol or any mixture thereof. Preferably t-butanol and Isopropyl alcohol is used as a solvent.

25

Preferably, the aminoketone moiety is reduced in the presence of a rhodium or ruthenium-based catalyst, at a temperature ranging from room temperature to 75°C, more preferably 65-70°C, under a pressure ranging from 3 to 30 bar, more preferably 25 bar, and in the presence of a base.

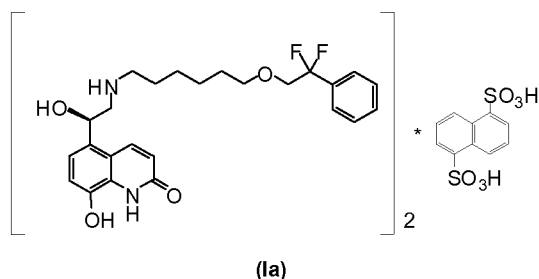
30

As a skilled person will appreciate, the reaction conditions used in to remove protecting groups P^1 and P^3 will depend on the exact nature of protecting groups P^1 and P^3 . A skilled person can readily determine suitable reaction conditions, for example by consulting the reference identified above. For example, if P^1 and P^3 represent benzyl, then typically these will be removed using Pd/C under hydrogen, preferably using a AcOH/MeOH solvent.

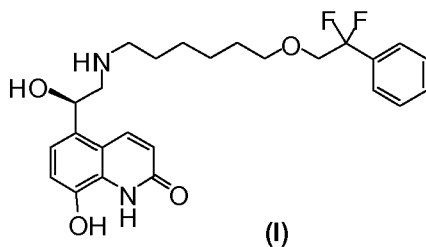
If an intermediate or compound is required in the form of a pharmaceutically acceptable salt, then this may be prepared by treating the intermediate or compound with the corresponding pharmaceutically acceptable acid.

Thus, pharmaceutically acceptable salts of compounds of formula (I) may be prepared by d) treating the compound of formula (I) with a pharmaceutically acceptable acid, to form the pharmaceutically acceptable salt.

Typically, the pharmaceutically acceptable acid used in step d) is selected from naphthalene 1,5-disulphonic acid and methane sulphonic acid. Preferably the pharmaceutically acceptable acid used in step d) is the naphthalene 1,5-disulphonic acid thus obtaining the napadisylate salt of formula (Ia):



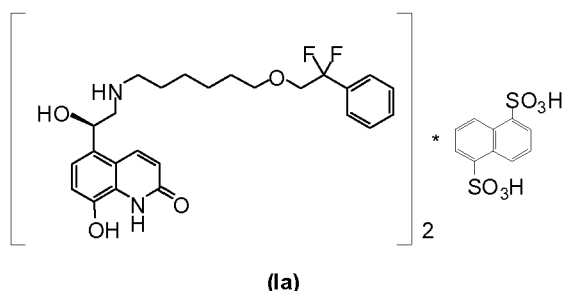
Alternatively, step d) may typically be omitted and compound (I) is obtained in a form of a free base.



In the particular case wherein the pharmaceutically acceptable salt is napadisylate, this salt is typically the one described in WO 2008/095720. Preferably the napadisylate salt

15

is a heminapadisylate salt or a mononapadisylate salt. A mononapadisylate salt typically contains between about 0.8 and 1.2 molar equivalents of naphthalene-1,5-disulfonic acid per molar equivalent of the free base, more typically about 1.0 molar equivalents of naphthalene-1,5-disulfonic acid per molar equivalent of the free base. A heminapadisylate salt typically contains between about 0.35 and 0.65 molar equivalents of naphthalene-1,5-disulfonic acid per molar equivalent of the free base, more typically about 0.5 molar equivalents of naphthalene-1,5-disulfonic acid per molar equivalent of the free base as disclosed in formula (Ia)

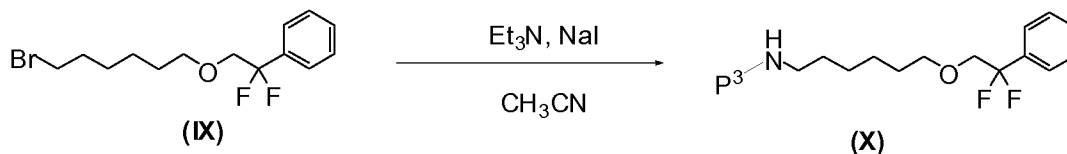


In one aspect of the present invention, compounds of formula (**Ap**) may be prepared in a form of any pharmaceutically acceptable salt thereof such as hydrochloride, napadisylate, sulfate, hydrogensulfate, methanesulfonate and trifluoroacetate.

In another aspect of the present invention, the reduction process of step b1) may be carried out using the intermediate (**Ap**) in its pharmaceutically acceptable salt form, such as for example, a napadisylate or a hydrochloride. In this case the reduced compound (**Bp**) is obtained in a free base form.

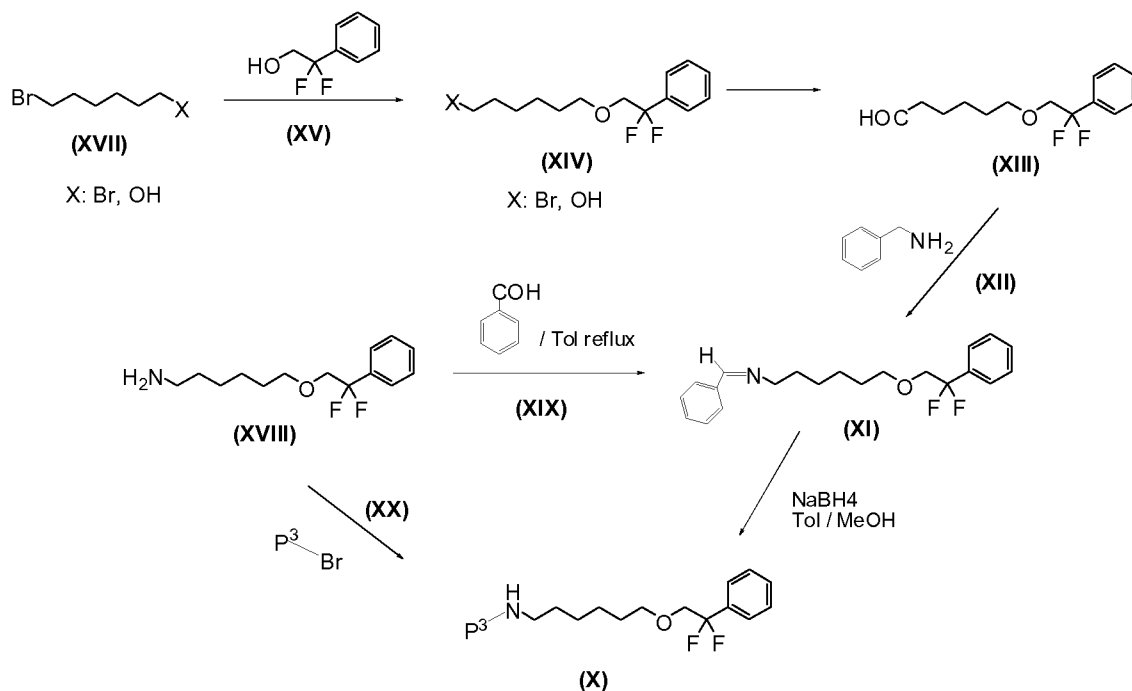
The starting compound of formula (X) may be obtained by addition of the corresponding amine to the bromated derivative of formula (IX) in the presence of a base such as triethylamine as depicted in Scheme 7. The reaction is carried out under inert atmosphere at a temperature ranging from 40-50°C.

Scheme 7



Alternatively, Intermediate of formula (**X**) can also be obtained according to the following scheme 8.

Scheme 8



- 5 Intermediate of formula (X) may be obtained from intermediate (XI) in the presence of Sodium Borohydride in a mixture of Toluene-Methanol. Intermediate of formula (XI) may be similarly obtained by reaction of benzylamine of formula (XII) with the aldehyde derivative of formula (XIII). Alternatively, intermediates of formula (XI) may also be obtained by reacting the amine derivative of formula (XVIII) with benzaldehyde of
- 10 formula (XIX) in the presence in a suitable solvent such as toluene at a temperature ranging from 100°C to reflux.

Intermediate of formula (XIII) may be obtained by reacting the bromo derivative of formula (XVII) with intermediates of formula (XV) in the presence of a base as NaOH,

15 yielding intermediates (XIV) which in turn may be transformed into intermediates of formula (XIII).

Alternatively, the protected amine derivative of formula (X) may be obtained by reaction of the corresponding amine of formula (XVIII) with a suitable protective group of

20 formula (XX) following a synthetic procedure already known in the art.

Intermediates of formula (X) may optionally be obtained in a form of a pharmaceutically acceptable salt thereof, preferably hydrochloride salt. In this case, this salt may be

prepared by treating a solution of intermediates of formula (X) with concentrated HCl following conventional synthetic methods already known in the art.

5 The reagents and solvents used in the present invention are commercially available, for example from Aldrich Chemical Company, Inc. or Fluka Chemie GmbH.

The method of synthesis described in the present invention will be further illustrated by the following examples. The examples are given by the way of illustration only and are not to be construed as limiting.

10

The structures of the prepared compounds were confirmed by ¹H-NMR and MS. NMR were recorded using a Varian Gemini-200 NMR spectrometer operating at frequency of 200 or 300 MHz. Tetramethyl silane was used as a reference and samples were solved in deuterated dimethylsulphoxide (DMSO-d₆) or deuterated chloroform (CDCl₃).

15

Their purity was determined by HPLC, in Alliance 2795 Waters instrument equipped with diode array detector (DAD) and ZMD or ZQ mass detector (electrospray ionization). HPLC method used a Symmetry C18 column (3.5 μm, 21x100 mm) and mobile phase was composed by two phases: Phase A: Buffered (Formic acid/ammonia) aqueous solution at pH: 3. Phase B: 50:50 mixture acetonitrile/methanol with ammonia formiate. Gradient was from 0% to 95% of phase B in 10 minutes.

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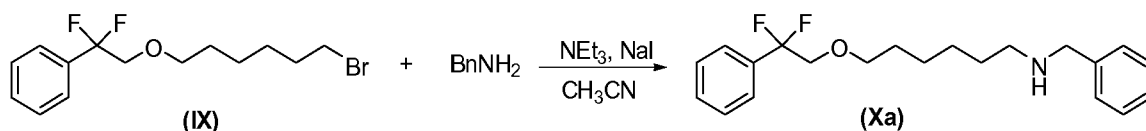
Preparative HPLC-MS experiments were performed on a Gilson instrument equipped with a binary pump (Gilson piston pump 321); a vacuum degasser (Gilson 864); an injector-fraction collector (Gilson liquid handler 215); two injection modules, analytical and preparative (Gilson 819); a valve (Gilson Valvemate 7000); a 1/1000 splitter (Acurate by LC Packings); a make-up pump (Gilson 307); a diode array detector (Gilson 170) and a MS detector (a Thermoquest Finnigan aQa, a quadrupole mass spectrometer with ES and APCI ionisation modes). The HPLC-MS instrument was controlled by an IBM PC.

25

30

Experimental section

Intermediate (Xa). *N*-Benzyl-6-(2,2-difluorophenylethoxy)hexane-1-amine.



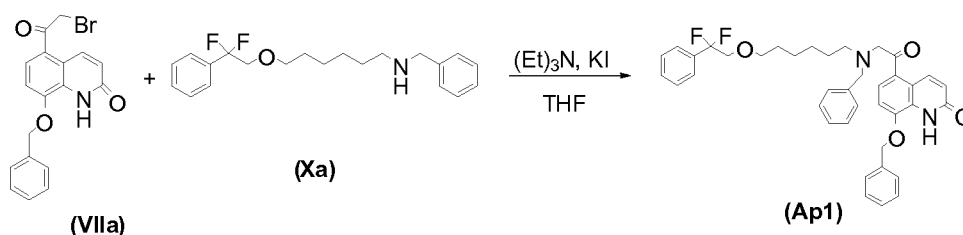
To a solution of 13.8 ml (0.126 mol) of benzylamine in 60 ml of acetonitrile were added 11.7 ml of triethylamine and 0.64 g (4.2 mmol) of NaI. The reaction mixture was heated at 40°C. To this solution, the difluorobenzyl bromated derivative of formula (IX) (14.49 g, 0.042 mol) was added dropwise followed by 10 ml of acetonitrile.

The reaction mixture was stirred for 5 hours at 45°C under Nitrogen atmosphere. Once finished, the solvent was removed and the oily residue was treated with dichloromethane (70 ml) and water (70 ml). The aqueous phase was extracted with dichloromethane (70 ml). Finally the organic extracts were dried with MgSO_4 and the solvent removed under reduced pressure. The crude thus obtained was dissolved in 5 volumes of CH_2Cl_2 (106 ml), then 3 equivalents of hydrochloride acid (6M solution, 31 ml) were added. The mixture was stirred at room temperature during 15 minutes. The organic layer was washed twice with water (50 ml x 2) and dried with MgSO_4 . The solvent was removed under reduced pressure giving the title product in a form of hydrochloride salt as white foam. The product obtained was additionally treated with 4 volumes of diethyl ether (Et_2O) and stirred at room temperature for at least 1 hour. The resulting solid is filtered and dried under vacuum (14.466 g of the hydrochloride salt are obtained).

This salt is solved again in CH_2Cl_2 (72 ml) and treated with a saturated aqueous solution of Sodium Bicarbonate (115 ml). After stirring at room temperature during 45 minutes, the layers are separated and the organic one is washed with water (36 ml), dried over MgSO_4 and the final solution evaporated to dryness. The title intermediate is obtained as a free base (12.681 g; yield: 81%).

Step a)

a.1) 5-(2-(benzyl(6-(2,2-difluoro-2-phenylethoxy)hexyl)amino)acetyl)-8-(benzyloxy)-quinolin-2(1H)-one (Ap1). (wherein both P^1 and P^3 represent a benzyl group).



To a solution of 8-(benzyloxy)-5-(2-bromoacetyl)quinolin-2(1H)-one (**VIIa**) in THF (47.89 g, 200 ml) were added 20.6 ml of triethylamine and 2.14 g of KI. Then, 44.7 g of *N*-Benzyl-6-(2,2-difluorophenylethoxy)hexane-1-amine (**Xa**) in 100 ml of THF were added dropwise to the previous mixture during about 5 minutes. The reaction system was purged and heated to 60°C under argon atmosphere. Once the reaction was completed (2 h approx.), the solvent was concentrated under vacuum and the resulting crude treated with 320 ml of Ethyl acetate and 320 ml of water. The organic layer was washed with 320 ml of saturated solution of NaCl, dried with MgSO₄ and solvent removed under reduced pressure. 82.2 g of crude (**Ap1**) free base in a form of an oily residue is obtained (purity by HPLC: 85% approx).

Purification process of Ap1

This oily residue can be purified by column chromatography, or by means of an appropriate salt crystallization.

When the crude product is purified by column chromatography, **Ap1** is obtained, with a purity of 97-98% by HPLC. The global yield (reaction + purification) is around 70%.

In case of purification by recrystallization, the process may be carried out as follows:

Napadisylate of 5-(2-(benzyl(6-(2,2-difluoro-2-phenylethoxy)hexyl)amino)acetyl)-8-(benzyloxy)-quinolin-2(1H)-one (Ap1** Napadisylate).**

82.2 g of crude (**Ap1**) are dissolved in Methanol (822 ml) and the Naphthalene-1,5-disulfonic acid tetrahydrate (23.19 g) is added, and the solution heated at reflux. The solvent is removed, giving rise to 98.2 g of the salt. This product is maintained at 55-60°C during about 2 h in a mixture of *tert*-butylmethylether (786 ml) and Methanol (491 ml). The mixture is cooled to 0°C, filtered and the solid obtained is washed with more solvent (TBME / MeOH (1.6:1)). After drying, 73.2 g of product are obtained (HPLC purity: 98.2%). The global yield, including preparation of crude (**Ap1**), and crystallization of the napadisylate, is 72%.

Once purified as the napadisylate, intermediate **Ap1** can be obtained as a free base with the following method:

Ap1 Napadisylate (73.2 g) is charged in a reactor with CH₂Cl₂ (740 ml) and stirred at room temperature with an aqueous 1 M solution of NaOH (470 ml). After dissolution of the product the layers are separated. The organic layer is washed again with more

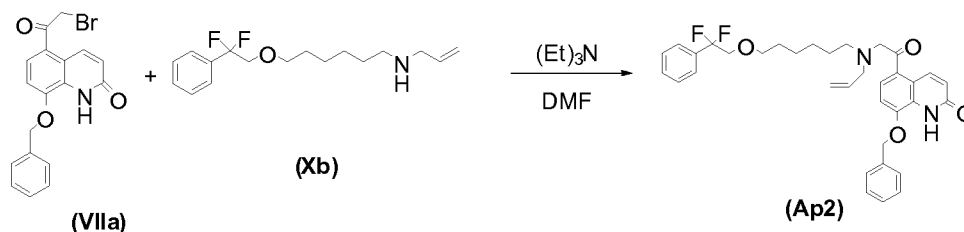
water (750 ml). After removing the solvent from the organic extract, **Ap1** is obtained as a residue in an almost quantitative way (yield 100% approx.).

Hydrochloride of 5-(2-(benzyl(6-(2,2-difluoro-2-phenylethoxy)hexyl)amino)acetyl)-8-(benzyloxy)-quinolin-2(1H)-one (Ap1 HCl**).**

60.2 g of product (**Ap1**) is dissolved in 740 ml of CH₂Cl₂. Then, to the resulting solution, 8.4 ml of concentrated HCl 37% are added. The solvent is removed under reduced pressure giving the corresponding (**Ap1**) **HCl** as a white foam.

Step a)

a.2.) 5-(2-(allyl(6-(2,2-difluoro-2-phenylethoxy)hexyl)amino)acetyl)-8-(benzyloxy)-quinolin-2(1H)-one. (Ap2**)** (**P**¹ represents a benzyl group while **P**³ represents an allyl group).

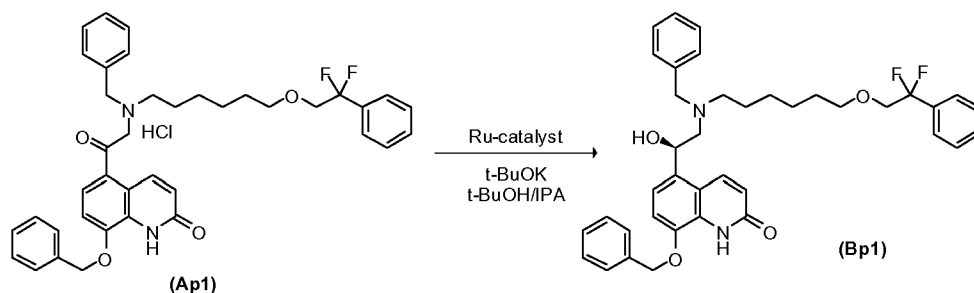


To a solution of 8-(benzyloxy)-5-(2-bromoacetyl)quinolin-2(1H)-one (**VIIa**) in DMF (7.46 g, 12 ml) was added 3.3 ml of triethylamine. Then, 8.938 g of *N*-Allyl-6-(2,2-difluorophenylethoxy)hexane-1-amine (**Xb**) in 8 ml of DMF were added dropwise to the previous mixture. The reaction system was purged and heated to 60°C under Nitrogen atmosphere. Once the reaction was completed (3 h approx.), the reaction mixture is treated with 33 ml of Ethyl acetate and 33 ml of water. The organic layer was washed with a saturated solution of NaCl, dried with Na₂SO₄ and solvent removed under reduced pressure. 14.677 g of crude (**Ap2**) free base in a form of an oily residue are obtained.

This oily residue is purified by flash chromatography. **Ap2** is obtained, with a purity of 94.4% by HPLC. The global yield (reaction + purification) is 63%.

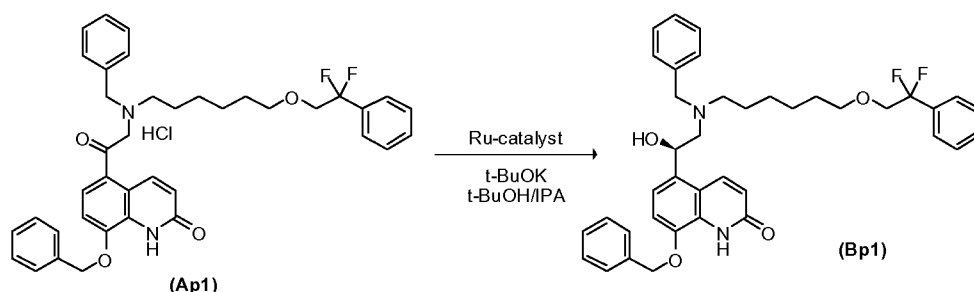
Step b) (R)-5-(2-(benzyl(6-(2,2-difluoro-2-phenylethoxy)hexyl)amino)-1-hydroxy-ethyl)-8-(benzyloxy)quinolin-2(1H)-one. (Bp1**).**

Example 1: Step b) using Ap1 (base) as a reagent



In a 1000 ml stainless steel reactor equipped with overhead stirring were charged 115 mg of (R)-tol-BINAP RuCl₂ DAIPEN. 57.96 g **(Ap1)** were dissolved in 341 ml of isopropanol by gently warming. The warm solution was charged to the reactor. The reactor was sealed and purged three times with N₂. The reactor was then purged five times with N₂ while stirring. The reactor was then charged with 137 ml of 1M t-BuOK in *t*-Butanol. The reactor was again purged three times with N₂ without stirring and then purged five times with N₂ while stirring. The reactor was then purged with H₂ five times while stirring and pressurized to 4 bars. The reactor was heated to 65 °C (internal temperature). After the temperature was reached, the reactor was further pressurized to 25 bars and allowed to stir for 12 hours while the hydrogen consumption was monitored. After 12 hours the reactor was cooled, vented and purged with N₂. The reactor was then opened and the mixture was filtered on 200 g Silica using an additional 1 l of isopropanol as a rinse. The reaction mixture was then concentrated on a rotary evaporator to give a brown oil of (R)-8-(benzyloxy)-5-(2-((tert-butyldimethylsilyl)(6-(2,2-difluoro-2-phenylethoxy)hexyl)amino)-1-hydroxyethyl)quinolin-2(1H)-one **(Bp1)** (56 g, 97% yield). The samples were analyzed by HPLC. (Total impurities by HPLC: 6%; e.e.: 99%)

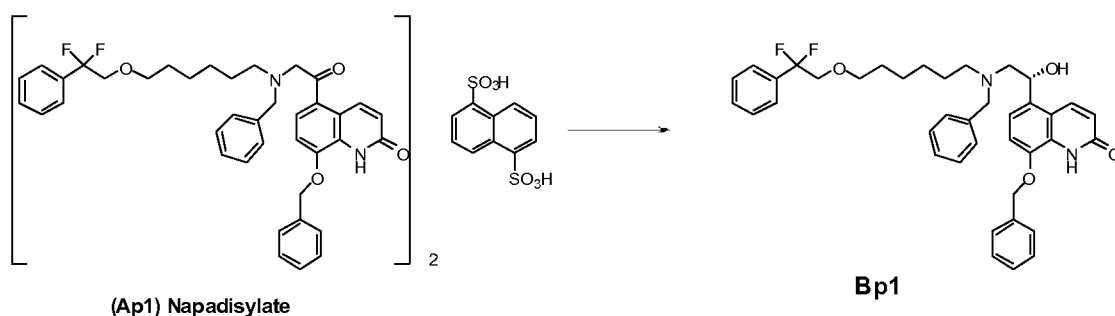
Example 2: Step b) using Ap1 HCl as a reagent



In a 1000 ml stainless steel reactor, equipped with overhead stirring, was charged 84.7 mg of (R)-tol-BINAP RuCl₂ DAIPEN, 49.1 g **(Ap1 HCl)** and 304 ml of isopropanol. The reactor was sealed and purged three times with N₂. The reactor was then purged five

times with N₂ while stirring. The reactor was then charged with 183 ml of 1M *t*-BuOK in *t*-Butanol. The reactor was again purged three times with N₂ without stirring and then purged five times with N₂ while stirring. The reactor was then purged with H₂ five times while stirring and pressurized to 4 bars. The reactor was heated to 65 °C (internal temperature). After the temperature was reached, the reactor was further pressurized to 25 bars and the hydrogen consumption was monitored. Once completed the reactor was cooled, vented and purged with N₂. The reactor was then opened and the mixture was filtered on 160 g Silica using an additional 1 L of isopropanol as a rinse. The reaction mixture was then concentrated on a rotary evaporator to give a brown oil of (R)-8-(benzyloxy)-5-(2-((tert-butyldimethyl-silyl) (6-(2,2-difluoro-2-phenylethoxy)hexyl)-amino)-1-hydroxyethyl)quinolin-2(1H)-one (**Bp1**) (45.45 g, 97% yield). The samples were analyzed by HPLC. (Total impurities by HPLC: 9%; e.e.: 97%).

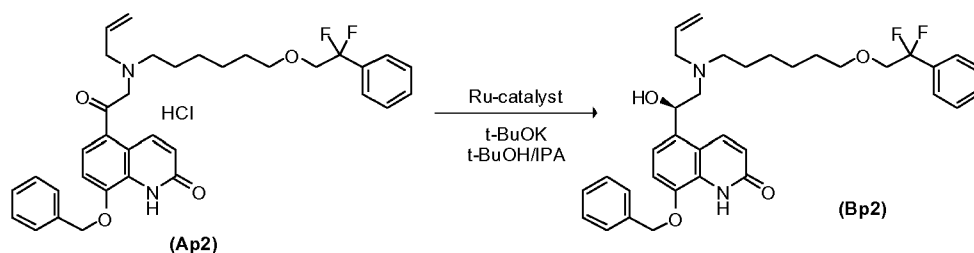
Example 3: Step b) using napadisylate salt of (**Ap1**) as a reagent



In a reactor equipped with overhead stirring was charged 8 mg (R)-tol-BINAP RuCl₂ DAIPEN, 6.1 g of **Ap1 napadisylate** and 25 mL of isopropanol. The reactor was purged with nitrogen 5 times without stirring and 5 times with stirring. 28 mL of 1 M *t*-BuOK in *t*-BuOH was added. The reactor was again purged with nitrogen five times without stirring and five times while stirring. The reactor was then pressurized to 4 bar hydrogen and heated to 65 °C (internal temperature). After the temperature was reached, the reactor was further pressurized to 25 bar hydrogen and allowed to stir for 23 hours while the hydrogen consumption was monitored. After 23 hours the reactor was cooled, vented and purged with N₂. The solution was filtrated and concentrated on a rotary evaporator to give a brown oil (3.65 g, 73% yield).

Step b) (R)-5-(2-(allyl(6-(2,2-difluoro-2-phenylethoxy)hexyl)amino)-1-hydroxyethyl)-8-(benzyloxy)quinolin-2(1H)-one. (Bp2)

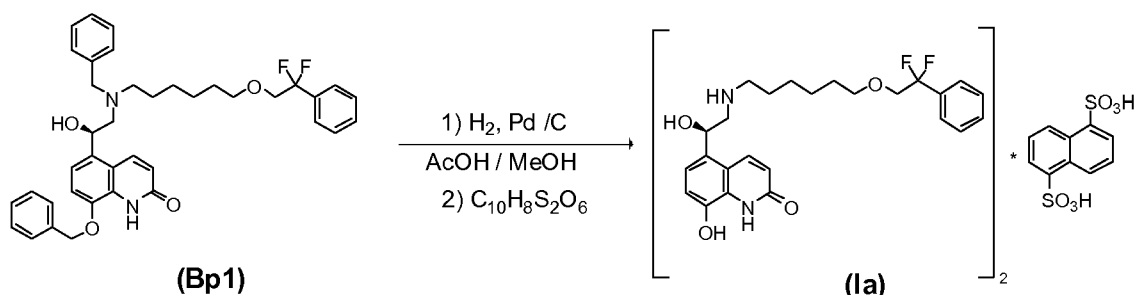
Step b) using Ap2 HCl as a reagent



In a 50 ml Parr autoclave are charged 8.6 mg of (R)-tol-BINAP RuCl₂ DAIPEN, 470 mg **Ap2.HCl** and 5 ml Isopropanol. The autoclave is closed and inerted with Nitrogen. Then 1.61 ml of t-BuOK 1M in t-BuOH are added and the mixture purged several times with Hydrogen. The mixture is heated to 45°C and pressurized with Hydrogen to 25 bar, maintaining these conditions during 16 hours. After standard work-up, the crude product is isolated and analyzed (HPLC purity 94%; e.e.: 95.5%).

Step c)

- 5-((1*R*)-2-[[6-(2,2-difluoro-2-phenylethoxy)hexyl]amino]-1-hydroxyethyl)-8-hydroxyquinolin-2(1*H*)-one, napadisylate salt (compound **la**)



- Intermediate of formula (**Bp1**) (30.1 g) was dissolved in 150 ml of Methanol and 150 ml of Acetic Acid, and 4.80 g of Pd/C 10%, 50% water were added. After several purges of nitrogen, the reaction mixture was hydrogenated at atmospheric pressure and a temperature of 20-30 °C during 8 hours. The catalyst was then filtered and washed with 120 ml of methanol. After that, more methanol (30 ml) and Acetic Acid (150 ml) were added to the liquid filtrate.

- A solution of 12.0 g of 1,5-naphthalenedisulfonic acid tetrahydrate in 30 ml of Methanol and 30 ml of Acetic Acid was added to the previous solution. The mixture was heated to reflux during 30 minutes and cooled to room temperature. The solid was filtered and washed with methanol. Finally, the wet cake was suspended again in methanol (870 ml) and heated to reflux during 30 minutes and cooled to room temperature. The

obtained solid was filtered and washed with methanol. After drying the product at 50°C under vacuum, 18.8 g of compound (**1a**) are obtained (yield 66.3%).

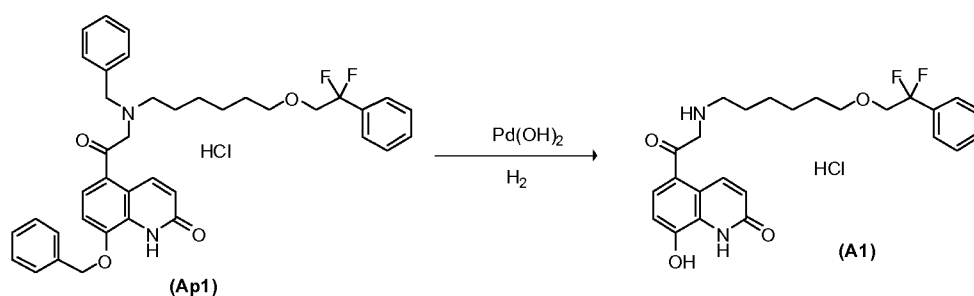
The analysis of this product shows a level of HPLC impurities of 1.03% and 0.6% of S enantiomer.

the overall yield of 5-((1*R*)-2-[[6-(2,2-difluoro-2-phenylethoxy)hexyl]amino]-1-hydroxyethyl)-8-hydroxyquinolin-2(1*H*)-one napadisylate salt (**1a**) is calculated to be about 50 %, being the product obtained of the adequate purity (HPLC imp = 1.03%, e.e. > 99%).

From intermediate **VIIa**, the overall yield of 5-((1*R*)-2-[[6-(2,2-difluoro-2-phenylethoxy)hexyl]amino]-1-hydroxyethyl)-8-hydroxyquinolin-2(1*H*)-one napadisylate salt (**1a**) is calculated to be about 50 % being the product obtained of the adequate purity (HPLC imp = 1.03%, e.e. > 99%).

The following example describes the synthetic process for preparing intermediate A1 (wherein both P¹ and P³ are a hydrogen atom)

5-(2-(6-(2,2-Difluoro-2-phenylethoxy)hexylamino)acetyl)-8-(hydroxyquinolin-2(1H)-one Hydrochloride. (A1 HCl)



In a 1000 ml stainless steel reactor equipped with overhead stirring are charged 17.978 g of **Ap1.HCl** and 180 ml of Methanol. Under Argon atmosphere, 1.79 g of Palladium Hydroxide are charged. After purging several times with Hydrogen, the reaction mixture is maintained stirring at room temperature under a Hydrogen atmosphere. Once the reaction is completed (approx. 40 minutes), Hydrogen is purged with Argon and the catalyst removed by filtration. After evaporating the solvent, the residue is solved in a hot mixture of 150 ml of Acetonitrile and 50 ml of Methanol. When cooling to 0°C, **A1 HCl** crystallizes. The solid is filtered, washed and dried, yielding 6.29 g (purity HPLC: 99.2%).

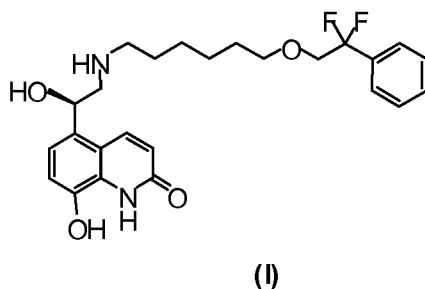
Table 1: comparative results

Steps	According to WO 2006/122788	According to WO 2010/102831	According to the present invention
VIIa to Ia	6-8%	45%	46 %
Impurities of final product (Ia)	5.8%	1.5%	1.0%

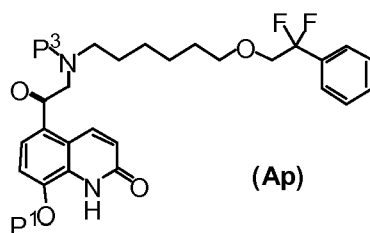
As it can be observed from the table, the new process according to the present
5 invention allows obtaining compound (**Ia**) within similar yields using only 3 reaction
steps when compared with the previous processes described in the art. In addition, the
impurity level of compound (**Ia**) is lower than the product obtained with previous
procedures. This is achieved by using a new intermediate compound (**Ap**) thus
simplifying the reaction steps and avoiding the use and handling of other substances
10 which are known to be very toxic and highly potent.

CLAIMS

1. A process for preparing a 5-(2-[[6-(2,2-difluoro-2-phenylethoxy) hexyl]amino]-
1(R)-hydroxyethyl)-8-hydroxyquinolin-2(1*H*)-one compound of formula (I) or a
5 pharmaceutically acceptable salt thereof,



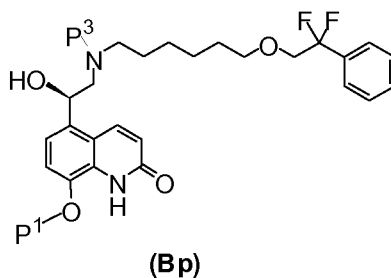
which process comprises reducing and deprotecting a compound of formula (Ap) or a pharmaceutically acceptable salt thereof,



wherein P¹ represents a hydroxy protecting group and P³ represents an amino protecting group, to give a compound of formula (I) or a pharmaceutically acceptable salt thereof, wherein the aminoketone moiety is reduced in the presence of a rhodium or ruthenium-based catalyst.

2. A process according to claim 1, which comprises:

b1) reduction of the aminoketone moiety of the compound of formula (Ap) or a pharmaceutically acceptable salt thereof, to give a compound of formula (Bp) or a pharmaceutically acceptable salt thereof,

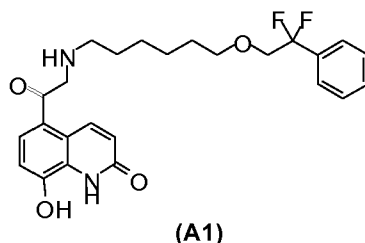


and

c1) removal of protecting groups P¹ and P³ from the compound of formula (**Bp**) or a pharmaceutically acceptable salt thereof.

5 3. A process according to claim 1 which comprises:

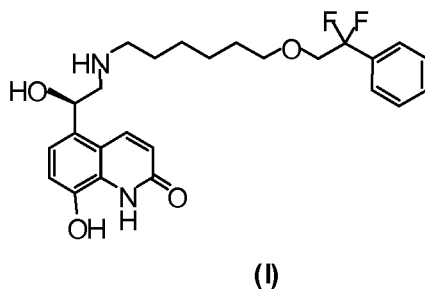
c2) removal of protecting groups P¹ and P³ from the compound of formula (**Ap**) or a pharmaceutically acceptable salt thereof, to give a compound of formula (**A1**) or a pharmaceutically acceptable salt thereof:



and

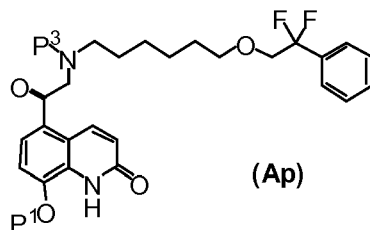
b2) reduction of the aminoketone moiety of the compound of formula (**A1**) or a pharmaceutically acceptable salt thereof.

4. A process for preparing a 5-(2-([6-(2,2-difluoro-2-phenylethoxy) hexyl]amino)-1(R)-hydroxyethyl)-8-hydroxyquinolin-2(1H)-one compound of formula (**I**) or a pharmaceutically acceptable salt thereof,

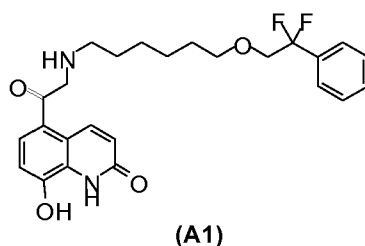


which process comprises:

c2) removal of protecting groups P¹ and P³ from the compound of formula (**Ap**) or a pharmaceutically acceptable salt thereof,



wherein P^1 represents a hydroxy protecting group and P^3 represents an amino protecting group, to give a compound of formula (A1) or a pharmaceutically acceptable salt thereof:



5

and

b2) reduction of the aminoketone moiety of the compound of formula (A1) or a pharmaceutically acceptable salt thereof.

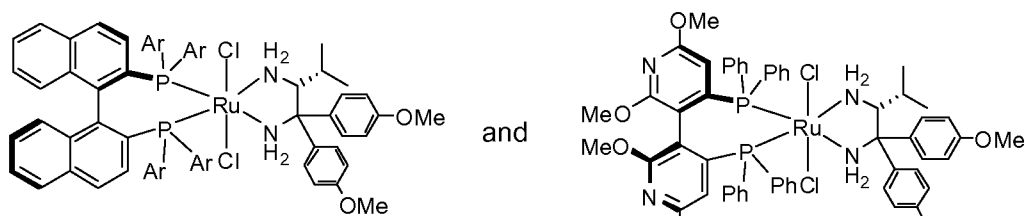
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5. A process according to claim 4, wherein the aminoketone moiety is reduced in the presence of a rhodium or ruthenium-based catalyst.

6. A process according to any one of claims 1 to 3 and 5, wherein the

15 aminoketone moiety is reduced in the presence of a ruthenium-based catalyst.

7. A process according to claim 6, wherein the ruthenium-based catalyst is selected from:



20

wherein each Ar is the same and selected from phenyl and tolyl group.

8. A process according any one of claims 1 to 3 and 5 to 7, wherein the aminoketone moiety is reduced at a temperature ranging from room temperature to

25 75°C, under a pressure ranging from 3 to 30 bar and in the presence of a base.

9. A process according to claim 8, wherein the aminoketone moiety is reduced at a temperature ranging from 65-70°C, preferably at a pressure of 25 bar.

5 10. A process according to claim 8 or 9 wherein the base is potassium tertiary butoxide.

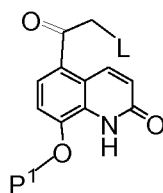
11. A process according to any one of the preceding claims, wherein P¹ and P³ are the same or different, and each represent a benzyl group or an allyl group, preferably a
10 benzyl group.

12. A process according to any one of the preceding claims, wherein both P¹ and P³ represent the same protecting group.

15 13. A process according to any one of the preceding claims, wherein protecting groups P¹ and P³ are removed in a single step.

14. A process for preparing a 5-(2-[[6-(2,2-difluoro-2-phenylethoxy) hexyl]amino]-1(R)-hydroxyethyl)-8-hydroxyquinolin-2(1H)-one compound of formula (I) or a
20 pharmaceutically acceptable salt thereof, which comprises

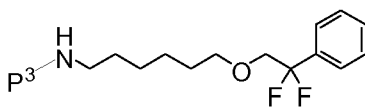
(i) preparing a compound of formula (Ap) as defined in any one of claims 1, 11 or 12 or a pharmaceutically acceptable salt thereof, by a) reacting an intermediate of formula (VII)



(VII)

25

wherein L is a leaving group, with a 6-(2,2-difluoro-2-phenylethoxy)hexan-1-amine derivative of formula (X),



(X)

in the presence of a base, wherein P¹ and P³ are as defined in any one of claims 1, 11 or 12, and then

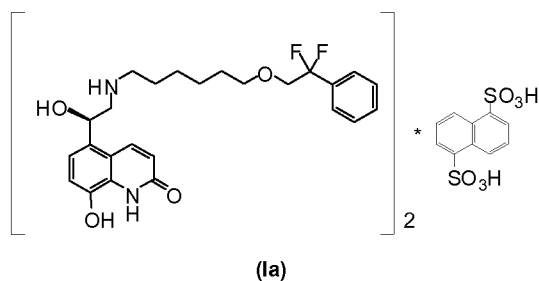
(ii) reducing and deprotecting the compound of formula (**Ap**), or a pharmaceutically acceptable salt thereof, by a process as defined in any one of claims 1 to 13, to give a compound of formula (**I**) or a pharmaceutically acceptable salt thereof

15. A process according to claim 14, wherein the leaving group L is halogen atom, preferably a bromine atom.

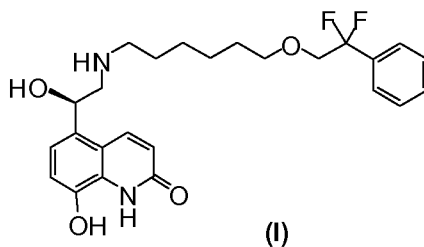
16. A process according to claim 14 or 15, wherein the base is selected from triethylamine, diisopropylethylamine or potassium carbonate, preferably triethylamine.

17. A process according to any one of claims 1 to 16, which subsequently further comprises d) treating the compound of formula (**I**) thus obtained with a pharmaceutically acceptable acid, to form the corresponding pharmaceutically acceptable salt.

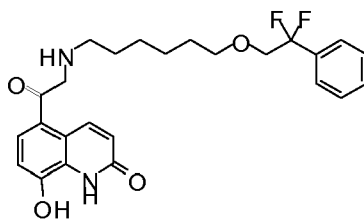
18. A process according to claim 17, wherein the pharmaceutically acceptable acid used in step d) is the naphthalene 1,5-disulphonic acid and the pharmaceutically acceptable acid is the napadisylate salt of formula (**Ia**):



19. A process according to any one of claims 1 to 16, wherein compound (**I**) is obtained in a form of a free base.

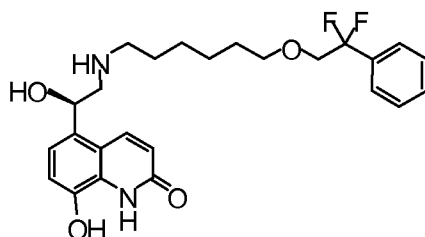


20. A compound of formula (**A1**) or a pharmaceutically acceptable salt thereof.



(A1)

21. A process for preparing a 5-(2-[[6-(2,2-difluoro-2-phenylethoxy) hexyl]amino]-
1(R)-hydroxyethyl)-8-hydroxyquinolin-2(1*H*)-one compound of formula (I) or a
5 pharmaceutically acceptable salt thereof,



(I)

which process comprises reduction of the aminoketone moiety of the compound of
formula (A1) as defined in claim 20, or a pharmaceutically acceptable salt thereof,
under conditions as defined in any one of claims 5 to 10.

22. A process for preparing a compound of formula (A1) as defined in claim 20 or a
pharmaceutically acceptable salt thereof, which process comprises removal of
protecting groups P¹ and P³ from a compound of formula (Ap) as defined in any one of
claims 1, 11 or 12 or a pharmaceutically acceptable salt thereof, under conditions as
15 defined in claim 4 or 13.