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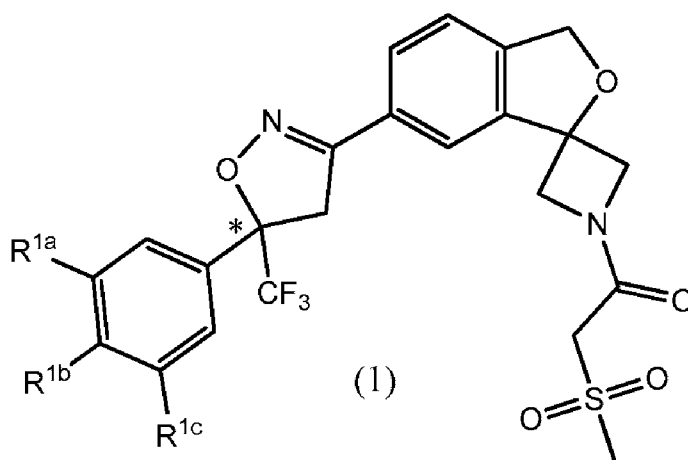
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(54) **Title:** SYNTHESIS OF SPIROCYCLIC ISOXAZOLINE DERIVATIVES



(57) **Abstract:** The invention recites an improved process for preparing spirocyclic isoxazoline derivatives of Formula (1) wherein "*" , R^{1a}, R^{1b}, and R^{1c} are as described herein.

SYNTHESIS OF SPIROCYCLIC ISOXAZOLINE DERIVATIVES

FIELD OF THE INVENTION

5 This invention relates to an improved process for preparing spirocyclic isoxazoline derivatives having parasitocidal activity. The spirocyclic isoxazoline derivatives have exceptional activity against insects and acarids with low toxicity which makes them particularly valuable for use in domestic animals.

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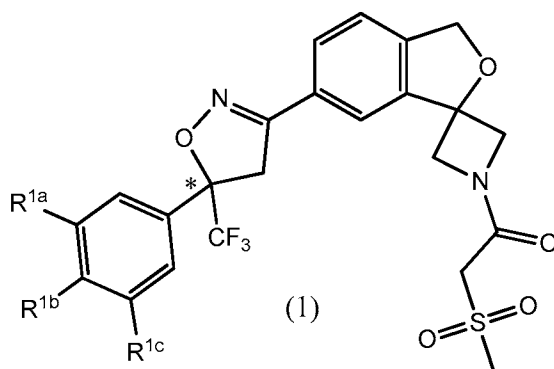
BACKGROUND

 As described in an earlier application, WO2012/120399, the spiro-azetidine isobenzofuran derivatives were prepared using a substituent, i.e., protecting group, to block or protect the amine moiety on the compound. For example, non-limiting amine protecting groups include acyl groups, acyloxy groups, diphenylmethane, and benzylcarbamates. Removal of the BOC
15 protecting group was accomplished under acidic conditions with subsequent coupling reactions to obtain the chiral amides. Further, the process for preparing the crystalline form of (S)-(5'-(5-(3,5-dichloro-4-fluorophenyl)-5-trifluoromethyl)-4,5-dihydroisoxazol-3-yl)-3'H-spiro[azetidine-3,1'-isobenzofuran]-1-yl)-2-(methylsulfonyl)ethanone is fully described in PCT/US2013/56945.
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 The present invention provides an improved process for preparing the methylsulfonylethanone spiro[azetidine-3,1-isobenzofuran] isoxazoline derivatives. The benzenesulfonic acid salt of the intermediate amine is neutralized and then undergoes simple coupling with a nitrophenyl
25 sulfonylacetate reactant.

SUMMARY

 The present invention describes an improved process for preparing the methylsulfonylethanone spiro[azetidine-3,1-isobenzofuran] isoxazoline
30 derivatives of Formula 1



where R^{1a} , R^{1b} , and R^{1c} are each independently selected from hydrogen, halogen, or CF_3 ; and "*" represents a chiral center.

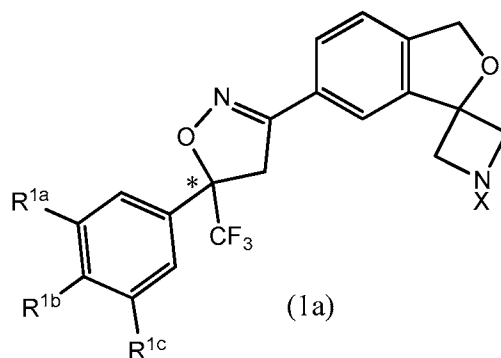
In another aspect of the invention is a process for preparing a Formula (1) compound wherein R^{1a} , R^{1b} , and R^{1c} are each independently halogen.

In another aspect of the invention is a process for preparing a Formula (1) compound wherein R^{1a} , R^{1b} , and R^{1c} are each independently selected from fluoro and chloro.

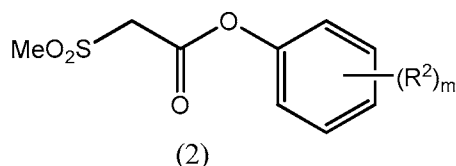
In another aspect of the invention is a process for preparing a Formula (1) compound wherein R^{1a} and R^{1c} are each chloro and R^{1b} is fluoro.

In another aspect of the invention is a process for preparing a Formula (1) compound wherein at least one of R^{1a} , R^{1b} , and R^{1c} is CF_3 .

In another aspect of the invention is a process for preparing a Formula (1) compound by reacting a Formula (1a) compound

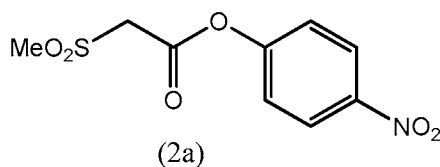


wherein "*", R^{1a} , R^{1b} , and R^{1c} are as described herein, and X is an acid addition salt, with a Formula (2) compound, in an organic solvent, wherein R^2 is hydrogen,



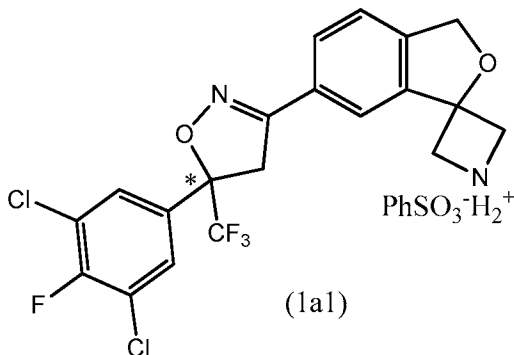
halogen, or nitro, and m is the integer 1, 2, 3, 4, or 5, and wherein at least one of R^2 is halo or nitro, provided that only one of R^2 is nitro; in the presence of a non-aqueous base.

- 5 In yet another aspect of the invention is a process for preparing a Formula (1) compound by reacting a Formula (1a) compound wherein "*", R^{1a} , R^{1b} , and R^{1c} are as described herein, and a Formula (2a) compound, in an organic solvent,



- 10 in the presence of a non-aqueous base.

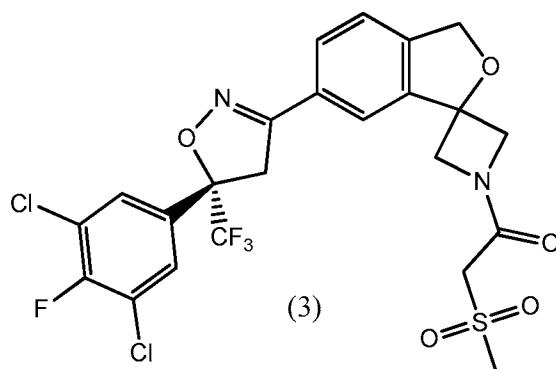
In another aspect of the invention is a process for preparing a Formula (1) compound by reacting a Formula (1a1) compound, wherein "*" is as defined



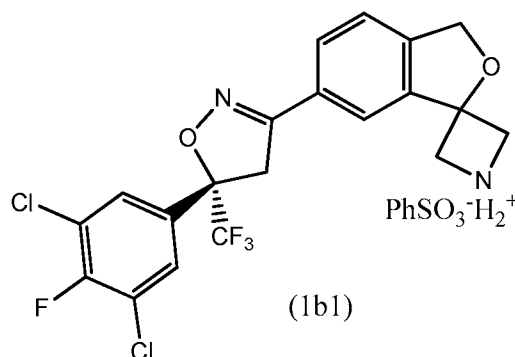
- 15 herein, and a Formula (2) compound, in an organic solvent, wherein R^2 and m are as defined herein, in the presence of a non-aqueous base.

In another aspect of the invention is a process for preparing a Formula (1) compound by reacting a Formula (1a1) compound with a Formula (2a) compound, in an organic solvent, in the presence of a non-aqueous base.

- 20 In another aspect of the invention is a process for preparing a Formula (3) compound



by reacting a Formula (1b1) compound



with the Formula (2) compound, in an organic solvent, wherein R² and m are as
5 defined herein, in the presence of a non-aqueous base.

In another aspect of the invention is a process for preparing a Formula (3)
compound by reacting a Formula (1b1) compound with a Formula (2a)
compound, in an organic solvent, in the presence of a non-aqueous base.

In another aspect of the invention, non-limiting examples of the organic
10 solvent include: isopropyl acetate, tetrahydrofuran, methyl tert-butyl ether, ethyl
acetate, toluene, and the like. A preferred organic solvent is isopropyl acetate.

In another aspect of the invention, non-limiting examples of a non-
aqueous base include: trialkylamines (e.g., trimethylamine, triethylamine,
diisopropylethylamine, and the like), pyridine, diazaobicyclo-undec-7-ene (DBU),
15 and the like. A preferred non-aqueous base is triethylamine.

In another aspect of the invention the Formula (1a) compound and
Formula (2) compound; Formula (1a) compound and Formula (2a) compound;
Formula (1a1) compound and Formula (2) compound; Formula (1a1) compound
and Formula (2a) compound; Formula (1b1) compound and Formula (2)
20 compound; and Formula (1b1) compound and Formula (2a) compound are

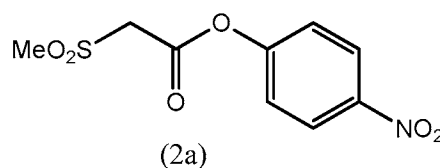
reacted in about equimolar amounts, in an organic solvent, in the presence of a non-aqueous base.

In another aspect of the invention, the solids that precipitate out of the organic solution (i.e., isopropyl acetate) are removed and the remaining organic solution is sequentially washed at least two times with an aqueous base and then at least two times with water. Non-limiting examples of an aqueous base include hydroxides, carbonates, and the like. A preferred aqueous base is selected from sodium hydroxide, potassium hydroxide, ammonium hydroxide, sodium carbonate, potassium carbonate, sodium bicarbonate, and potassium bicarbonate. An even more preferred aqueous base is a hydroxide, for example sodium hydroxide, potassium hydroxide, and ammonium hydroxide. The organic solution is then concentrated under vacuum.

In one aspect of the invention, the concentrated organics are added to a volume of alcohol, for example, methanol, ethanol, propanol, butanol, and the like. A preferred alcohol is methanol. The methanolic solution is then slowly added to water while stirring. The resulting amorphous solids are filtered and dried.

In yet another aspect of the invention, the concentrated organics are added to a volume of a solution comprising ethyl acetate, n-heptane, and ethanol. Ethyl acetate is about 5% volume/volume, n-heptane is about 35% volume/volume, and ethanol is about 60% volume/volume. Crystal seeds of polymorphic Form A, (S)-(5'-(5-(3,5-dichloro-4-fluorophenyl)-5-trifluoromethyl)-4,5-dihydroisoxazol-3-yl)-3'H-spiro[azetidene-3,1'-isobenzofuran]-1-yl)-2-(methylsulfonyl)ethanone, are added. The mixture is cooled and the resulting crystalline solids are isolated by filtration and dried.

In another aspect of the invention is a process for preparing a Formula (2a) compound



comprising mixing methanesulfonylacetic acid, acetonitrile, and triethylamine. The reaction mixture is cooled and then p-nitrophenylchloroformate in acetonitrile is added. Water is added and the reaction mixture is filtered and

substituted. For example, the term "(C₁-C₆)alkyl" refers to a monovalent, straight or branched aliphatic group containing 1 to 6 carbon atoms. Non-exclusive examples of (C₁-C₆) alkyl groups include, but are not limited to methyl, ethyl, propyl, isopropyl, sec-butyl, t-butyl, n-propyl, n-butyl, i-butyl, s-butyl, n-pentyl, 1-methylbutyl, 2-methylbutyl, 3-methylbutyl, neopentyl, 3,3-dimethylpropyl, 2-methylpentyl, hexyl, and the like. The alkyl moiety may be attached to the chemical moiety by any one of the carbon atoms of the aliphatic chain. Alkyl groups are optionally substituted as described herein. Further when used in compound words such as alkylphenyl, said alkyl moiety has the same meaning as herein defined and may be attached to the chemical moiety by any one of the carbon atoms of the aliphatic chain. Non-limiting examples of the compound word, alkylphenyl include: C₁alkylphenyl is -CH₂phenyl, C₂alkylphenyl is -CH₂CH₂phenyl, C₀phenyl is phenyl, and the like.

"Alkenyl" as used herein, unless otherwise indicated, refers to a straight or branched aliphatic hydrocarbon chain having 2- to 6-carbon atoms and containing at least one carbon-carbon double bond (for example -C=C-, or -C=CH₂). Non-exclusive examples of alkenyl include: vinyl, 1-propenyl, 2-propenyl, isopropenyl, 1-butenyl, 2-butenyl, 3-butenyl, 2-pentenyl, and the like.

"Alkynyl" as used herein, unless otherwise indicated, refers to straight or branched aliphatic hydrocarbon chain having 2- to 6-carbon atoms and containing at least one carbon-carbon triple bond (for example, -C≡C- or -C≡CH). Non-exclusive examples of alkynyl include: ethynyl, 2-propynyl, 1-methyl-2-propynyl, 2-butylnyl, 3-butylnyl, 2-methyl-3-butylnyl, and the like.

"Chiral", as used herein, unless otherwise indicated, refers to the structural characteristic of a molecule that makes it impossible to superimpose it on its mirror image, (e.g., "R" and "S" enantiomers). The term is also depicted as an asterisk (i.e., *) in the Examples and preparations and refers to a chiral center which includes both the S and R enantiomers.

"Cycloalkyl", as used herein, unless otherwise indicated, includes fully saturated or partially saturated carbocyclic alkyl moieties. Non-limiting examples of partially saturated cycloalkyls include: cyclopropene, cyclobutene, cycloheptene, cyclooctene, cyclohepta-1,3-diene, and the like. Preferred cycloalkyls are 3- to 6-membered saturated monocyclic rings including

cyclopropyl, cyclobutyl, cyclopentyl, and cyclohexyl. The cycloalkyl group may be attached to the chemical moiety by any one of the carbon atoms within the carbocyclic ring. Cycloalkyl groups are optionally substituted with at least one substituent. Further when used in compound words such as alkylcycloalkyl, said
5 alkyl and cycloalkyl moiety has the same meaning as herein defined and may be attached to the chemical moiety by any one of the carbon atoms of the aliphatic chain. Examples of C₀-C₆alkylC₃-C₆cycloalkyl include, methylcyclopropane (C₁alkylC₃cycloalkyl or -CH₂cyclopropane), ethylcyclopropane (C₂alkylC₃cycloalkyl or -CH₂CH₂cyclopropane), methylcyclobutane
10 (C₁alkylC₄cycloalkyl or -CH₂cyclobutane), ethylcyclobutane (C₂alkylC₄cycloalkyl or -CH₂CH₂cyclobutane), methylcyclohexane (C₁alkylC₆cycloalkyl or -CH₂cyclohexane), and the like. C₀alkylC₃-C₆cycloalkyl is C₃-C₆cycloalkyl. Cycloalkyl moieties are optionally substituted as described herein

"Halogen" or "halo", as used herein, unless otherwise indicated, refers to
15 fluorine, chlorine, bromine and iodine. Further, when used in compound words such as "haloalkyl", "haloalkoxy", "haloalkenyl", or "haloalkynyl", said alkyl, alkoxy, alkenyl, and alkynyl may be partially or fully substituted with halogen atoms which may be the same or different and said alkyl, alkoxy, alkenyl, and alkynyl moiety has the same meaning as above and may be attached to the
20 chemical moiety by any one of the carbon atoms of the aliphatic chain. Examples of "haloalkyl" include F₃C-, ClCH₂-, CF₃CH₂- and CF₃CCl₂-, and the like. The term "haloalkoxy" is defined analogously to the term "haloalkyl". Examples of "haloalkoxy" include CF₃O-, CCl₃CH₂O-, HCF₂CH₂CH₂O- and CF₃CH₂O-, and the like. The term "haloalkenyl" is defined analogously to the
25 term "haloalkyl" except that the aliphatic chain contains at least one carbon-carbon double bond. Examples of "haloalkenyl" include CF₃HC=CH-, CCl₃HC=CH-, and HCF₂HC=CH-, and the like.

"Heteroaryl" or "Het", as used herein, unless otherwise indicated, refers to
30 a 5- to 6-membered aromatic monocyclic ring or an 8- to 10-membered fused aromatic ring where said monocyclic- and fused-ring moiety contains one or more heteroatoms each independently selected from N, O, or S, preferably from one to four heteroatoms. Non-exclusive examples of monocyclic heteroaryls include pyrrolyl, furanyl, thiophenyl, pyrazolyl, imidazolyl, triazolyl, tetrazolyl,

thiazolyl, isoxazolyl, oxazolyl, oxadiazolyl, thiadiazolyl, pyridinyl, pyridazinyl, pyrimidinyl, pyrazinyl, and the like. Non-exclusive examples of fused heteroaryls include: benzofuranyl, benzothiophenyl, indolyl, benzimidazolyl, indazolyl, benzotriazolyl, thieno[2,3-c]pyridine, thieno[3,2-b]pyridine, benzo[1,2,5]thiadiazole, and the like. The heteroaryl group may be attached to the chemical moiety by any one of the carbon atoms or nitrogen heteroatoms within the monocyclic or fused ring. Further when used in compound words such as alkylheteroaryl, said alkyl and heteroaryl moiety have the same meaning as herein defined and may be attached to the chemical moiety by any one of the carbon atoms of the aliphatic chain. For example, C₀alkylheteroaryl is heteroaryl, C₁alkylheteroaryl is -CH₂heteroaryl, C₂alkylheteroaryl is -CH₂CH₂heteroaryl, and the like. Heteroaryls are optionally substituted as described herein.

“Heterocycle”, as used herein, unless otherwise indicated, refers to a partially saturated or saturated 3- to 7-membered monocyclic ring containing one or more heteroatoms each independently selected from N, O, or S, preferably from one to four heteroatoms. The heterocyclic ring can be part of a fused ring or spiro-ring moiety. Non-exclusive examples of heterocycle include oxirane, thiarane, aziridine, oxetane, azetidine, thiatane, tetrahydrofuran, tetrahydrothiophene, pyrrolidine, tetrahydropyrane, piperidine, piperazine, tetrahydropyridine, 2H-azirine, 2,3-dihydro-azete, 3,4-dihydro-2H-pyrrole, and the like. The heterocycle group may be attached to the chemical moiety by any one of the carbon atoms or nitrogen heteroatoms within the ring. Further when used in compound words such as alkylheterocycle, said alkyl and heterocycle moiety have the same meaning as herein defined and may be attached to the chemical moiety by any one of the carbon atoms of the aliphatic chain. For example, C₀alkylheterocycle is heterocycle, C₁alkylheterocycle is -CH₂heterocycle, C₂alkylheterocycle is -CH₂CH₂heterocycle, and the like. Heterocycles are optionally substituted as described herein.

“Optionally substituted”, is used herein interchangeably with the phrase substituted or unsubstituted. Unless otherwise indicated, an optionally substituted group may have a substituent at each substitutable position of the group, and each substitution is independent of the other. An optionally

substituted group also may have no substituents. Therefore, the phrase “optionally substituted with at least one substituent” means that the number of substituents may vary from zero up to a number of available positions for substitution.

5 “Protecting group” or “Pg”, as used herein, unless otherwise indicated, refers to a substituent that is commonly employed to block or protect an amine on the compound thereby protecting its functionality while allowing for the reaction of other functional groups on the compound

“Seed(s)” or “Crystal Seed(s)”, as used herein, unless otherwise
10 indicated, refer to crystals of polymorphic Form A of (S)-(5'-(5-(3,5-dichloro-4-fluorophenyl)-5-trifluoromethyl)-4,5-dihydroisoxazol-3-yl)-3'H-spiro[azetidine-3,1'-isobenzofuran]-1-yl)-2-(methylsulfonyl)ethanone as described in PCT/US2013/56945.

15 DETAILED DESCRIPTION

The present invention provides an improved process for preparing Formula (1) compounds by reacting spiro[azetidinea-isobenzofuran] isoxazolines with compounds of Formula (2).

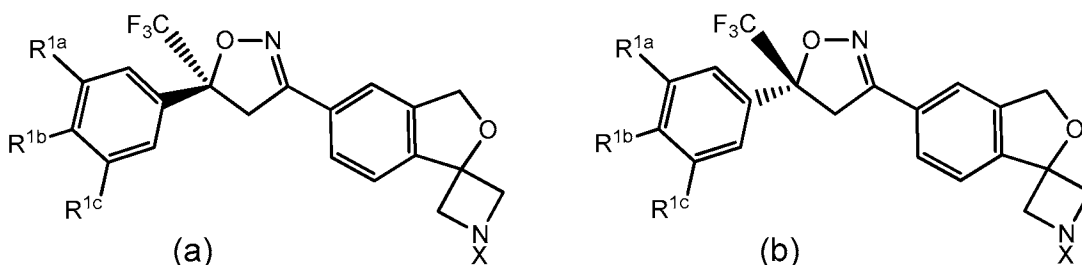
Compounds of the present invention may be synthesized by synthetic
20 routes that include processes analogous to those well known in the chemical arts, particularly in light of the description contained herein. The starting materials are generally available from commercial sources such as Aldrich Chemicals (Milwaukee, Wis.) or are readily prepared using methods well known to those skilled in the art (e.g., prepared by methods generally described in Louis
25 F. Fieser and Mary Fieser, “Reagents for Organic Synthesis”, 1; 19, Wiley, New York (1967, 1999 ed.), or Beilsteins Handbuch der organischen Chemie, 4, Aufl. ed. Springer-Verlag, Berlin, including supplements (also available *via* the Beilstein online database)). For illustrative purposes, the reaction schemes depicted below demonstrate potential routes for synthesizing compounds of the
30 present invention, and key intermediates. For a more detailed description of the individual reaction steps, see the Examples section below. A skilled artisan will appreciate that other suitable starting materials, reagents, and synthetic routes may be used to synthesize the compounds of the present invention and a variety

of derivatives thereof. Further, many of the compounds prepared by the methods described below can be further modified in light of this disclosure using conventional chemistry well known to the skilled artisan.

Compounds of the present invention described herein contain at least one
5 asymmetric or chiral center; and, therefore, exist in different stereoisomeric forms. The R and S configurations are based upon knowledge of known chiral inversion/retention chemistry. Unless specified otherwise, it is intended that all stereoisomeric forms of the compounds of the present invention as well as mixtures thereof, including racemic mixtures and diastereomeric mixtures, form
10 part of the present invention.

Enantiomeric mixtures can be separated into their individual enantiomers on the basis of their physical chemical differences by methods well known to those skilled in the art, such as chromatography and/or fractional crystallization. A more detailed description of techniques that can be used to resolve
15 stereoisomers of compounds from their racemic mixture can be found in Jean Jacques Andre Collet, Samuel H. Wilen, *Enantiomers, Racemates and Resolutions*, John Wiley and Sons, Inc. (1981).

Compounds of this invention can exist as one or more stereoisomers. The various stereoisomers include enantiomers, diastereomers and atropisomers.
20 One skilled in the art will appreciate that one stereoisomer may be more active and/or may exhibit beneficial effects when enriched relative to the other stereoisomer(s) or when separated from the other stereoisomer(s). Additionally, the skilled artisan knows how to separate, enrich, and/or to selectively prepare said stereoisomers. The compounds of the invention may be present as a
25 mixture of stereoisomers, individual stereo isomers or as an optically active form. For example, two possible enantiomers of Formula 1 are depicted as Formula (a) (S-isomer) and Formula (b) (R-isomer) involving the isoxazoline chiral center. Molecular depictions drawn herein follow standard conventions for depicting stereochemistry. The variables R^{1a} , R^{1b} , R^{1c} , and X are as defined herein.

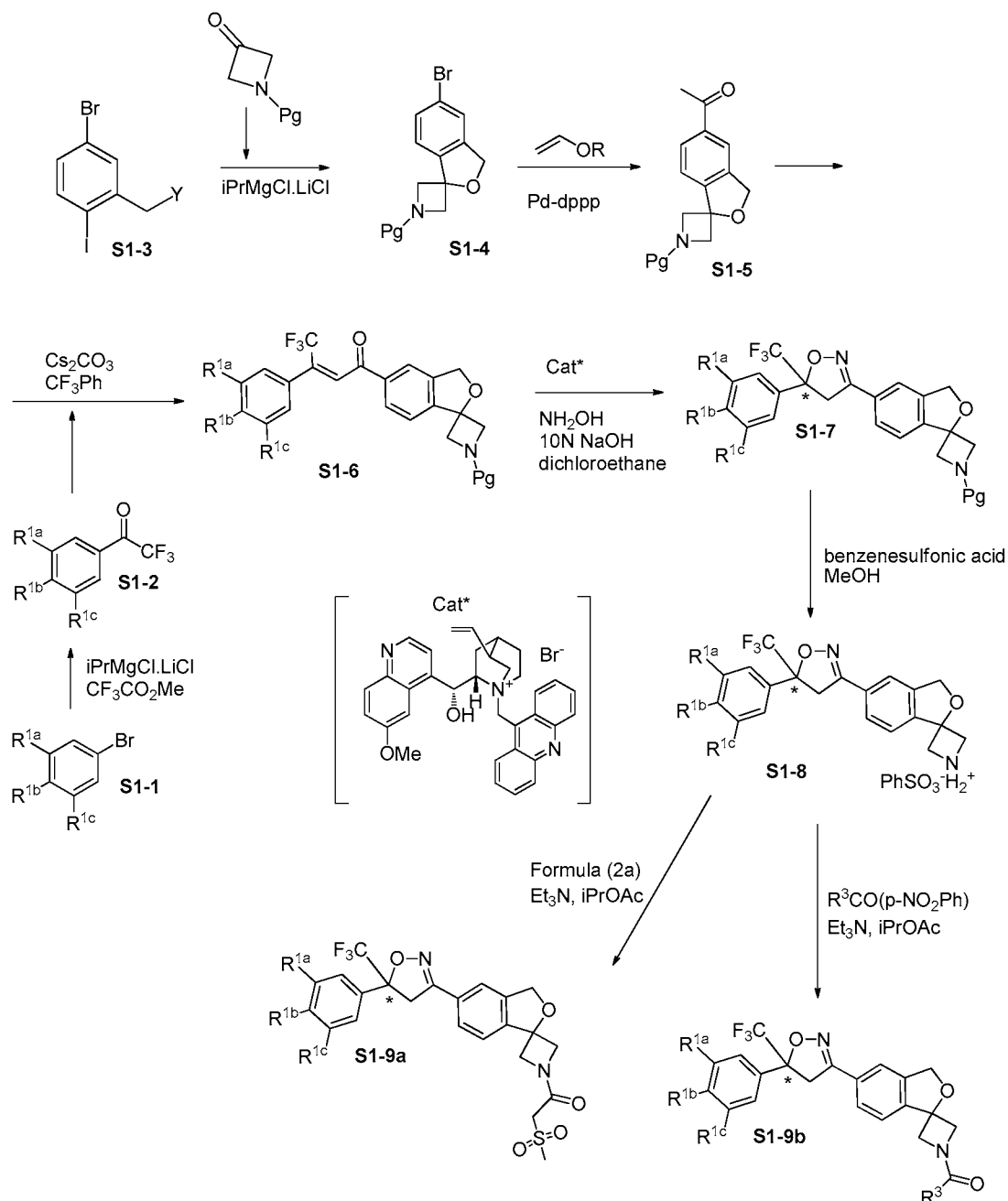


For illustrative purposes, the reaction schemes depicted below demonstrate potential routes for synthesizing key intermediates and compounds of the present invention. For a more detailed description of the individual reaction steps, see the Examples section below. Those skilled in the art will appreciate that other suitable starting materials, reagents, and synthetic routes may be used to synthesize the intermediates and compounds of the present invention and a variety of derivatives thereof. Further, many of the compounds prepared by the methods described below can be further modified in light of this disclosure using conventional chemistry. Scheme 1 outlines the general procedures useful for the preparation and isolation of compounds of the present invention. It is to be understood, however, that the invention, as fully described herein and as recited in the claims, is not intended to be limited by the details of the following schemes or modes of preparation.

In the preparation of compounds of the present invention, protection of remote functionality of intermediates from undesired reactions can be accomplished with a protecting group. For example, an amine-protecting group is a substituent attached to an amine that blocks or protects the amine-functionality of the compound or intermediate. Suitable amine protecting groups include: acyl groups (e.g., formyl, acetyl, chloroacetyl, trichloro-acetyl, *o*-nitrophenylacetyl, *o*-nitrophenoxyacetyl, trifluoroacetyl, acetoacetyl, 4-chlorobutyryl, isobutyryl, *o*-nitrocinnamoyl, picolinoyl, acylisothiocyanate, aminocaproyl, benzoyl, and the like); and acyloxy groups (e.g., 1-*tert*-butyloxycarbonyl (Boc), methoxycarbonyl, 9-fluorenyl-methoxycarbonyl, 2,2,2-trifluoroethoxy-carbonyl, 2-trimethylsilylethoxycarbonyl, vinylloxycarbonyl, allyloxycarbonyl, 1,1-dimethyl-propynyloxycarbonyl, benzyloxy-carbonyl, *p*-nitrobenzyloxycarbonyl, 2,4-dichlorobenzyloxycarbonyl, and the like), diphenylmethane, and benzylcarbamates. Similarly, diphenylmethane and benzylcarbamates can be used as amine protecting groups. Suitable protecting

groups and their respective uses are readily determined by one skilled in the art. For a general description of protecting groups and their use, see T. W. Greene, Protective Groups in Organic Synthesis, John Wiley & Sons, New York, 1991.

5 Scheme 1 – Chiral synthesis



R^{1a} , R^{1b} , and R^{1c} are as defined herein. In Scheme 1, the R substituent depicts a C_1 - C_6 alkyl moiety (e.g., methyl, ethyl, propyl, isopropyl, butyl, and the like). The R^3 substituent depicts hydrogen, C_1 - C_6 alkyl, C_2 - C_6 alkenyl,

C_0 - C_6 alkyl/ C_3 - C_6 -cycloalkyl, C_0 - C_6 alkylphenyl, C_0 - C_6 alkylheteroaryl, or C_0 - C_6 alkylheterocycle; wherein each R^3 C_1 - C_6 alkyl or C_0 - C_6 alkyl/ C_3 - C_6 cycloalkyl moiety can be optionally and independently substituted by at least one substituent selected from cyano, halo, hydroxyl, oxo, C_1 - C_6 alkoxy,

5 C_1 - C_6 haloalkoxy, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl, hydroxyl/ C_1 - C_6 alkyl-, $-S(O)_pC_1$ - C_6 alkyl, $-SH$, $-S(O)_pNR^aR^b$, $-NR^aR^b$, $-NR^aC(O)R^b$, $-SC(O)R$, $-SCN$, or $-C(O)NR^aR^b$; wherein R^a is hydrogen, C_1 - C_6 alkyl, or C_0 - C_3 alkyl/ C_3 - C_6 cycloalkyl, wherein the R^a alkyl and alkylcycloalkyl is optionally substituted by cyano or at least one halo substituent; R^b is hydrogen, C_1 - C_6 alkyl, C_3 - C_6 cycloalkyl,

10 C_0 - C_3 alkylphenyl, C_0 - C_3 alkylheteroaryl, or C_0 - C_3 alkylheterocycle, each R^b can be optionally substituted, where chemically possible, with at least one substituent selected from hydroxyl, cyano, halo, or $-S(O)_pC_1$ - C_6 alkyl; and wherein R^3 C_0 - C_6 alkylphenyl, C_0 - C_6 alkylheteroaryl, or C_0 - C_6 alkylheterocycle moiety can be further optionally substituted with at least one substituent selected from cyano,

15 halo, oxo, =S, hydroxyl, C_1 - C_6 alkoxy, hydroxyl/ C_1 - C_6 alkyl-, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, $-SH$, $-S(O)_pC_1$ - C_6 alkyl, and C_1 - C_6 haloalkoxy; p is the integer 0, 1, or 2. Pg is a protecting group, for example Boc, diphenylmethane, or a benzylcarbamate and Y can be bromine, chlorine, iodine, hydroxyl, or a sulfonate leaving group. The asterisk (*) depicts a chiral center, (i.e., (R) or (S)

20 stereochemistry).

A chiral synthesis of the compounds described within can be achieved according to Scheme 1. From the iodobromobenzyl derivative (**S1-3**), Grignard formation and condensation with tert-butyl 3-oxoazetidine-1-carboxylate provides the cyclized tert-butyl 5'-bromo-3'H-spiro[azetidine-3,1'-isobenzofuran]-1-

25 carboxylate (**S1-4**) in a one-pot reaction or a step-wise fashion. Palladium catalyzed condensation with a vinyl ether provides the acetophenone (**S1-5**) which can undergo condensation with the trifluoroacetophenone (**S1-2**) to give the chalcone (**S1-6**). Addition of hydroxylamine and cyclization in the presence of a chiral catalyst (Cat*) provides the desired enantiomer of the isoxazoline

30 (**S1-7**). Removal of the Boc protecting group can be achieved under acidic conditions such as benzene sulfonic acid in methanol to provide the chiral azetidine (**S1-8**) which can undergo couplings as previously described to provide the chiral compounds (**S1-9a** and **S1-9b**).

When the compounds of the present invention possess a free base form, for example, non-protected Formula (S1-8) compounds; wherein the Pg group is displaced with an acid addition salt ("X"), the compounds can be prepared as an acid addition salt by reacting the free base form of the compound with an acceptable inorganic or organic acid, e.g., hydrohalides such as hydrochloride, hydrobromide, hydrofluoride, hydroiodide; other mineral acids and their corresponding salts such as sulfate, nitrate, phosphate; and alkyl and monoarylsulfonates such as ethanesulfonate, toluenesulfonate, and benzene sulfonate; and other organic acids and their corresponding salts such as aliphatic mono- and dicarboxylic acids, phenyl-substituted alkanolic acids, hydroxy alkanolic acids, alkanedioic acids, aromatic acids, aliphatic and aromatic sulfonic acids, etc. Such salts include sulfate, pyrosulfate, bisulfate, sulfite, bisulfite, nitrate, phosphate, monohydrogenphosphate, dihydrogenphosphate, metaphosphate, pyrophosphate, trifluoroacetate, propionate, caprylate, isobutyrate, oxalate, malonate, succinate, suberate, sebacate, fumarate, acetate, maleate, mandelate, benzoate, chlorobenzoate, methylbenzoate, dinitrobenzoate, phthalate, benzenesulfonate, toluenesulfonate, phenylacetate, citrate, lactate, malate, tartrate, methanesulfonate, and the like. Also contemplated are salts of amino acids such as arginate, gluconate, galacturonate, and the like. See, e.g., Berge S. M., et al., *Pharmaceutical Salts*, *J. Pharm. Sci.*, 66:1 (1977).

One skilled in the art will recognize that, in some cases, after the introduction of a given reagent as it is depicted in the schemes, it may be necessary to perform additional routine synthetic steps not described in detail to complete the synthesis of Formula (1) and Formula (2) compounds.

The skilled person will appreciate that the compounds of the present invention could be made by methods other than those herein described as incorporated herein by reference, by adaptation of the methods herein described and/or adaptation of methods known in the art, for example the art described herein, or using standard textbooks such as "Comprehensive Organic Transformations - A Guide to Functional Group Transformations", RC Larock, Wiley-VCH (1999 or later editions).

The reactions set forth below were done generally under a positive pressure of argon or nitrogen or with a drying tube, at ambient temperature (unless otherwise stated), in anhydrous solvents, and the reaction flasks were fitted with rubber septa for the introduction of substrates and reagents *via* syringe. Glassware was oven dried and/or heat dried. Analytical thin layer chromatography (TLC) was performed using glass-backed silica gel 60 F 254 precoated plates and eluted with appropriate solvent ratios (v/v). Reactions were assayed by TLC or LCMS and terminated as judged by the consumption of starting material. Visualization of the TLC plates was done with UV light (254 nm wavelength) or with an appropriate TLC visualizing solvent and activated with heat. Flash column chromatography (Still et al., J. Org. Chem., 43, 2923, (1978)) was performed using silica gel (RediSep Rf) or various MPLC systems, such as Biotage or ISCO purification system.

Conventional methods and/or techniques of separation and purification known to one of ordinary skill in the art can be used to isolate the compounds of the present invention, as well as the various intermediates related thereto. Such techniques will be well-known to one of ordinary skill in the art and may include, for example, all types of chromatography (high pressure liquid chromatography (HPLC), column chromatography using common adsorbents such as silica gel, and thin-layer chromatography (TLC), recrystallization, and differential (i.e., liquid-liquid) extraction techniques.

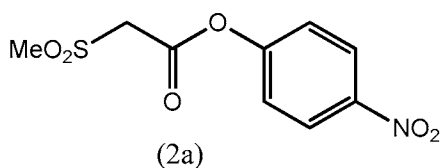
The compound structures in the examples below were confirmed by one or more of the following methods: proton magnetic resonance spectroscopy, and mass spectroscopy. Proton magnetic resonance (^1H NMR) spectra were determined using a Bruker spectrometer operating at a field strength of 400 megahertz (MHz). Chemical shifts are reported in parts per million (ppm, δ) downfield from an internal tetramethylsilane standard. Mass spectra (MS) data were obtained using Agilent mass spectrometer with atmospheric pressure chemical ionization. Method: Acquity UPLC with chromatography performed on a Waters BEH C18 column (2.1 x 50 mm, 1.7 μm) at 50°C. The mobile phase was a binary gradient of acetonitrile (containing 0.1% trifluoroacetic acid) and water (5–100%).

Embodiments of the present invention are illustrated by the following Examples. It is to be understood, however, that the embodiments of the invention are not limited to the specific details of these Examples, as other variations thereof will be known, or apparent in light of the instant disclosure, to one of ordinary skill in the art.

EXAMPLES

The following intermediates and example provide a more detailed description of the process conditions for preparing Formula (1) compounds. It is to be understood, however, that the invention, as fully described herein and as recited in the claims, is not intended to be limited by the details of the scheme or modes of preparation as described herein.

Intermediate 1. (4-nitrophenyl)-2-methylsulfonylacetate (Formula (2a))

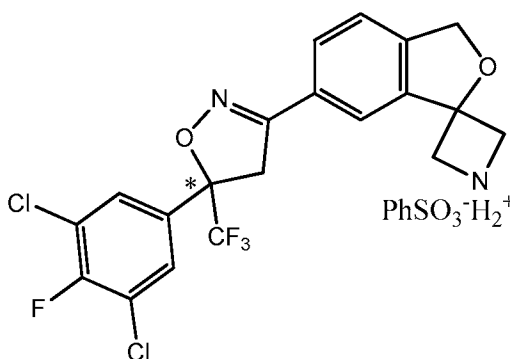


Add 100.0g methanesulfonylacetic acid (724mmol) to 500mL of acetonitrile. Add triethylamine (3.78 grams, 724mmol) and cool the reaction to 0°C. Slowly add a solution of p-nitrophenylchloroformate (161g, 1.08 equivalents) in 240mL acetonitrile at a temperature of <5°C. Stir at about 5-10°C for 15 minutes after addition. Add 1500mL water and stir the resulting slurry for 15 minutes. Filter and wash with a solution of 25% acetonitrile in water. Dry the material. The material is further purified by heating to 80°C in isopropyl acetate (835mL). Cool the mixture to 20°C over two hours and isolate the product by filtration. Wash the filter cake with 200mL *tert*-butyl methyl ether. Dry the material under vacuum at 50°C to afford 147 grams (78%) of a white solid. ¹H NMR (CDCl₃, 600MHz) 8.35 (d, 2H), 7.37 (d, 2H), 4.28 (s, 2H), 3.23 (s, 3H). MS M+1 = 260.

Alternatively, (4-nitrophenyl)-2-methylsulfonylacetate can be prepared by stirring methanesulphonylacetic acid (59g), 4-nitrophenol (119g), and acetonitrile (600mL), under nitrogen. Cool the mixture in an ice/water bath to an internal

temperature of about 3°C. Add N-(3-dimethylaminopropyl)-N'-ethylcarbodiimide hydrochloride (EDAC, 100g) portionwise over 30 minutes. The internal temperature rises to a maximum of about 8°C during the addition. Allow the reaction to cool to about 1-3°C while stirring for 1 hour. Quench the reaction mixture by adding water (1200mL) over 15 minutes at a maximum temperature of 10°C. Stir the mixture in the ice/water bath for 1-hour. Isolate the product by filtration. The yellow filter cake was washed with water until the liquors ran colorless. The filter cake was dried at 50°C under vacuum to afford 79g (71% yield) of a white solid. ¹H NMR (CDCl₃, 600MHz) 8.35 (d, 2H), 7.37 (d, 2H), 4.28 (s, 2H), 3.23 (s, 3H). MS M+1 = 260.

Intermediate 2. Chiral-5'-(5-(3,5-dichloro-4-fluorophenyl)-5-(trifluoromethyl)-4,5-dihydroisoxazol-3-yl)-3'H-spiro[azetidine-3,1'-isobenzofuran] benzene sulfonate (Formula (1a1))



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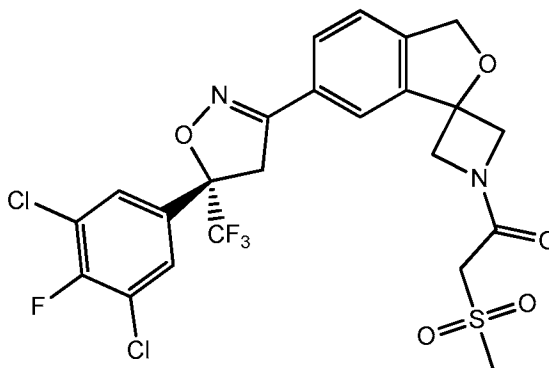
The compound was prepared similarly to that in Preparation 31 of WO2012/120399, except that the p-toluene sulfonic acid was replaced with benzene sulfonic acid. Chiral-*tert*-butyl 5'-(5-(3,5-dichloro-4-fluorophenyl)-5-(trifluoromethyl)-4,5-dihydroisoxazol-3-yl)-3'H-spiro[azetidine-3,1'-isobenzofuran]-1-carboxylate (195g, 348mmol) was dissolved in methanol (600mL) at 60°C. Benzenesulfonic acid (66.7g, 418mmol) was added to the reaction over 30 minutes as a solution in methanol (60mL). The reaction was stirred at 60°C for thirty minutes and then *tert*-butylmethyl ether (455mL) was added. The reaction was cooled to 20°C and was filtered to isolate the product. The product was washed with *tert*-butylmethyl ether (200mL) and was dried to afford 167.4g (92%) of a white powder. ¹H NMR, 600MHz (d₆-DMSO) d ppm:

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9.08 (br s, 1H), 8.89 (d, 1H), 7.95 (d, 1H), 7.83 (m, 3H), 7.72 (s, 1H), 7.62 (d, 2H), 7.33 (m, 3H), 5.13 (s, 2H), 4.36 (m, 6H), 2.25; m/z (CI) 461 [M+H] (free amine). The asterisk (*) depicts the chiral center.

- 5 Example 1. (S)-5'-5-(3,5-dichloro-4-fluorophenyl)-5-trifluoromethyl)-4,5-dihydroisoxazol-3-yl)-3'H-spiro[azetidine-3,1'-isobenzofuran]-1-yl)-2-(methylsulfonyl)ethanone (Formula (3))



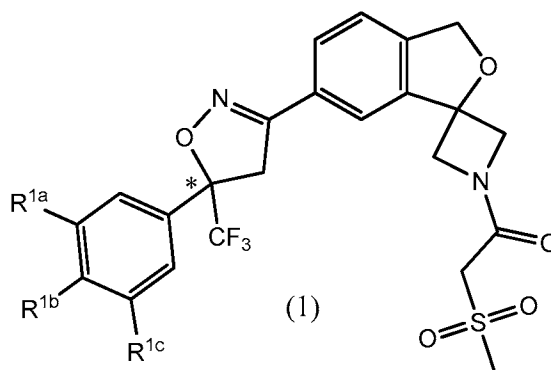
A slurry of (S)-5'-5-(3,5-dichloro-4-fluorophenyl)-5-trifluoromethyl)-4,5-
 10 dihydroisoxazol-3-yl)-3'H-spiro[azetidine-3,1'-isobenzofuran]benzene sulfonate
 (Intermediate 2, 50.0g) and (4-nitrophenyl)-2-methylsulfonylacetate (Intermediate
 1, 22.4g, 1.07 equivalents) in isopropyl acetate (450mL) was cooled to about
 7°C. Besides isopropyl acetate, alternate non-limiting organic solvents can be
 used, for example: tetrahydrofuran, ethyl acetate, toluene, methyl tert-butyl
 15 ether, and the like. To this was added triethylamine (9.26g, 1.10 equivalents).
 The reaction was stirred for 15 minutes at about 5-10°C and then at about 20°C
 for two hours. The solids which formed were removed by filtration. The
 remaining organic solution was washed sequentially with 6N aqueous
 ammonium hydroxide (2x250mL) and then with water (2x200mL). Besides
 20 ammonium hydroxide, alternate non-limiting aqueous bases can be used, for
 example: carbonates and other hydroxides (e.g., sodium hydroxide and
 potassium hydroxide), and the like. The washed organics were concentrated
 under vacuum to a small volume. The concentrated organics were then added
 to 300mL methanol. The methanolic solution was added slowly to 20°C water
 25 (300mL) while stirring over 30 minutes. After stirring for an additional 15
 minutes, the solids were isolated by filtration. The resulting white powder was
 dried under vacuum at 50°C to a final yield of 38g. Alternatively, the crystal

form of the product can be isolated by adding the concentrated organics to a solution (300mL) containing ethyl acetate (5%), n-heptane (35%) and ethanol (60%). The reaction mixture was heated to about 60°C and then cooled to about 45°C over a period of about 15-20 minutes. Crystal seeds of (S)-(5'-(5-(3,5-dichloro-4-fluorophenyl)-5-trifluoromethyl)-4,5-dihydroisoxazol-3-yl)-3'H-spiro[azetidine-3,1'-isobenzofuran]-1-yl)-2-(methylsulfonyl)ethanone were added to the mixture. [The crystal seeds were made by dissolving amorphous (S)-1-(5'-(5-(3,5-dichloro-4-fluorophenyl)-5-(trifluoromethyl)-4,5-dihydroisoxazol-3-yl)-3'H-spiro[azetidine-3,1'-isobenzofuran]-1-yl)-2-(methylsulfonyl)ethanone in methanol and allowing vapor diffusion of an outer layer of diisopropyl ether to slowly convert the amorphous form to the crystal form over a period of about 5 days at room temperature.] The reaction mixture was maintained at about 45°C for about 2 hours then cooled to about 30°C at a rate of about 1.5°C per hour, then cooled to 10°C over three hours, linearly, then held at 10°C for about 4.5 hours. The white slurry was cooled to about 0-1°C over 20 minutes and held overnight (approximately 23 hours) at about 0-1°C. The product was isolated by filtration and dried. ¹H NMR, 600MHz (d₆-DMSO): 7.88 (d, 2H), 7.82 (d, 1H), 7.73 (m, 2H), 5.18 (s, 2H), 4.62 (dd, 2H), 4.42 (dd, 2H), 4.28 (m, 4H), 3.20 (s, 3H). MS: M+H = 582.

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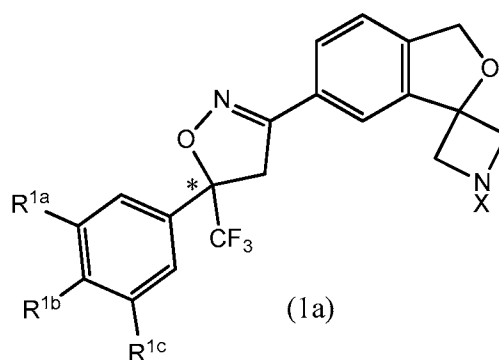
We claim:

1. A process for preparing a Formula (1) compound



5 by

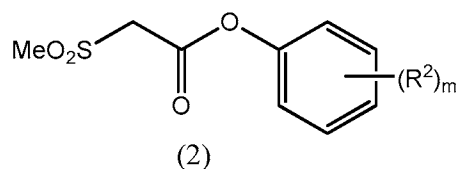
- a) reacting a Formula (1a) compound



wherein R^{1a} , R^{1b} , and R^{1c} are each independently selected from hydrogen, halogen, or CF_3 ; X is an acid addition salt; and "*" represents a chiral center;

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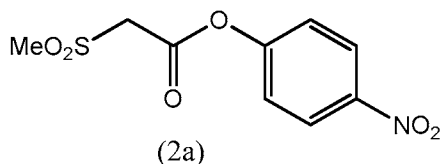
- b) with a Formula (2) compound



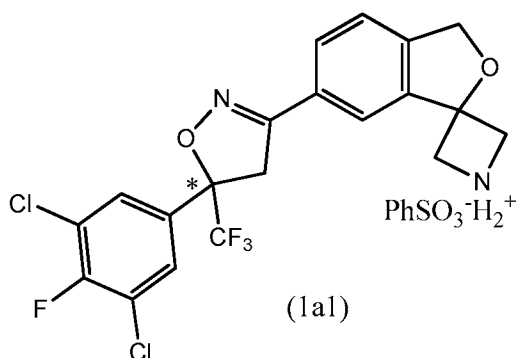
wherein R^2 is hydrogen, halogen, or nitro, and m is the integer 1, 2, 3, 4, or 5, and wherein at least one of R^2 is halo or nitro, provided that only one of R^2 is nitro; in an organic solvent, in the presence of a non-aqueous base.

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2. The process of Claim 1 wherein Formula (2) is a compound of Formula (2a)



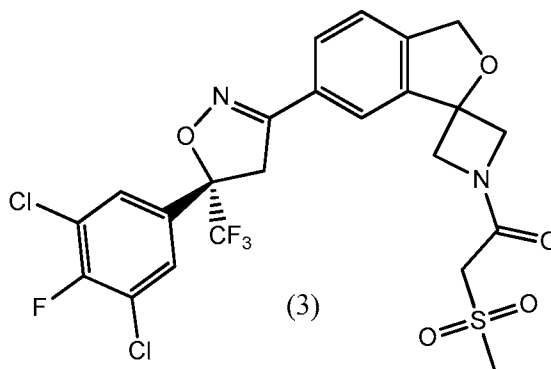
- 5 3. The process of Claim 2 wherein R^{1a}, R^{1b}, and R^{1c} are each independently selected from hydrogen, fluoro, and chloro; the organic solvent is selected from the group consisting of isopropyl acetate, tetrahydrofuran, methyl tert-butyl ether, ethyl acetate, and toluene; and wherein the acid addition salt is benzene sulfonic acid.
- 10 4. The process of Claim 3 wherein the Formula (1a) compound is a Formula (1a1) compound



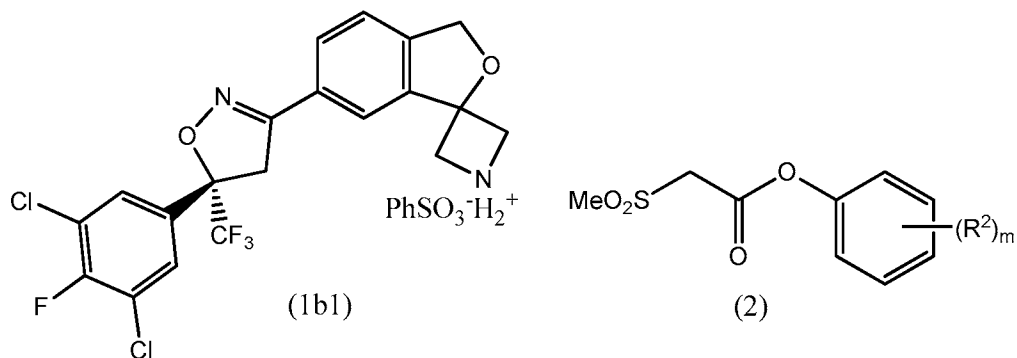
and wherein the non-aqueous base is triethylamine.

- 15 5. The process of Claim 4 wherein
- a) equimolar amounts of the Formula (1a1) compound and Formula (2a) compound are reacted in isopropyl acetate;
 - b) the solids are removed and the organics sequentially washed with an aqueous base and water; and
 - c) the organics are concentrated.
- 20 6. The process of Claim 5 further comprising:
- a) addition of alcohol to the concentrated organics;
 - b) slowly adding the alcohol solution to water while stirring; and
- 25

- c) filter and dry the resulting solids.
7. The process of Claim 5 wherein the concentrated solids are washed twice with an aqueous base selected from a hydroxide or carbonate and then washed twice with water.
- 5
8. The process of Claim 7 wherein the aqueous base is selected from sodium hydroxide, potassium hydroxide, or ammonium hydroxide.
- 10
9. The process of Claim 6 wherein the alcohol is methanol.
10. The process of Claim 5 further comprising:
- a) the concentrated organics are added to a solution comprising ethyl acetate, n-heptane, and ethanol;
- 15
- b) add crystal seeds to the solution and cool; and
- c) filter and dry the resulting solids.
11. A process for preparing a Formula (3) compound

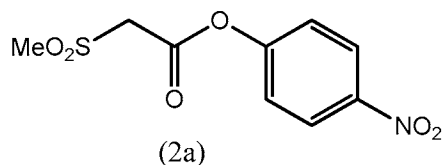


- 20
- by reacting a Formula (1b1) compound with a Formula (2) compound, in an organic solvent, in the presence of a non-aqueous base,



wherein R^2 is hydrogen, halogen, or nitro, and m is the integer 1, 2, 3, 4, or 5, and wherein at least one of R^2 is halo or nitro, provided that only one of R^2 is nitro.

- 5 12. The process of Claim 11 wherein the Formula (2) compound is a compound of Formula (2a)

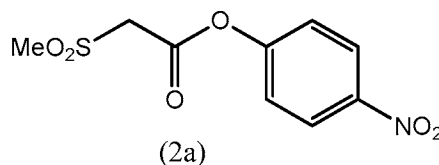


10 the organic solvent is selected from the group consisting of isopropyl acetate, ethyl acetate, toluene, tetrahydrofuran, and methyl tert-butyl ether; and the non-aqueous base is triethylamine.

13. The process of Claim 12, wherein the organic solvent is isopropyl acetate, remove the solids, sequentially wash the organics with an aqueous base and water, and concentrate the organics.

15 14. The process of Claim 13 wherein the concentrated organics are either added to methanol, slowly mixed with water, and the resulting solids isolated by filtration and dried; or the concentrated organics are added to a solution comprising ethyl acetate, n-heptane, and ethanol, then mixed
20 with crystal seeds, allowed to cool, and the resulting solids isolated by filtration and dried.

15. A process for preparing a Formula (2a) compound



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comprising either

- A) a) mixing methanesulfonylacetic acid, acetonitrile, and triethylamine, b) cooling the reaction mixture and adding p-nitrophenylchloroformate in acetonitrile, c) adding water, d) filtering and washing the reaction mixture

with acetonitrile/water (1:3), e) drying the solids and further purifying the solids by heating to about 80°C in isopropyl acetate, f) cooling the mixture, filtering and washing the solids with tert-butyl methyl ether, g) and drying the solids; or

- 5 B) a) mixing methanesulfonylacetic acid, 4-nitrophenol, and acetonitrile under nitrogen, b) cooling the reaction mixture, c) add N-(3-dimethylaminopropyl)-N'-ethylcarbodiimide hydrochloride portionwise, d) quenching the reaction mixture with water, e) filtering and washing the solids with water and f) drying the solids.

10

INTERNATIONAL SEARCH REPORT

International application No PCT/US2013/070959

A. CLASSIFICATION OF SUBJECT MATTER INV. C07D491/10 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C07D		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data, CHEM ABS Data, BEILSTEIN Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2012/120399 A1 (PFIZER [US]; BILLEN DENIS [US]; CHUBB NATHAN ANTHONY LOGAN [US]; CURTI) 13 September 2012 (2012-09-13) cited in the application	1-14
A	page 96; compound 31 page 98; example 9	15
Y	WO 2012/017359 A1 (PFIZER [US]; CHUBB NATHAN A L [US]; CURTIS MICHAEL PAUL [US]; HOWSON W) 9 February 2012 (2012-02-09)	1-14
A	page 94; example 6	15
Y	WO 2004/113347 A1 (CELLTECH R&D LTD [GB]; BROOKINGS DANIEL CHRISTOPHER [GB]; DAVIS JEREMY) 29 December 2004 (2004-12-29)	1-14
A	page 89; compound 87	15
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<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
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"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
Date of the actual completion of the international search	Date of mailing of the international search report	
29 January 2014	17/02/2014	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Jeanjean, Fabien	

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/070959

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	page 27; example 42; compounds AIT-0085 -----	15
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Information on patent family members

International application No

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