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(71) Applicant(s)
Jiangsu Hengrui Medicine Co., Ltd.;Shanghai Hengrui Pharmaceutical Co., Ltd.

(72) Inventor(s)
Tu, Wangyang;Xu, Guoji;Zhang, Haitang;Chi, Jiangtao;Dong, Qing

(74) Agent / Attorney
Davies Collison Cave Pty Ltd, Level 15 1 Nicholson Street, MELBOURNE, VIC, 3000, AU

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(71) 申请人: **江苏恒瑞医药股份有限公司 (JIANGSU HENGRUI MEDICINE CO., LTD.)** [CN/CN]; 中国江苏省连云港市经济技术开发区昆仑山路 7 号, Jiangsu 222047 (CN)。 **上海恒瑞医药有限公司 (SHANGHAI HENGRUI PHARMACEUTICAL CO., LTD.)** [CN/CN]; 中国上海市闵行区文井路 279 号, Shanghai 200245 (CN)。

(72) 发明人: **屠汪洋 (TU, Wangyang)**; 中国上海市闵行区文井路 279 号, Shanghai 200245 (CN)。 **徐国际 (XU, Guoji)**; 中国上海市闵行区文井路 279 号, Shanghai 200245 (CN)。 **张海棠 (ZHANG, Haitang)**; 中国上海市闵行区文井路 279 号, Shanghai 200245 (CN)。 **池江涛 (CHI, Jiangtao)**; 中国上海市闵行区文井路 279 号, Shanghai 200245 (CN)。 **董庆 (DONG, Qing)**; 中国上海市闵行区文井路 279 号, Shanghai 200245 (CN)。

(74) 代理人: **北京戈程知识产权代理有限公司 (GE CHENG & CO., LTD.)**; 中国北京市东城区东长安街 1 号东方广场东三办公楼 19 层程伟, Beijing 100738 (CN)。

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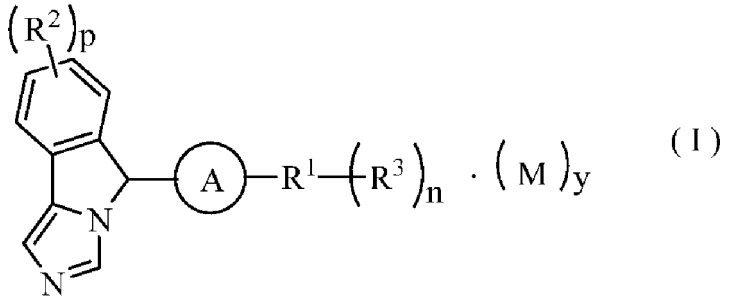
(54) Title: IMIDAZO ISOINDOLE DERIVATIVE, PREPARATION METHOD THEREFOR AND MEDICAL USE THEREOF

(54) 发明名称 : 咪唑并异吲哚类衍生物、其制备方法及其在医药上的应用



(I)

(57) Abstract: The present invention relates to an imidazo isoindole derivative, a preparation method therefor and a medical use thereof. In particular, the present invention relates to the imidazo isoindole derivative as shown in the formula (I), a preparation method and pharmaceutical composition containing the derivative, and a use thereof for treating diseases with the pathological characteristic of IDO-mediated tryptophan metabolic pathways. The diseases comprise cancers, Alzheimer's disease, autoimmune diseases, depression, anxiety disorders, cataracts, psychological disorders and AIDS, wherein the substituents in the formula (I) are the same as those defined in the description.

(57) 摘要: 本发明涉及咪唑并异吲哚类衍生物、其制备方法及其在医药上的应用。特别地，本发明涉及通式(I)所示的咪唑并异吲哚类衍生物、其制备方法及含有该衍生物的药物组合物，以及其治疗具有 IDO 介导的色氨酸代谢途径病理学特征的疾病的用途，所述的疾病包括癌症、阿尔茨海默病、自身免疫性疾病、抑郁症、焦虑症、白内障、心理障碍和艾滋病，其中通式(I)中的各取代基与说明书中的定义相同。

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RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG)。

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IMIDAZO ISOINDOLE DERIVATIVE, PREPARATION METHOD THEREFOR AND MEDICAL USE THEREOF

FIELD OF THE INVENTION

The present invention belongs to the field of medicine, and relates to an imidazo isoindole derivative, a preparation method therefor and a medical use thereof. The present invention discloses that the derivative is used as an IDO inhibitor for treating a disease with the pathological feature of IDO-mediated tryptophan metabolic pathway. The disease comprises cancer, Alzheimer's disease, autoimmune disease, depression, anxiety, cataract, psychological disorder and AIDS.

BACKGROUND OF THE INVENTION

Tumor is one of the major diseases that seriously endanger human life, while more than half of tumors are occurring in developing countries. The overall incidence of malignant tumor in China is on the rise, increasing by the average annual rate of 3% to 5%. By 2020, it is predicted that 4 million people will suffer from cancer, and 3 million people will be died of cancer. The main reasons are due to aging, urbanization, industrialization and lifestyle changes. In the hospital drug market of China, the scale of anti-tumor drug sales has been steadily growth in recent years. It was reached 66.42 billion yuan in 2012, with an increment of 13.07% year on year; By 2017, the scale of anti-tumor drug market is predicted to reach 105.57 billion yuan, with an increment of 7.57% year on year.

Due to the unlimited growth, infiltration and metastasis of malignant tumors, tumor cells can't be completely cut off or killed by three conventional treatment methods (surgery, radiation therapy, and chemotherapy) used in clinical, and tumor metastasis or recurrence occur frequently. Tumor biotherapy is a new therapy for tumor prevention and treatment using modern biotechnology and related products thereof. Because of its safety, efficacy and rare adverse reactions, tumor biotherapy becomes the fourth mode of tumor therapy after surgery, radiotherapy and chemotherapy, which achieves an antitumor effect by mobilizing the host's natural defense mechanism (such as inhibition of IDO-mediated tumor immune escape mechanism) or administering naturally occurring highly targeted substances.

Indoleamine-pyrrole-2,3-dioxygenase (IDO) is a heme-containing monomeric protein, consisting of 403 amino acid residues, including of two folded α-helix domains, wherein the large domain contains a catalytic pocket, hydrophobic interaction and the like can be carried out between the substrate and IDO in the catalytic pocket. IDO is an enzyme that catalyzes the conversion of tryptophan to formyl kynurenine, widely distributed in tissues of humans and other mammals (rabbits, mice) with the exception

of liver. It is the only rate-limiting enzyme which can catalyze the metabolism of tryptophan enzyme, in addition to the liver. It is known that tryptophan is not only an essential amino-acid for maintaining the activation and proliferation of cells, but also an important indispensable component to form protein. IDO is closely related to many kinds of cytokines such as interferon (IFN), interleukin (IL), tumor necrosis factor (TNF) etc., which can activate IDO under certain conditions. There is an adjustment point that is very sensitive to the level of tryptophan in the cell cycle of T-cell. On the one hand, IDO can lead to the depletion of local tryptophan, resulting in the stagnation of T-cell in the middle of G1 phase, thereby inhibiting the proliferation of T-cell; On the other hand, canine urea, which is the main product of tryptophan metabolism catalyzed by IDO, induces the apoptosis of T-cell by the changes of intracellular oxidants and antioxidants induced by the mediation of oxygen free radicals, which is an inherent immunosuppressive mechanism in the body. A large number of studies have shown that IDO is highly expressed in leukemic cells, the proliferation of local T-cell and T-cell-mediated immune response are inhibited, the transduction of T-cell activation signal is blocked, thereby mediating the tumor cell to escape from the attack of immune system. It has been found that IDO is expressed constitutively in most human tumors. Thus, IDO is a potential target for cancer immunotherapy.

Patent applications disclosing selective inhibitors of IDO include WO2012142237, WO2004094409, WO2006122150, WO2007075598, WO2010005958 and WO2014066834, etc.

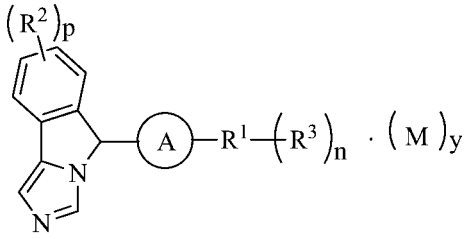
IDO inhibitors have a good application prospects as a drug in the pharmaceutical industry, but at present, a good IDO inhibitor which can be used as a marketed drug has not been found. In order to achieve better tumor treatment, and to better meet the market needs, the inventors hope to develop a new generation of selective IDO inhibitors with highly efficiency and low toxicity. The present invention provides a novel compound as a selective IDO inhibitor, and it is found that the compound having such a structure shows excellent effect and function, particularly excellents pharmacokinetic activity.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

SUMMARY OF THE INVENTION

The present invention is directed to a compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, wherein the structure of the compound represented by the formula (I) is as follows:



(I)

wherein:

M is inorganic acid or organic acid, preferably trifluoroacetic acid;

A is selected from the group consisting of cycloalkyl, heterocyclyl, aryl and heteroaryl, wherein the cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, amino, nitro, hydroxy, cyano, alkoxy, hydroxyalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl;

R^1 is selected from the group consisting of hydrogen, alkyl, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-OR^4$, $-C(O)R^4$, $-C(O)OR^4$, $-S(O)_mR^4$, $-NR^5R^6$, $-C(O)NR^5R^6$, $-C(O)NHR^5$, $-NR^5C(O)R^6$ and $-NR^5S(O)_mR^6$;

R^2 are identical or different and each independently selected from the group consisting of hydrogen, alkyl, haloalkyl, alkoxy, haloalkoxy, halogen, amino, nitro, hydroxy, cyano, cycloalkyl, heterocyclyl, aryl and heteroaryl;

R^3 are identical or different and each independently selected from the group consisting of hydrogen, alkyl, haloalkyl, alkoxy, haloalkoxy, halogen, amino, nitro, hydroxy, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-OR^4$, $-C(O)R^4$, $-C(O)OR^4$, $-S(O)_mR^4$, $-NR^5R^6$, $-C(O)NR^5R^6$, $-NR^5C(O)R^6$ and $-NR^5S(O)_mR^6$, wherein the alkyl, haloalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, haloalkyl, halogen, amino, nitro, cyano, hydroxy, alkoxy, haloalkoxy, hydroxyalkyl, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-R^a$, $-OR^7$, $-C(O)R^7$, $-C(O)OR^7$, $-S(O)_mR^7$, $-NR^7R^8$, $-C(O)NR^7R^8$, $-NR^7C(O)R^8$ and $-NR^7S(O)_mR^8$;

R^a is selected from the group consisting of alkyl, haloalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl, wherein the alkyl, haloalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, amino, nitro, hydroxy, alkoxy, hydroxyalkyl, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-OR^4$, $-C(O)R^4$, $-C(O)OR^4$, $-S(O)_mR^4$, $-NR^5R^6$, $-C(O)NR^5R^6$, $-NR^5C(O)R^6$ and $-NR^5S(O)_mR^6$;

R^4 is selected from the group consisting of hydrogen, alkyl, haloalkyl, hydroxy, amino, alkoxy, haloalkoxy, cycloalkyl, heterocyclyl, aryl and heteroaryl, wherein the alkyl, haloalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, amino, nitro, cyano, hydroxy, hydroxyalkyl, alkoxy, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-R^a$, $-OR^7$, $-C(O)R^7$, $-C(O)OR^7$, $-S(O)_mR^7$, $-NR^7R^8$, $-C(O)NR^7R^8$,

$-NR^7C(O)R^8$ and $-NR^7S(O)_mR^8$;

R^5 and R^6 are identical or different and each independently selected from the group consisting of hydrogen, alkyl, hydroxy, amino, cycloalkyl, heterocyclyl, aryl and heteroaryl, wherein the alkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, hydroxy, amino, nitro, cyano, alkoxy, hydroxyalkyl, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-R^a$, $-OR^7$, $-C(O)R^7$, $-C(O)OR^7$, $-S(O)_mR^7$, $-NR^7R^8$, $-C(O)NR^7R^8$, $-NR^7C(O)R^8$ and $-NR^7S(O)_mR^8$;

R^7 and R^8 are identical or different and each independently selected from the group consisting of hydrogen, alkyl, hydroxy, amino, cycloalkyl, heterocyclyl, aryl and heteroaryl, wherein the alkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, hydroxy, amino, nitro, cyano, alkoxy, hydroxyalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl;

p is an integer of 0, 1, 2, 3 or 4;

y is an integer of 0, 1, 2 or 3;

m is an integer of 0, 1 or 2; and

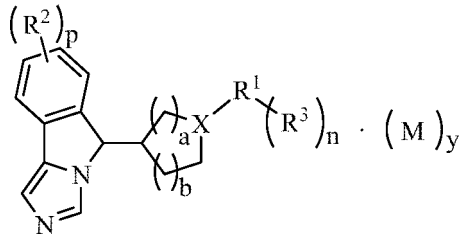
n is an integer of 0, 1, 2, 3, 4 or 5.

In a preferred embodiment of the present invention, in a compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, y is 0, 1 or 3, particularly 0.

In a preferred embodiment of the present invention, in a compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, A is selected from the group consisting of heterocyclyl and cycloalkyl, wherein the heterocyclyl and cycloalkyl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, amino, nitro, hydroxy, cyano, alkoxy, hydroxyalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl.

In a preferred embodiment of the present invention, in a compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, n is an integer of 0, 1 or 2.

In a preferred embodiment of the present invention, a compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, is a compound of formula (II), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,



(II)

wherein:

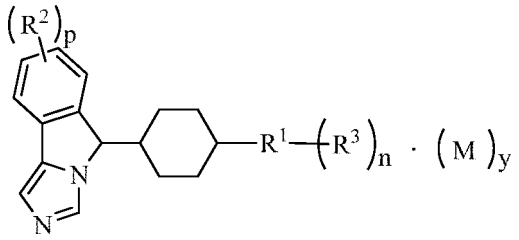
X is CH or N;

R^1 to R^3, M, p, n and y are as defined in formula (I);

a is an integer of 0, 1, 2 or 3; and

b is an integer of 0, 1, 2 or 3.

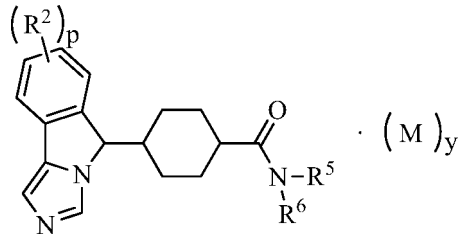
In a preferred embodiment of the present invention, a compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, is a compound of formula (II-A), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,



(II-A)

wherein R^1 to R^3, M, p, n and y are as defined in formula (I).

In a preferred embodiment of the present invention, a compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, is a compound of formula (II-B), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,

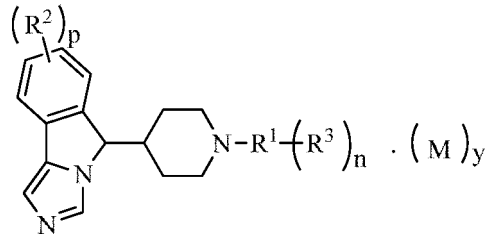


(II-B)

wherein R^2, R^5, R^6, M, p and y are as defined in formula (I).

In a preferred embodiment of the present invention, a compound of formula (II), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof,

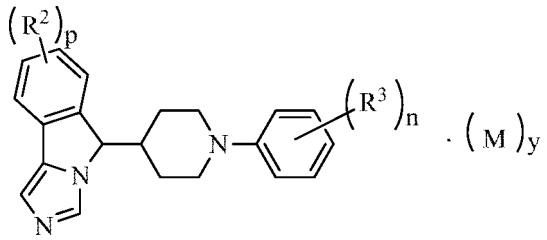
or a pharmaceutically acceptable salt thereof, is a compound of formula (III), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,



(III)

wherein R^1 to R^3, M, p, n and y are as defined in formula (I).

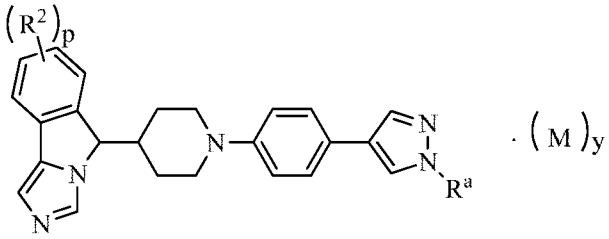
In a preferred embodiment of the present invention, a compound of formula (III), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, is a compound of formula (IV), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,



(IV)

wherein R^2, R^3, M, p, n and y are as defined in formula (I).

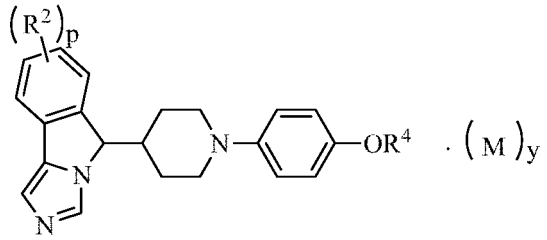
In a preferred embodiment of the present invention, a compound of formula (III), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, is a compound of formula (IV-1), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,



(IV-1)

wherein R^2, R^a, M, p and y are as defined in formula (I).

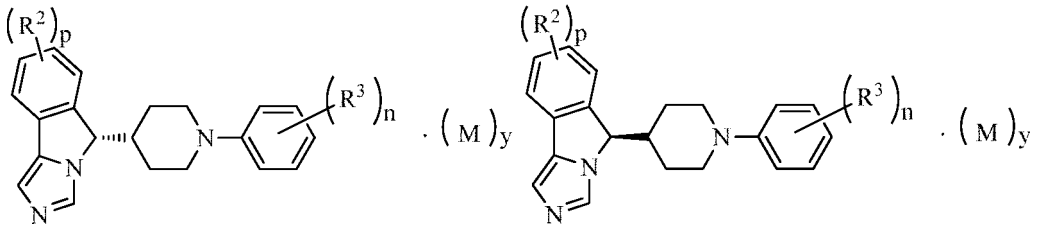
In a preferred embodiment of the present invention, a compound of formula (III), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, is a compound of formula (IV-2), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,



(IV -2)

wherein R^2, R^4, M, p and y are as defined in formula (I).

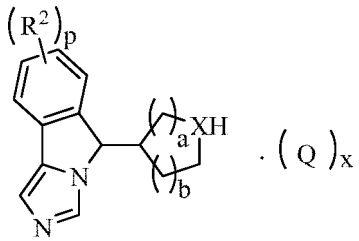
In a preferred embodiment of the present invention, a compound of formula (IV), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, is a compound of formula (IV-A) or formula (IV-B),



(IV-A) (IV-B)

wherein R^2, R^3, M, p, n and y are as defined in formula (I).

In another aspect, the present invention is also directed to a compound of formula (V), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, which is an intermediate for preparing a compound of formula (II), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof,



(V)

wherein:

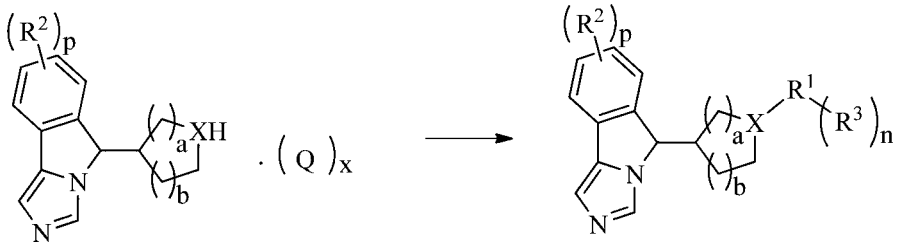
Q is inorganic acid or organic acid, preferably trifluoroacetic acid;

X is CH or N;

R^2, p, a and b are as defined in formula (II); and

x is an integer of 0, 1, 2 or 3.

In another aspect, the present invention is also directed to a process for preparing a compound of formula (II-1), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, comprising the steps of:



(V) (II-1)

coupling a compound of formula (V) with a halide of R^1 under an alkaline condition in the presence of a catalyst, then optionally reacting the resulting product with a boric acid or borate ester of R^3 to obtain the compound of formula (II-1);

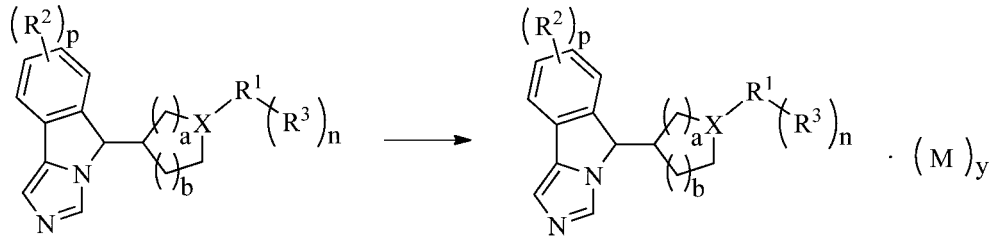
wherein:

X is N;

R^1 to R^3, p, n, a and b are as defined in formula (II); and

Q and x are as defined in formula (V).

In another aspect, the present invention is also directed to a process for preparing the compound of formula (II), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, comprising a step of:



(II-1) (II)

salifying a compound of formula (II-1) under an acidic condition to obtain the compound of formula (II);

wherein:

X is CH or N;

R^1 to R^3, M, p, y, n, a and b are as defined in formula (II).

In another aspect, the present invention is also directed to a pharmaceutical composition comprising a therapeutically effective amount of the compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, diluent or excipient. The present invention is also directed to a process for the preparation of the aforementioned composition comprising a step of mixing a compound represented by each formula or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, with a pharmaceutically acceptable carrier, diluent or excipient.

The present invention is further directed to use of the compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof,

or a pharmaceutically acceptable salt thereof, or a pharmaceutical composition comprising the same, in the preparation of a medicament for preventing and/or treating a disease with the pathological feature of IDO-mediated tryptophan metabolic pathway. IDO inhibitors can be used for the inhibition of cardiac disorders and the treatment of other diseases with the pathological feature of IDO-mediated tryptophan metabolic pathway, which include virus infection (such as AIDS), cell infection (such as Lyme disease and streptococcal infection), neurodegenerative disorder (such as Alzheimer's disease, Huntington's disease and Parkinson's disease), autoimmune disease, depression, anxiety, cataract, psychological disorder, AIDS, cancers (including T-cell leukemia and colon cancer), eye disease (such as cataract and age-related yellowing), and autoimmune disease, wherein the cancer can be selected from the group consisting of breast cancer, cervical cancer, colon cancer, lung cancer, gastric cancer, rectal cancer, pancreatic cancer, brain cancer, skin cancer, oral cancer, prostate cancer, bone cancer, kidney cancer, ovarian cancer, bladder cancer, liver cancer, tubal tumor, ovarian tumor, peritoneal tumor, phase IV melanoma, glioma, neuroblastoma, hepatocellular carcinoma, papillomatosis, head and neck tumor, leukemia, lymphoma, myeloma and non-small cell lung cancer.

The present invention is also directed to the compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, or the pharmaceutical composition comprising the same, for use in the prevention and/or treatment of a disease with the pathological feature of IDO-mediated tryptophan metabolic pathway, which include virus infection (such as AIDS), cell infection (such as Lyme disease and streptococcal infection), neurodegenerative disorder (such as Alzheimer's disease, Huntington's disease and Parkinson's disease), autoimmune disease, depression, anxiety, cataract, psychological disorder, AIDS, cancer (including T-cell leukemia and colon cancer), eye disease (such as cataract and age-related yellowing), and autoimmune disease, wherein the cancer can be selected from the group consisting of breast cancer, cervical cancer, colon cancer, lung cancer, gastric cancer, rectal cancer, pancreatic cancer, brain cancer, skin cancer, oral cancer, prostate cancer, bone cancer, kidney cancer, ovarian cancer, bladder cancer, liver cancer, tubal tumor, ovarian tumor, peritoneal tumor, phase IV melanoma, glioma, neuroblastoma, hepatocellular carcinoma, papillomatosis, head and neck tumor, leukemia, lymphoma, myeloma and non-small cell lung cancer.

The present invention is also directed to a method for the prevention and/or treatment of a disease with the pathological feature of IDO-mediated tryptophan metabolic pathway, comprising a step of administrating to a patient in need thereof a therapeutically effective amount of the compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, or the pharmaceutical composition comprising the same, wherein the disease include virus infection (such as AIDS), cell infection

(such as Lyme disease and streptococcal infection), neurodegenerative disorder (such as Alzheimer's disease, Huntington's disease and Parkinson's disease), autoimmune disease, depression, anxiety, cataract, psychological disorder, AIDS, cancer (including T-cell leukemia and colon cancer), eye disease (such as cataract and age-related yellowing), and autoimmune disease, wherein the cancer can be selected from the group consisting of breast cancer, cervical cancer, colon cancer, lung cancer, gastric cancer, rectal cancer, pancreatic cancer, brain cancer, skin cancer, oral cancer, prostate cancer, bone cancer, kidney cancer, ovarian cancer, bladder cancer, liver cancer, tubal tumor, ovarian tumor, peritoneal tumor, phase IV melanoma, glioma, neuroblastoma, hepatocellular carcinoma, papillomatosis, head and neck tumor, leukemia, lymphoma, myeloma and non-small cell lung cancer.

In another aspect, the present invention is also directed to a method for the treatment of cancer, comprising a step of administrating to a patient in need thereof a therapeutically effective amount of the compound of formula (I), or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof. This method shows remarkable efficacy and fewer side effects, wherein the cancer can be selected from the group consisting of breast cancer, cervical cancer, colon cancer, lung cancer, gastric cancer, rectal cancer, pancreatic cancer, brain cancer, skin cancer, oral cancer, prostate cancer, bone cancer, kidney cancer, ovarian cancer, bladder cancer, liver cancer, tubal tumor, ovarian tumor, peritoneal tumor, phase IV melanoma, glioma, neuroblastoma, hepatocellular carcinoma, papillomatosis, head and neck tumor, leukemia, lymphoma, myeloma and non-small cell lung cancer, preferably tubal tumor, peritoneal tumor, phase IV melanoma, myeloma and breast cancer, more preferably breast cancer.

The pharmaceutical compositions containing the active ingredient can be in a form suitable for oral administration, for example, tablet, troche, lozenge, aqueous or oily suspension, dispersible powder or granule, emulsion, hard or soft capsule, or syrup or elixir. Oral compositions can be prepared according to any known method for the preparation of pharmaceutical compositions in the art. Such compositions can contain one or more agents selected from the group consisting of sweetening agents, flavoring agents, colorants and preservatives, in order to provide a pleasing and palatable pharmaceutical formulation. The tablet contains the active ingredient in admixture with non-toxic pharmaceutically acceptable excipients suitable for the manufacture of tablet. These excipients can be inert excipients, granulating agents, disintegrating agentsand lubricating agents. The tablet can be uncoated or coated by known techniques to mask the taste of the drug or delay the disintegration and absorption of the drug in the gastrointestinal tract, thereby providing sustained release over an extended period.

Oral formulations can also be provided with soft gelatin capsules in which the active ingredient is mixed with an inert solid diluent, a water-soluble carrier, an oil medium or olive oil.

Aqueous suspension contains the active ingredient in admixture with excipients suitable for the manufacture of aqueous suspension. Such excipients are suspending agents, dispersing or wetting agents. The aqueous suspension can also contain one or more preservatives, such as ethylparaben or n-propylparaben, one or more coloring agents, one or more flavoring agents, and one or more flavoring agents.

Oil suspension can be formulated by suspending the active ingredient in a vegetable oil, or in a mineral oil. The oil suspension can contain a thickening agent. The sweetening agents and flavoring agents mentioned above can be added to provide a palatable preparation. These compositions can be preserved by adding an antioxidant.

The active ingredient in admixture with the dispersing or wetting agents, suspending agent or one or more preservatives can be prepared to dispersible powder and granule suitable for the preparation of an aqueous suspension by adding water. Suitable dispersant or wetting agents and suspending agents are exemplified by those already mentioned above. Additional excipients, such as sweetening, flavoring, and coloring agents, can also be added.

The present pharmaceutical composition can also be in the form of oil-in-water emulsion. The oil phase can be a vegetable oil, a mineral oil or mixture thereof. Suitable emulsifying agent can be naturally occurring phosphatides or partial ester. The emulsion can also contain sweetening agents, flavoring agents, preservatives and antioxidants. The pharmaceutical composition can be in the form of sterile injectable aqueous solution. The acceptable vehicles and solvents that can be employed are water, Ringer's solution and isotonic sodium chloride solution. The sterile injectable preparation can also be a sterile injectable oil-in-water microemulsion in which the active ingredient is dissolved in the oil phase. The injectable solution or microemulsion can be introduced into an individual's bloodstream by local bolus injection.

The pharmaceutical composition can be in the form of a sterile injectable aqueous or oily suspension for intramuscular and subcutaneous administration. Such suspension can be formulated with suitable dispersing or wetting agents and suspending agents as described above according to known techniques. The sterile injectable preparation can also be a sterile injectable solution or suspension prepared in a nontoxic parenterally acceptable diluents or solvent. Moreover, a sterile fixed oil can easily be used conveniently as a solvent or suspending medium.

The present compound can be administrated in the form of suppository for rectal administration. These pharmaceutical compositions can be prepared by mixing drug with a suitable non-irritating excipient which is solid at ordinary temperatures but liquid in rectum, thereby melting in the rectum to release the drug.

It is well known for those skilled in the art that the dosage of a drug depends on a variety of factors including, but not limited to the following factors: activity of a specific compound, age of the patient, weight of the patient, general health of the patient, behavior of the patient, and diet of the patient, administration time, administration route,

excretion rate, drug combination and the like. In addition, the best treatment, such as treatment mode, daily dose of the compound of formula (I) or the type of pharmaceutically acceptable salt thereof can be verified by the traditional therapeutic regimen.

DETAILED DESCRIPTION OF THE INVENTION

Unless otherwise stated, the terms used in the specification and claims have the meanings described below.

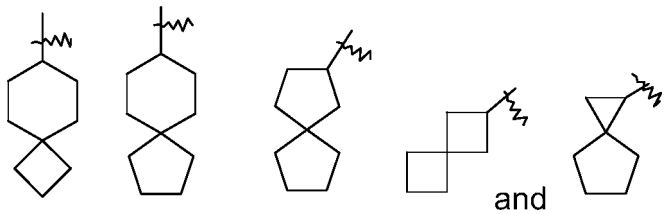
"Alkyl" refers to a saturated aliphatic hydrocarbon group including C_1 to C_{20} straight chain and branched chain groups, preferably, an alkyl having 1 to 12 carbon atoms, and more preferably, an alkyl having 1 to 6 carbon atoms. Non-limiting examples include methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, sec-butyl, n-pentyl, 1,1-dimethylpropyl, 1,2-dimethylpropyl, 2,2-dimethylpropyl, 1-ethylpropyl, 2-methylbutyl, 3-methylbutyl, n-hexyl, 1-ethyl-2-methylpropyl, 1,1,2-trimethylpropyl, 1,1-dimethylbutyl, 1,2-dimethylbutyl, 2,2-dimethylbutyl, 1,3-dimethylbutyl, 2-ethylbutyl, 2-methylpentyl, 3-methylpentyl, 4-methylpentyl, 2,3-dimethylbutyl, n-heptyl, 2-methylhexyl, 3-methylhexyl, 4-methylhexyl, 5-methylhexyl, 2,3-dimethylpentyl, 2,4-dimethylpentyl, 2,2-dimethylpentyl, 3,3-dimethylpentyl, 2-ethylpentyl, 3-ethylpentyl, n-octyl, 2,3-dimethylhexyl, 2,4-dimethylhexyl, 2,5-dimethylhexyl, 2,2-dimethylhexyl, 3,3-dimethylhexyl, 4,4-dimethylhexyl, 2-ethylhexyl, 3-ethylhexyl, 4-ethylhexyl, 2-methyl-2-ethylpentyl, 2-methyl-3-ethylpentyl, n-nonyl, 2-methyl-2-ethylhexyl, 2-methyl-3-ethylhexyl, 2,2-diethylpentyl, n-decyl, 3,3-diethylhexyl, 2,2-diethylhexyl, and the branched isomers thereof. More preferably an alkyl group is a lower alkyl having 1 to 6 carbon atoms, and the non-limiting examples include methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, sec-butyl, n-pentyl, 1,1-dimethylpropyl, 1,2-dimethylpropyl, 2,2-dimethylpropyl, 1-ethylpropyl, 2-methylbutyl, 3-methylbutyl, n-hexyl, 1-ethyl-2-methylpropyl, 1,1,2-trimethylpropyl, 1,1-dimethylbutyl, 1,2-dimethylbutyl, 2,2-dimethylbutyl, 1,3-dimethylbutyl, 2-ethylbutyl, 2-methylpentyl, 3-methylpentyl, 4-methylpentyl, 2,3-dimethylbutyl, and the like. The alkyl group can be substituted or unsubstituted. When substituted, the substituent group(s) can be substituted at any available connection point. The substituent group(s) is preferably one or more groups independently selected from the group consisting of alkyl, alkenyl, alkynyl, alkoxy, alkylthio, alkylamino, halogen, thiol, hydroxy, nitro, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, cycloalkoxy, heterocylic alkoxy, cycloalkylthio, heterocyclic alkylthio, oxo, carboxyl, and alkoxycarbonyl.

"Alkylene" refers to an alkyl of which a hydrogen atom is further substituted, for example, "methylene" refers to $-CH_2-$, "ethylene" refers to $-(CH_2)_2-$, "propylene" refers to $-(CH_2)_3-$, "butylene" refers to $-(CH_2)_4-$, and the like. "Alkenyl" refers to an alkyl as

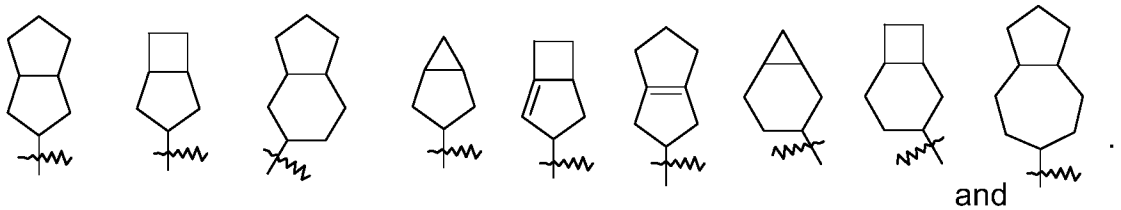
defined above that has at least two carbon atoms and at least one carbon-carbon double bond, for example, ethenyl, 1-propenyl, 2- propenyl, 1-, 2- or 3-butenyl and the like. The alkenyl group can be substituted or unsubstituted. When substituted, the substituent group(s) is preferably one or more groups independently selected from the group consisting of alkyl, alkenyl, alkynyl, alkoxy, alkylthio, alkylamino, halogen, thiol, hydroxy, nitro, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, cycloalkoxy, heterocylic alkoxy, cycloalkylthio and heterocyclic alkylthio.

"Cycloalkyl" refers to a saturated or partially unsaturated monocyclic or polycyclic hydrocarbon group having 3 to 20 carbon atoms, preferably 3 to 12 carbon atoms, more preferably 3 to 8 carbon atoms, and most preferably 3 to 6 carbon atoms. Non-limiting examples of monocyclic cycloalkyl include cyclopropyl, cyclobutyl, cyclopentyl, cyclopentenyl, cyclohexyl, cyclohexenyl, cyclohexadienyl, cycloheptyl, cycloheptatrienyl, cyclooctyl, and the like. Polycyclic cycloalkyl includes a cycloalkyl having a spiro ring, fused ring or bridged ring.

"Spiro cycloalkyl" refers to a 5 to 20 membered polycyclic group with rings connected through one common carbon atom (called a spiro atom), wherein one or more rings can contain one or more double bonds, but none of the rings has a completely conjugated pi-electron system, preferably 6 to 14 membered spiro cycloalkyl, and more preferably 7 to 10 membered spiro cycloalkyl. According to the number of the spiro atoms shared between the rings, spiro cycloalkyl can be divided into mono-spiro cycloalkyl, di-spiro cycloalkyl, or poly-spiro cycloalkyl, and preferably a mono-spiro cycloalkyl or di-spiro cycloalkyl, and more preferably 4-membered/4-membered, 4-membered/5-membered, 4-membered/6-membered, 5-membered/5-membered, or 5-membered/6-membered mono-spiro cycloalkyl. Non-limiting examples of spiro cycloalkyls include:

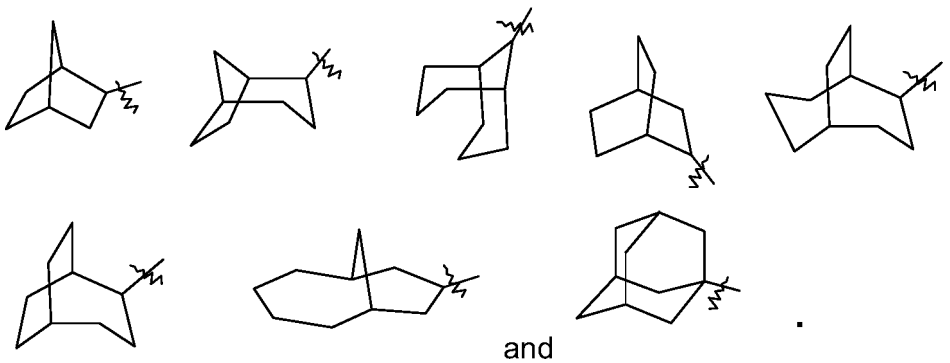


"Fused cycloalkyl" refers to a 5 to 20 membered all-carbon polycyclic group, wherein each ring in the system shares an adjacent pair of carbon atoms with another ring, wherein one or more rings can contain one or more double bonds, but none of the rings has a completely conjugated pi-electron system, preferably 6 to 14 membered fused cycloalkyl, and more preferably 7 to 10 membered fused cycloalkyl. According to the number of membered rings, fused cycloalkyl can be divided into bicyclic, tricyclic, tetracyclic or polycyclic fused cycloalkyl, preferably bicyclic, or tricyclic fused cycloalkyl, and more preferably 5-membered/5-membered, or 5-membered/6-membered bicyclic fused cycloalkylc. Non-limiting examples of fused cycloalkyl include:



and

"Bridged cycloalkyl" refers to a 5 to 20 membered all-carbon polycyclic group, wherein every two rings in the system share two disconnected carbon atoms, wherein the rings can have one or more double bonds, but none of the rings has a completely conjugated pi-electron system, preferably 6 to 14 membered bridged cycloalkyl, and more preferably 7 to 10 membered bridged cycloalkyl. According to the number of membered rings, bridged cycloalkyl can be divided into bicyclic, tricyclic, tetracyclic or polycyclic bridged cycloalkyl, and preferably bicyclic, tricyclic or tetracyclic bridged cycloalkyl, and more preferably bicyclic or tricyclic bridged cycloalkyl. Non-limiting examples of bridged cycloalkyls include:



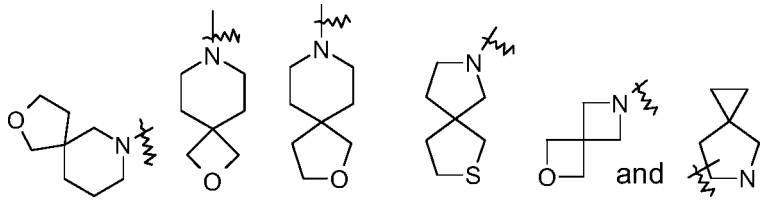
and

The ring of cycloalkyl can be fused to the ring of aryl, heteroaryl or heterocyclyl, wherein the ring bound to the parent structure is cycloalkyl. Non-limiting examples include indanyl, tetrahydronaphthyl, benzocycloheptyl and the like. The cycloalkyl can be optionally substituted or unsubstituted. When substituted, the substituent group(s) is preferably one or more groups independently selected from the group consisting of alkyl, alkenyl, alkynyl, alkoxy, alkylthio, alkylamino, halogen, thiol, hydroxy, nitro, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, cycloalkoxy, heterocylic alkoxy, cycloalkylthio, heterocyclic alkylthio, oxo, carboxyl, alkoxycarbonyl.

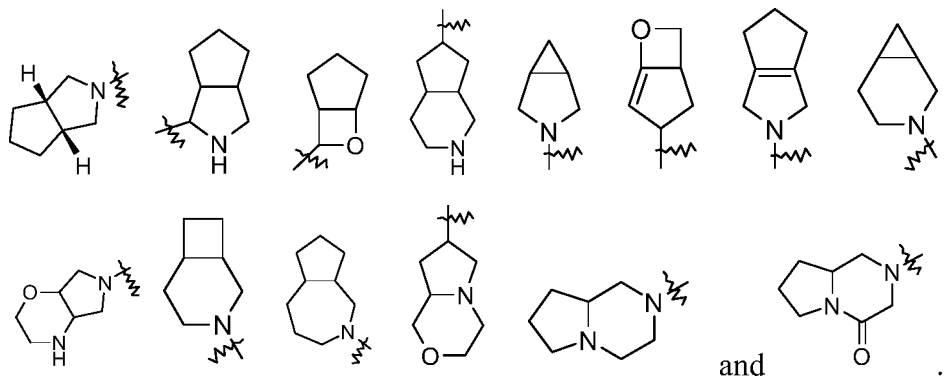
"Heterocyclyl" refers to a 3 to 20 membered saturated or partially unsaturated monocyclic or polycyclic hydrocarbon group having one or more heteroatoms selected from the group consisting of N, O, and $S(O)_m$ (wherein m is an integer of 0 to 2) as ring atoms, but excluding -O-O-, -O-S- or -S-S- in the ring, with the remaining ring atoms being carbon atoms. Preferably, heterocyclyl has 3 to 12 atoms wherein 1 to 4 atoms are heteroatoms, more preferably 3 to 6 atoms. Non-limiting examples of monocyclic heterocyclyl include pyrrolidinyl, imidazolidinyl, tetrahydrofuranyl, tetrahydrothienyl, dihydroimidazolyl, dihydrofuranyl, dihydropyrazolyl, dihydropyrrolyl, piperidyl, piperazinyl, morpholinyl, thiomorpholinyl, homopiperazinyl and the like, preferably piperidyl or pyrrolidinyl. Polycyclic heterocyclyl includes a heterocyclyl having a spiro

ring, fused ring or bridged ring.

"Spiro heterocyclyl" refers to a 5 to 20 membered polycyclic heterocyclyl with rings connected through one common atom (called a spiro atom), wherein the rings have one or more heteroatoms selected from the group consisting of N, O, and $S(O)_m$ (wherein m is an integer of 0 to 2) as ring atoms, with the remaining ring atoms being carbon atoms, wherein one or more rings can contain one or more double bonds, but none of the rings has a completely conjugated pi-electron system; preferably 6 to 14 membered spiro heterocyclyl, and more preferably 7 to 10 membered spiro heterocyclyl. According to the number of the spiro atoms shared between the rings, spiro heterocyclyl can be divided into mono-spiro heterocyclyl, di-spiro heterocyclyl, or poly-spiro heterocyclyl, preferably mono-spiro heterocyclyl or di-spiro heterocyclyl, and more preferably 4-membered/4-membered, 4-membered/5-membered, 4-membered/6-membered, 5-membered/5-membered, or 5-membered/6-membered mono-spiro heterocyclyl. Non-limiting examples of spiro heterocyclyls include:

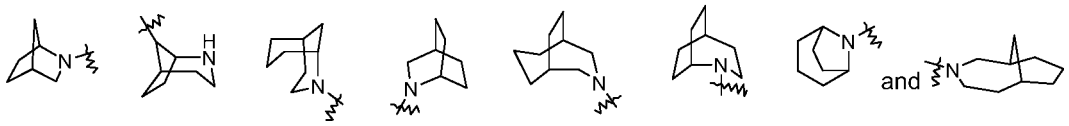


"Fused heterocyclyl" refers to a 5 to 20 membered polycyclic heterocyclyl group, wherein each ring in the system shares an adjacent pair of atoms with another ring, wherein one or more rings can contain one or more double bonds, but none of the rings has a completely conjugated pi-electron system, and wherein the rings have one or more heteroatoms selected from the group consisting of N, O, and $S(O)_m$ (wherein m is an integer of 0 to 2) as ring atoms, with the remaining ring atoms being carbon atoms; preferably 6 to 14 membered fused heterocyclyl, and more preferably 7 to 10 membered fused heterocyclyl. According to the number of membered rings, fused heterocyclyl can be divided into bicyclic, tricyclic, tetracyclic or polycyclic fused heterocyclyl, preferably bicyclic or tricyclic fused heterocyclyl, and more preferably 5-membered/5-membered, or 5-membered/6-membered bicyclic fused heterocyclyl. Non-limiting examples of fused heterocyclyl include:

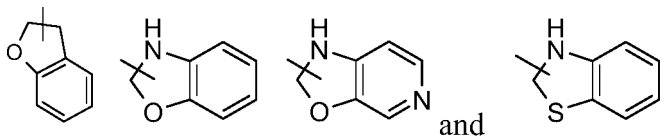


"Bridged heterocyclyl" refers to a 5 to 14 membered polycyclic heterocyclyl group,

wherein every two rings in the system share two disconnected atoms, wherein the rings can have one or more double bonds, but none of the rings has a completely conjugated pi-electron system, and the rings have one or more heteroatoms selected from the group consisting of N, O, and S $(O)_m$ (wherein m is an integer of 0 to 2) as ring atoms, with the remaining ring atoms being carbon atoms; preferably 6 to 14 membered bridged heterocyclyl, and more preferably 7 to 10 membered bridged heterocyclyl. According to the number of membered rings, bridged heterocyclyl can be divided into bicyclic, tricyclic, tetracyclic or polycyclic bridged heterocyclyl, and preferably bicyclic, tricyclic or tetracyclic bridged heterocyclyl, and more preferably bicyclic or tricyclic bridged heterocyclyl. Non-limiting examples of bridged heterocyclyls include:



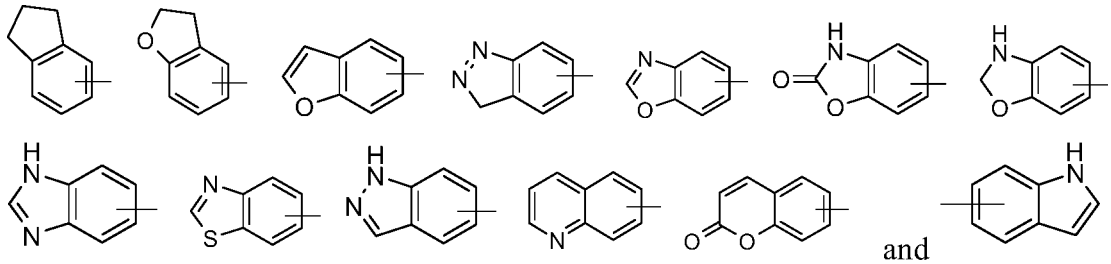
The ring of heterocyclyl can be fused to the ring of aryl, heteroaryl or cycloalkyl, wherein the ring bound to the parent structure is heterocyclyl. Non-limiting examples include:



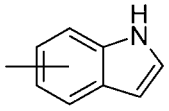
, etc.

The heterocyclyl can be optionally substituted or unsubstituted. When substituted, the substituent group(s) is preferably one or more groups independently selected from the group consisting of alkyl, alkenyl, alkynyl, alkoxy, alkylthio, alkylamino, halogen, thiol, hydroxy, nitro, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, cycloalkoxy, heterocylic alkoxy, cycloalkylthio, heterocyclic alkylthio, oxo, carboxyl, alkoxycarbonyl.

"Aryl" refers to a 6 to 14 membered all-carbon monocyclic ring or polycyclic fused ring (i.e. each ring in the system shares an adjacent pair of carbon atoms with another ring in the system) having a completely conjugated pi-electron system; preferably 6 to 10 membered aryl, for example, phenyl and naphthyl, and more preferably phenyl. The aryl can be fused to the ring of heteroaryl, heterocyclyl or cycloalkyl, wherein the ring bound to the parent structure is aryl. Non-limiting examples include:

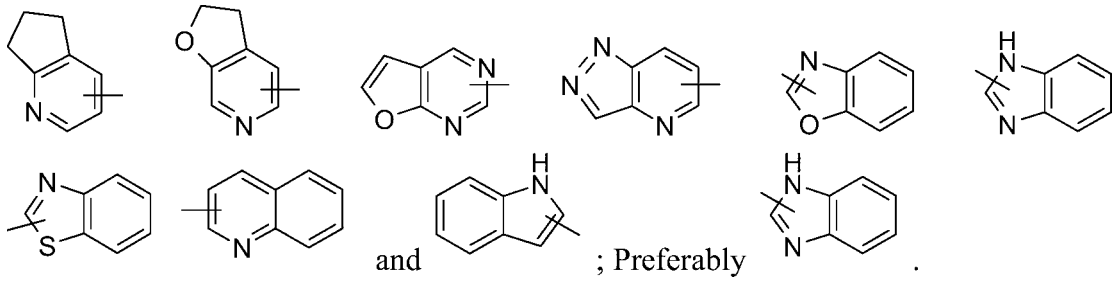


;

preferably  .

The aryl can be optionally substituted or unsubstituted. When substituted, the substituent group(s) is preferably one or more groups independently selected from the group consisting of alkyl, alkenyl, alkynyl, alkoxy, alkylthio, alkylamino, halogen, thiol, hydroxy, nitro, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, cycloalkoxy, heterocylic alkoxy, cycloalkylthio, heterocyclic alkylthio, carboxyl, alkoxycarbonyl.

"Heteroaryl" refers to a 5 to 14 membered heteroaromatic system having 1 to 4 heteroatoms selected from the group consisting of O, S and N as ring atoms; preferably 5 to 10 membered heteroaryl, and more preferably 5 or 6 membered heteroaryl, for example, imidazolyl, furyl, thienyl, thiazolyl, pyrazolyl, oxazolyl, pyrrolyl, tetrazolyl, pyridyl, pyrimidinyl, thiadiazolyl, pyrazinyl and the like, preferably imidazolyl, pyrazolyl, pyimidinyl or thiazolyl, and more preferably pyrazolyl. The heteroaryl can be fused to the ring of aryl, heterocyclyl or cycloalkyl, wherein the ring bound to the parent structure is heteroaryl. Non-limiting examples include:

 and ; Preferably .

The heteroaryl can be optionally substituted or unsubstituted. When substituted, the substituent group(s) is preferably one or more groups independently selected from the group consisting of alkyl, alkenyl, alkynyl, alkoxy, alkylthio, alkylamino, halogen, thiol, hydroxy, nitro, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, cycloalkoxy, heterocylic alkoxy, cycloalkylthio, heterocyclic alkylthio, carboxyl or alkoxycarbonyl.

"Alkoxy" refers to an -O-(alkyl) or an -O-(unsubstituted cycloalkyl) group, wherein the alkyl is as defined above. Non-limiting examples include, methoxy, ethoxy, propoxy, butoxy, cyclopropyloxy, cyclobutyloxy, cyclopentyloxy, cyclohexyloxy, and the like. The alkoxy can be optionally substituted or unsubstituted. When substituted, the substituent is preferably one or more groups independently selected from the group consisting of alkyl, alkenyl, alkynyl, alkoxy, alkylthio, alkylamino, halogen, thiol, hydroxy, nitro, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, cycloalkoxy, heterocylic alkoxy, cycloalkylthio, heterocyclic alkylthio, carboxyl, alkoxycarbonyl.

"Haloalkyl" refers to an alkyl substituted by one or more halogens, wherein the alkyl is as defined above.

"Haloalkoxy" refers to an alkoxy substituted by one or more halogens, wherein the alkoxy is as defined above.

"Hydroxyalkyl" refers to an alkyl substituted by hydroxy, wherein the alkyl is as

defined above.

"Hydroxy" refers to an -OH group.

"Halogen" refers to fluorine, chlorine, bromine or iodine.

"Amino" refers to an $-NH_2$ group.

"Cyano" refers to a -CN group.

"Nitro" refers to an $-NO_2$ group.

"Oxo" refers to =O.

"Carboxyl" refers to a -C(O)OH group.

"Alkoxycarbonyl" refers to a -C(O)O(alkyl) or (cycloalkyl) group, wherein the alkyl and cycloalkyl are as defined above.

"Acyl halide" refers to a -C(O)-halogen group.

All of "X is selected from the group consisting of A, B, or C", "X is selected from the group consisting of A, B and C", "X is A, B or C", "X is A, B and C" and the like, are the same meaning. It means that X can be any one or more of A, B, and C.

"Optional" or "optionally" means that the event or circumstance described subsequently can, but need not occur, and this description includes the situation in which the event or circumstance does or does not occur. For example, "the heterocyclic group optionally substituted by an alkyl" means that an alkyl group can be, but need not be, present, and this description includes the situation of the heterocyclic group being substituted by an alkyl and the heterocyclic group being not substituted by an alkyl.

"Substituted" refers to one or more hydrogen atoms in a group, preferably up to 5, more preferably 1 to 3 hydrogen atoms, independently substituted by a corresponding number of substituents. It goes without saying that the substituents only exist in their possible chemical position. The person skilled in the art is able to determine whether the substitution is possible or impossible by experiments or theory without paying excessive efforts. For example, the combination of amino or hydroxy having free hydrogen and carbon atoms having unsaturated bonds (such as olefinic) can be unstable.

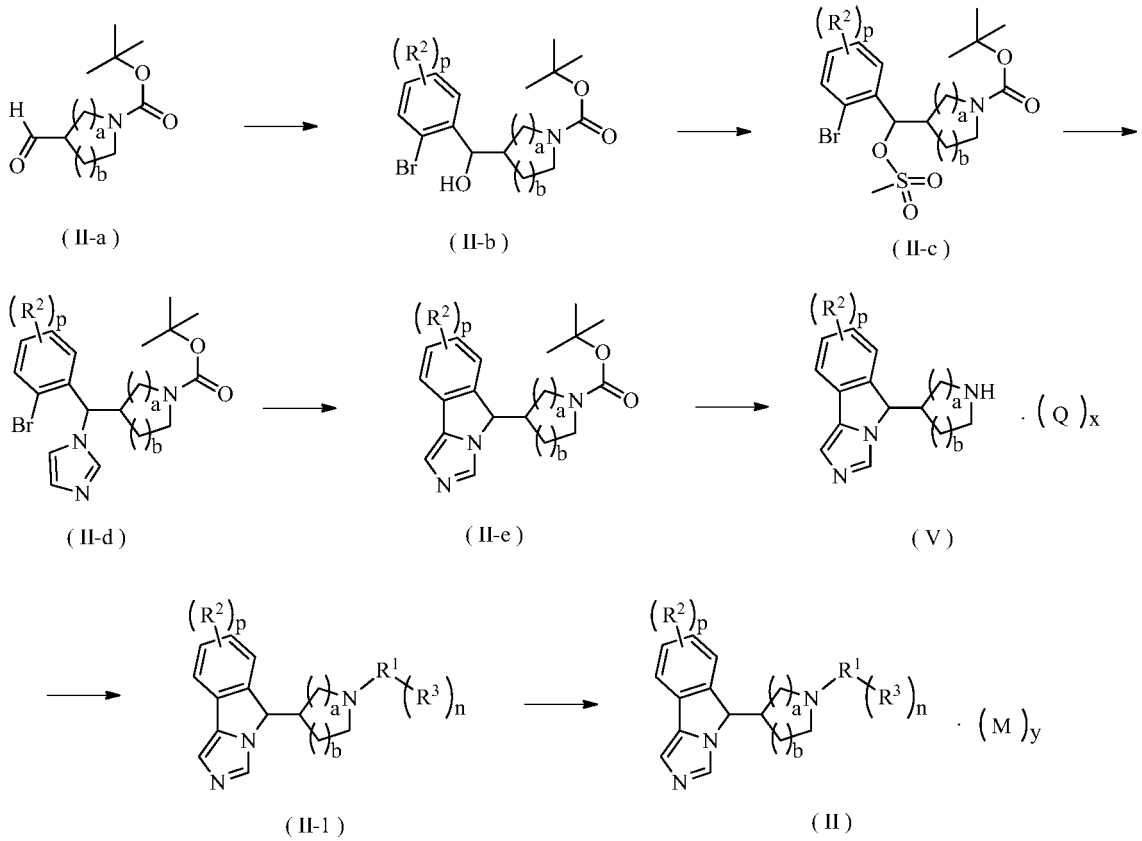
A "pharmaceutical composition" refers to a mixture of one or more of the compounds according to the present invention or physiologically/pharmaceutically acceptable salts or prodrugs thereof and other chemical components such as physiologically/pharmaceutically acceptable carriers and excipients. The purpose of a pharmaceutical composition is to facilitate administration of a compound to an organism, which is conducive to the absorption of the active ingredient, thus displaying biological activity.

A "pharmaceutically acceptable salt" refers to a salt of the compound of the present invention which is safe and effective in mammals and have the desired biological activity.

SYNTHESIS METHOD OF THE COMPOUND OF THE PRESENT INVENTION

In order to achieve the object of the present invention, the present invention applies the following technical solutions.

A process for preparing a compound of formula (II) and formula (II-1) of the present invention, or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof, comprising the steps as follows:



Scheme 1

A compound of formula (II-a) is reactedwith a bromobenzene compound via an addition reaction under an alkaline condition (a reagent which provides the alkaline condition is preferably lithium diisopropylamide) at low temperature to obtain a compound of formula (II-b); the compound of formula (II-b) is reacted with a methanesulfonyl chloride compound under an alkaline condition (a reagent which provides the alkaline condition is preferably sodium hydride or triethylamine) to obtain a compound of formula (II-c); the resulting compound offormula (II-c) is reacted with imidazole under an alkaline condition to obtain a compound of formula (II-d); the resulting compound of formula (II-d) is intramolecular coupled upon heating in the presence of a base and a phosphine palladium-based catalyst (the catalyst is preferably triphenylphosphine and palladium acetate) to obtain a compound of formula (II-e); the resulting compound of formula (II-e) is deprotected under an acidic condition to obtain a compound of formula (V) or a salt thereof; the compound of formula (V) is further coupled with a halide of R^3 under an alkaline condition (a reagent which provides the

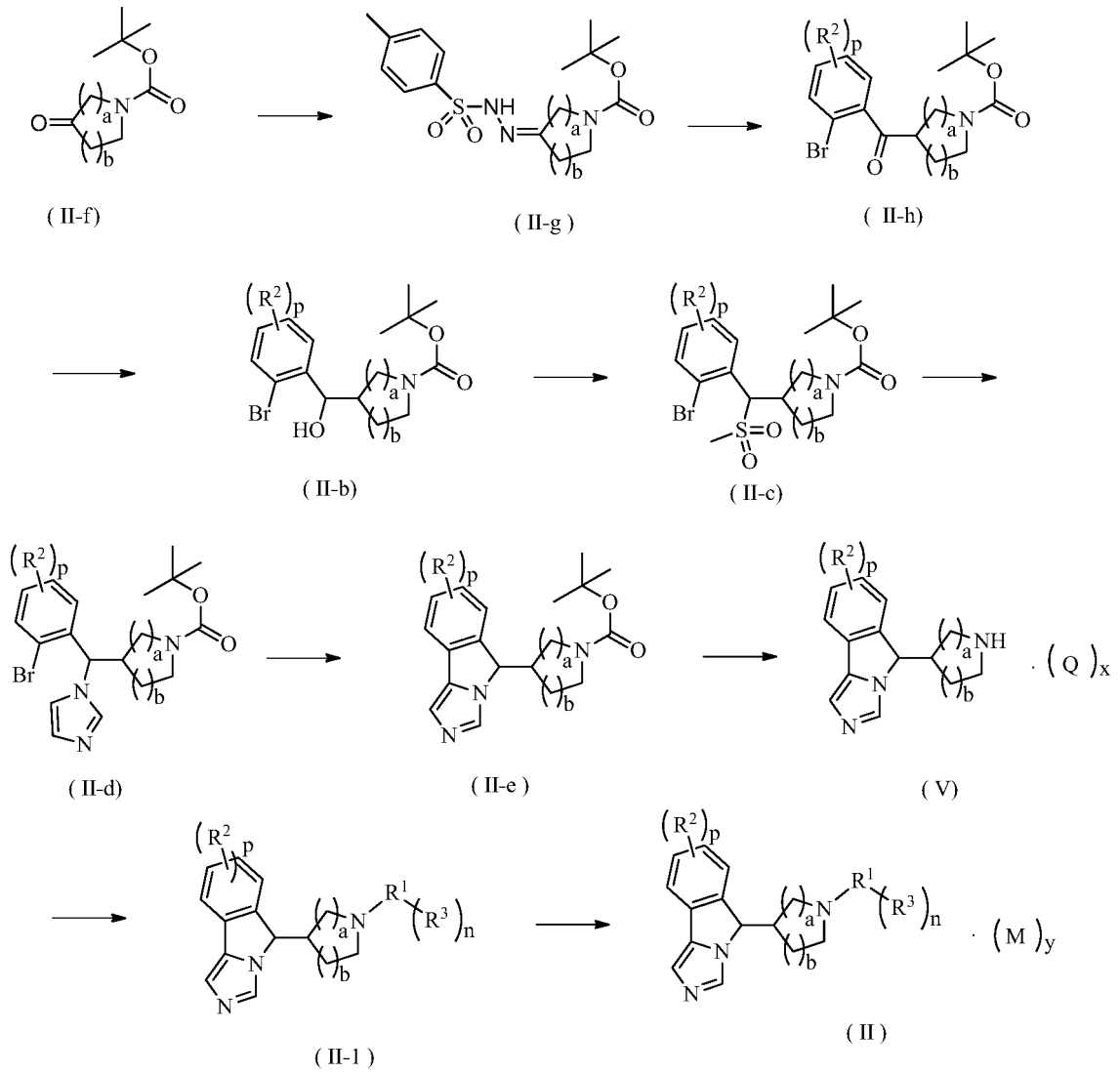
alkaline condition is preferably sodium tert-butoxide), in the presence of a phosphine palladium-based catalyst, then the resulting productis optionally further coupled with a boric acid or borate ester of R^3 to obtain a compound of formula (II-1); and the compound of formula (II-1) is salified under an acidic condition, to obtain a compound of formula (II-b).

The agent which provides the alkaline condition includes organic base and inorganic base, wherein the organic base includes, but is not limited to, triethylamine, *N*,*N*-disopropylethylamine, *n*-butyllithium, lithium diisopropylamide, potassium acetate, sodium tert-butoxide or potassium tert-butoxide, wherein the inorganic base includes, but is not limited to, sodium hydride, potassium phosphate, sodium carbonate, potassium carbonate or cesium carbonate.

The mentioned phosphine palladium-based catalyst includes, but is not limited to, 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl, (±)-2,2'-bis(diphenylphosphino) -1,1'-binaphthyl, tris(dibenzylideneacetone)dipalladium, palladium diacetate, [1,1'-bis(diphenylphosphino)ferrocene]dichloropalladium, triphenylphosphine and tetrakis(triphenylphosphine)palladium.

Wherein:

R^1 to R^3, M, p, n, a, b and y are as defined in formula (II); and Q, x are as defined in formula (V).



Scheme 2

A compound of formula (II-f) is reacted with p-toluenesulfonyl hydrazide to obtain a compound of formula (II-g); the resulting compound of formula (II-g) is reacted with a bromobenzaldehyde compound under an alkaline condition to obtain a compound of formula (II-h); the resulting compound of formula (II-h) is reduced to a compound of formula (II-b) in the presence of a reducing agent (preferably, the reducing agent is sodium borohydride); the compound of formula (II-b) is reacted with a sulfonyl chloride compound under an alkaline condition (a reagent which provides the alkaline condition is preferably sodium hydride or triethylamine) to obtain a compound of formula (II-c); the resulting compound of formula (II-c) is reacted with imidazole under an alkaline condition to obtain a compound of formula (II-d); The resulting compound of formula (II-d) is intramolecular coupled upon heating in the presence of a base and a phosphine palladium catalyst (the catalyst is preferably triphenylphosphine and palladium acetate) to obtain a compound of formula (II-e); the resulting compound of formula (II-e) is deprotected under an acidic condition to obtain a compound of formula (V) or a salt thereof; the compound of formula (V) is further coupled with a halide of R^3 under an

alkaline condition (a reagent which provides the alkaline condition is preferably sodium tert-butoxide), in the presence of a phosphine palladium-based catalyst, then the resulting product is optionally further reacted with a boric acid or borate ester of R^3 to obtain a compound of formula (II-1); and the compound of formula (II-1) is salified under an acidic condition, to obtain a compound of formula (II-b).

The agent which provides the alkaline condition includes organic base and inorganic base, wherein the organic base includes, but is not limited to, triethylamine, *N*,*N*-disopropylethylamine, *n*-butyllithium, lithium diisopropylamide, potassium acetate, sodium tert-butoxide or potassium tert-butoxide, wherein the inorganic base includes, but is not limited to, sodium hydride, potassium phosphate, sodium carbonate, potassium carbonate or cesium carbonate.

The mentioned phosphine palladium-based catalyst includes, but is not limited to, 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl, (±)-2,2'-bis(diphenylphosphino) -1,1'-binaphthyl, tris(dibenzylideneacetone)dipalladium, palladium diacetate, [1,1'-bis(diphenylphosphino)ferrocene]dichloropalladium, triphenylphosphine and tetrakis(triphenylphosphine)palladium.

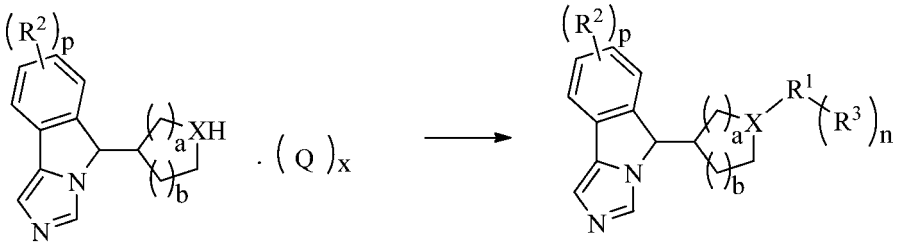
The mentioned reducing agent includes, but is not limited to, Fe powder, Zn powder, H_2, sodium borohydride, sodium triacetoxyborohydride, sodium cyanoborohydride or lithium aluminum hydride.

Wherein:

R^1 to R^3, M, p, n, a, b and y are as defined in formula (II); and Q, x are as defined in formula (V).

Scheme 3

There are several synthetic methods to prepare the compound of formula (II-1) from the compound of formula (V) according to the different reagents as follows,



(V) (II-1)

Method 1: The compound of formula (V) is coupled with a halide of R^1 upon direct heating or in a microwave reaction instrument under an inert gas at high temperature under an alkaline condition and in the presense of a phosphine palladium catalyst, the resulting product is optionally further coupled with a boronic acid or a borate ester of R^1 to obtain a compound of formula (II-1); wherein the halide of R^3 is preferably an aryl halide compound, and the alkaline agent is preferably sodium tert-butoxide.

Method 2: The compound of formula (V) is directly compled with a halide of R^1 at high temperature under an alkaline condition, the resulting product is optionally further

coupled with a boronic acid or a borate ester of R^3 to obtain a compound of formula (II-1); wherein the halide of R^1 is preferably a heteroaryl halide compound, and the alkaline agent is preferably triethylamine.

Method 3: The compound of formula (V) is directly reacted with a halide of R^3 to obtain a compound of formula (II-1) at room temperature under an alkaline condition; wherein the halide used in the reaction is preferably an iodide or a high activity acyl halide compound, and the alkaline agent under this condition is preferably potassium carbonate.

The mentioned phosphine palladium-based catalyst includes, but is not limited to, 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl, (±)-2,2'-bis(diphenylphosphino)-1,1'-binaphthyl, tris(dibenzylideneacetone)dipalladium, palladium diacetate, [1,1'-bis(diphenylphosphino)ferrocene]dichloropalladium, triphenylphosphine and tetrakis(triphenylphosphine)palladium.

The agent which provides the alkaline condition includes organic base and inorganic base, wherein the organic base includes, but is not limited to, sodium tert-butoxide, triethylamine, *N*,*N*-disopropylethylamine, *n*-butyllithium, lithium diisopropylamide, sodium tert-butoxide, potassium acetate, or potassium tert-butoxide, preferably sodium tert-butoxide; wherein the inorganic base includes, but is not limited to, sodium hydride, potassium phosphate, sodium carbonate, potassium carbonate or cesium carbonate.

Wherein:

X is N;

R^1 to R^3, p, n, a and b are as defined in formula (II); and Q and x are as defined in formula (V).

PREFERRED EMBODIMENTS

The present invention will be further described with reference to the following examples, but the examples should not be considered as limiting the scope of the invention.

Examples

The structures of the compounds are identified by nuclear magnetic resonance (NMR) and/or mass spectrometry (MS). NMR is determined by a Bruker AVANCE-400 machine. The solvents for determination are deuterated-dimethyl sulfoxide (DMSO-d_6), deuterated-chloroform ($CDCl_3$) and deuterated-methanol (CD_3OD), and the internal standard is tetramethylsilane (TMS). NMR chemical shifts (δ) are given in 10^{-6} (ppm).

MS is determined by a FINNIGAN LCQAd (ESI) mass spectrometer (manufacturer: Thermo, type: Finnigan LCQ advantage MAX).

High performance liquid chromatography (HPLC) is determined on an Agilent 1200DAD high pressure liquid chromatography spectrometer (Sunfire C18 150×4.6 mm

chromatographic column) and a Waters 2695-2996 high pressure liquid chromatography spectrometer (Gimini C18 150×4.6 mm chromatographic column).

The average inhibition rate of kinase and IC_{50} values are determined by a NovoStar ELISA (BMG Co., Germany).

Yantai Huanghai HSGF254 or Qingdao GF254 silica gel plate is used for thin-layer silica gel chromatography (TLC). The dimension of the silica gel plate used in TLC is 0.15 mm to 0.2 mm, and the dimension of the silica gel plate used in product purification is 0.4 mm to 0.5 mm.

Yantai Huanghai 200 to 300 mesh silica gel is used as carrier for column chromatography.

The known raw materials of the present invention can be prepared by the conventional synthesis methods in the art, or can be purchased from ABCR GmbH & Co. KG, Acros Organnics, Aldrich Chemical Company, Accela ChemBio Inc., or Dari chemical Company, etc.

Unless otherwise stated, the reactions are carried out under nitrogen atmosphere or argon atmosphere.

The term "nitrogen atmosphere" or "argon atmosphere" means that a reaction flask is equipped with a 1 L nitrogen or argon balloon.

The term "hydrogen atmosphere" means that a reaction flask is equipped with a 1 L hydrogen balloon.

Pressured hydrogenation reactions are carried out with a Parr 3916EKX hydrogenation instrument and a QL-500 hydrogen generator or HC2-SS hydrogenation instrument.

In hydrogenation reactions, the reaction system is generally vacuumed and filled with hydrogen, and the above operation is repeated three times.

CEM Discover-S 908860 type microwave reactor is used in microwave reaction.

Unless otherwise stated, the solution used in the reactions refers to an aqueous solution.

Unless otherwise stated, the reaction temperature in the reactions refers to room temperature.

Room temperature is the most appropriate reaction temperature, and the range of the temperature is 20°C to 30°C.

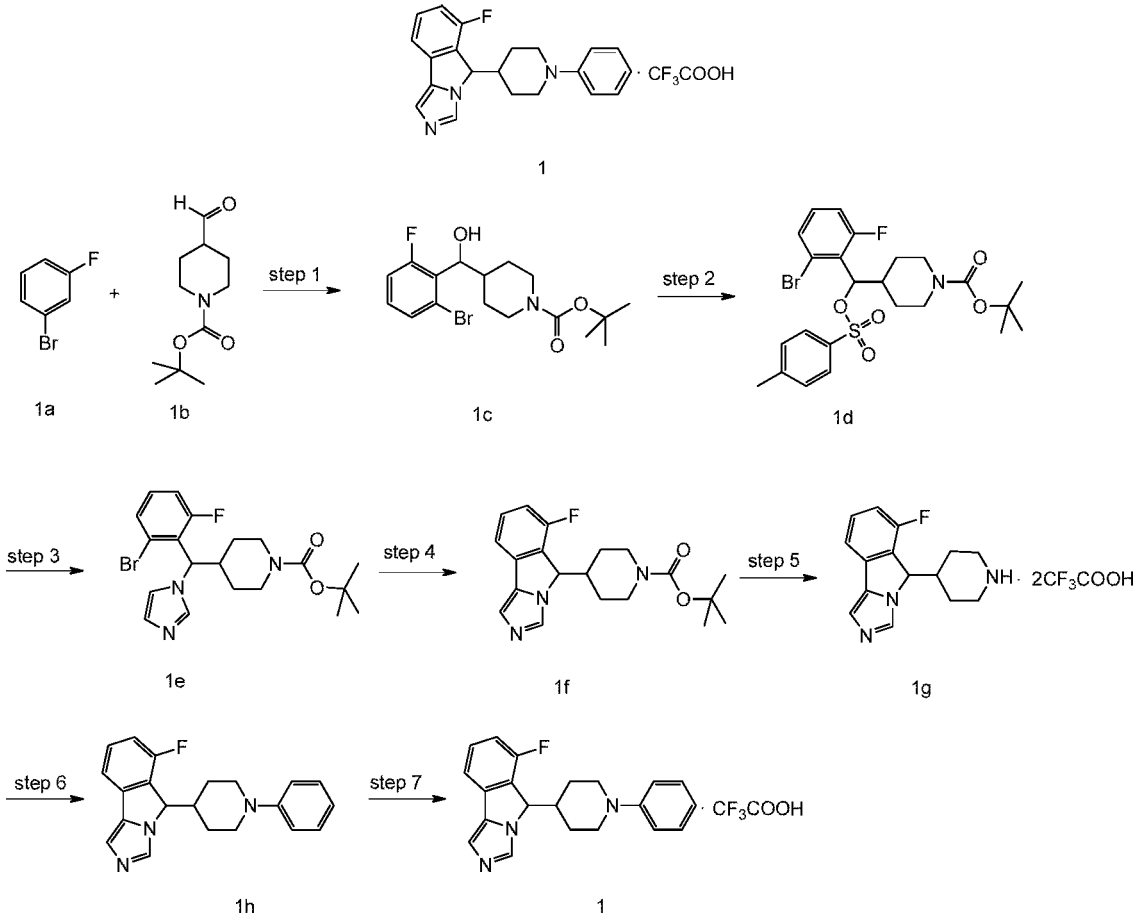
The reaction process is monitored by thin layer chromatography (TLC), and the system of developing solvent includes: A: dichloromethane and methanol system, B: *n*-hexane and ethyl acetate system, C: petroleum ether and ethyl acetate system, D: acetone. The ratio of the volume of the solvent can be adjusted according to the polarity of the compounds.

The elution system for purification of the compounds by column chromatography and thin layer chromatography includes: A: dichloromethane and methanol system, B: *n*-hexane and ethyl acetate system, C: *n*-hexane, ethyl acetate and dichloromethane

system, D: petroleum ether and ethyl acetate system, E: ethyl acetate. The ratio of the volume of the solvent can be adjusted according to the polarity of the compounds, and sometimes a little alkaline reagent such as triethylamine or acidic reagent can be added.

Example 1

6-fluoro-5-(1-phenylpiperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



Step 1

tert-butyl 4-((2-bromo-6-fluorophenyl)(hydroxy)methyl)piperidine-1-carboxylate **1c**

Lithium diisopropylamide (32.5 mL, 65.0 mmol) was added into 50 mL of tetrahydrofuran, then 25 mL of a pre-prepared solution of 1-bromo-3-fluorobenzene **1a** (8.75 g, 50.0 mmol) in tetrahydrofuran was added dropwise at -78°C, and the resulting mixture was stirred for 1 hour at -78°C. Then 25 mL of a pre-prepared solution of *tert*-butyl 4-formylpiperidine-1-carboxylate **1b** (8.75 g, 50.0 mmol) in tetrahydrofuran was added dropwise at -78°C. The reaction was continuely stirred for 1 hour at -78°C. After the completion of the reaction, 25 mL of methanol was added dropwise to quench the reaction at -78°C, and the reaction solution was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system B to obtain compound **1c** (16.3 g, yield 84.0%) as a yellow syrup solid.

MS m/z (LC-MS): 332.0 [M-56]

Step 2

tert-butyl 4-((2-bromo-6-fluorophenyl)(tosyloxy)methyl)piperidine-1-carboxylate **1d**

compound **1c** (15 g, 38.63 mmol) was dissolved in 350 mL of tetrahydrofuran, then sodium hydride (3.09 g, 77.26 mmol) was added in batches, the resulting mixture was stirred till no gas was released. Then 250 mL of a pre-prepared solution of *p*-toluensulfonyl chloride (8.10 g, 42.49 mmol) in tetrahydrofuran was added dropwise. The reaction was stirred at room temperature for 30 mins, then under reflux for 4 hours, and then at 70°C for another 48 hours. After the reaction was completed, the mixture was cooled to 0°C, 50 mL of water was added dropwise to quench the reaction. 50 mL of saturated sodium chloride solution was added, then two phases were separated and the organic phase was dried over anhydrous sodium sulfate. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system B to obtain compound **1d** (6.6 g, yield 31.8%) as a light yellow viscous solid.

MS m/z (LC-MS): 314.0/316.0 [M-56-TsO]

Step 3

tert-butyl 4-((2-bromo-6-fluorophenyl)(1*H*-imidazol-1-yl)methyl)piperidine-1-carboxylate **1e**

Imidazole (12.5 g, 184.3 mmol) was dissolved in 50 mL of *N*,*N*-dimethylformamide, then sodium hydride (7.40 g, 184.3 mmol) was added in batches. The resulting mixture was stirred for 1 hour at room temperature. Then 20 mL of a pre-prepared solution of compound **1d** (10.0 g, 18.43 mmol) in *N*,*N*-dimethylformamide was added dropwise. The reaction was stirred for 12 hours at 100°C. After the reaction was completed, 300 mL of ethyl acetate was added, the mixture was washed with saturated sodium chloride solution (150 mL×3), then the organic phase was dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system A to obtain compound **1e** (1.90 g, yield 23.5%) as a brown viscous solid.

MS m/z (ESI): 438.1/440.1 [M+1]

Step 4

tert-butyl 4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidine-1-carboxylate **1f**

Compound **1e** (1.90 g, 4.33 mmol), *N*,*N*-dicyclohexylmethylamine (1.35 g, 6.93 mmol) and triphenylphosphine (908 mg, 3.46 mmol) were dissolved in 10 mL of *N*,*N*-dimethylformamide. Palladium acetate (390 mg, 1.74 mmol) was added under argon atmosphere. The reaction mixture was stirred for 4.5 hours at 100°C. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system B to obtain compound **1f** (1.30 g, yield 83.8%) as a yellow viscous solid.

MS m/z (LC-MS): 358.1 [M+1]

Step 5

6-fluoro-5-(piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole ditrifluoroacetate **1g**

Compound **1f** (1.30 g, 3.64 mmol) was dissolved in 5 mL of dichloromethane, then 5 mL of trifluoroacetate was added dropwise. The resulting mixture was stirred for 1 hour at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain a curde compound **1g** (1.77 g) as a brown viscous solid, which was used directly in the next step without further purification.

MS m/z (LC-MS): 258.3 [M+1]

Step 6

6-fluoro-5-(1-phenylpiperidin-4-yl)-5H-imidazo[5,1-a]isoindole **1h**

The crude compound **1g** (230 mg, 0.50 mmol), bromobenzene (314 mg, 2.00 mmol), (±)-2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (39 mg, 0.0625 mmol), sodium *tert*-butoxide (192 mg, 2.0 mmol) were dissolved in 5 mL of 1,4-dioxane, then tri(dibenzylideneacetone)dipalladium (46 mg, 0.05 mmol) was added under argon atmosphere. The resulting mixture was stirred for 4 hours at 100°C. After the reaction was completed, 20 mL of ethyl acetate was added, the mixture was washed with water (10 mL×3), then the organic phase was dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **1h** (6.3 mg, yield 3.6%) as a brown viscous solid.

MS m/z (ESI): 334.3 [M+1]

Step 7

6-fluoro-5-(1-phenylpiperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **1**

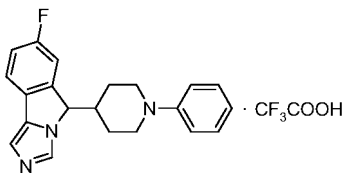
Compound **1h** (6.3 mg, 0.018 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.01 mL of trifluoroacetic acid was added. The resulting mixture was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **1** (8.3 mg, yield 100%) as a brown solid.

MS m/z (ESI): 334.3 [M+1]

^{1}H NMR (400 MHz, CD_3OD) δ 9.35 (s, 1H), 7.93 (s, 1H), 7.74 (d, 1H), 7.69-7.64 (m, 1H), 7.60-7.50 (m, 5H), 7.38-7.34 (m, 1H), 6.15 (d, 1H), 3.79-3.71 (m, 1H), 3.69-3.61 (m, 2H), 3.61-3.51 (m, 1H), 3.02-2.92 (m, 1H), 2.14-2.04 (m, 2H), 1.76-1.59 (m, 2H).

Example 2

7-fluoro-5-(1-phenylpiperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



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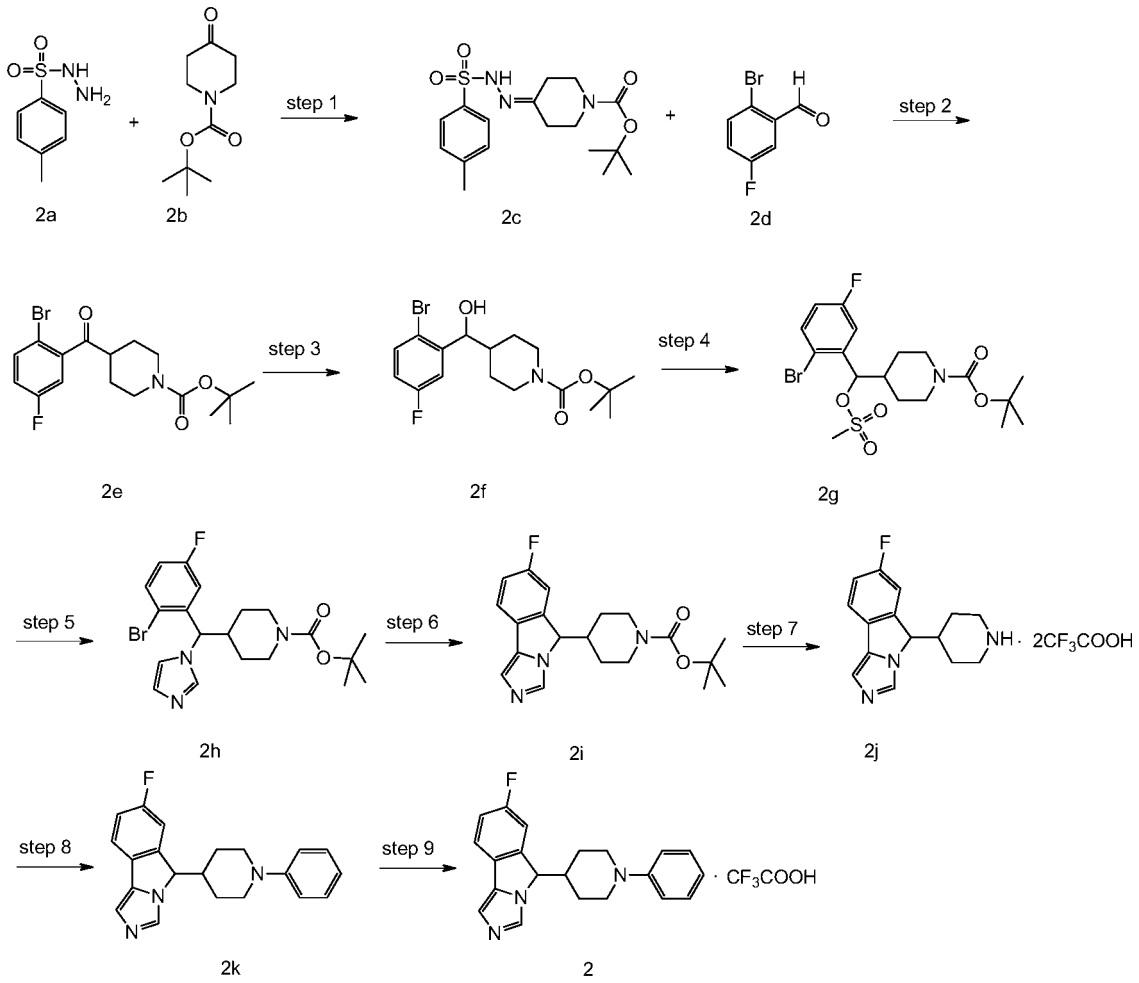


Step 1

tert-butyl 4-(2-tosylhydrazono)piperidine-1-carboxylate **2c**

p-toluenesulfonyl hydrazide **2a** (9.31 g, 50.0 mmol) was dissolved in 100 mL of methanol, then *N-tert*-butoxycarbonyl-4-piperidone **2b** (9.96 g, 50.0 mmol, prepared by a well-known method disclosed in "*ACS Medicinal Chemistry Letters*, 2014, 5(5), 550-555") was added, and the resulting mixture was stirred for 2 hour at room temperatura. After the completion of the reaction, the reaction solution was concentrated under reduced pressure. The resulting residue was dried to obtain a crude compound **2c** (18.37 g) as a white solid, which was used directly in the next step without further purification.

MS m/z (LC-MS): 368.0 [M+1]

Step 2

tert-butyl 4-(2-bromo-5-fluorobenzoyl)piperidine-1-carboxylate **2e**

The crude compound **2c** (5.52 g, 15.0 mmol), 2-bromo-5-fluorobenzaldehyde **2d** (3.05 g, 15.0 mmol) and cesium carbonate (7.33 g, 22.5 mmol) were added into a sealed tube. 60 mL of 1,4-dioxane was added, and the reaction was stirred for 10 hours at 110°C under argon atmosphere. After the reaction was completed, 20 mL of ethyl acetate was added, the mixture was washed with water (100 mL×1) and saturated sodium chloride solution (100 mL×2), dried over anhydrous sodium sulfate and filtered.

The filtrate was concentrated under reduced pressure to obtain a crude compound **2e** (6.17 g) as a yellow viscous solid, which was used directly in the next step without further purification.

MS m/z (LC-MS): 330.0/332.0 [M-56]

Step 3

tert-butyl 4-((2-bromo-5-fluorophenyl)(hydroxy)methyl)piperidine-1-carboxylate **2f**

The crude compound **2e** (6.17 g, 16.0 mmol) was dissolved in 100 mL of methanol, and the reaction system was cooled to 0°C. Sodium borohydride (1.21 g, 32.0 mmol) was added slowly at 0°C. The reaction system was stirred for 1 hour at 0°C. After the reaction was completed, 200 mL of ethyl acetate was added. The mixture was washed with saturated sodium chloride solution (100 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain the crude title compound **2f** (6.21 g) as a yellow syrup, which was used directly in the next step without further purification.

MS m/z (ESI): 332.0/334.0 [M-56]

Step 4

tert-butyl 4-((2-bromo-5-fluorophenyl)((methylsulfonyl)oxy)methyl)piperidine-1-carboxylate **2g**

The crude compound **2f** (6.21 g, 16.0 mmol) was dissolved in 100 mL of dichloromethane, and the resulting mixture was cooled to 0°C. Triethylamine (3.24 g, 32.0 mmol) was added. Then methylsufonyl chloride (2.75 g, 24.0 mmol) were added dropwise. The reaction system was stirred for 1 hour at 0°C. After the reaction was completed, the reaction solution was washed with water (50 mL×3), dried over sodium anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain a curde compound **2g** (7.46 g) as a brown viscous solid, which was used directly in the next step without further purification.

Step 5

tert-butyl 4-((2-bromo-5-fluorophenyl)(1*H*-imidazol-1-yl)methyl)piperidine-1-carboxylate **2h**

The crude compound **2g** (7.46 g, 16.0 mmol),1-*H*-imidazole (10.89 g, 160.0 mmol) and *N*,*N*-diisopropylethylamine (20.68 g, 160.0 mmol) were added into a sealed tube. 50 mL of acetonitrile was added. The reaction system was stirred for 12 hours at 120°C. After the reaction was completed, the reaction system was cooled to room temperature. 200 mL of ethyl acetate was added, the mixture was washed with water (100×3) and saturated sodium chloride solution (100 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system A to obtain compound **2h** (4.68 g, yield 66.7%) as a brown bubble solid.

MS m/z (LC-MS): 438.1/440.1 [M+1]

Step 6

tert-butyl 4-(7-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidine-1-carboxylate **2i**

Compound **2h** (4.68 g, 10.68 mmol), *N*,*N*-dicyclohexylmethylamine (3.34 g, 17.08 mmol) and triphenylphosphine (2.24 g, 8.54 mmol) were dissolved in 50 mL of *N*,*N*-dimethylformamide. Palladium acetate (960 mg, 4.28 mmol) was added under argon atmosphere. The reaction system was stirred for 17 hours at 100°C. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system A to obtain compound **2i** (3.81 g, yield 99.0%) as a yellow solid.

MS m/z (LC-MS): 358.1 [M+1]

Step 7

7-fluoro-5-(piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole ditrifluoroacetate **2j**

Compound **2i** (3.81 g, 10.68 mmol) was dissolved in 10 mL of dichloromethane, then 10 mL of trifluoroacetic acid was added dropwise. The resulting mixture was stirred for 2 hours at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain a crude compound **2j** (5.18 g) as a brown viscous solid, which was used directly in the next step without further purification.

MS m/z (ESI): 258.3 [M+1]

Step 8

7-fluoro-5-(1-phenylpiperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **2k**

The crude compound **2j** (115 mg, 0.25 mmol), bromobenzene (47 mg, 0.30 mmol), 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl (6 mg, 0.025 mmol), sodium *tert*-butoxide (96 mg, 1.0 mmol) and palladium acetate (6.0 mg, 0.025 mmol) were dissolved in 1.8 mL of a mixture of toluene and *tert*-butanol (V:V=5:1). The reaction system was stirred for 1 hour at 120°C in microwave. After the reaction was completed, 50 mL of dichloromethane was added. The mixture was washed with saturated sodium sulfite solution (25 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **2k** (12.6 mg, yield 15.2%) as a brown syrup.

MS m/z (ESI): 334.3 [M+1]

Step 9

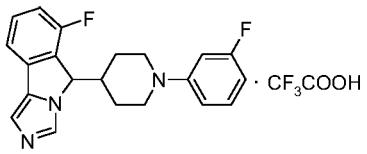
7-fluoro-5-(1-phenylpiperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **2**

Compound **2k** (12.6 mg, 0.038 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.01 mL of trifluoroacetic acid was added. The resulting mixture was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **2** (16.9 mg, yield 100%) as a light brown solid.

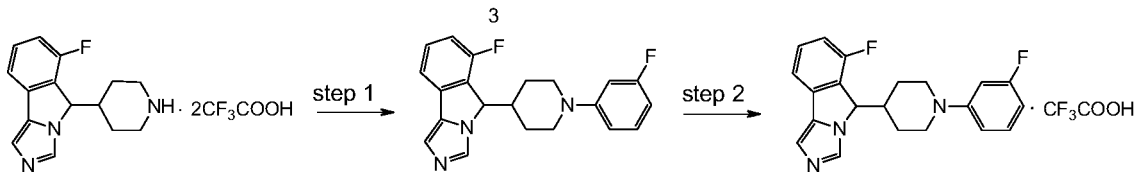
MS m/z (ESI): 334.3 [M+1]

Example 3

6-fluoro-5-(1-(3-fluorophenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



3



1g 3a 3

Step 1

6-fluoro-5-(1-(3-fluorophenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **3a**

The crude compound **1g** (230 mg, 0.5 mmol), 3-fluoro-1-bromobenzene (105 mg, 0.6 mmol), 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl (24 mg, 0.05 mmol), sodium *tert*-butoxide (192 mg, 2.0 mmol) were dissolved in 3 mL of a mixture of toluene and *tert*-butanol (V:V=5:1). Then palladium acetate (12.0 mg, 0.05 mmol) was added under argon atmosphere. The reaction system was stirred for 12 hours at 120°C. After the reaction was completed, 20 mL of dichloromethane was added. The mixture was washed with water (10 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **3a** (17.3 mg, yield 10%) as a black syrup.

MS m/z (ESI): 352.3 [M+1]

Step 2

6-fluoro-5-(1-(3-fluorophenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **3**

Compound **3a** (17.3 mg, 0.05 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.01 mL of trifluoroacetic acid was added. The resulting mixture was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **3** (23 mg, yield 100%) as a light brown solid.

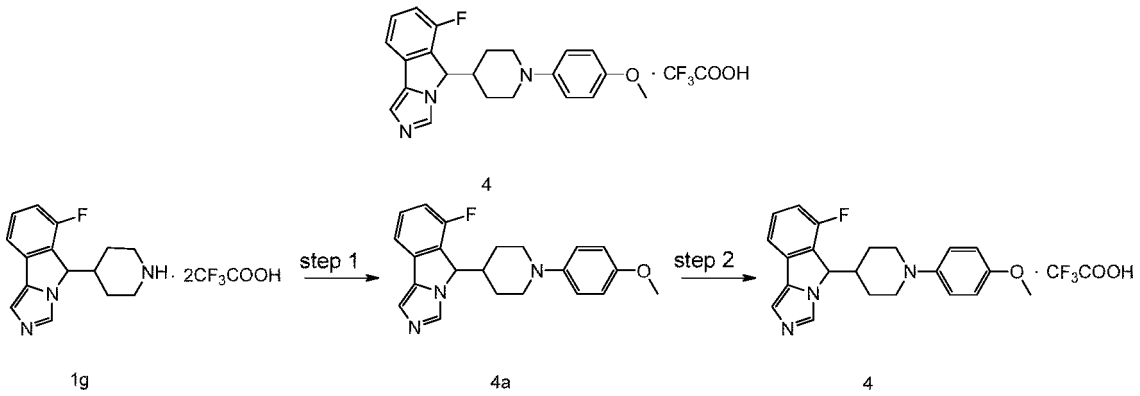
MS m/z (ESI): 352.3 [M+1]

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.51 (s, 1H), 8.06 (s, 1H), 7.76 (d, 1H), 7.67-7.62 (m, 1H), 7.47-7.32 (m, 1H), 7.23-7.10 (m, 1H), 6.76-6.62 (m, 2H), 6.57-6.45 (m, 1H), 6.12 (d, 1H), 3.85-3.73 (m, 1H), 3.73-3.63 (m, 1H), 2.79-2.67 (m, 1H), 2.67-2.50 (m, 2H), 1.83-1.68 (m, 1H), 1.61-1.45 (m, 1H), 1.35-1.23 (m, 1H), 1.10-0.94 (m, 1H).

Example 4

6-fluoro-5-(1-(4-methoxyphenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole

trifluoroacetate



4

1g 4a 4

Step 1

6-fluoro-5-(1-(4-methoxyphenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **4a**

The crude compound **1g** (115 mg, 0.25 mmol), 4-iodoanisole (70 mg, 0.3 mmol), 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl (12 mg, 0.025 mmol), sodium *tert*-butoxide (96 mg, 1.0 mmol) were dissolved in 1.8 mL of a mixture of toluene and *tert*-butanol (V:V=5:1). Then palladium acetate (6.0 mg, 0.025 mmol) was added under argon atmosphere. The reaction system was stirred for 30 mins at 160°C in microwave. After the reaction was completed, the mixture was washed with saturated sodium sulphite solution (25 mL×3), extracted with dichloromethane (20 mL×3), the combined organic phases were washed with saturated sodium sulphite solution (25 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain the title compound **4a** (29 mg, yield 33.6%) as a brown syrup.

MS m/z (ESI): 364.3 [M+1]

Step 2

6-fluoro-5-(1-(4-methoxyphenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **4**

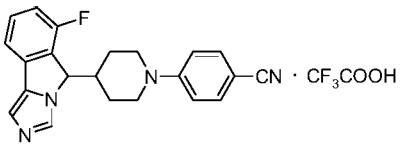
Compound **4a** (29 mg, 0.084 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.5 mL of trifluoroacetic acid was added. The resulting mixture was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **4** (40 mg, yield 100%) as a light brown solid.

MS m/z (ESI): 364.3 [M+1]

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.41 (s, 1H), 8.02 (s, 1H), 7.75 (d, 1H), 7.68-7.63 (m, 1H), 7.44-7.39 (m, 1H), 7.21-7.10 (m, 2H), 6.97-6.87 (m, 2H), 6.14 (d, 1H), 3.71 (s, 3H), 3.59-3.50 (m, 1H), 3.49-3.40 (m, 1H), 3.18-2.82 (m, 2H), 2.69-2.55 (m, 2H), 1.95-1.83 (m, 1H), 1.83-1.66 (m, 1H), 1.42-1.30 (m, 1H), 1.26-1.10 (m, 1H).

Example 5

4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)benzonitrile trifluoroacetate



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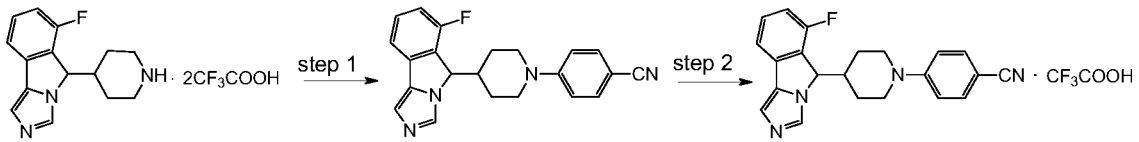


1g 5a 5

Step 1

4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)benzonitrile **5a**

The crude compound **1g** (230 mg, 0.5 mmol), 4-iodobenzonitrile (137 mg, 0.6 mmol), 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl (24 mg, 0.05 mmol), sodium *tert*-butoxide (192 mg, 2.0 mmol) and palladium acetate (12.0 mg, 0.05 mmol) were dissolved in 3 mL of a mixture of toluene and *tert*-butanol (V:V=5:1). The resulting mixture was stirred for 1 hour at 120°C in microwave under argon atmosphere. After the reaction was completed, 20 mL of dichloromethane was added. The mixture was washed with saturated sodium sulphite solution (10 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **5a** (67 mg, yield 29.7%) as a brown syrup.

MS m/z (ESI): 359.1 [M+1]

Step 2

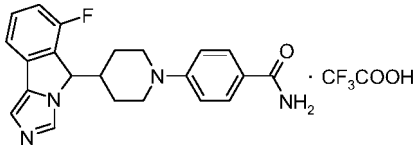
4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)benzonitrile trifluoroacetate **5**

Compound **5a** (67 mg, 0.188 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.1 mL of trifluoroacetic acid was added. The resulting mixture was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **5** (70 mg, yield 100%) as a light brown solid.

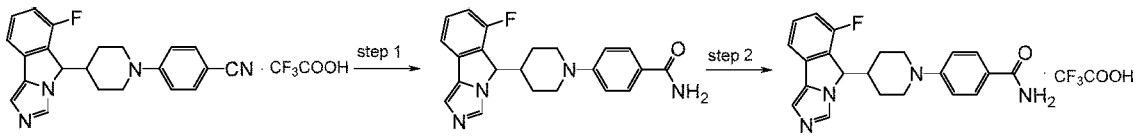
MS m/z (ESI): 359.1 [M+1]

Example 6

4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)benzamide trifluoroacetate



6



5 6a 6

Step 1

4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)benzamide **6a**

Compound **5** (60 mg, 0.127 mmol), zinc powder (340 mg, 5.2 mmol), 3 mL of acetic acid and 0.2 mL of concentrated hydrochloric acid were added into a flask. The resulting mixture was stirred for 19 hours at 125°C. After the reaction was completed, the zinc powder was filtered off. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **6a** (4.5 mg, yield 9.4%) as a brown syrup.

MS m/z (ESI): 377.4 [M+1]

Step 2

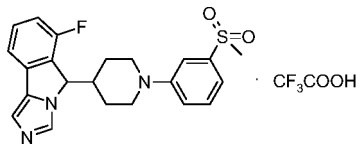
4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)benzamide trifluoroacetate **6**

Compound **6a** (4.5 mg, 0.012 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.1 mL of trifluoroacetic acid was added. The resulting mixture was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **6** (5.8 mg, yield 100%) as a light brown solid.

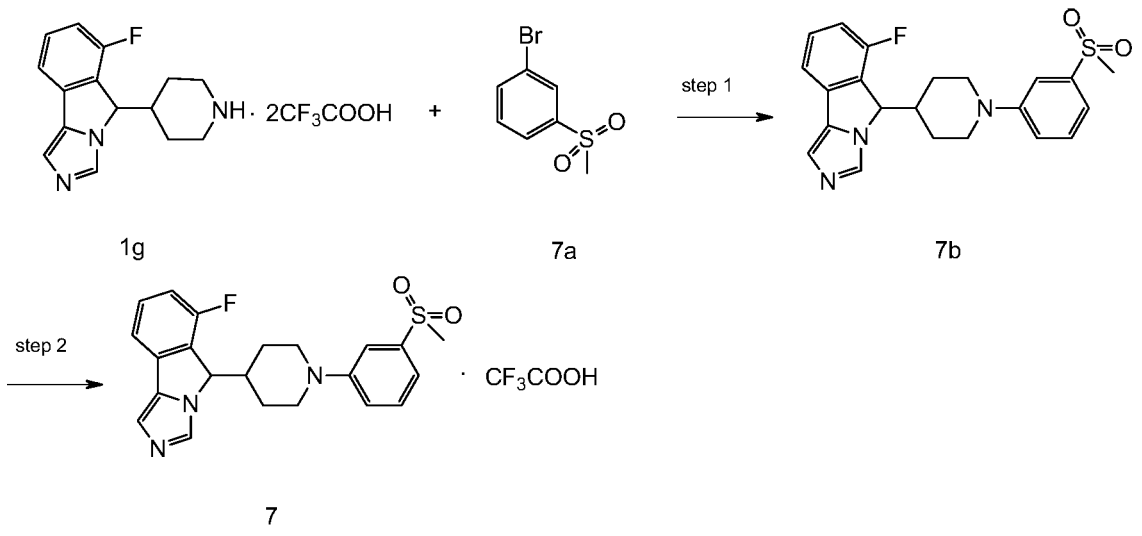
MS m/z (ESI): 377.4 [M+1]

Example 7

6-fluoro-5-(1-(4-(methylsulfonyl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



7



Step 1

6-fluoro-5-(1-(3-(methylsulfonyl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **7b**

The crude compound **1g** (150 mg, 0.33 mmol), 1-bromo-3-(methylsulfonyl)benzene **7a** (93 mg, 0.40 mmol), 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl (16 mg, 0.033 mmol), sodium *tert*-butoxide (158 mg, 1.65 mmol) and palladium acetate (20.0 mg, 0.083 mmol) were dissolved in 3 mL of a mixture of toluene and *tert*-butanol (V:V=5:1). The reaction system was stirred for 30 mins at 160°C in microwave. After the reaction was completed, the reaction mixture was filtered through diatomite. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **7b** (14.5 mg, yield 13.0%) as a light orange solid.

MS m/z (ESI): 412.0 [M+1]

Step 2

6-fluoro-5-(1-(3-(methylsulfonyl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **7**

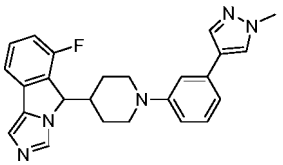
Compound **7b** (14.5 mg, 0.035 mmol) was dissolved in 5 mL of dichloromethane, then 0.5 mL of trifluoroacetic acid was added. The resulting mixture was stirred for 12 hour at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **7** (18 mg, yield 100%) as a light orange solid.

MS m/z (ESI): 412.0 [M+1]

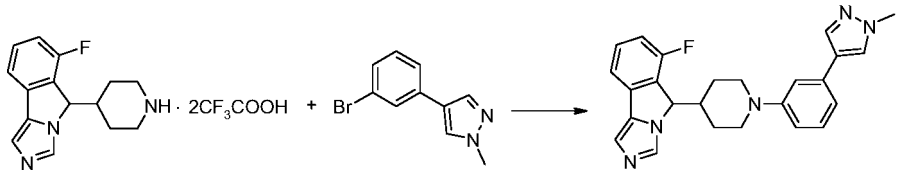
^{1}H NMR (400 MHz, $CDCl_3$) δ 9.05 (br.s, 1H), 7.60-7.56 (m, 3H), 7.45-7.38 (m, 3H), 7.26-7.22 (t, 1H), 7.14-7.12 (d, 1H), 5.75 (s, 1H), 3.06 (s, 3H), 2.91-2.75 (m, 2H), 1.94-1.74 (m, 2H), 1.49-1.46 (m, 1H), 1.37-1.19 (m, 4H).

Example 8

6-fluoro-5-(1-(3-(1-methyl-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole



8



1g 8a 8

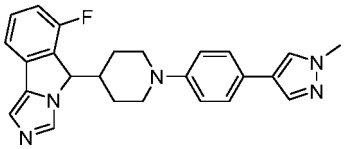
The crude compound **1g** (229 mg, 0.5 mmol) and 4-(3-bromophenyl)-1-methyl-1*H*-pyrazole **8a** (236 mg, 1 mmol, prepared by a method disclosed in the patent application "WO2013043946") were dissolved in 10 mL of toluene, then (±)2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (31.1 mg, 0.05 mmol), sodium *tert*-butoxide (192 mg, 2 mmol) and tri(dibenzylideneacetone)dipalladium (45.78 mg, 0.05 mmol) were added. The reaction system was stirred for 1 hour at 120°C in microwave. After the reaction was completed, the filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **8** (30 mg, yield 11.3%) as a white solid.

MS m/z (ESI): 414.2 [M+1]

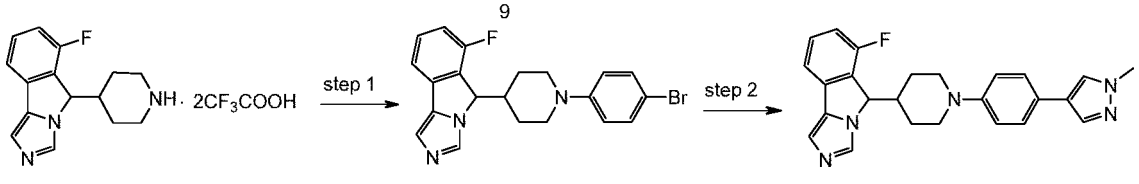
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18-8.16 (m, 2H), 7.99-7.93 (m, 1H), 7.90-7.85 (m, 2H), 7.74-7.72 (m, 1H), 7.69-7.65 (m, 4H), 7.36-7.32 (m, 1H), 6.66 (s, 1H), 3.96 (s, 3H), 3.36 (m, 1H), 3.15 (m, 1H), 2.78 (m, 1H), 2.66 (m, 1H), 2.40 (m, 1H), 2.03 (m, 1H), 1.78 (m, 1H), 1.28 (m, 1H), 1.01 (m, 1H).

Example 9

6-fluoro-5-(1-(4-(1-methyl-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole



9



1g 9a 9

Step 1

5-(1-(4-bromophenyl)piperidin-4-yl)-6-fluoro-5*H*-imidazo[5,1-a]isoindole **9a**

The crude compound **1g** (1.45 g, 3 mmol) was dissolved in 30 mL of toluene, 1,4-dibromobenzene (1.41 g, 6 mmol), then

(±)2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (187 mg, 0.3 mmol), sodium *tert*-butoxide (1.15 g, 12 mmol) and tri(dibenzylideneacetone)dipalladium (275 mg, 0.3 mmol) were added under argon atmosphere. The reactin system was stirred for 12 hours at 80°C. After the reaction was completed, the filtrate was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromtography with elution system A to obtain compound **9a** (670 mg, yield 50%) as a yellow solid.

MS m/z (ESI): 412.2 [M+1]

Step 2

6-fluoro-5-(1-(4-(1-methyl-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **9**

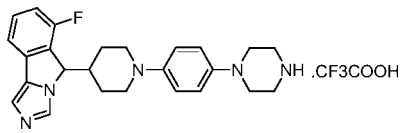
The crude compound **9a** (165 mg, 0.4 mmol) was dissolved in 5 mL of 1,2-dimethoxyethane, then 1-methyl-4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1*H*-pyrazole (166 mg, 0.8 mmol), sodium carbonate (127 mg, 1.2 mmol) and water (0.5 mL) were added. After mixing uniformly, [1,1'-bis(diphenylphosphino)ferrocene]dichloropalladium (29 mg, 0.04 mmol) was added and the reaction system was stirred for 40 minutes at 120°C in microwave under argon atmosphere. After the reaction was completed, 50 mL of ethyl acetate and 20 mL of water were added. Two phase were separated, and the aqueous phase was extracted with ethyl acetate (30 mL). The organic phases were combined, washed with saturated sodium chloride solution (40 mL), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **9** (10 mg, yield 6.06%) as a white solid.

MS m/z (LC-MS): 414.4 [M+1]

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.99 (s, 1H), 7.95 (s, 1H), 7.71 (s, 1H), 7.51-7.46 (m, 2H), 7.35 (d, 2H), 7.23 (s, 1H), 7.16-7.13 (m, 1H), 6.87 (d, 2H), 5.70 (s, 1H), 3.83 (s, 3H), 3.76-3.73 (m, 1H), 3.63-3.60 (m, 1H), 2.70-2.64 (m, 1H), 2.37-2.34 (m, 1H), 1.79-1.76 (m, 1H), 1.70-1.65 (m, 1H), 1.34-1.30 (m, 1H), 1.20-1.17 (m, 1H), 0.91-0.87 (m, 1H).

Example 10

6-fluoro-5-(1-(4-(piperazin-1-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



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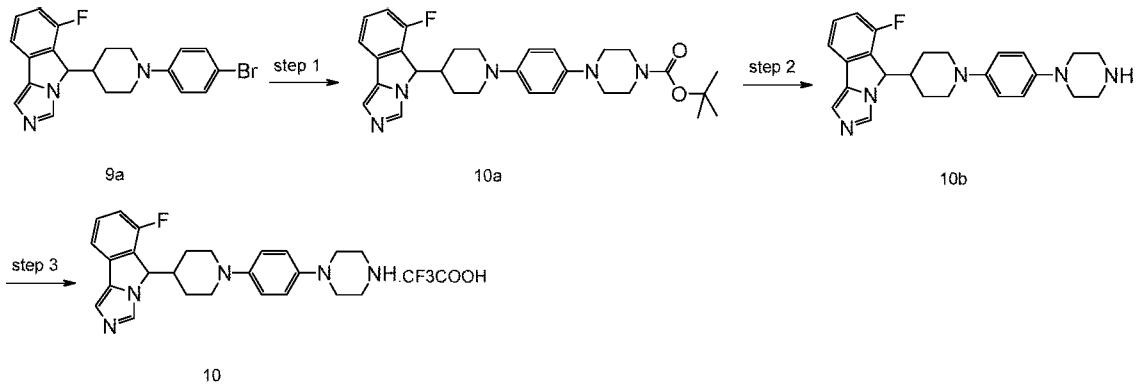


9a 10a 10b 10

Step 1

tert-butyl 4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)piperazine-1-carboxylate **10a**

Compound **9a** (82 g, 2 mmol) and tert-butyl 1-piperazinecarboxylate (760 mg, 4 mmol) were dissolved in 15 mL of toluene, then (±)2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (125 mg, 0.2 mmol), sodium *tert*-butoxide (576 g, 6 mmol) and tri(dibenzylideneacetone)dipalladium (183 mg, 0.2 mmol) were added. The reaction system was stirred for 75 mins at 120°C in microwave. After the reaction was completed, the reaction mixture was filtered through diatomite. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromtography with elution system A to obtain compound **10a** (517 mg, yield 50%) as a yellow solid.

MS m/z (ESI): 518.2 [M+1]

Step 2

6-fluoro-5-(1-(4-(piperazin-1-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **10b**

Compound **10a** (517 mg, 1 mmol) was dissolved in 16 mL of dichloromethane, then 4 mL of trifluoroacetic acid was added. The reaction was stirred overnight at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **10b** (15.4 mg, yield 3.7%) as a light yellow solid.

MS m/z (LC-MS): 418.2 [M-1]

Step 3

6-fluoro-5-(1-(4-(piperazin-1-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **10**

Compound **10b** (14.5 mg, 0.035 mmol) was dissolved in 5 mL of dichloromethane, then 0.5 mL of trifluoroacetic acid was added. The reaction was stirred for 12 hour at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **10** (20 mg, yield 100%) as a light yellow solid.

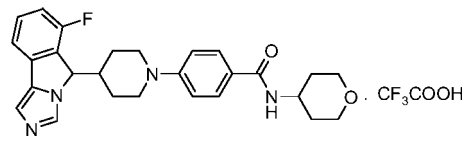
MS m/z (ESI): 418.2 [M+1]

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (s, 1H), 7.34-7.38 (m, 3H), 7.22 (s, 1H),

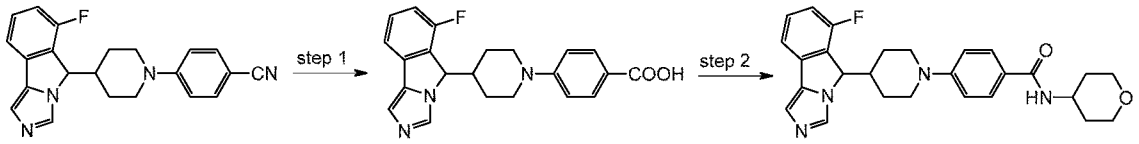
6.98-6.96 (m, 1H), 6.85-6.84 (m, 3H), 5.38 (s, 1H), 3.65 (m, 1H), 3.62 (m, 1H), 3.34 (m, 1H), 3.09 (m, 1H), 2.70 (m, 1H), 2.56 (m, 2H), 2.38 (m, 2H), 1.86 (m, 3H), 1.31-1.16 (m, 5H).

Example 11

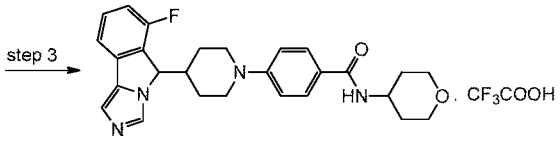
4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-*N*-(tetrahydro-2*H*-pyran-4-yl)benzamide trifluoroacetate



11



5a 11a 11b



11

Step 1

4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)benzoic acid **11a**

Compound **5a** (630 g, 1.76 mmol) was added into 15 mL of 6*N* hydrochloric acid. The reaction system was stirred for 12 hours at 100°C. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was dried to obtain a crude compound **11a** (664 mg) as a light brown solid, which was used directly in the next step without further purification.

MS m/z (LC-MS): 378.1 [M+1]

Step 2

4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-*N*-(tetrahydro-2*H*-pyran-4-yl)benzamide **11b**

The crude compound **11a** (75 mg, 0.2 mmol), 4-aminotetrahydropyran (40 mg, 0.4 mmol) and triethylamine (0.14 mL, 1.0 mmol) were dissolved in 1.0 mL of *N*,*N*-dimethylformamide, then 2-(7-azabenzotriazol-1-yl)-*N*,*N*,*N*',*N*'-tetramethyluronium hexafluorophosphate (152 mg, 0.4 mmol) was added. The reaction system was stirred for 12 hours at 50°C. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **11b** (48 mg, yield 52.1%) as a light brwon solid.

MS m/z (LC-MS): 461.4 [M+1]

Step 3

4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-*N*-(tetrahydro-2*H*-pyran-4-yl)benzamide trifluoroacetate **11**

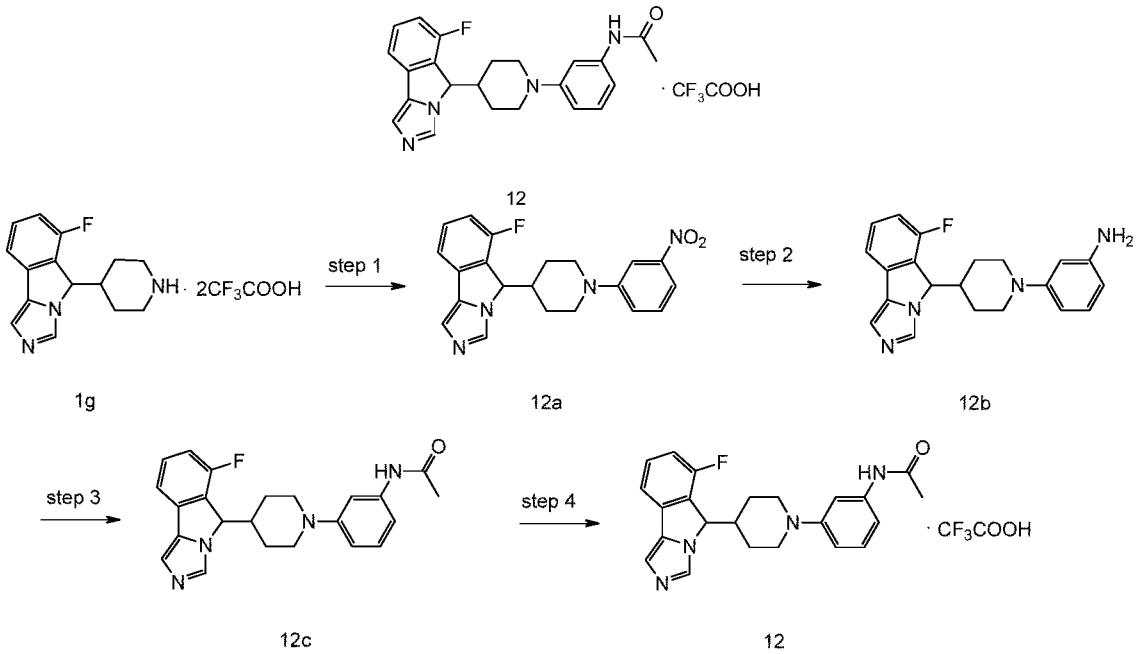
Compound **11b** (48 mg, 0.104 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.1 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **11** (60 mg, yield 100%) as a light brown solid.

MS m/z (ESI): 461.4[M+1]

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.46 (s, 1H), 8.04 (s, 1H), 7.98 (d, 1H), 7.76-7.63 (m, 4H), 7.44-7.39 (m, 1H), 6.89 (d, 2H), 6.11 (d, 1H), 3.98-3.80 (m, 5H), 3.38-3.32 (m, 2H), 2.83-2.73 (m, 1H), 2.73-2.63 (m, 1H), 2.62-2.54 (m, 1H), 1.79-1.68 (m, 3H), 1.59-1.48 (m, 3H), 1.34-1.25 (m, 1H), 1.05-0.95 (m, 1H).

Example 12

N-(3-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)acetamide trifluoroacetate



Step 1

6-fluoro-5-(1-(3-nitrophenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **12a**

The crude compound **1g** (230 mg, 0.5 mmol), 1-iodo-3-nitrobenzene (149 mg, 0.6 mmol), 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl (24 mg, 0.05 mmol), sodium *tert*-butoxide (192 mg, 2.0 mmol) and palladium acetate (12.0 mg, 0.05 mmol) were dissolved in 3 mL of a mixture of toluene and *tert*-butanol (V:V=5:1). The reaction system was stirred for 30 mins at 160°C in microwave. After the reaction was completed, 20 mL of saturated sodium sulphite solution was added, and the mixture was extracted with dicholoromethane (20 mL×3). The organic phases were combined, washed with saturated sodium sulphite solution (20 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and

the resulting residue was purified by silica gel column chromatography with elution system A to obtain compound **12a** (50 mg, yield 26.5%) as a brown viscous material.

MS m/z (LC-MS): 379.1 [M+1].

Step 2

3-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)aniline **12b**

Compound **12a** (50 mg, 0.132 mmol) and 10% Pd/C (10 mg) were added into 2 mL of a mixture of methanol and tetrahydrofuran(V:V=1:1). The reaction system was purged with hydrogen three times, and stirred at room temperature for 3 hours. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain a crude compound **12b** (46 mg) as a red brwon viscous solid, which was used directly in the next step without further purification.

MS m/z (LC-MS): 349.0 [M+1]

Step 3

N-(3-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)acetamide **12c**

The crude compound **12b** (46 mg, 0.132 mmol), acetic acid (16 mg, 0.264 mmol), 1-hydroxybenzotriazole (36 mg, 0.264 mmol), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (51 mg, 0.264 mmol) and *N*,*N*-diisopropylethylamine (85 mg, 0.66 mmol) were added into 1 mL of *N*,*N*-dimethylformamide. The reaction system was stirred for 2 hours at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **12c** (8.4 mg, yield 16.3%) as a brown syrup.

MS m/z (LC-MS): 391.4 [M+1]

Step 4

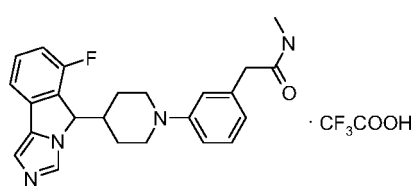
N-(3-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)acetamide trifluoroacetate **12**

Compound **12c** (8.4 mg, 0.021 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.05 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **12** (10.8 mg, yield 100%) as a light brown solid.

MS m/z (LC-MS): 391.4 [M+1]

Example 13

2-(3-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-*N*-methylaceta mide trifluoroacetate



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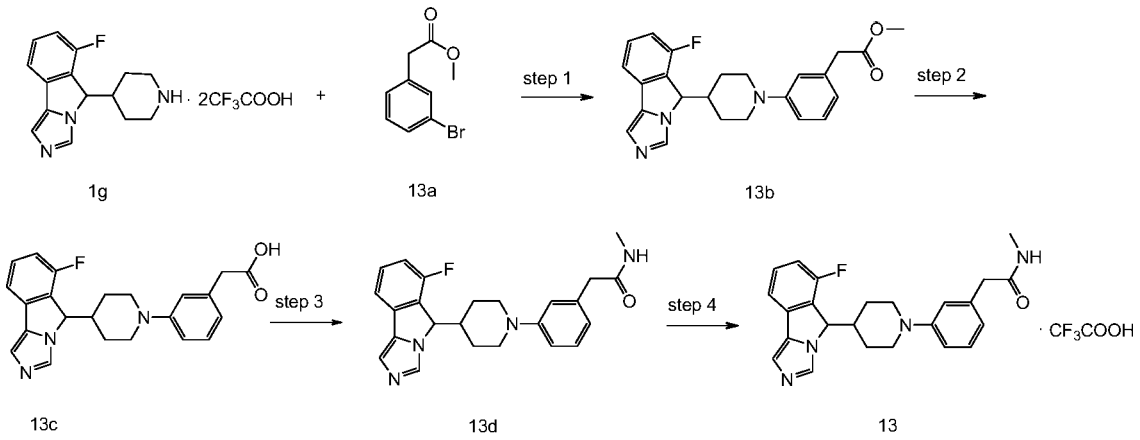


Step 1

methyl 2-(3-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)acetate **13b**

The crude compound **1g** (1.21 g, 2.5 mmol), methyl 2-(3-bromophenyl)acetate **13a** (1.15 g, 5.0 mmol, prepared by a well-known method disclosed in "*Journal of Medicinal Chemistry*, 2008, 51 (3), 392-395"), copper iodide (95 mg, 0.5 mmol), *L*-proline (115 mg, 1 mmol) and potassium carbonate (1.38 g, 10.0 mmol) were added into 10 mL of dimethyl sulfoxide. The reaction system was stirred for 24 hours at 90°C under argon atmosphere. After the reaction was completed, 100 mL of ethyl acetate was added. The mixture was washed with water (250 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system A to obtain the title compound **13b** (410 mg, yield 40.5%) as a brown syrup.

MS m/z (LC-MS): 406.0 [M+1]

Step 2

2-(3-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)acetic acid **13c**

Compound **13b** (410 mg, 1.0 mmol) was dissolved in 4 mL of tetrahydrofuran, then 4 mL of 1*M* sodium hydroxide solution was added. The resulting mixture was stirred for 12 hours at room temperature. After the reaction was completed, 40 mL of water was added. The mixture was extracted with ethyl acetate (25 mL×3). The aqueous phase was added dropwise with acetic acid to adjust the pH to 6 and extracted with dichloromethane (20 mL×3). The organic phases were combined, dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain a crude compound **13c** (190 mg) as a brwon solid, which was used directly in the next step without further purification.

MS m/z (LC-MS): 392.0 [M+1]

Step 3

2-(3-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-*N*-methylaceta mide **13d**

The crude compound **13c** (190 mg, 0.485 mmol), methylamine hydrochloride (65 mg, 0.97 mmol), 2-(7-azabenzotriazol-1-yl)-*N*,*N*,*N*',*N*'-tetramethyluronium

hexafluorophosphate (369 mg, 0.097 mmol) and triethylamine (245 mg, 2.425 mmol) were added into 2 mL of *N*,*N*-dimethylformamide. The reaction system was stirred for 12 hours at 50°C. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **13d** (39 mg, yield 19.9%) as a brown solid.

MS m/z (LC-MS): 405.0 [M+1]

Step 4

2-(3-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-*N*-methylaceta mide trifluoroacetate **13**

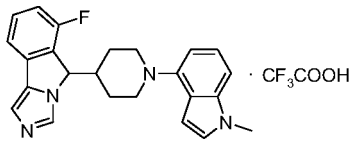
Compound **13d** (39 mg, 0.096 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.05 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **13** (50 mg, yield 100%) as a light brown solid.

MS m/z (ESI): 405.0[M+1]

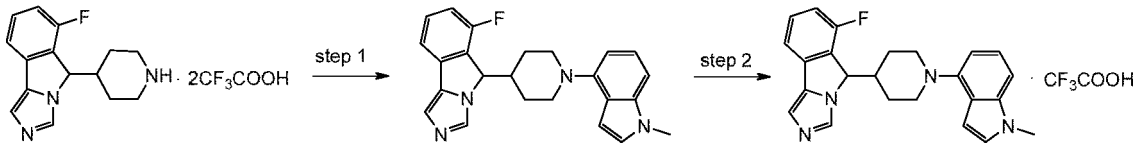
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.52 (s, 1H), 8.07 (s, 1H), 7.97-7.89 (m, 1H), 7.76 (d, 1H), 7.70-7.64 (m, 1H), 7.46-7.41 (m, 1H), 7.22-7.14 (m, 1H), 7.04-6.73 (m, 3H), 6.14 (d, 1H), 3.73-3.63 (m, 1H), 3.63-3.53 (m, 1H), 3.32 (s, 2H), 3.00-2.70 (m, 2H), 2.63-2.53 (m, 1H), 2.55 (d, 3H), 1.91-1.81 (m, 1H),1.73-1.58 (m, 1H), 1.38-1.28 (m, 1H), 1.10-1.00 (m, 1H).

Example 14

6-fluoro-5-(1-(1-methyl-1*H*-indol-4-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



14



1g 14a 14

Step 1

6-fluoro-5-(1-(1-methyl-1*H*-indol-4-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **14a**

The crude compound **1g** (367 mg, 0.76 mmol), 4-bromo-1-methyl-1*H*-indole (150 mg, 0.714 mmol) was dissolved in 15 mL of a mixture of toluene and tert-butanol (V:V=5:1), then 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl (34 mg, 0.071 mmol), sodium *tert*-butoxide (274 mg, 2.86 mmol) and palladium acetate (16.0 mg, 0.071 mmol) were added under argon atmosphere. The reaction system was stirred for

12 hours at 120°C. After the reaction was completed, the reaction solution was filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **14a** (23 mg, yield 8.4%) as a yellow solid.

MS m/z (ESI): 387.4 [M-1].

Step 2

6-fluoro-5-(1-(1-methyl-1*H*-indol-4-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **14**

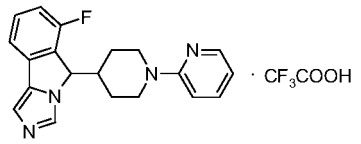
Compound **14a** (23 mg, 0.06 mmol) was dissolved in 2 mL of dichloromethane, then 0.1 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **14** (30 mg, yield 100%) as a yellow solid.

MS m/z (LC-MS): 387.4 [M+1]

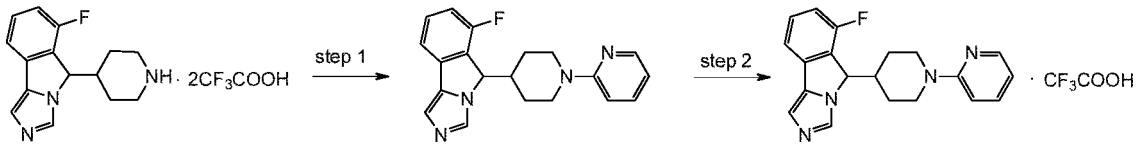
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.54 (s, 1H), 8.09 (s, 1H), 7.78 (d, 1H), 7.65-7.71 (m, 1H), 7.45 (t, 1H), 7.02-7.33 (m, 3H), 6.75 (br.s, 1H), 6.41 (br. s, 1H), 6.12 (s, 1H), 3.75 (s, 3H), 3.55-3.74 (m, 2H), 2.52-2.80 (m, 2H), 1.70-2.00 (m, 3H), 1.30-1.40 (m, 1H), 1.20-1.30 (m, 1H).

Example 15

6-fluoro-5-(1-(pyridin-2-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



15



1g 15a 15

Step 1

6-fluoro-5-(1-(pyridin-2-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **15a**

The crude compound **1g** (115 mg, 0.25 mmol), 2-bromopyridine (47 mg, 0.30 mmol), 2-(dicyclohexylphosphino)-2,4,6-triisopropylbiphenyl (12.0 mg, 0.025 mmol) and sodium *tert*-butoxide (96 mg, 1.0 mmol) were dissolved in 1.8 mL of a mixture of toluene and tert-butanol (V:V=5:1). After mixing uniformly, palladium acetate (6.0 mg, 0.025 mmol) was added. The reaction system was stirred for 30 mins at 160°C in microwave. After the reaction was completed, 20 mL of water was added. The mixture was extracted with dichloromethane (20×3mL). The organic phases were combined, dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid

chromatography to obtain compound **15a** (7.1 mg, yield 6.8%) as a brown syrup.

MS m/z (LC-MS): 335.0 [M+1].

Step 2

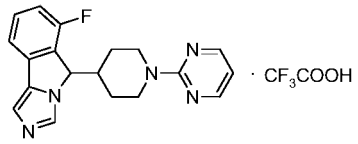
6-fluoro-5-(1-(pyridin-2-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **15**

Compound **15a** (7.1 mg, 0.21 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.1 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **15** (9.5 mg, yield 100%) as a brown solid.

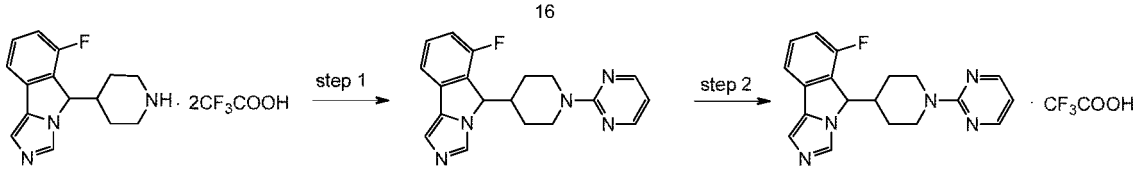
MS m/z (LC-MS): 335.0 [M+1]

Example 16

6-fluoro-5-(1-(pyrimidin-2-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



16



1g 16a 16

Step 1

6-fluoro-5-(1-(pyrimidin-2-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **16a**

The crude compound **1g** (230 mg, 0.5 mmol), 2-chloropyimidine (57 mg, 0.50 mmol), triethylamine (202 mg, 2.0 mmol) were added into a sealed tube. 5 mL of ethanol was added. The reaction system was stirred for 12 hours at 100°C. After the reaction was completed, The reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **16a** (127 mg, yield 75.5%) as a light brown syrup.

MS m/z (LC-MS): 336.0 [M+1]

Step 2

6-fluoro-5-(1-(pyrimidin-2-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **16**

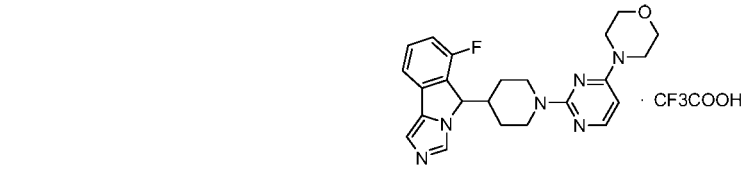
Compound **16a** (127 mg, 0.38 mmol) was dissolved in 2 mL of dichloromethane, then 0.5 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **16** (170 mg, yield 100%) as a light brown solid.

MS m/z (ESI): 336.0 [M+1]

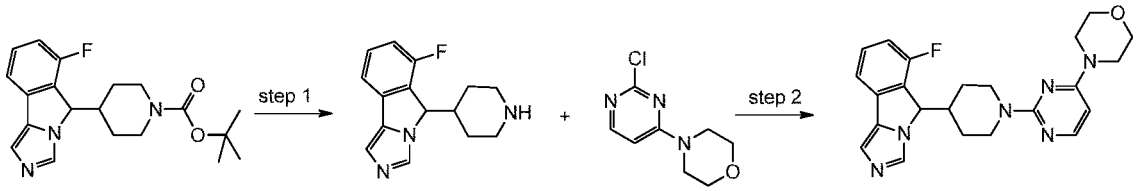
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.48 (s, 1H), 8.31(d, 2H), 8.04 (s, 1H), 7.75 (d, 1H), 7.67-7.61 (m, 1H), 7.42-7.37 (m, 1H), 6.58-6.56 (m, 1H), 6.10 (d, 1H), 4.85-4.75 (m, 1H), 4.71-4.61 (m, 1H), 2.93-2.81 (m, 1H), 2.81-2.62 (m, 3H),1.85-1.74 (m, 1H), 1.46-1.36 (m, 1H), 1.32-1.22 (m, 1H), 0.87-0.77 (m, 1H).

Example 17

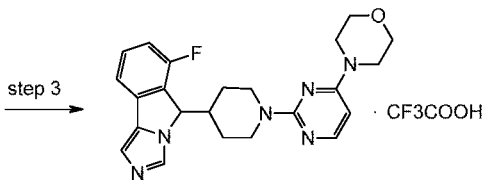
4-(2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)pyrimidin-4-yl)morpholine trifluoroacetate



17



1f 17a 17b 17c



17

Step 1

6-fluoro-5-(piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **17a**

The compound **1f** (17.1 g, 47.9 mmol) was dissolved in 100 mL of dichloromethane, then 50 mL of trifluoroacetic acid was added. The reaction was stirred for 12 hours at room temperature. After the reaction was completed, most of dichloromethane and trifluoroacetic acid were removed by concentration under reduced pressure. 100 mL of dichloromethane was added. Saturated sodium bicarbonate solution was added dropwise till no bubbles were released, and the pH was adjusted to 7. Two phases were separated and the aqueous phase was extracted with dichloromethane (200 mL×3). The organic phases were combined, dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain a crude compound **17a** (12.3 g) as a brown syrup, which was used directly in the next step without furhter purification.

MS m/z (LC-MS): 258.3 [M+1]

Step 2

4-(2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)pyrimidin-4-yl)morpho

line **17c**

The crude compound **17a** (260 mg, 1.005 mmol) was dissolved in 2.5 ml of ethanol, then 4-(2-chloropyrimidin-4-yl)morpholine **17b** (100 mg, 0.503 mmol, prepared by a well-known method disclosed in"*Chemistry & Biology Interface*, 2012, 2(5), 347-361") and triethylamine(203 mg, 2.012 mmol) were added. The reaction was stirred for 48 hours at 100°C in a sealed pot. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **17c** (59 mg, yield 30%) as a yellow solid.

MS m/z (LC-MS): 421.3 [M+1].

Step 3

4-(2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)pyrimidin-4-yl)morpholine trifluoroacetate **17**

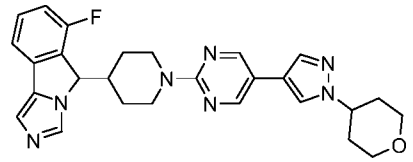
Compound **17c** (59 mg, 0.14mmol) was dissolved in 3 mL of dichloromethane, then 0.1 mL of trifluoroacetic acid was added. The reaction was stirred for 30 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **17** (75 mg, yield 100%) as a yellow jelly.

MS m/z (ESI): 421.3 [M+1]

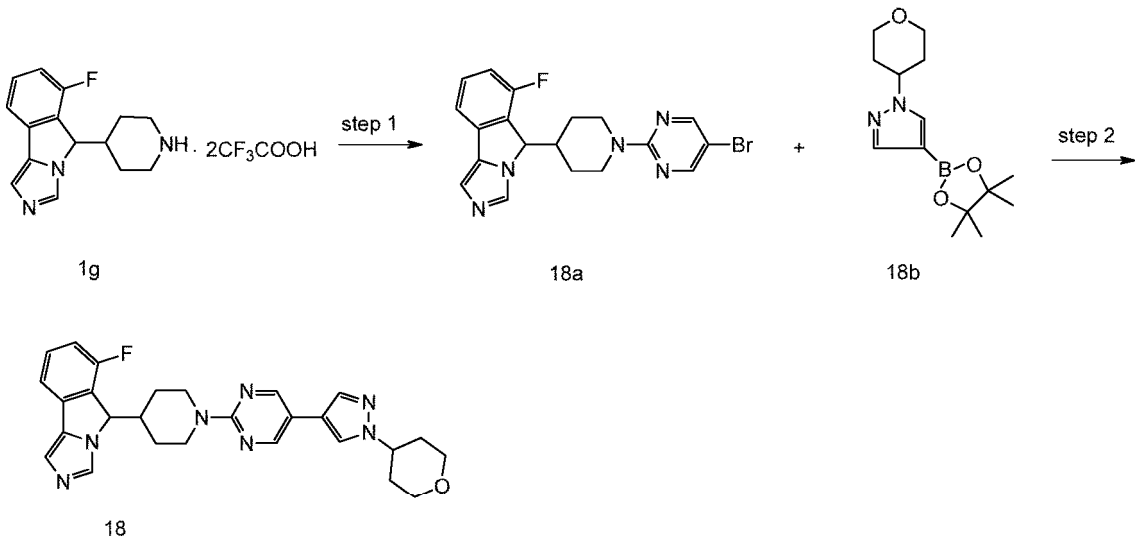
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.36 (s, 1H), 8.03 (s, 1H), 7.86 (d, 1H), 7.75 (d, 1H), 7.63-7.68 (m, 1H), 7.41 (t, 1H), 6.52 (d, 1H), 6.10 (d, 1H), 4.30-4.55 (m, 2H), 3.60-3.85 (m, 8H), 3.09 (t, 1H), 2.99 (t, 1H), 2.70-2.80 (m, 1H), 1.82-1.88 (m, 1H), 1.36-1.55 (m, 1H), 1.30-1.36 (m, 1H), 0.88-1.05 (m, 1H).

Example 18

6-fluoro-5-(1-(5-(1-(tetrahydro-2*H*-pyran-4-yl)-1*H*-pyrazol-4-yl)pyrimidin-2-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole



18



1g 18a 18b

18

Step 1

5-(1-(5-bromopyrimidin-2-yl)piperidin-4-yl)-6-fluoro-5*H*-imidazo[5,1-a]isoindole **18a**

The crude compound **1g** (1.0 g, 2.2 mmol), 5-bromo-2-chloropyrimidine (468 mg, 2.42 mmol) and triethylamine(1.1 g, 11 mmol) were added into 20 mL of ethanol in a sealed tube. The reaction was stirred for 12 hours at 90°C. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system A to obtain compound **18a** (730 mg, yield 80.2%) as an orange yellow solid.

MS m/z (LC-MS): 414.2 [M+2]

Step 2

6-fluoro-5-(1-(5-(1-(tetrahydro-2*H*-pyran-4-yl)-1*H*-pyrazol-4-yl)pyrimidin-2-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **18**

Compound **18a** (124 mg, 0.3 mmol) was dissolved in 5 ml of a mixture of 1,2-dimethoxyethane and water, then 1-(tetrahydro-2H-pyran-4-yl)-4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1*H*-pyrazole **18b** (125 mg, 0.45 mmol, prepared by a well-known method disclosed in "*Bioorganic & Medicinal Chemistry*, 2013, 21(21), 6804-6820"), tetrakis(triphenylphosphine)palladium (69 mg, 0.06 mmol) and sodium carbonate (63.6 mg, 0.6 mmol) were added under argon atmosphere. The reaction was stirred for 12 hours at 80°C. After the reaction was completed, 30 mL of water was added. The mixture was extracted with dichloromethane (40×3mL). The organic phases were combined, washed with saturated sodium chloride solution (40 mL), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **18** (30 mg, yield 20.7%) as a white solid.

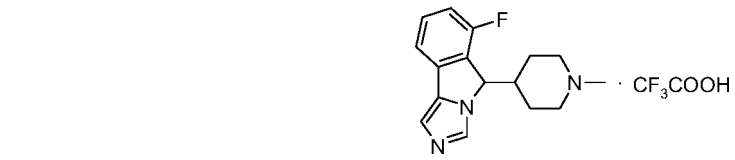
MS m/z (LC-MS): 486.5 [M+1]

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.56 (s, 2H), 8.18 (s, 1H), 7.94 (s, 1H), 7.82 (s, 1H), 7.48-7.46 (m, 2H), 7.20 (s,1H), 7.16-7.11 (m, 1H), 5.68 (s, 1H), 4.81-4.78 (m, 1H), 4.64-4.61 (m, 1H), 4.42-4.36 (m, 1H), 3.98-3.95 (m, 2H), 3.50-3.44 (m, 2H), 2.92-2.86

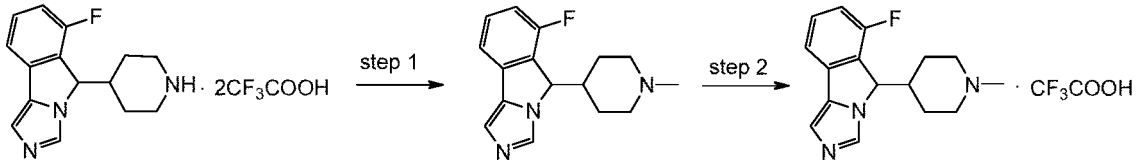
(m, 1H), 2.78-2.72 (m, 1H), 2.01-1.89 (m, 4H), 1.81-1.78 (m, 1H), 1.53-1.45 (m, 1H), 1.26-1.24 (m, 1H), 1.19-1.17 (m, 1H), 0.73-0.63 (m, 1H).

Example 19

6-fluoro-5-(1-methylpiperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



19



1g 19a 19

Step 1

6-fluoro-5-(1-methylpiperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **19a**

The crude compound **1g** (121 mg, 0.25 mmol) was dissolved in 2 mL of *N*,*N*-dimethylformamide, then potassium carbonate (173 mg, 1.25 mmol) was added. After mixing uniformly, methyl iodide (21 mg, 0.15 mmol) was added. The reaction was stirred for 48 hours at room temperature. After the reaction was completed, 20 mL of ethyl acetate was added. The mixture was washed with water (10 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **19a** (16.0 mg, yield 38.9%) as a light brown viscous material.

MS m/z (LC-MS): 272.0 [M+1]

Step 2

6-fluoro-5-(1-methylpiperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **19**

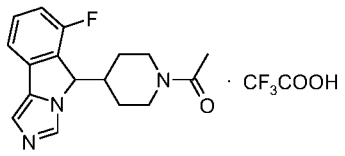
The crude compound **19a** (16.0 mg, 0.59 mmol) was dissolved in 0.5 ml of dichloromethane, then 0.05 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **19** (22.6 mg, yield 100%) as a light brown solid.

MS m/z (LC-MS): 272.0 [M+1]

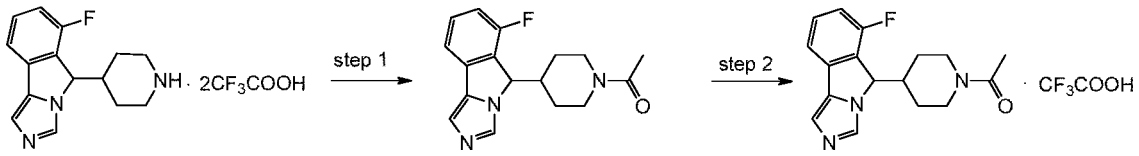
^{1}H NMR (400 MHz, CD_3OD) δ 9.31 (s, 1H), 7.91 (s, 1H), 7.73 (d, 1H), 7.67-7.62 (m, 1H), 7.36-7.31 (m, 1H), 6.08 (d, 1H), 3.61-3.52 (m, 1H), 3.52-3.43 (m, 1H), 3.12-2.98 (m, 2H), 2.88-2.76 (m, 1H), 2.83 (s, 3H), 2.01-1.92 (m, 1H), 1.87-1.73 (m, 1H), 1.73-1.62 (m, 1H), 1.54-1.39 (m, 1H).

Example 20

1-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)ethanone trifluoroacetate



20



1g 20a 20

Step 1

1-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)ethanone **20a**

The crude compound **1g** (31 mg, 0.084 mmol) was dissolved in 2 mL of dichloromethane, then triethylamine (13 mg, 0.168 mmol) was added. The mixture was mixed uniformly, and acetylchloride (13 mg, 0.168 mmol) was added. The reaction was stirred for 48 hours at room temperature. After the reaction was completed, the mixture was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **20a** (7.2 mg, yield 40%) as a brown solid.

MS m/z (LC-MS): 300 [M+1]

Step 2

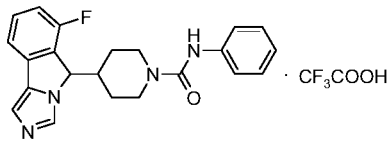
1-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)ethanone trifluoroacetate

The crude compound **20a** (7.2 mg, 0.024 mmol) was dissolved in 0.5 ml of dichloromethane, then 0.01 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **20** (10 mg, yield 100%) as a light brown solid.

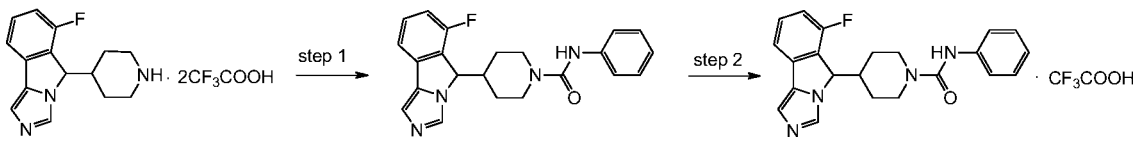
MS m/z (LC-MS): 300.0 [M+1]

Example 21

4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)-*N*-phenylpiperidine-1-carboxamide trifluoroacetate



21



1g 21a 21

Step 1

4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)-*N*-phenylpiperidine-1-carboxamide **21a**

Bis(trichloromethyl) carbonate (297 mg, 1.0 mmol) was dissolved in 2 mL of dichloromethane, then 2 mL of a pre-prepared soluiton of phenylamine (93 mg, 1.0 mmol) in dichloromethane and 1 mL of a pre-prepared soluiton of triethylamine (0.28 mL) in dichloromethane were added dropwise. The reaction was stirred for 10 mins at room temperature. After the mixture was concentrated under reduced pressure, 5 mL of tetrafuran, 0.28 mL of triethylamine and compound **1g** (243 mg, 0.5 mmol) were added. The reaction was stirred for 12 hours at room temperature. After the reaction was completed, 20 mL of ethyl acetate and 20 mL of water were added. Two phases were separated, and the organic phase was dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **21a** (92 mg, yield 48.9%) as a light brown solid.

MS m/z (LC-MS): 377.0 [M-1]

Step 2

4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)-*N*-phenylpiperidine-1-carboxamide trifluoroacetate **21**

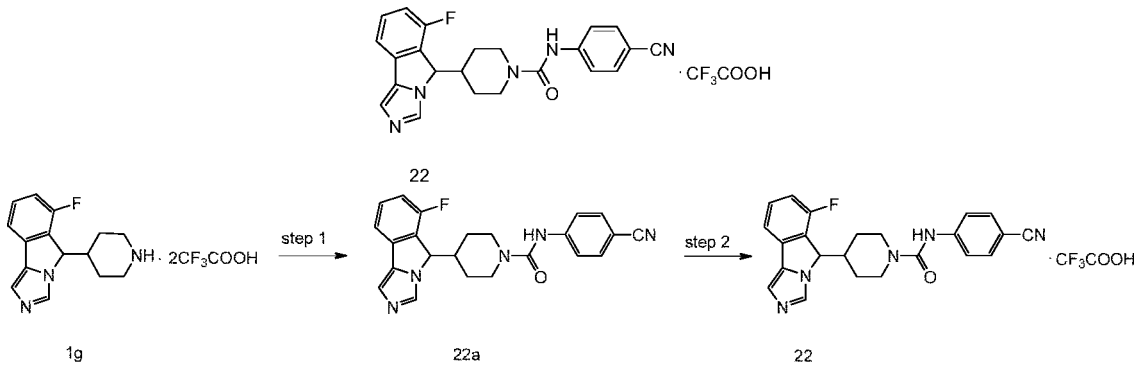
The crude compound **21a** (92 mg, 0.244 mmol) was dissolved in 2 mL of dichloromethane, then 0.5 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **21** (120 mg, yield 100%) as a light brown solid.

MS m/z (LC-MS): 377.0 [M-1]

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.47 (s, 1H), 8.45 (s, 1H), 8.04 (s, 1H), 7.75 (d, 1H), 7.68-7.63 (m, 1H), 7.43-7.37 (m, 3H), 7.21-7.17 (m, 2H), 6.91-6.88 (m, 1H), 6.08 (d, 1H), 4.28-4.18 (m, 1H), 4.15-4.05 (m, 1H), 2.83-2.68 (m, 2H), 2.64-2.54 (m, 1H), 1.76-1.67 (m, 1H), 1.42-1.32 (m, 1H), 1.28-1.19 (m, 1H), 0.91-0.81 (m, 1H).

Example 22

N-(4-cyanophenyl)-4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidine-1-carboxamide trifluoroacetate



Step 1

N-(4-cyanophenyl)-4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidine-1-carboxam

ide **22a**

Bis(trichloromethyl) carbonate (297 mg, 1.0 mmol) was dissolved in 2 mL of dichloromethane, then 2 mL of a pre-prepared soluiton of 4-aminobenzonitrile (118 mg, 1.0 mmol) in dichloromethane and 1 mL of a pre-prepared soluiton of triethylamine (0.28 mL) in dichloromethane were added dropwise. The reaction was stirred for 1 hour at room temperature. After the mixture was concentrated under reduced pressure, 5 mL of tetrafuran, 0.28 mL of triethylamine and compound **1g** (243 mg, 0.5 mmol) were added. The reaction was stirred for 12 hours at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **22a** (101 mg, yield 50.5%) as a light brown solid.

MS m/z (LC-MS): 402.0 [M+1]

Step 2

N-(4-cyanophenyl)-4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidine-1-carboxamide trifluoroacetate **22**

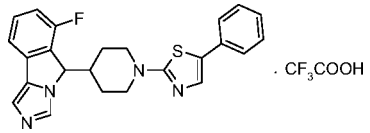
The crude compound **22a** (101 mg, 0.25 mmol) was dissolved in 2 mL of dichloromethane, then 0.5 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **22** (130 mg, yield 100%) as a light brown solid.

MS m/z (LC-MS): 402.0 [M+1]

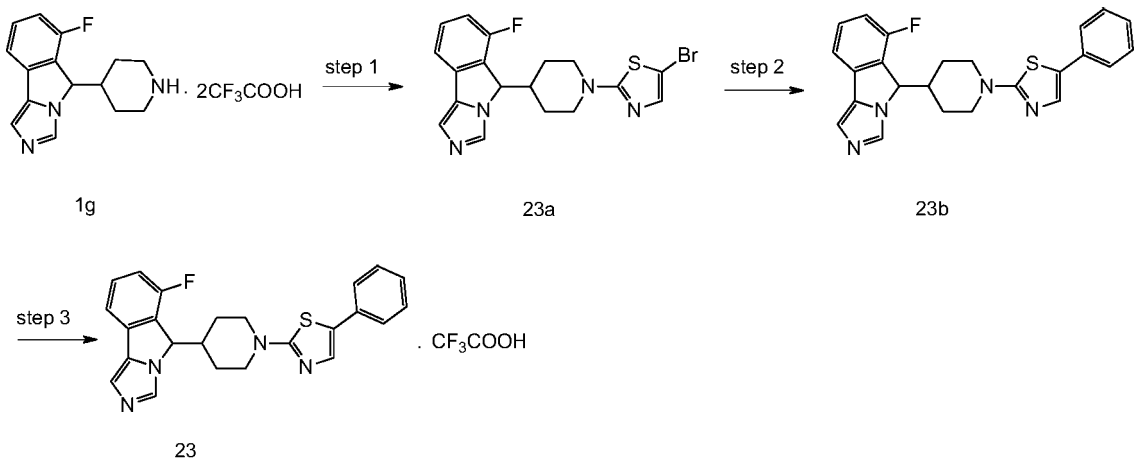
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.47 (s, 1H), 8.99 (s, 1H), 8.06 (s, 1H), 7.76 (d, 1H), 7.68-7.60 (m, 5H), 7.44-7.39 (m, 1H), 6.09 (d, 1H), 4.30-4.20 (m, 1H), 4.15-4.05 (m, 1H), 2.91-2.81 (m, 1H), 2.81-2.71 (m, 1H), 2.68-2.58 (m, 1H), 1.79-1.68 (m, 1H), 1.44-1.34 (m, 1H), 1.31-1.21 (m, 1H) , 0.93-0.83 (m, 1H).

Example 23

2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-5-phenylthiazole trifluoroacetate



23



Step 1

5-bromo-2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)thiazole **23a**

The crude compound **1g** (2.43 g, 5.0 mmol), 2,5-dibromothiazole (1.82 g, 7.5 mmol) and triethylamine (2.02 g, 20.0 mmol) were dissolved in 15 mL of methyl sulfoxide. The reaction system was stirred in microwave for 1.5 hours at 120°C. After the reaction was completed, 250 mL of ethyl acetate was added. The mixture was washed with water (150 mL×3) and saturated sodium chloride solution (150 mL), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system A to obtain compound **23a** (710 mg, yield 33.9%) as a brown solid.

MS m/z (LC-MS): 420.0 [M+1]

Step 2

2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-5-phenylthiazole **23b**

Compound **23a** (105 mg, 0.25 mmol), phenylboronic acid (46 mg, 0.375 mmol), tetrakis(triphenylphosphine)palladium (58 mg, 0.05 mmol), potassium phosphate trihydrate (133 mg, 0.5 mmol) were dissolved in 1.4 mL of a mixture of *N*,*N*-dimethylformamide and water (V:V=6:1). The reaction system was stirred in microwave for 35 mins at 120°C. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **23b** (24 mg, yield 22.7%) as a brown syrup.

MS m/z (LC-MS): 417.0 [M+1]

Step 3

2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-5-phenylthiazole trifluoroacetate **23**

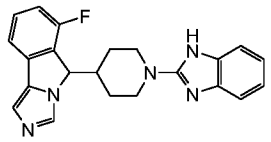
Compound **23b** (24 mg, 0.057 mmol) was dissolved in 0.5 mL of dichloromethane, then 0.05 mL of trifluoroacetic acid was added. The reaction was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **23** (30 mg, yield 100%) as a light brown solid.

MS m/z (LC-MS): 417 [M+1]

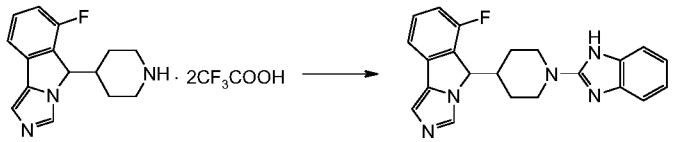
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.42 (s, 1H), 8.02 (s, 1H), 7.74 (d, 1H), 7.68-7.62 (m, 1H), 7.57 (s, 1H), 7.44-7.38 (m, 3H), 7.35-7.31 (m, 2H), 7.18-7.22 (m, 1H), 6.11 (d, 1H), 4.06-3.99 (m, 1H), 3.92-3.84 (m, 1H), 3.17-3.07 (m, 1H), 3.04-2.94 (m, 1H), 2.70-2.60 (m, 1H), 1.91-1.81 (m, 1H), 1.67-1.52 (m, 1H) , 1.34-1.25 (m, 1H) , 1.04-0.93 (m, 1H).

Example 24

5-(1-(1*H*-benzo[d]imidazol-2-yl)piperidin-4-yl)-6-fluoro-5*H*-imidazo[5,1-a]isoindole



24



1g 24

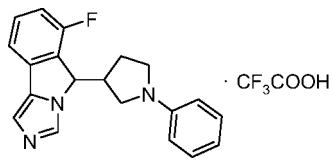
The crude compound **1g** (257 mg, 1.0 mmol) and 2-chlorobenzimidazole (153 mg, 1 mmol) were dissolved in 10 mL of *N*-methyl pyrrolidinone, then *N*,*N*-diisopropylethylamine (390 mg, 3 mmol) was added. The reaction was stirred for 12 hours at 90°C. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system A to obtain compound **24** (20 mg, yield 41%) as a white solid.

MS m/z (LC-MS): 374.2 [M-1]

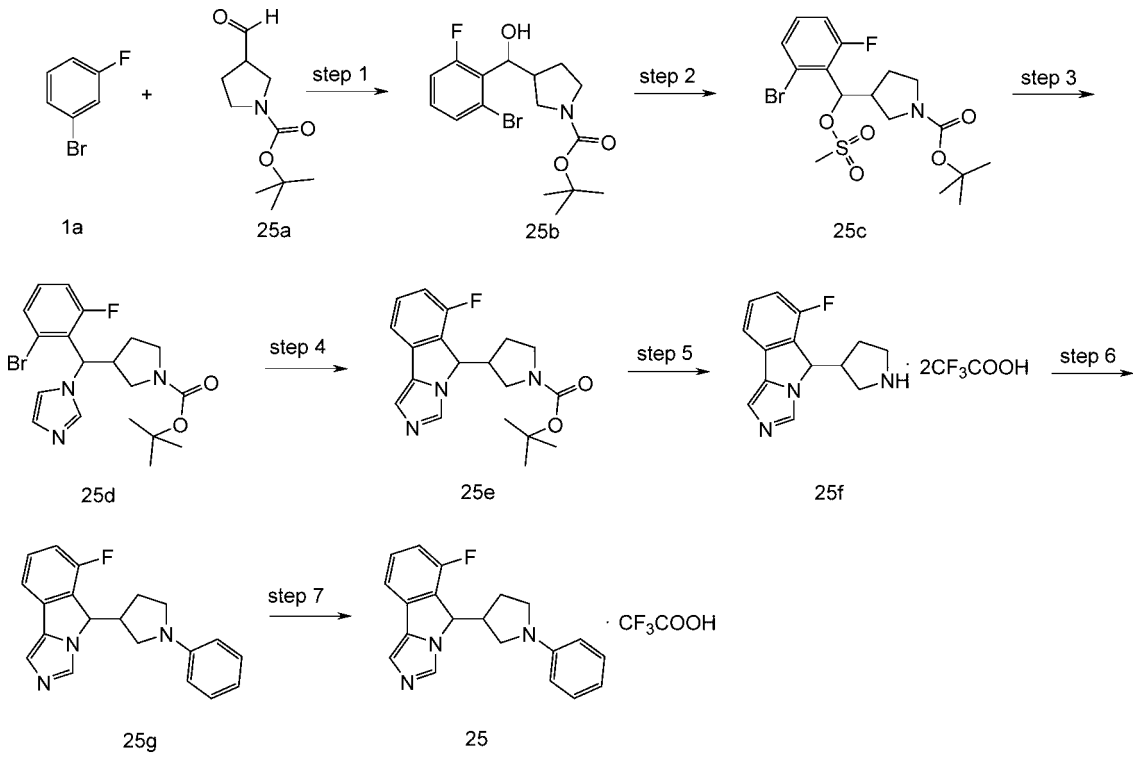
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.74 (s, 1H),7.38-7.17 (m, 5H), 7.17 (s, 1H), 6.98 (s, 2H), 5.32 (s, 1H), 4.38-4.21 (m, 2H), 3.04-2.93 (m, 2H), 2.48 (m 1H), 1.82-1.71 (m, 2H), 1.29-1.23 (m, 1H), 0.92 (m, 1H).

Example 25

6-fluoro-5-(1-phenylpyrrolidin-3-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



25



Step 1

tert-butyl 3-((2-bromo-6-fluorophenyl)(hydroxy)methyl)pyrrolidine-1-carboxylate **25b**

Lithium diisopropylamide (13 mL, 26 mmol) was added into 20 mL of tetrahydrofuran under argon atmosphere. The mixture was cooled to -78°C, 10 mL of a pre-prepared solution of 1-bromo-3-fluorobenzene **1a** (3.5 g, 20.0 mmol) in tetrahydrofuran was added dropwise at -78°C, the resulting mixture was stirred for 1 hour at -78°C. Then 15 mL of a pre-prepared solution of *tert*-butyl 3-formylpyrrolidine-1-carboxylate **25a** (3.985 g, 20.0 mmol, prepared by a well known method disclosed in "*Jpn. Tokkyo Koh*, 2009, 03 Jun, 4272338") in tetrahydrofuran was added dropwise at -78°C. The reaction was continuely stirred for 1 hour at -78°C. After the completion of the reaction, 10 mL of methanol was added dropwise to quench the reaction at -78°C. The reaction solution was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with eluent system B to obtain compound **25b** (5.15 g, yield 68.8%) as a yellow oil.

MS m/z (LC-MS): 320.0 [M-56]

Step 2

tert-butyl 3-((2-bromo-6-fluorophenyl)((methylsulfonyl)oxy)methyl)pyrrolidine-1-carboxylate **25c**

Compound **25b** (5.1 g, 13.6 mmol) was dissolved in 50 mL of dichloromethane, then triethylamine (3.8 mL, 27.7 mmol) was added, methanesulfonyl chloride (1.639 g, 14.3 mmol) was added dropwise in an ice-water bath. The reaction was stirred for 1 hour at room temperature. After the reaction was completed, 50 mL of dichloromethane was added. The mixture was washed with water (60 mL) and 60 mL of saturated sodium chloride solution, dried over anhydrous sodium sulfate and filtered. The filtrate was

concentrated under reduced pressure to obtain a crude compound **25c** (5.9 g) as a yellow viscous solid, which was used directly in the next step without further purification.

MS m/z (LC-MS): 300.0 [M-56-95]

Step 3

tert-butyl 3-((2-bromo-6-fluorophenyl)(1*H*-imidazol-1-yl)methyl)pyrrolidine-1-carboxylate **25d**

The crude compound **25c** (2.4 g, 5.3 mmol) was dissolved in 10 mL of acetonitrile, then imidazole (3.6 g, 53 mmol) and *N*,*N*-diisopropylethylamine (6.85 g, 53 mmol) were added. The resulting mixture was stirred in microwave for 1 h 40 mins at 120°C. After the reaction was completed, 100 mL of ethyl acetate was added. The mixture was washed with water (60 mL×2) and saturated sodium chloride solution (60 mL), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain compound **25d** (2.7 g) as a brown viscous solid, which was used directly in the next step without further purification.

MS m/z (LC-MS): 424.3 [M+1]

Step 4

tert-butyl 3-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)pyrrolidine-1-carboxylate **25e**

The crude compound **25d** (2.4 g, 5.66 mmol) was dissolved in 10 mL of *N*,*N*-dimethylformamide, then *N*,*N*-dicyclohexylmethylamine (1.77 g, 9.05 mmol), triphenylphosphine (594 mg, 2.264 mmol) and palladium acetate (254 mg, 1.132 mmol) were added. The reaction mixture was stirred in microwave for 1 hour at 120°C. After the reaction was completed, the reaction mixture was concentrated under reduced pressure to remove *N*,*N*-dimethylformamide. 100 mL of ethyl acetate was added, the mixture was washed with water (40 mL×2) and saturated sodium chloride solution (60 mL), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure and the resulting residue was purified by silica gel column chromatography with elution system B to obtain compound **25e** (1.62 g, yield 78.3%) as a light brown viscous solid.

MS m/z (LC-MS): 344.2 [M+1]

Step 5

6-fluoro-5-(pyrrolidin-3-yl)-5*H*-imidazo[5,1-a]isoindole ditrifluoroacetate **25f**

Compound **25e** (1.62 g, 4.71 mmol) was dissolved in 20 mL of dichloromethane, then 2.69 mL of trifluoroacetate was added dropwise. The resulting mixture was stirred for 4 hours at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain a curde compound **25f** (2.76 g) as a brown oil, which was used directly in the next step without further purification.

MS m/z (LC-MS): 243.9 [M+1]

Step 6

6-fluoro-5-(1-phenylpyrrolidin-3-yl)-5*H*-imidazo[5,1-a]isoindole **25g**

The crude compound **25f** (292 mg, 0.50 mmol) was dissolved in 1.5 mL of a

mixture of toluene and ethanol (V:V=5:1), then bromobenzene (94 mg, 0.6 mmol), 2-dicyclohexylphosphino-2',4',6'-triisopropylbiphenyl (24 mg, 0.05 mmol), sodium *tert*-butoxide (240 mg, 2.50 mmol) and palladium acetate (11 mg, 0.05 mmol) were added under argon atmosphere. The resulting mixture was stirred for 50 mins at 120°C in microwave. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **25g** (23 mg, yield 14.3%) as a brown oil.

MS m/z (ESI): 320.3 [M+1]

Step 7

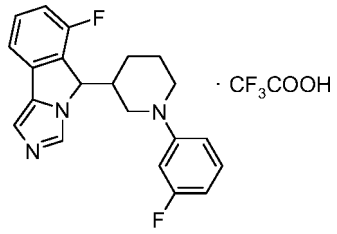
6-fluoro-5-(1-phenylpyrrolidin-3-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **25**

Compound **25g** (23 mg, 0.072 mmol) was dissolved in 5 mL of dichloromethane, then 0.5 mL of trifluoroacetic acid was added. The resulting mixture was stirred for 60 mins at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **25** (31 mg, yield 100%) as a brown solid.

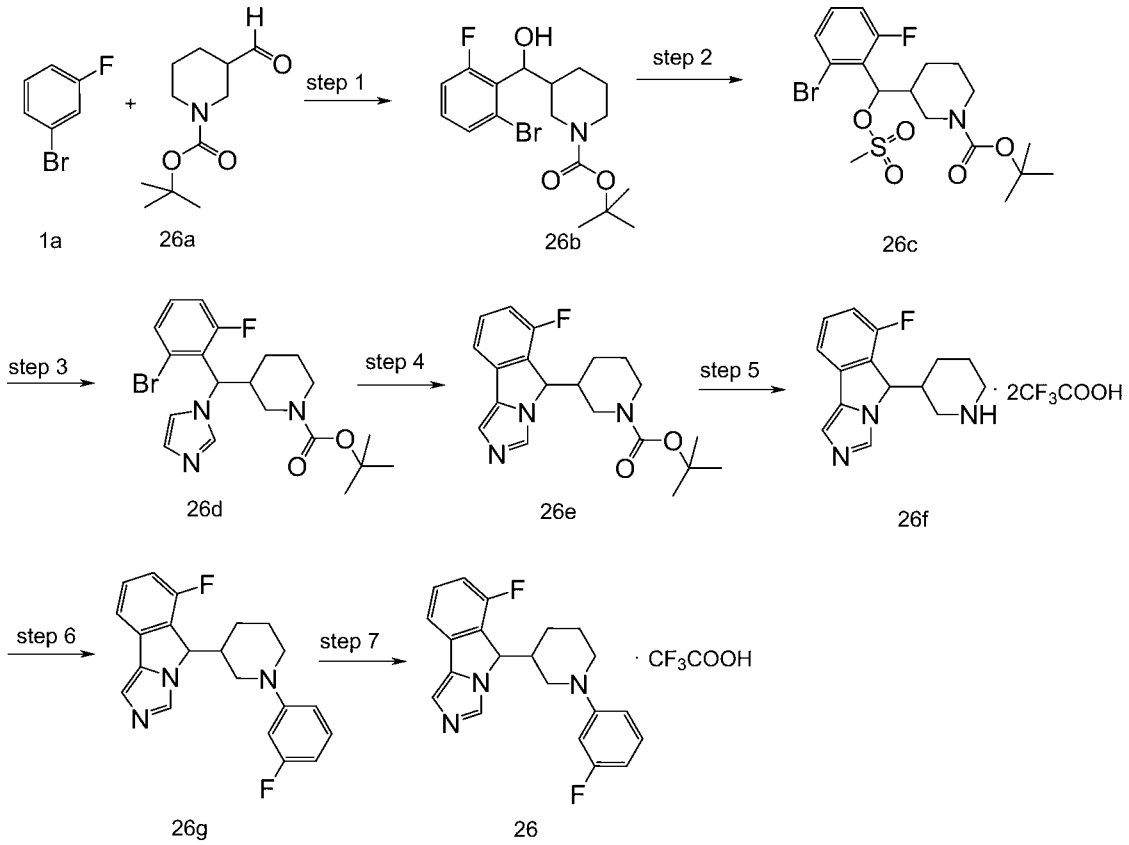
MS m/z (ESI): 320.3 [M+1]

Example 26

6-fluoro-5-(1-(3-fluorophenyl)piperidin-3-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



26



Step 1

tert-butyl 3-((2-bromo-6-fluorophenyl)(hydroxy)methyl)piperidine-1-carboxylate **26b**

15 mL of tetrahydrofuran was added into a flask, then the solution was cooled to -78°C under argon atmosphere. Lithium diisopropylamide (9.3 mL, 18.6 mmol) was added, 1-bromo-3-fluorobenzene **1a** (2.5 g, 14.3 mmol) was added dropwise, the resulting mixture was stirred for 1 hour at -78°C. Then 5 mL of a pre-prepared solution of *tert*-butyl 3-formylpiperidine-1-carboxylate **26a** (3.0 g, 14.3 mmol) in tetrahydrofuran was added dropwise. The reaction was continuely stirred for 1 hour at -78°C. After the completion of the reaction, 15 mL of methanol was added dropwise to quench the reaction at -78°C. The reaction solution was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with eluent system B to obtain compound **26b** (3.9 g, yield 34%) as a light yellow solid.

MS m/z (LC-MS): 334.0 [M-55]

Step 2

tert-butyl 3-((2-bromo-6-fluorophenyl)((methylsulfonyl)oxy)methyl)piperidine-1-carboxylate **26c**

Compound **26b** (3.9 g, 10 mmol) was dissolved in 40 mL of dichloromethane, triethylamine (2.02 g, 20 mmol) was added, then methanesulfonyl chloride (1.2 g, 10.05 mmol) was added dropwise. The reaction was stirred for 12 hour at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system B to obtain compound **26c** (1.9 g, yield 40.7%) as a light yellow oil.

MS m/z (LC-MS): 314.0 [M-152]

Step 3

tert-butyl 3-((2-bromo-6-fluorophenyl)(1*H*-imidazol-1-yl)methyl)piperidine-1-carboxylate **26d**

Compound **26c** (2.0 g, 4.28 mmol) was dissolved in 5 mL of acetonitrile, imidazole (2.9 g, 42.8 mmol) and *N*,*N*-diisopropylethylamine (5.5 g, 42.8 mmol) were added. The resulting mixture was stirred in microwave for 1 hour at 120°C. After the reaction was completed, the reaction solution was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain the title compound **26d** (0.85 g, yield 47%) as a light brown oil.

MS m/z (LC-MS): 440.0 [M+2]

Step 4

tert-butyl 3-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidine-1-carboxylate **26e**

Compound **26d** (1.0 g, 2.28 mmol) was dissolved in 5 mL of *N*,*N*-dimethylformamide, then *N*,*N*-dicyclohexylmethylamine (712 mg, 3.65 mmol), triphenylphosphine (239 mg, 0.91 mmol) and palladium acetate (100 mg, 0.45 mmol) were added. The reaction mixture was stirred in microwave for 1 hour at 120°C. After the reaction was completed, the reaction solution was concentrated to obtain a title compound **26e** (1.21 g) as an orange oil, which was used directly in the next step without further purification.

MS m/z (LC-MS): 358.2 [M+1]

Step 5

6-fluoro-5-(piperidin-3-yl)-5*H*-imidazo[5,1-a]isoindole ditrifluoroacetate **26f**

The crude compound **26e** (1.7 g, 4.76 mmol) was dissolved in 20 mL of dichloromethane, then 1 mL of trifluoroacetate was added dropwise. The resulting mixture was stirred for 48 hours at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain a curde compound **26f** (2.5 g) as a brown oil, which was used directly in the next step without further purification.

MS m/z (LC-MS): 258.0 [M+1]

Step 6

6-fluoro-5-(1-(3-fluorophenyl)piperidin-3-yl)-5*H*-imidazo[5,1-a]isoindole **26g**

The crude compound **26f** (200 mg, 0.44 mmol), 1-bromo-3-fluorobenzene (93 mg, 0.53 mmol), 2-dicyclohexylphosphino-2',4',6'-triisopropylbiphenyl (21 mg, 0.044mmol), sodium *tert*-butoxide (211 mg, 2.20 mmol) and palladium acetate (20 mg, 0.089 mmol) were dissoloved in 5 mL of a mixture of toluene and ethanol (V:V=5:1). The resulting mixture was stirred in microwave for 1 hour at 120°C. After the reaction was completed, the mixture was filtered through diatomite, the filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain compound **26g** (3.7 mg, yield 3%) as a brown oil.

MS m/z (ESI): 352.0 [M+1]

Step 7

6-fluoro-5-(1-(3-fluorophenyl)piperidin-3-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **26**

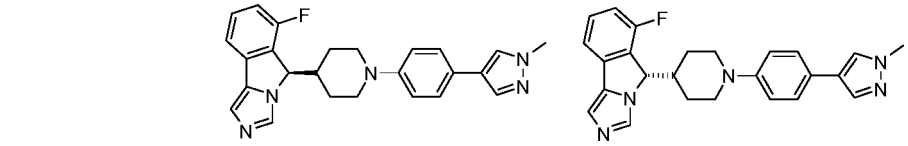
Compound **26g** (3.7 mg, 0.01 mmol) was dissolved in 5 mL of dichloromethane, then 0.5 mL of trifluoroacetic acid was added. The resulting mixture was stirred for 12 hours at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure to obtain compound **26** (4.8 mg, yield 100%) as a brown oil.

MS m/z (ESI): 352.0 [M+1]

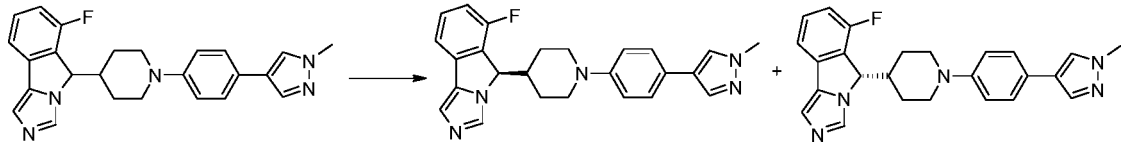
Examples 27, 28

(*R*)-6-fluoro-5-(1-(4-(1-methyl-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **27**

(*S*)-6-fluoro-5-(1-(4-(1-methyl-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **28**



27 28



9 27 28

Step 1

Compound **9** was separated chirally (separation conditions: chiral column CHIRALPAK IF, mobile phase: dichloromethane: methanol=70:30, flow rate: 30 mL/min), the relevant fractions were collected and concentrated under reduced pressure to obtain compound **27** (700 mg, 1.69 mmol) with a yield of 73.7% and compound **28** (640 mg, 1.54 mmol) with a yield of 67.4%.

27:

MS m/z (ESI): 414.4 [M+1]

Chiral HPLC analysis: retention time: 2.466 mins, ee value>99.0%. (chromatographic column: CHIRALPAK ID; mobile phase: DCM/MeOH/TEA =80/20/0.1(V/V/V)

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.98 (s, 1H), 7.94 (s, 1H), 7.70 (s, 1H), 7.44-7.51 (m, 2H), 7.34 (d, 2H), 7.22 (s, 1H), 7.11-7.17 (m, 1H), 6.86 (d, 2H), 5.69 (s, 1H), 3.82 (s, 3H), 3.73 (d, 1H), 3.60 (d, 1H), 2.63-2.69 (m, 1H), 2.33-2.36 (m, 1H), 1.75-1.78 (m, 1H), 1.64-1.69 (m, 1H), 1.16-1.33 (m, 2H), 0.87-0.90 (m, 1H).

28:

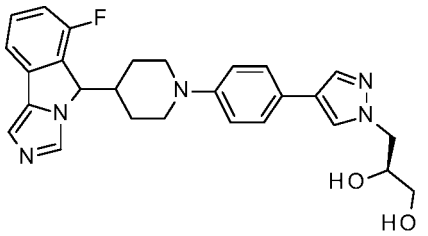
MS m/z (ESI): 414.4 [M+1]

Chiral HPLC analysis: retention time: 4.122 mins, ee value>99.0%. (chromatographic column: CHIRALPAK ID; mobile phase: DCM/MeOH/TEA =80/20/0.1(V/V/V)

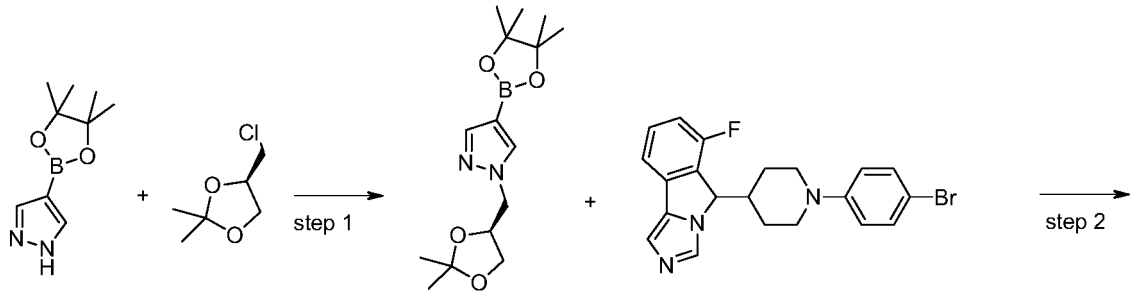
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.98 (s, 1H), 7.94 (s, 1H), 7.70 (s, 1H), 7.44-7.51 (m, 2H), 7.34 (d, 2H), 7.22 (s, 1H), 7.11-7.17 (m, 1H), 6.86 (d, 2H), 5.69 (s, 1H), 3.82 (s, 3H), 3.73 (d, 1H), 3.60 (d, 1H), 2.63-2.69 (m, 1H), 2.33-2.36 (m, 1H), 1.75-1.78 (m, 1H), 1.64-1.69 (m, 1H), 1.16-1.33 (m, 2H), 0.87-0.90 (m, 1H).

Example 29

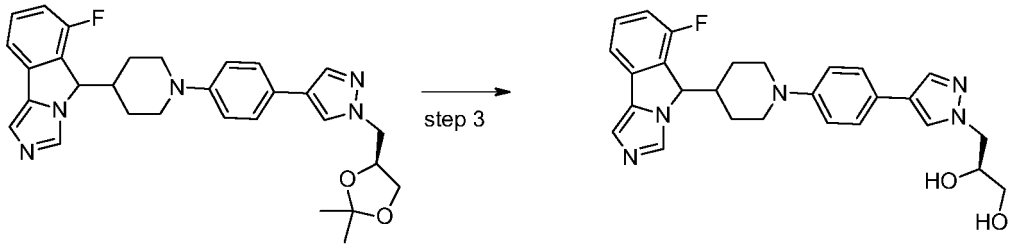
(2*S*)-3-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)propane-1,2-diol



29



29a 29b 29c 9a



29d 29

Step 1

(*S*)-1-((2,2-dimethyl-1,3-dioxolan-4-yl)methyl)-4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1*H*-pyrazole **29c**

4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1*H*-pyrazole **29a** (1 g, 5.15 mmol) was dissolved in 6 mL of *N*,*N*-dimethylformamide, then sodium hydride (250 mg, 60%) was added at room temperature. After the reaction was stirred for 20 mins at room temperature, (*R*)-4-(chloromethyl)-2,2-dimethyl-1,3-dioxolane **29b** (1.164 g, 7.73 mmol) was added. The reaction was warmed up to 100°C and stirred for 12 hours. After

cooling to room temperature, the mixture was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system A to obtain the title compound **29c** (790 mg, yield 50%) as a yellow oil.

Step 2

5-(1-(4-(1-(((*S*)-2,2-dimethyl-1,3-dioxolan-4-yl)methyl)-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-6-fluoro-5*H*-imidazo[5,1-a]isoindole **29d**

Compounds **9a** (250 mg, 0.606 mmol) and **29c** (560 mg, 1.82 mmol) were dissolved in 7 mL of *n*-butanol, potassium phosphate (386 mg, 1.82 mmol), tris(dibenzylideneacetone)dipalladium (41.7 mg, 0.0455 mmol) and 2-dicyclohexylphosphino-2',4',6'-triisopropylbiphenyl (87 mg, 0.182 mmol) were added. The reaction was warmed up to 100°C and stirred for 12 hours. After cooling to room temperature, the mixture was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system A, then by thin layer chromatography with elution system A to obtain the title compound **29d** (120 mg, yield 38.6%) as a yellow solid.

Step 3

(2*S*)-3-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)propane-1,2-diol **29**

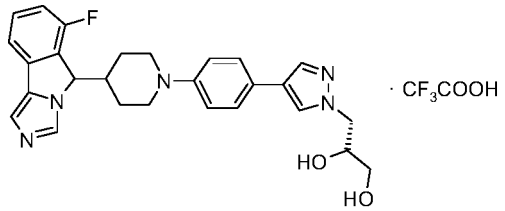
Compound **29d** (120 mg, 0.234 mmol) was dissolved in 4 mL of methanol, then 2 mL of 2*N* hydrochloric acid was added. The reaction was stirred for 3 hours at room temperature. After the reaction was completed, the reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain the title compound **29** (95 mg, yield 79%) as an orange yellow solid.

MS m/z (ESI): 474.5 [M+1]

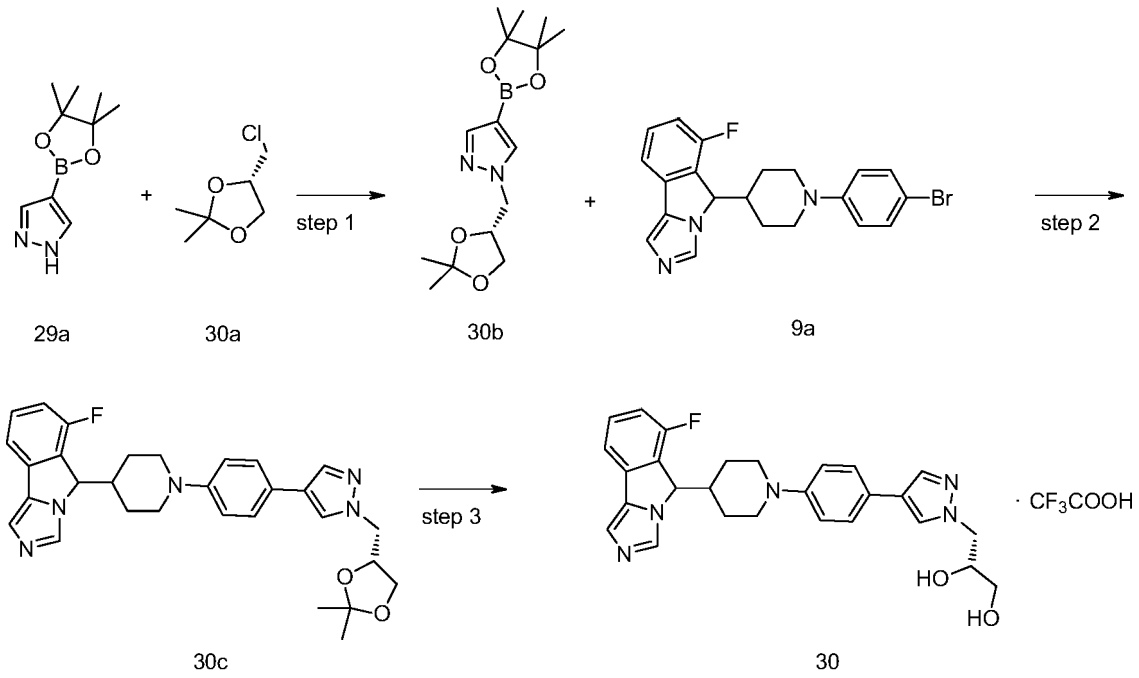
^{1}H NMR(400MHz, DMSO-d_6) δ 9.59 (s, 1H), 8.17 (s, 1H), 8.12 (s, 1H), 7.92 (s, 1H), 7.65-7.83 (m, 6H), 7.46 (t, 1H), 6.24 (s, 1H), 4.23 (dd,1H), 3.95-4.05 (m, 1H), 3.80-3.86 (m,1H), 3.50-3.75 (m, 2H), 3.25-3.50 (m, 4H), 2.78-2.95 (m, 1H), 2.00-2.30 (m, 2H), 1.50-1.70 (m, 2H).

Example 30

(2*R*)-3-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)propane-1,2-diol trifluoroacetate



30



29a 30a 30b 9a

30c 30

Step 1

(*R*)-1-((2,2-dimethyl-1,3-dioxolan-4-yl)methyl)-4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1*H*-pyrazole **30b**

29a (500 mg, 2.58 mmol) was dissolved in 3 mL of *N*,*N*-dimethylformamide, then sodium hydride (113 mg, 60%) was added at room temperature. After the reaction was stirred for 20 mins at room temperature, (*S*)-4-(chloromethyl)-2,2-dimethyl-1,3-dioxolane **30a** (505 mg, 3.35 mmol) was added. The reaction was warmed up to 100°C and stirred for 12 hours. 0.5 mL of methanol was added into the reaction solution to quench the reaction. The mixture was concentrated under reduced pressure to remove *N*,*N*-dimethylformamide. 50 mL of ethyl acetate and 5 mL of water were added to the resulting residue. Two phases were separated, then the organic phase was dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain the crude title compound **30b** (400 mg) as a yellow oil, which was used directly in the next step without further purification.

Step 2

5-(1-(4-(1-(((*R*)-2,2-dimethyl-1,3-dioxolan-4-yl)methyl)-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-6-fluoro-5*H*-imidazo[5,1-a]isoindole **30c**

Compound **9a** (250 mg, 0.606 mmol) and the crude compound **30b** (223 mg, 0.726 mmol) were dissolved in 5 mL of *n*-butanol, then potassium phosphate (154 mg, 0.726 mmol), tris(dibenzylideneacetone)dipalladium(22 mg, 0.0242 mmol) and 2-dicyclohexylphosphino-2',4',6'-triisopropylbiphenyl (46 mg, 0.0968 mmol) were added. The reaction was warmed up to 100°C and stirred for 12 hours. The reaction solution was cooled to room temperature, then a crude title compound **30c** (150 mg) was obtained as a brown-yellow oil, which was used directly in the next step without further purification.

Step 3

(2*R*)-3-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)propane-1,2-diol trifluoroacetate **30**

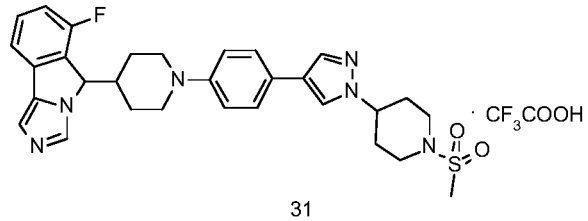
Compound **30c** (150 mg, 0.292 mmol) was dissolved in 5 mL of methanol, then 5 mL of 2*N* hydrochloric acid was added. The reaction was stirred for 12 hours at room temperature. After the reaction solution was concentrated under reduced pressure, the resulting residue was purified by high performance liquid chromatography to obtain the title compound **30** (8 mg, yield 5.8%) as a white solid.

MS m/z (ESI): 474.4 [M+1]

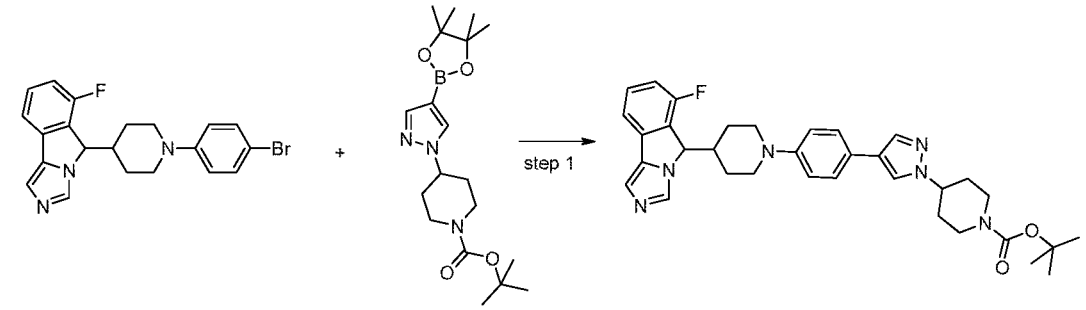
^{1}H NMR(400MHz, DMSO-d_6) δ 9.51 (s, 1H), 8.07 (s, 1H), 8.01(s, 1H), 7.75-7.80 (m, 2H), 7.65-7.70 (m, 1H), 7.40-7.55 (m, 3H), 7.00-7.10 (m, 2H), 6.15 (s, 1H), 4.20 (dd, 1H), 3.94-4.02 (m, 1H), 3.60-3.85 (m, 3H), 3.25-3.40 (m, 2H), 2.70-3.02 (m, 2H), 2.60-2.70 (m, 1H), 1.82-1.90 (m,1H), 1.65-1.80 (m, 1H), 1.30-1.40 (m, 1H), 1.15-1.20 (m, 1H).

Example 31

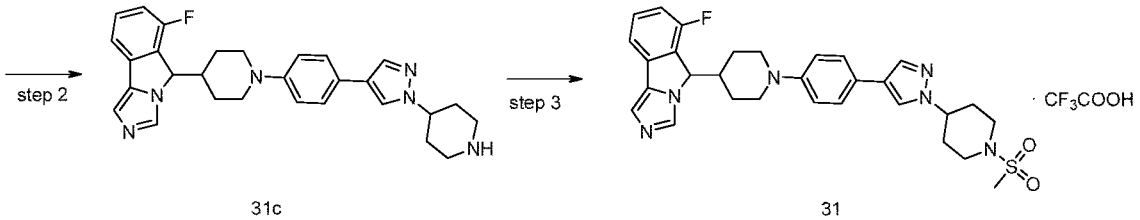
6-fluoro-5-(1-(4-(1-(1-(methylsulfonyl)piperidin-4-yl)-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



31



9a 31a 31b



31c 31

Step 1

tert-butyl 4-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)piperidine-1-carboxylate **31b**

Compound **9a** (250 mg, 0.606 mmol) and tert-butyl 4-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1H-pyrazol-1-yl)piperidine-1-carbox

ylate **31a** (343 mg, 0.91 mmol, prepared by a well known method disclosed in "*Bioorganic & Medicinal Chemistry*, 2013, 21(21), 6804-6820") were dissolved in 5 mL of *n*-butanol, then potassium phosphate (260 mg, 1.212 mmol), tris(dibenzylideneacetone)dipalladium (17 mg, 0.018 mmol) and 2-dicyclohexylphosphino-2',4',6'-triisopropylbiphenyl (35 mg, 0.073 mmol) were added. The reaction was warmed up to 100°C and stirred for 12 hours. After cooling to room temperature, the mixture was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with elution system A to obtain the title compound **31b** (160 mg, yield 45.3%) as a yellow solid.

Step 2

6-fluoro-5-(1-(4-(1-(piperidin-4-yl)-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **31c**

Compound **31b** (160 mg, 0.275 mmol) was dissolved in 3 mL of dichloromethane, then 0.5 mL of trifluoroacetic acid was added. The reaction was stirred for 2 hours at room temperature. The reaction solution was concentrated under reduced pressure to obtain the crude title compound **31c** (250 mg) as a yellow oil, which was used directly in the next step without further purification.

Step 3

6-fluoro-5-(1-(4-(1-(1-(methylsulfonyl)piperidin-4-yl)-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **31**

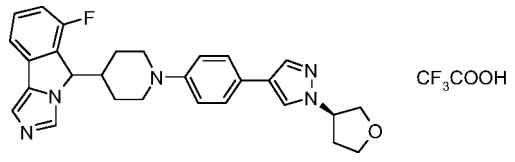
The crude compound **31c** (125 mg, 0.138 mmol) was dissolved in 3 mL of dichloromethane, then 0.5 mL of trifluoroactic acid and methylsufonyl chloride (47 mg, 0.412 mmol) were added. The reaction was stirred for 2 hours at room temperature. 10 mL of dichloromethane and 2 mL of water were added into the reaction solution. Two phases were separated, then the organic phase was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain the title compound **31** (12 mg, yield 12.9%) as a white solid.

MS m/z (ESI): 561.5 [M+1]

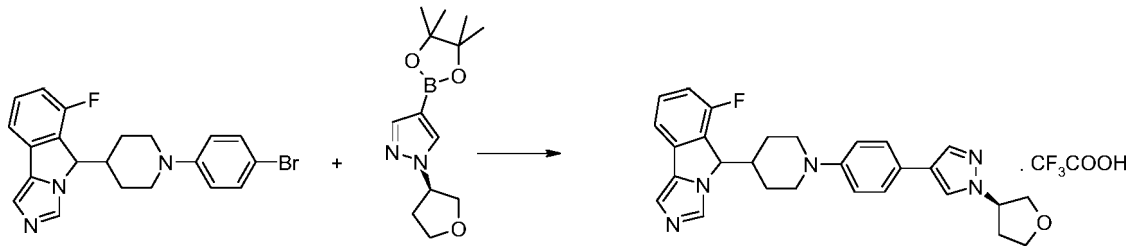
^{1}H NMR(400MHz, DMSO-d_6) δ 9.47(s, 1H), 8.16 (s, 1H), 8.05 (s, 1H),7.74-7.80 (m, 2H), 7.63-7.70 (m, 1H),7.38-7.50 (m, 3H), 6.96 (d, 2H), 6.13 (s, 1H), 4.25-4.34 (m, 1H), 3.60-3.80 (m, 4H), 2.90-3.00 (m, 5H), 2.50-2.70 (m, 3H), 2.10-2.20 (m, 2H), 1.92-2.05 (m, 2H), 1.81-1.85 (m, 1H), 1.61-.165 (m, 1H), 1.30-1.34 (m, 1H), 1.00-1.15 (m, 1H).

Example 32

6-fluoro-5-(1-(4-(1-((*R*)-tetrahydrofuran-3-yl)-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



32



9a 32a 32

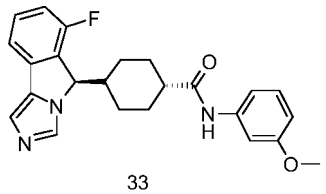
Compound **9a** (103 mg, 0.25 mmol) and (*R*)-1-(tetrahydrofuran-3-yl) -4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1*H*-pyrazole **32a** (99 mg, 0.375 mmol, prepared by a method disclosed in patent application "WO201493647") were dissolved in 3 mL of *n*-butanol, then potassium phosphate (106 mg, 0.5 mmol), tris(dibenzylideneacetone)dipalladium (17 mg, 0.018 mmol) and 2-dicyclohexylphosphino-2',4',6'-triisopropylbiphenyl (36 mg, 0.075 mmol) were added. The reaction was warmed up to 100°C and stirred for 12 hours. After cooling to room temperature, the reaction solution was filtered through diatomite, the filtrate was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain the title compound **32** (55 mg, yield 37.9%) as a white solid.

MS m/z (ESI): 470.5 [M+1];

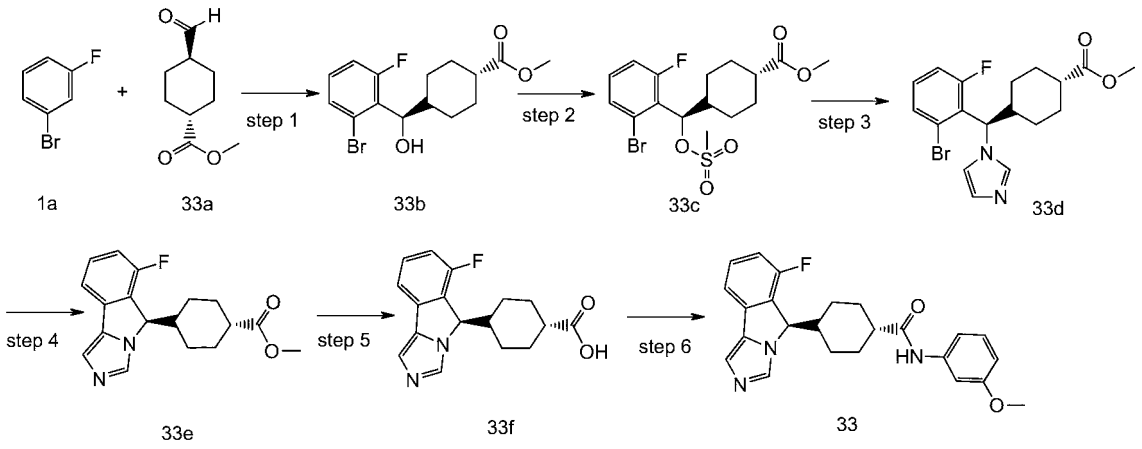
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.49 (s, 1H), 8.10 (s, 1H), 8.06 (s, 1H), 7.8 (s, 1H), 7.76-7.78 (m, 1H), 7.41-7.45 (m, 3H), 6.97 (d, 2H), 6.14 (s, 1H), 4.98-5.00 (m, 1H), 3.97-4.02 (m, 2H), 3.89-3.92 (m, 1H), 3.80-3.86 (m, 1H), 3.73-3.76 (m, 1H), 3.63-3.66 (m, 1H), 2.75-2.85 (m, 1H), 2.62-2.75 (m, 1H), 2.53-2.59 (m, 1H), 2.29-2.41 (m, 2H), 1.82-1.85 (m, 1H), 1.62-1.64 (m, 1H), 1.31-1.34 (m, 1H), 1.07-1.13 (m, 1H), 0.85-0.87 (m, 1H).

Example 33

(1*S*,4*s*)-4-((*R*)-6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)-*N*-(3-methoxyphenyl)cyclohex anecarboxamide



33



Step 1

(1*S*,4*s*)-methyl 4-((*R*)-(2-bromo-6-fluorophenyl)(hydroxy)methyl)-cyclohexanecarboxylate **33b**

Lithium diisopropylamide (26.8 mL) was dissolved in 50 mL of tetrahydrofuran, then the solution was cooled to -78°C. 20 mL of a pre-prepared solution of compound **1a** (7.2 g, 41.18 mmol) in tetrahydrofuran was added dropwise, the resulting mixture was stirred for 1 hour. Then 50 mL of a pre-prepared solution of (1*r*,4*r*)-methyl 4-formylcyclohexanecarboxylate **33a** (7 g, 41.18 mmol, prepared by a method disclosed in patent application "WO2013050334") in tetrahydrofuran was added dropwise. The reaction was continuely stirred for 2 hours. 10 mL of methanol was added into the reaction solution to quench the reaction. The reaction was warmed up to room temperature, then 100 mL of ethyl acetate was added. The mixture was washed with water (100 mL), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure, and the resulting residue was purified by silica gel column chromatography with eluent system B to obtain the title compound **33b** (6.8 g, yield 47.9%) as a brown yellow oil.

Step 2

(1*S*,4*s*)-methyl 4-((*R*)-(2-bromo-6-fluorophenyl)((methylsulfonyl)oxy)methyl)-cyclohexanecarboxylate **33c**

Compound **33b** (6.8 g, 19.7 mmol) was dissolved in 100 mL of dichloromethane, then triethylamine (3.99 g, 39.4 mmol) was added, and methanesulfonyl chloride (2.48 g, 21.67 mmol) was added dropwise. The reaction was stirred for 12 hour at room temperature. 50 mL of dichloromethane was added into the reaction solution, then the mixture was washed with saturated sodium chloride solution (100 mL), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain the crude compound **33c** (8.33 g) as a brown oil, which was used directly in the next step without further purification.

Step 3

(1*S*,4*s*)-methyl 4-((*R*)-(2-bromo-6-fluorophenyl)(1*H*-imidazol-1-yl)methyl)-cyclohexanecarboxylate **33d**

The crude compound **33c** (1.4 g, 3.3 mmol) was dissolved in 5 mL of acetonitrile, then 1*H*-imidazole (2.25 g, 33 mmol) and *N*,*N*-diisopropylethylamine (4.26 g, 33 mmol) were added. The resulting mixture was stirred in microwave for 45 mins at 130°C. After cooling to room temperature, the reaction solution was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system B to obtain the title compound **33d** (2.8 g, yield 35.95%) as a brown oil.

Step 4

(1*S*,4*s*)-methyl 4-((*R*)-6-fluoro-5H-imidazo[5,1-a]isoindol-5- yl)cyclohexanecarboxylate **33e**

Compound **33d** (2.8 g, 7.08 mmol) was dissolved in 12 mL of *N*,*N*-dimethylformamide, then *N*,*N*-dicyclohexylmethylamine (2.2 mg, 11.328 mmol), triphenylphosphine (743 mg, 2.8 mmol) and palladium acetate (318 mg, 1.4 mmol) were added. The reaction mixture was stirred in microwave for 1 hour at 120°C. After cooling to room temperature, the reaction solution was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system B to obtain the title compound **33e** (628 mg, yield 28.5%) as a brown solid.

Step 5

(1*S*,4*s*)-4-((*R*)-6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)cyclohexanecarboxylic acid **33f**

Compound **33e** (628 mg, 2 mmol) was dissolved in 20 mL of methanol, then 5 mL of water and sodium hydroxide (400 mg, 10 mmol) were added. The resulting mixture was stirred for 12 hours at room temperature. The reaction solution was concentrated under reduced pressure to remove methanol. The resulting residue was added with 30 mL of water and extracted with ethyl acetate (50 mL). The aqueous was added dropwise with 6 *M* hydrochloric acid to adjust the pH to 5-6 and extracted with a mixture of dichloromethane and methanol (V/V=5:1) (60 mL×3). The organic phases were combined, dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain the title compound **33f** (600 mg) as a brown oil, which was used directly in the next step without further purification.

Step 6

(1*S*,4*s*)-4-((*R*)-6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)-*N*-(3-methoxyphenyl)cyclohexanecarboxamide **33**

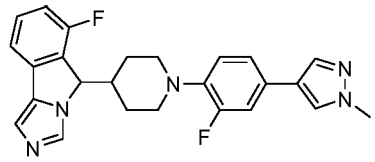
The crude compound **33f** (60 mg, 0.2 mmol) was dissolved in 2 mL of *N*,*N*-dimethylformamide, then 3-methoxyaniline (25 mg, 0.2 mmol), 1-hydroxybenzotriazole (32 mg, 0.24 mmol), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (46 mg, 0.24 mmol) and *N*-diisopropylethylamine (129 mg, 1 mmol) were added. The resulting mixture was stirred for 48 hours at room temperature. The reaction solution was purified by high performance liquid chromatography to obtain the title compound **33** (13 mg, yield 16.25%) as a white solid.

MS m/z (ESI): 406.4[M+1]

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.72 (s, 1H), 7.97 (s, 1H), 7.44-7.49 (m, 2H), 7.26-7.3 (m, 1H), 7.21 (s, 1H), 7.11-7.18 (m, 2H), 7.05-7.10 (m, 1H), 6.56-6.59 (m, 1H), 5.60 (s, 1H), 3.69 (s, 3H), 2.10-2.36 (m, 3H), 1.69-1.92 (m, 3H), 1.44-1.58 (m, 1H), 1.28-1.43 (m, 2H), 0.55-0.68 (m, 1H).

Example 34

6-fluoro-5-(1-(2-fluoro-4-(1-methyl-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole



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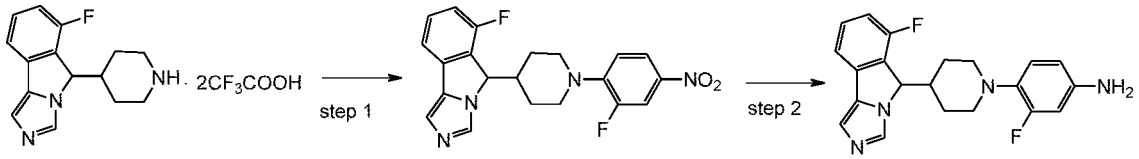
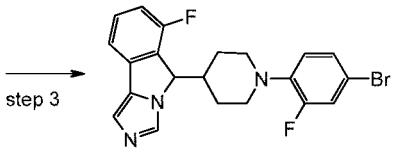


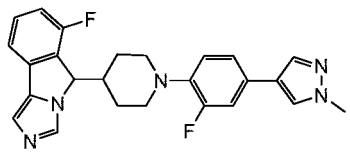
1g

34a

34b



34c



34

Step 1

6-fluoro-5-(1-(2-fluoro-4-nitrophenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **34a**

The crude compound **1g** (1.7 g, 3.51 mmol) was dissolved in 20 mL of dimethyl sulfoxide, then 1,2-difluoro-4-nitrobenzene (0.557 g, 3.51 mmol) and triethylamine (1.42 g, 14.04 mmol) were added. The resulting mixture was stirred for 2.5 hours at room temperature. The reaction solution was added with 150 mL of ethyl acetate and washed with water(100 mL×2). The organic phase was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain the title compound **34a** (970 mg, yield 53.8%) as a yellow solid.

Step 2

3-fluoro-4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)aniline **34b**

Compound **34a** (970 mg, 2.45 mmol) was dissolved in 20 mL of methanol, then 10% Pd/C (200 mg) was added. The reaction system was purged with hydrogen three times, and stirred for 12 hours at room temperature. The reaction solution was concentrated under reduced pressure to obtain the crude compound **34b** (920 mg) as a yellow solid, which was used directly in the next step without further purification.

Step 3

5-(1-(4-bromo-2-fluorophenyl)piperidin-4-yl)-6-fluoro-5*H*-imidazo[5,1-a]isoindole **34c**

The crude compound **34b** (620 mg, 1.692 mmol) was dissolved in a 40% hydrobromic acid solution, then the reaction system was cooled to 0-5°C. 1 mL of a pre-preparated solution of sodium nitrite (128 mg, 1.86 mmol) was added dropwise. Upon completion of the addition, the reaction was stirred for 40 mins at 0°C, then the reaction solution was poured to a hydrobromic acid solution which was cooled to 0°C. The mixture was warmed up to 60°C and stirred for 2 hours. The pH was adjusted to 8-9 by a solution of 2 *N* sodium hydroxide. The mixture was extracted with ethyl acetate (100 mL×2). The organic phases were combined, washed with water (100 mL) and saturated sodium chloride solution (100 mL), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain the title compound **34c** (450 mg, yield 61.8%) as a white solid.

Step 4

6-fluoro-5-(1-(2-fluoro-4-(1-methyl-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **34**

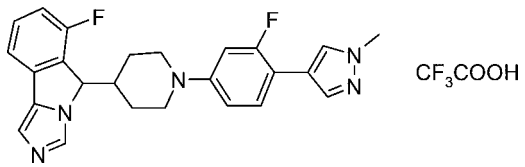
Compound **34c** (200 mg, 0.465 mmol) was dissolved in 11mL of a mixture of 1,2-dimethoxyethane and water (V:V=10:1), then 1-methyl-4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1H-pyrazole (145 mg, 0.697 mmol), tetrakis(triphenylphosphine)palladium(54 mg, 0.0465 mmol) and sodium carbonate (99 mg, 0.93 mmol) were added. The reaction mixture was warmed up to 80°C and stirred for 48 hours. After cooling to room temperature, the mixture was concentrated under reduced pressure. The resulting residue was purified by high performance liquid chromatography to obtain the title compound **34** (160 mg, yield 35%) as a brown solid.

MS m/z (ESI): 432.4 [M+1]

^{1}HNMR(400MHz, DMSO-d_6) δ 8.06 (s, 2H), 7.80 (s, 1H), 7.45-7.55 (m, 2H), 7.22-7.40 (m, 3H), 7.16-7.21 (m, 1H), 6.97 (t, 1H), 5.71 (s, 1H), 3.83 (s, 3H), 3.20-3.45 (m, 2H), 2.68 (t, 1H), 2.56 (t, 1H), 2.35 (t, 1H), 1.65-1.85 (m, 2H), 1.14-1.25 (m, 1H), 0.85-1.00 (m, 1H).

Example 35

6-fluoro-5-(1-(3-fluoro-4-(1-methyl-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



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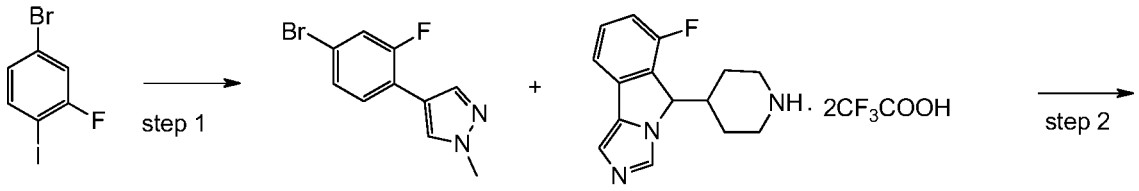
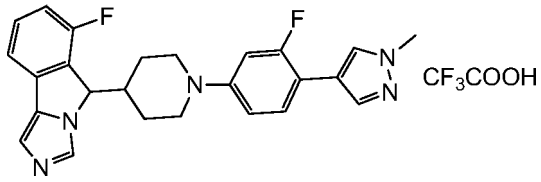


35a 35b 1g



35

Step 1

4-(4-bromo-2-fluorophenyl)-1-methyl-1*H*-pyrazole **35b**

4-bromo-2-fluoro-1-iodobenzene **35a** (301 mg, 1 mmol) was dissolved in 3 mL of dimethyl sulfoxide, then 1-methyl-4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1*H*-pyrazole (139 mg, 0.67 mmol), (1,1'-bis(diphenylphosphino)ferrocene)dichloropalladium (49 mg, 0.067 mmol), potassium acetate (66 mg, 0.67 mmol) and cesium carbonate (650 mg, 2.01 mmol) were added. The mixture was warmed up to 80°C and stirred for 1 hour. The reaction solution was cooled to room temperature, then 350 mL of water was added. The mixture was extracted with ethyl acetate (60 mL×3). The organic phases were combined, washed with water (120 mL×2) and saturated sodium chloride solution (60 mL), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain the title compound **35b** (170 mg) as a brown solid, which was used directly in the next step without further purification.

Step 2

6-fluoro-5-(1-(3-fluoro-4-(1-methyl-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **35**

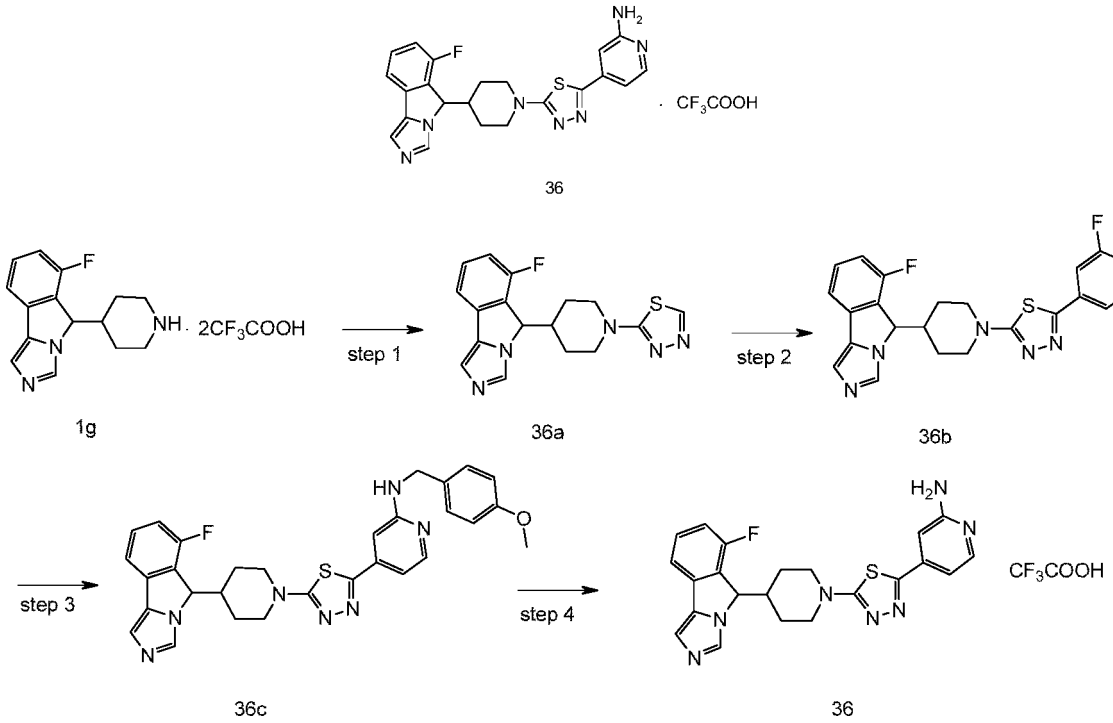
The crude compound **1g** (200 mg, 0.41 mmol) was dissolved in 10 mL of toluene, then the crude compound **35d** (170 mg, 0.67 mmol), tris(dibenzylideneacetone)dipalladium (61 mg, 0.067 mmol), (±)-2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (442 mg, 0.067 mmol) and sodium tert-butoxide (257 mg, 2.68 mmol) were added. The reaction was warmed up to 80°C and stirred for 12 hours. The reaction solution was cooled to room temperature, then 30 mL of water was added. The mixture was extracted with dichloromethane (30 mL×3). The organic phases were combined, dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain the title compound

35 (5 mg, yield 2.8%) as a white solid.

MS m/z (ESI): 432.3[M+1]

Example 36

4-(5-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-1,3,4-thiadiazol-2-yl)pyridin-2-amine trifluoroacetate



Step 1

2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-1,3,4-thiadiazole **36a**

The crude compound **1g** (4.85 g, 10.0 mmol), 2-bromo-1,3,4-thiadiazole (1.65 g, 10.0 mmol) and triethylamine (10.1 g, 100.0 mmol) were dissolved in 20 mL of dimethyl sulfoxide. The resulting mixture was warmed up to 120°C and stirred for 12 hours in sealed tube. The reaction solution was cooled to room temperature, then 200 mL of dichloromethane was added. The mixture was washed with water (200 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain the title compound **36a** (1.09 g, yield 31.9%) as a light brown solid.

Step 2

2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-5-(2-fluoropyridin-4-yl)-1,3,4-thiadiazole **36b**

Compound **36a** (800 mg, 2.34 mmol), 4-bromo-2-fluoropyridine (824 mg, 4.68 mmol), palladium acetate(76 mg, 0.334 mmmol), tri-tert-butylphosphine (1.35 g, 0.668 mmol) and cesium carbonate(1.52 g, 4.68 mmol) were dissolved in 10 mL of *N*,*N*-dimethylformamide. The reaction was warmed to 150°C and stirred for 4 hours. The reaction solution was cooled to room temperature, then 150 mL of dichloromethane

was added. The mixture was washed with water (100 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain the title compound **36b** (260 mg, yield 25.5%) as a brown solid.

Step 3

4-(5-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-1,3,4-thiadiazol-2-yl)-*N*-(4-methoxybenzyl)pyridin-2-amine **36c**

Compound **36b** (260 mg, 0.60 mmol) was dissolved in 3 mL of dimethyl sulfoxide, then *N*-benzyl-4-methoxybenzylamine (823 mg, 6.0 mmol) was added. The reaction was warmed to 130°C and stirred for 4 hours. The reaction solution was cooled to room temperature, then 100 mL of dichloromethane was added. The mixture was washed with water (100 mL×3), dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain the title compound **36c** (130 mg, yield 39.1%) as a light brown solid.

Step 4

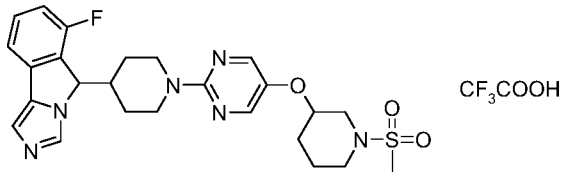
4-(5-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)-1,3,4-thiadiazol-2-yl)pyridin-2-amine trifluoroacetate **36**

Compound **36c** (130 mg, 0.235 mmol) was dissolved in 5 mL of trifluoroacetic acid. The reaction was warmed up to 60°C and stirred for 4 hours. The reaction solution was cooled to room temperature and concentrated under reduced pressure. The resulting residue was purified by high performance liquid chromatography to obtain the title compound **36** (30 mg, yield 23.4%) as a brown solid.

MS m/z (LC-MS): 434.3 [M+1]

Example 37

6-fluoro-5-(1-(5-((1-(methylsulfonyl)piperidin-3-yl)oxy)pyrimidin-2-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



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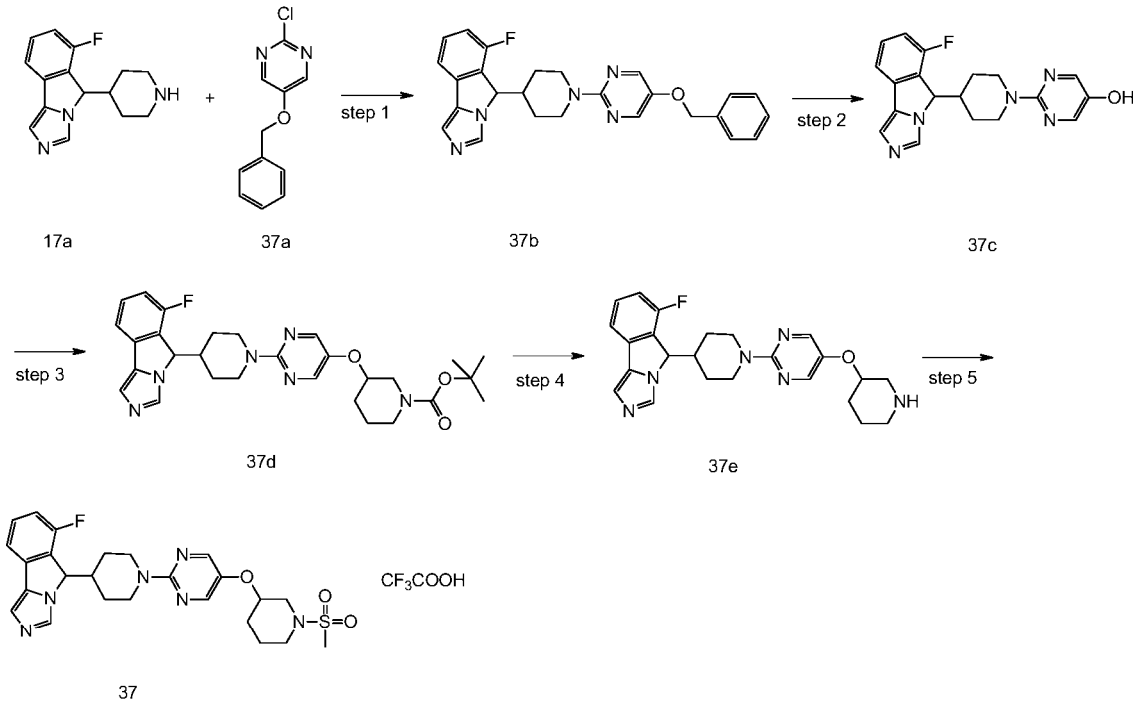


Step 1

5-(1-(5-(benzyloxy)pyrimidin-2-yl)piperidin-4-yl)-6-fluoro-5*H*-imidazo[5,1-a]isoindole **37a**

The crude compound **17a** (1.5 g, 5.83 mmol) and 5-(benzyloxy)-2-chloropyrimidine **37a** (1.29 g, 5.83 mmol) were dissolved in 10 mL of *N*,*N*-dimethylacetamide, then *N*,*N*-diisopropylethylamine (3.76 g, 29.1 mmol) was added. The resulting mixture was stirred for 1 hour at 150°C in microwave. The reaction solution was cooled to room temperature and filtered. The filter was added with 100 mL of ethyl acetate and 50 mL of water. Two phases were separated. The organic phase was washed with water and saturated sodium chloride solution, dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain the title compound **37a** (600 mg, yield 40%) as a light brown oil.

Step 2

2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)pyrimidin-5-ol **37c**

Compound **37b** (600 mg, 1.36 mmol) was dissolved in 15 mL of methanol, then Pd/C (10%) was added. The reaction system was purged with hydrogen three times, and stirred for 3 hours. The reaction solution was filtered to remove Pd/C. The filtrate was concentrated under reduced pressure to obtain the crude title compound **37c** (455 mg) as a yellow solid, which was used directly in the next step without further purified.

Step 3

tert-butyl 3-((2-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)pyrimidin-5-yl)oxy)piperidine-1-carboxylate **37d**

The crude compound **37c** (200 mg, 0.57 mmol), 1-Boc-3-hydroxypiperidine (114

mg, 0.57 mmol), diisopropyl azodicarboxylate (162 mg, 0.856 mmol) and triphenylphosphine (224 mg, 0.856 mmol) were dissolved in 5 mL of tetrahydrofuran. The reaction was stirred for 12 hours at room temperature. The reaction solution was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain the title compound **37d** (100 mg, yield 33.1%) as a light brown solid.

Step 4

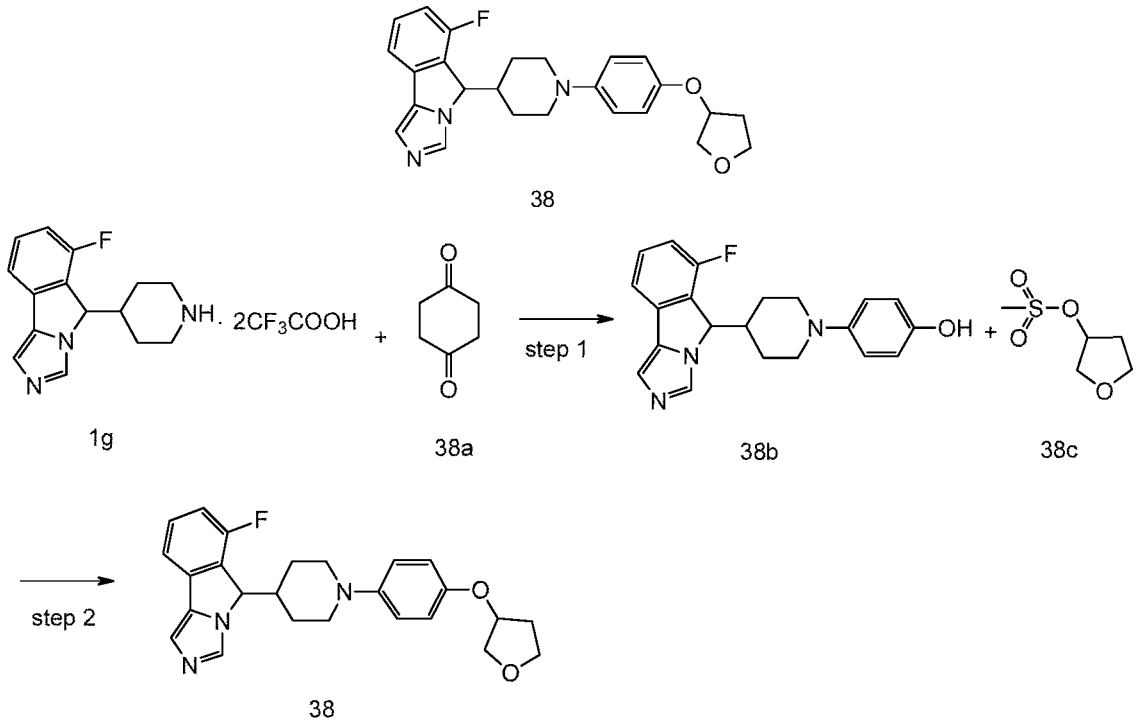
6-fluoro-5-(1-(5-((1-(methylsulfonyl)piperidin-3-yl)oxy)pyrimidin-2-yl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate **37**

Compound **37d** (38 mg, 0.087 mmol) was dissolved in 5 mL of dichloromethane, then 0.25 mL of trifluoroacetic acid and 11 drops of methylsulfonyl chloride. The reaction was stirred for 12 hours at room temperature. The reaction solution was concentrated under reduced pressure. The resulting residue was purified by high performance liquid chromatography to obtain the title compound **37** (14 mg, yield 20%) as a white solid.

MS m/z (ESI): 513.3[M+1]

Example 38

6-fluoro-5-(1-(4-((tetrahydrofuran-3-yl)oxy)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole



Step 1

4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenol **38b**

Compound **1g** (5.82 g, 12 mmol) and cyclohexane-1,4-dione **38a** (1.61 g, 14.4 mmol) was dissolved in 40 mL of ethanol, then triethylamine (2.424 g, 24 mmol) and Pd/C (10%, 200 mg) were added. The mixture was warmed up to 85°C and stirred for

12 hours. The reaction solution was cooled to room temperature, added with water and extracted with dichloromethane (50 mL×3). The organic phases were combined, washed with saturated sodium chloride solution, dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain the crude title compound **38b** (4.19 g) as a brown solid, which was used directly in the next step without further purification.

Step 2

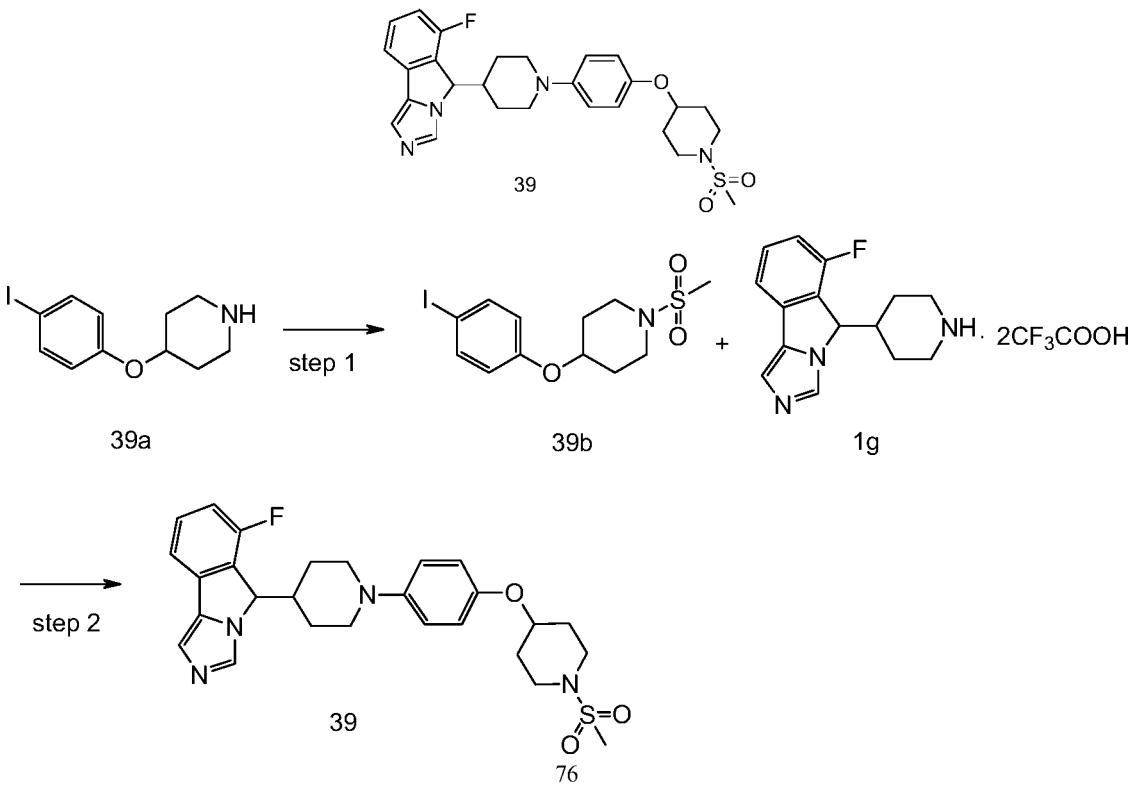
6-fluoro-5-(1-(4-((tetrahydrofuran-3-yl)oxy)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **38**

The crude compound **38b** (349 mg, 1 mmol) was dissolved in 5 mL of ethanol, then tetrahydrofuran-3-yl methanesulfonate **38c** (333 mg, 2 mmol, prepared by a method disclosed in patent application "WO2014049133") and potassium carbonate (420 mg, 3 mmol) were added. The reaction was stirred for 1 hour in microwave at 125°C. The reaction solution was cooled to room temperature and filtered. The filter was concentrated under reduced pressure. The resulting residue was added with water and extracted with dichloromthane (20 mL×3). The organic phases were combined, washed with saturated sodium chloride solution, dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure. The resulting residue was purified by high performance liquid chromatography to obtain the title compound **38** (20 mg, yield 4.8%) as a light yellow solid.

MS m/z (ESI): 420.5 [M+1]

Example 39

6-fluoro-5-(1-(4-((1-(methylsulfonyl)piperidin-4-yl)oxy)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole



Step 1

4-(4-iodophenoxy)-1-(methylsulfonyl)piperidine **39b**

4-(4-iodophenoxy)piperidine **39a** (600 mg, 2 mmol, prepared by a method disclosed in patent application "WO2004089373") was dissolved in 15 mL of dichloromethane, then triethylamine (404 mg, 4 mmol) and methylsulfonyl chloride (273.6 mg, 2.4 mmol) were added. The resulting mixture was stirred for 1 hour at room temperature. The reaction solution was added with water and extracted with ethyl acetate (20 mL×3). The organic phases were combined, washed with saturated sodium chloride solution, dried over anhydrous sodium sulfate and filtered. The filtrate was concentrated under reduced pressure to obtain the crude title compound **39b** (100 mg) as a light yellow solid, which was used directly in the next step without further purification.

Step 2

6-fluoro-5-(1-(4-((1-(methylsulfonyl)piperidin-4-yl)oxy)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **39**

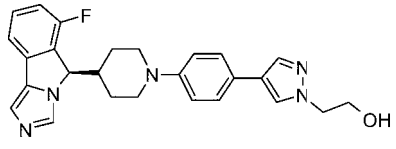
The crude compound **39b** (114 mg, 0.3 mmol) and **1g** (122 mg, 0.25 mmol) were dissolved in 5 mL of toluene, then tris(dibenzylideneacetone)dipalladium (22.9 mg, 0.025 mmol), 2-(dicyclohexylphosphino)-2',4',6'-triisopropylbiphenyl (12 mg, 0.025 mmol) and sodium tert-butoxide(36 mg, 0.375 mmol) were added. The reaction was stirred for 40 mins in microwave at 156°C. The reaction solution was cooled to room temperature. The resulting residue was purified by high performance liquid chromatography to obtain the title compound **39** (10 mg, yield 7.8%) as a light yellow solid.

MS m/z (ESI): 511.6 [M+1]

Examples 40, 41

(*R*)-2-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)ethanol **40**

(*S*)-2-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)ethanol **41**



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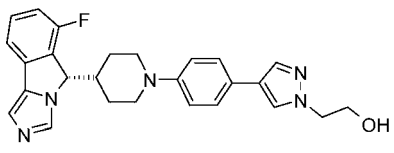

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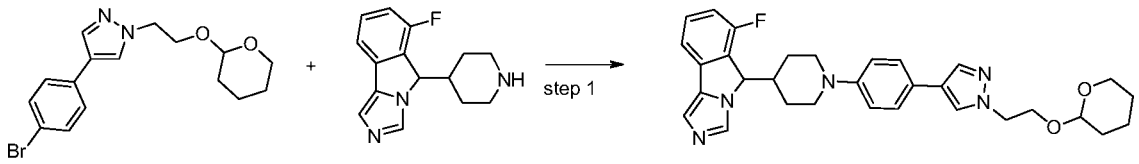
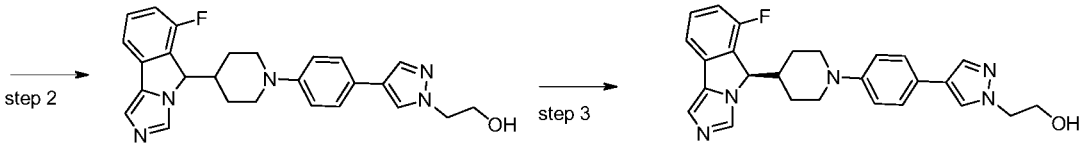
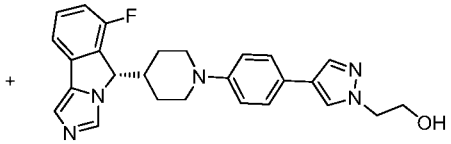


40a 17a 40b

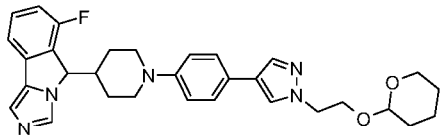


40c 40



41

Step 1



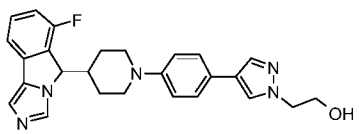
40b

6-fluoro-5-(1-(4-(1-(2-((tetrahydro-2*H*-pyran-2-yl)oxy)ethyl)-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **40b**

4-(4-bromophenyl)-1-(2-((tetrahydro-2*H*-pyran-2-yl)oxy)ethyl)-1*H*-pyrazole **40a** (14.8 g, 42 mmol) and 6-fluoro-5-(piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole **17a** (13.9 g, 42 mmol) were dissolved in 300 mL of *N*,*N*-dimethylformamide, then tri-*tert*-butylphosphonium tetrafluoroborate (1.863 g, 64.5 mmol) and potassium phosphate (35 g, 168 mmol) was added, and the reaction system was purged with argon three times. Tris(dibenzylideneacetone)dipalladium (2.92 g, 3.19 mmol) was added, and the reaction system was purged with argon once. The resulting solution was warmed up to 110°C and stirred for 2 hours. After the reaction was completed, the reaction solution was filtered and the filtrate was concentrated under reduced pressure to remove *N*,*N*-dimethylformamide. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain compound **40b** (6.38 g, yield 29%) as a gray oil.

MS m/z (LC-MS): 528.3 [M+1]

Step 2

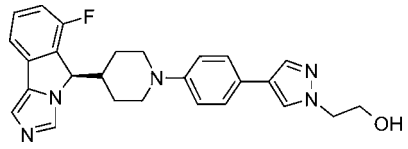


40c

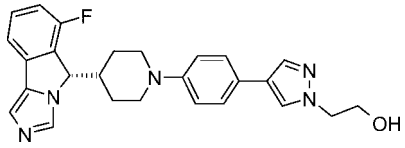
2-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)ethanol **40c**

Compound **40b** (9 g, 17.1 mmol) was dissolved in 100 mL methanol, then 5.7 mL of concentrated hydrochloric acid (12*M*) was added. The reaction solution was warmed up to 45°C and stirred for 1 hour. After the reaction was completed, the reaction solution was cooled to room temperature, the pH was adjusted to 8 by a saturated solution of sodium carbonate. The reaction mixture was filtered and the filtrate was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain compound **40c** (5.2 g, yield 65%) as a yellow solid.

Step 3



40



41

(*R*)-2-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)ethanol **40**

(*S*)-2-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)ethanol **41**

Compound **40c** (1.4 g, 3.16 mmol) was separated chirally (separation conditions: chiral preparation column: Superchiral S-AS (Chiralway), 2cm I.D. * 25 cm Length, 5μm; mobile phase: CO_2/MeOH/DEA =60/40/0.05 (v/v), flow rate: 50 mL/min), the relevant fractions were collected and concentrated under vacuum pressure to obtain compound **40** (630 mg, yellow solid) and compound **41** (652 mg, yellow solid).

40:

MS m/z (ESI): 444.5 [M+1];

Chiral HPLC analysis: retention time 3.064 mins, chiral purity: 97.79% (chromatographic column: Superchiral S-AS (Chiralway), 0.46 cm I.D. * 25 cm Length, 5 μm; mobile phase: CO2/ MeOH/DEA=60/40/0.05 (v/v)

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.97 (s, 2H), 7.73 (s, 1H), 7.44-7.51 (m, 2H), 7.36 (d, 2H), 7.22 (s, 1H), 7.10-7.19 (m, 1H), 6.87 (d, 2H), 5.70 (d, 1H), 4.91 (t, 1H), 4.12 (t, 2H), 3.70-3.79 (m, 3H), 3.62 (d, 1H), 2.62-2.73 (m, 1H), 2.52-2.58 (m, 1H), 2.31-2.43 (m, 1H), 1.55-1.83 (m, 2H), 1.13-1.23 (m, 1H), 0.82-0.96 (m, 1H).

41:

MS m/z (ESI): 444.5 [M+1];

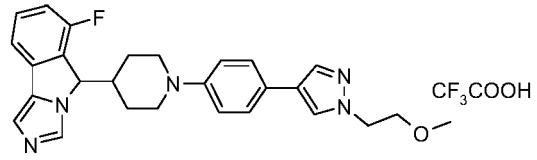
Chiral HPLC analysis: retention time 4.280 mins, chiral purity: 99.52%. (chromatographic column: Superchiral S-AS (Chiralway), 0.46 cm I.D. * 25 cm Length, 5 μm; mobile phase: CO2/ MeOH/DEA=60/40/0.05 (v/v)

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.97 (s, 2H), 7.73 (s, 1H), 7.44-7.51 (m, 2H),

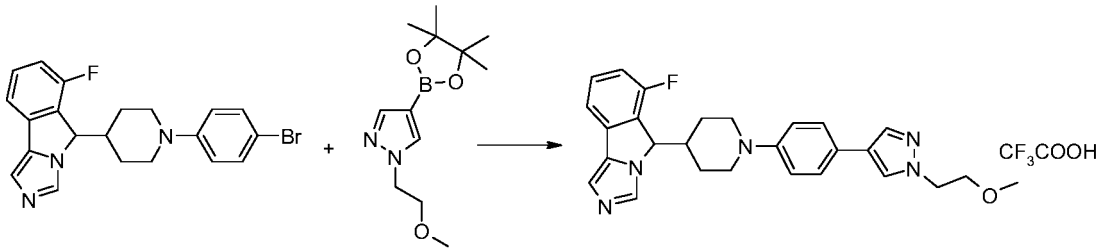
7.36 (d, 2H), 7.22 (s, 1H), 7.10-7.19 (m, 1H), 6.87 (d, 2H), 5.70 (d, 1H), 4.91 (t, 1H), 4.12 (t, 2H), 3.70-3.79 (m, 3H), 3.62 (d, 1H), 2.62-2.73 (m, 1H), 2.52-2.58 (m, 1H), 2.31-2.43 (m, 1H), 1.55-1.83 (m, 2H), 1.13-1.23 (m, 1H), 0.82-0.96 (m, 1H).

Example 42

6-fluoro-5-(1-(4-(1-(2-methoxyethyl)-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



42



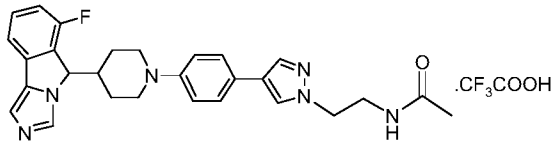
9a 42a 42

Compound **9a** (100 mg, 0.242 mmol) and 1-(2-methoxyethyl)-4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1*H*-pyrazole **42a** (91 mg, 0.363 mmol, prepared by a method disclosed in the patent application "WO2014015088") were dissolved in 5 mL of *n*-butanol, then tris(dibenzylideneacetone)dipalladium (13 mg, 0.0142 mmol), 2-(dicyclohexylphosphino)-2',4',6'-triisopropylbiphenyl (28 mg, 0.0581 mmol) and potassium phosphate (154 mg, 0.726 mmol) were added. The reaction was stirred for 2 hours at 100°C. The reaction solution was cooled to room temperature. The resulting residue was purified by high performance liquid chromatography to obtain the title compound **42** (8 mg, yield 5.8%) as a white solid.

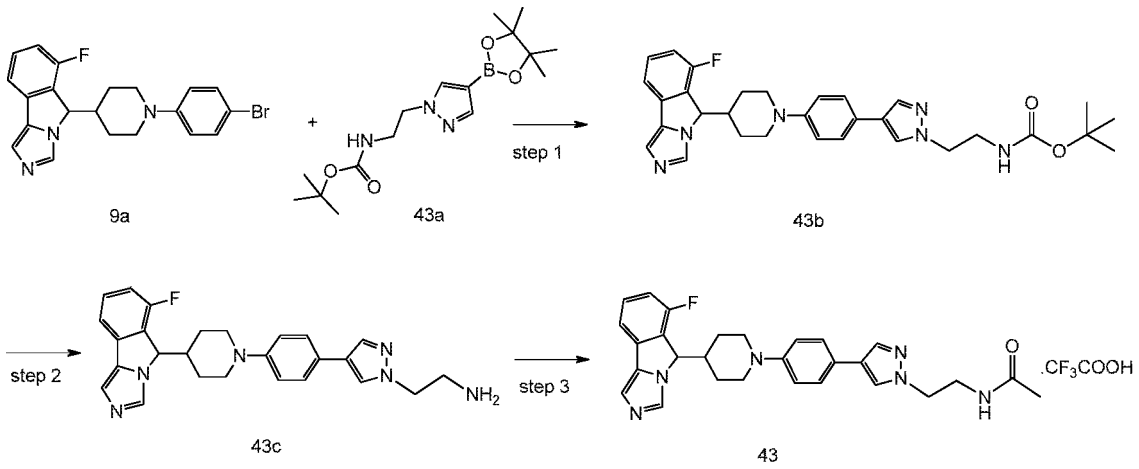
MS m/z (ESI): 458.4 [M+1]

Example 43

N-(2-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)ethyl)acetamide trifluoroacetate



43



Step 1

tert-butyl (2-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)ethyl)carbamate **43b**

Compound **9a** (100 mg, 0.243 mmol) was dissolved in 3 mL of *n*-butanol, then tert-butyl (2-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1H-pyrazol-1-yl)ethyl) carbamate **43a** (123 mg, 0.364 mmol, prepared by a method disclosed in the patent application "CN103087050"), tris(dibenzylideneacetone)dipalladium (11 mg, 0.0122 mmol), 2-(dicyclohexylphosphino)-2',4',6'-triisopropylbiphenyl (23 mg, 0.0486 mmol) and potassium phosphate (103 mg, 0.486 mmol) were added. The reaction system was warmed up to 100°C and stirred for 2 hours. The reaction solution was cooled to room temperature and concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography with eluent system A to obtain the title compound **43b** (50 mg, yield 38%) as a yellow solid.

Step 2

2-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)ethanamine **43c**

Compound **43b** (50 mg, 0.092 mmol) was dissolved in 3 mL dichloromethane, then 0.5 mL of trifluoroacetic acid was added. The reaction was stirred for 2 hours at room temperature. The reaction solution was concentrated under reduced pressure to obtain the crude title compound **43c** (60 mg) as a brown oil, which was used directly in the next step without further purification.

Step 3

N-(2-(4-(4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)phenyl)-1*H*-pyrazol-1-yl)ethyl)acetamide trifluoroacetate **43**

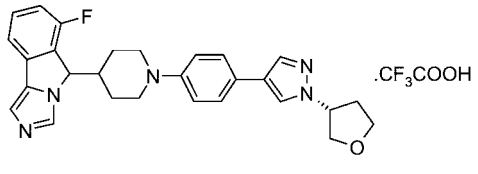
The crude compound **43c** (60 mg, 0.092 mmol) was dissolved in dichloromethane, then acetylchloride (14 mg, 0.184 mmol) and triehylamine (28 mg, 0.276 mmol) were added. The reaction was stirred for 3 hours at room temperature. The reaction solution was concentrated under reduced pressure, and the resulting residue was purified by high performance liquid chromatography to obtain the title compound **43** (7 mg, yield 13%) as an offwhite solid.

MS m/z (ESI): 485.5 [M+1];

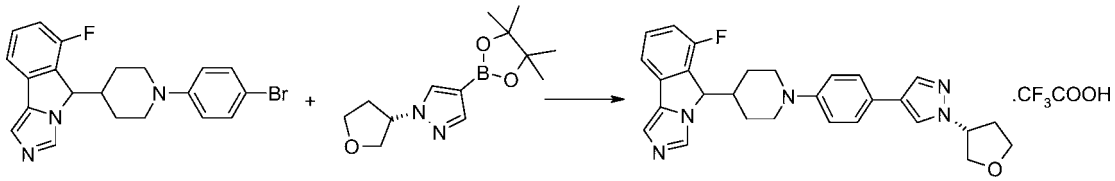
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.51 (s, 1H), 8.00-8.20 (m, 3H), 7.75-7.95 (m, 2H), 7.64-7.73 (m, 1H), 7.40-7.60 (m, 3H), 7.00-7.18 (m, 2H), 6.16 (s, 1H), 4.14 (t, 2H), 3.72 (d, 1H), 3.62 (d, 1H), 3.41-3.46 (m, 2H), 2.70-3.00 (m, 2H), 2.55-2.70 (m, 1H), 1.60-1.90 (m, 5H), 1.30-1.40 (m, 1H), 1.10-1.20 (m, 1H).

Example 44

6-fluoro-5-(1-(4-(1-((*R*)-tetrahydrofuran-3-yl)-1*H*-pyrazol-4-yl)phenyl)piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole trifluoroacetate



44



9a 44a 44

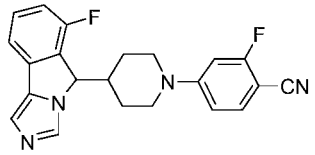
Compound **9a** (103 mg, 0.25 mmol) was dissolved in 3 mL of *n*-butanol, then (*S*)-1-(tetrahydrofuran-3-yl)-4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1*H*-pyrazole **44a** (99 mg, 0.375 mmol, prepared by a method disclosed in the patent application "US20080167287"), tris(dibenzylideneacetone)dipalladium (17 mg, 0.01875 mmol), 2-(dicyclohexylphosphino)-2',4',6'-triisopropylbiphenyl (36 mg, 0.075 mmol) and potassium phosphate (106 mg, 0.5 mmol) were added. The reaction system was warmed up to 100°C and stirred for 2 hours. The reaction solution was cooled to room temperature and filtered through diatomite to remove the insolubles. The filtrate was concentrated under reduced pressure. The resulting residue was purified by high performance liquid chromatography to obtain the title compound **44** (30 mg, yield 40.3%) as a white solid.

MS m/z (ESI): 470.5 [M+1];

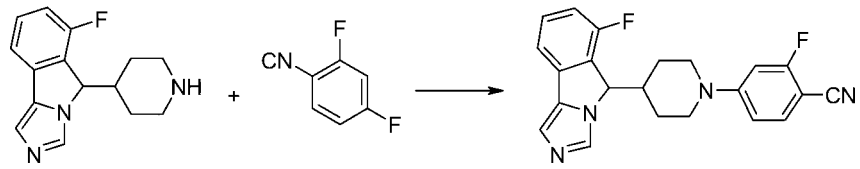
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.49 (s, 1H), 8.10 (s, 1H), 8.06 (s, 1H), 7.8 (s, 1H), 7.76-7.78 (m, 1H), 7.41-7.45 (m, 3H), 6.97 (d, 2H), 6.14 (s, 1H), 4.98-5.00 (m, 1H), 3.97-4.02 (m, 2H), 3.89-3.92 (m, 1H), 3.80-3.86 (m, 1H), 3.73-3.76 (m, 1H), 3.63-3.66 (m, 1H), 2.75-2.85 (m, 1H), 2.62-2.75 (m, 1H), 2.53-2.59 (m, 1H), 2.29-2.41 (m, 2H), 1.82-1.85 (m, 1H), 1.62-1.64 (m, 1H), 1.31-1.34 (m, 1H), 1.07-1.13 (m, 1H), 0.85-0.87 (m, 1H).

Example 45

2-fluoro-4-(4-(6-fluoro-5*H*-imidazo[5,1-a]isoindol-5-yl)piperidin-1-yl)benzonitrile



45



17a 45a 45

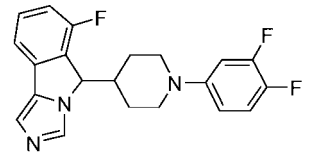
Compound **17a** (500 mg, 1.94 mmol), 2,4-difluorobenzonitrile **45a** (270 mg, 1.94 mmol) and triethylamine (216 mg, 2.14 mmol) was dissolved in 5 mL of dimethylsulfoxide. The reaction system was warmed up to 80°C and stirred for 12 hours. The reaction solution was cooled to room temperature, and the resulting residue was purified by high performance liquid chromatography to obtain the title compound **45** (190 mg, yield 26%) as a light brown solid.

MS m/z (ESI): 377.1[M+1]

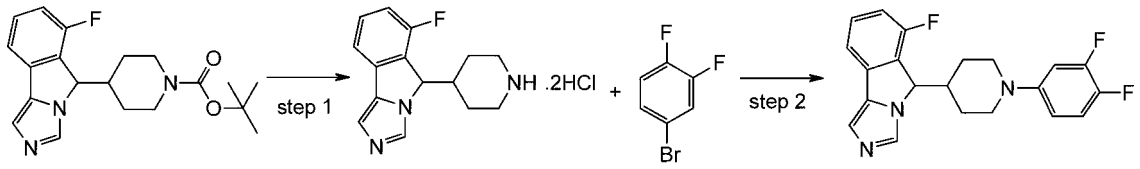
^{1}H NMR (400MHz, DMSO-d_6) δ 8.1 (s, 1H), 7.74 (dd, 1H), 7.46-7.49 (m, 2H), 7.24 (s, 1H), 7.17-7.12 (m, 1H), 6.96 (dd, 1H), 6.88 (td, 1H), 5.72 (s, 1H), 3.49-3.59 (m, 2H), 2.88 (t, 1H), 2.73 (t, 1H), 2.37-3.43 (m, 1H), 1.76-1.84 (m, 1H), 1.61-1.71 (m, 1H), 1.20-1.29 (m, 1H), 0.91-1.01 (m, 1H).

Example 46

5-(1-(3,4-difluorophenyl)piperidin-4-yl)-6-fluoro-5*H*-imidazo[5,1-a]isoindole



46



1f 46a 46b 46

Step 1

6-fluoro-5-(piperidin-4-yl)-5*H*-imidazo[5,1-a]isoindole hydrochloride **46a**

Compound **1f** (17.7 g, 49.6 mmol) was dissolved in 180 mL of a mixture of dichloromethane and 1,4-dioxane (V/V-5:1). After the mixture was cooled in an ice bath, 41.2 mL of concentrated hydrochloric acid was added dropwise. The reaction was stirred for 2 hours at room temperature. The reaction solution was concentrated under reduced pressure to obtain the crude title compound **46a** (16.37 mg) as a white solid, which was used directly in the next step without further purification.

Step 2

5-(1-(3,4-difluorophenyl)piperidin-4-yl)-6-fluoro-5*H*-imidazo[5,1-a]isoindole **46**

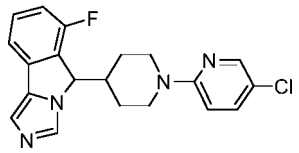
The crude compound **46a** (165 mg, 0.5 mmol) and 4-bromo-1,2-difluorobenzene **46b** (116 mg, 0.6 mmol) were dissolved in 6 mL of a mixture of toluene and tert-butanol (V/V=5:1), then palladium acetate (11.22 mg, 0.05 mmol), 2-(dicyclohexylphosphino)-2',4',6'-triisopropylbiphenyl (24 mg, 0.05 mmol) and sodium tert-butanol (200 mg, 2mmol) were added. The reaction was stirred for 0.5 hour in microwave at 160°C. The reaction solution was cooled to room temperature and concentrated under reduced pressure. The resulting residue was purified by high performance liquid chromatography to obtain the title compound **46** (10 mg, yield 5.4%) as a white solid.

MS m/z (ESI): 370.4 [M+1]

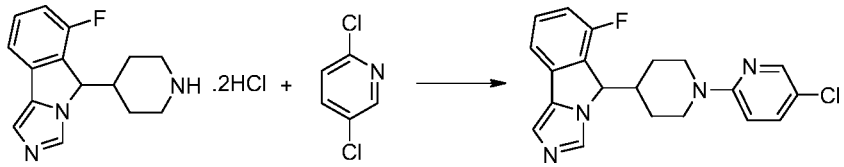
^{1}H NMR (400MHz, $CDCl_3$) δ 7.72 (s, 1H), 7.34 (dd, 1H), 7.22-7.26 (m, 2H), 6.96 (s, 2H), 6.54-6.65 (m, 2H), 5.57 (dd, 1H), 3.49-3.59 (m, 2H), 2.61 (t, 1H), 2.58 (t, 1H), 2.54 (m, 1H), 1.76-1.84 (m, 1H), 1.61-1.71 (m, 1H), 1.20-1.29 (m, 1H), 0.91-1.01 (m, 1H).

Example 47

5-(1-(5-chloropyridin-2-yl)piperidin-4-yl)-6-fluoro-5*H*-imidazo[5,1-a]isoindole



47



46a 47a 47

The crude compound **46a** (500 mg, 1.52 mmol) and 2,5-dichloropyridine **47a** (292 mg, 1.97 mmol) were dissolved in 10 mL of dimethylsulfoxide, then *N,N*-diisopropylethylamine (980 mg, 7.6 mmol) was added. The reaction was stirred for 3.5 hours in microwave at 140°C. The reaction solution was cooled to room temperature, and the resulting residue was purified by high performance liquid chromatography to obtain the title compound **47** (105 mg, yield 18.7%) as an orange-yellow solid.

MS m/z (ESI): 369.8[M+1]

^{1}H NMR (400MHz, DMSO-d_6) : δ 8.05-8.04 (d, 1H), 7.97 (s, 1H), 7.54-7.51 (dd, 1H), 7.48-7.46 (m, 2H), 7.23 (s, 1H), 7.17-7.12 (m, 1H), 6.81-6.79 (d, 1H), 6.70-6.69 (d, 1H), 4.39-4.36 (d, 1H), 4.22-4.19 (d, 1H), 2.85-2.79 (m, 1H), 2.72-2.66 (m, 1H), 1.54-1.45 (m, 1H), 1.30-1.24 (m, 2H), 1.97-1.14 (m, 2H).

BIOLOGICAL ASSAY

The present invention will be further described with reference to the following test examples, but the examples should not be considered as limiting the scope of the invention.

Test Example 1. Assay for determining the inhibition activity of the present compounds on human IDO1.

Human IDO1 activity was tested *in vitro* by the following method.

This method is used to determine the inhibition effect of the compounds of the present invention on the activity of human IDO1.

1. Experimental materials and instruments

(1) Synergy HT microplate reader (BIOTEK)

(2) Trytophan (T0254-5G, Sigma-Aldrich)

(3) Catalase origined from liver of cow (C1345-1G, Sigma-Aldrich)

(4) Methylene blue (M9140-25G, Sigma-Aldrich)

(5) L-sodium ascorbate (A7631-25G, Sigma-Aldrich)

(6) 4-(Dimethylamino)benzaldehyde (D2004-25G, Sigma-Aldrich)

(7) Trichloroacetic acid (T9159-100G, Sigma-Aldrich)

(8) Human IDO1 gene (SC126221, Origene)

2. Experimental procedure

Preparation of IDO1

Human IDO1 gene was transferred to Pet30a plasmids by gene cloning, and then transferred to competent Escherichia coli Rosseta; This IDO1 gene was scale-up cultured in liquid LB (Luria-Bertani) medium [which was prepared per liter according to "Molecular Cloning A Laboratory Manual" (J. Sambrook, D.W. Russell)]), the bacteria were collected and broken by the ultrasonic wave. The purified IDO1 was obtained through the column by elution.

Compound test:

24 μL of enzyme (IDO1) was diluted 100 times with 50 mM KPB to 2400 μL. The concentration of enzyme solution was 2.6 ng/μL. A 96 well reaction plate (AXYGEN, PCR-96-FLT-C) (hereinafter referred to as the reaction plate) was added with the enzyme solution at 24 μL/well. The blank well was added with 24 μL of KPB [Preparation of KPB buffer (50mM): 6.805 g of KH_2PO_4 was weighed by a analytical balance, and placed into a 1000 ml of beaker, deionized water was added with a measuring cylinder to 900 ml, the pH was adjusted to 6.5 by 1M KOH, then the mixture was introduced into a 1 L measuring cylinder, and water was added to 1 L. It was stored at 4°C]. 1 μL of a compound or DMSO was added into the corresponding wells in the reaction plate. Preparation of solution A: 200 μL of 500 mML-sodium ascorbate was added with 1050 μL of KPB, then the mixture was mixed uniformly for 3 seconds at the maximum speed in a turbine mixer. Solution B: 100 μL of 10 mM tryptophan was added with 100 μL of 100000 unit/ml catalase, 5 μL of 10 mM methylene blue, and 1050 μL of

KPB sucessively, then the mixture was mixed uniformly for 3 seconds at the maximum speed in a turbine mixer. 1200 μL of solution A and 1200 μL of solution B were taken and mixed uniformly for 3 seconds at the maximum speed in a turbine mixer. The mixture was added to the reaction plate at 24μL/well. The reaction plate was placed in a plate centrifuge and centrifuged for 15 seconds at the maximum speed, so the reaction liquids were converged to the bottom. The reaction mixture was mixed uniformly for 30 seconds on a shaker, and incubated for 1 hour at 37°C in a constant temperature incubator. In the reaction plate, 30% (W/V) trichloroacetic acid was added at 10 μL/well, then the mixture was incubated for 15 minutes at 65°C in a incubator. The reaction plate was centrifuged in a centrifuge for 5 mins at 4700RPM at room temperature. 40 μL of the supernatant was transferred from the reaction plate to the corresponding 96 wells test plate (Corning, #3599) by a multi-channel pipette. 2% (W/V) 4-(dimethylamino)benzaldehyde/glacial acetic acid solution was added at 40 μL/well, then the mixture was mixed uniformly for 1 minute on a shaker at the maximum speed. After incubation for 2 minutes at room temperature, the absorbance at 480 nm was read on Synergy HT (BIOTEK).

The inhibition activity of the compounds of the present invention on human IDO1 was tested by the assay described above. The IC_{50} values are shown in Table 1 below.

Table 1 IC_{50} of the compounds of the present inventionfor inhibiting the activity of human IDO1

Example No.	IC_{50} (nM)
1	87.40
3	71.74
4	96.21
5	81.17
8	78.84
9	25.69
11	73.17
12	68.71
18	34.02
22	56.93
23	48.16
28	5.17
29	35.86
30	58.75
31	14.22
32	32.98
33	36.06
34	15.81

35	7.65
36	10.55
37	17.83
38	28.10
39	15.51
41	9.22
42	36.31
43	63.33
44	16.59
45	8.84
46	6.68
47	7.23

Conclusion: The compounds of the present invention have significant inhibition effect on the activity of human IDO1.

Test Example 2. Assay for determining the inhibition activity of the compounds of the present invention on human TDO.

Human TDO activity was tested *in vitro* by the following method.

This method is used to determine the inhibition effect of the compounds of the present invention on the activity of human TDO.

1. Experimental materials and instruments

(1) Synergy HT microplate reader (BIOTEK)

(2) Trytophan (T0254-5G, Sigma-Aldrich)

(3) Catalase origined from liver of cow (C1345-1G, Sigma-Aldrich)

(4) Methylene blue (M9140-25G, Sigma-Aldrich)

(5) L-sodium ascorbate (A7631-25G, Sigma-Aldrich)

(6) 4-(Dimethylamino)benzaldehyde (D2004-25G, Sigma-Aldrich)

(7) Trichloroacetic acid (T9159-100G, Sigma-Aldrich)

(8) Human TDO (U32989.1, Suzhou Genewiz Biological Technology Co., Ltd.)

(9) Rosseta (CW0811A, Beijing Kangwei Century Biotechnology Co., Ltd.)

(10) Turbomixer (6776,Corning)

(11) Mini-plate centrifuge (Mini-P25, ABSON life science equipment)

2. Experimental procedure

Preparation of TDO

Plasmids constructed with human TDO gene were transferred to competent Escherichia coli Rosseta; This TDO gene was scale-up cultured in liquid LB (Luria-Bertani) medium [which was prepared per liter according to "Molecular Cloning A Laboratory Manual" (J. Sambrook, D.W. Russell)]), the bacteria were collected and broken by the ultrasonic wave. The purified TDO was obtained through the column by

elution.

Compound test:

24 μL of enzyme (TDO) was diluted 100 times with 50 mM KPB to 2400 μL. The concentration of enzyme solution was 2.6 ng/μL. A 96 wells reaction plate (AXYGEN, PCR-96-FLT-C) (hereinafter referred to as the reaction plate) was added with the enzyme solution at 24 μL/well. The blank well was added with 24 μL of KPB [Preparation of KPB buffer (50mM): 6.805 g of KH_2PO_4 was weighed by a analytical balance, and placed into a 1000 ml of beaker, deionized water was added with a measuring cylinder to 900 ml, the pH was adjusted to 6.5 by 1M KOH, then the mixture was introduced into a 1 L measuring cylinder, and water was added to 1 L. It was stored at 4°C]. 1 μL of a compound or DMSO was added into the corresponding wells in the reaction plate. Preparation of solution A: 200 μL of 500 mML-sodium ascorbate was added with 1050 μL of KPB, then the mixture was mixed uniformly for 3 seconds at the maximum speed in a turbine mixer. Solution B: 100 μL of 10 mM tryptophan was added with 100 μL of 100000 unit/ml catalase, 5 μL of 10 mM methylene blue, and 1050 μL of KPB sucessively, then the mixture was mixed uniformly for 3 seconds at the maximum speed in a turbine mixer. 1200 μL of solution A and 1200μL of solution B were taken and mixed uniformly for 3 seconds at the maximum speed in a turbine mixer. The mixture was added to the reaction plate at 24 μL/well. The reaction plate was placed in a plate centrifuge and centrifuged for 15 seconds at the maximum speed, so the reaction liquids were converged to the bottom. The reaction mixture was mixed uniformly for 30 seconds on a shaker, and incubated for 1 hour at 37°C in a constant temperature incubator. In the reaction plate, 30% (W/V) trichloroacetic acid was added at 10 μL/well, then the mixture was incubated for 15 minutes at 65°C in a incubator. The reaction plate was centrifuged in a centrifuge for 5 mins at 4700RPM at room temperature. 40 μL of the supernatant was transferred from the reaction plate to the corresponding 96 wells test plate (Corning, #3599) by a multi-channel pipette. 2% (W/V) 4-(dimethylamino)benzaldehyde/glacial acetic acid solution was added at 40 μL/well, then the mixture was mixed uniformly for 1 minute on a shaker at the maximum speed. After incubation for 2 minutes at room temperature, the absorbance at 480 nm was read on Synergy HT Reader.

The inhibition activity of the compounds of the present invention on human TDO was tested by the assay described above. The IC_{50} values are shown in Table 2 below.

Table 2 IC_{50} of the compounds of the present invention for inhibiting the activity of human TDO

Example No.	IC_{50} (nM)
1	338.4
2	214.9
3	370.9
5	393.7

6	393.9
9	131.7
18	361.2
23	399.0
25	256.6
28	30.6
29	219.8
30	318.7
31	103.5
32	296.5
33	184.0
34	142.6
35	64.6
36	104.4
39	243.1
41	42.0
42	217.1
43	247.3
44	202.5
45	234.4
46	68.9
47	194.9

Conclusion: The compounds of the present invention have significant inhibition effect on the activity of human TDO.

Test Example 3. Assay for determining the inhibition activity of the present compounds on IDO in HeLa cells.

IDO activity in HeLa cells was tested *in vitro* by the following method.

This method is used to determine the inhibition effect of the compounds of the present invention on the activity of IDO in HeLa cells. (Note: indoleamine 2,3-dioxygenase (IDO) is expressed in the HeLa cell line and induced by interferon gamma (INF-γ)).

1. Experimental materials and instruments

(1) Synergy HT microplate reader (BIOTEK)

(2) Trytophan (T0254-5G, Sigma-Aldrich)

(3) 4-(Dimethylamino)benzaldehyde (D2004-25G, Sigma-Aldrich)

(4) Trichloroacetic acid (T9159-100G, Sigma-Aldrich)

(5) Hela cell line (CCL-2, ATCC)

2. Experimental procedure

HeLa cell suspension was prepared with a fresh cell medium, and added into a 96

cell plate with 100 μL culture system at 10000 cells/well, then incubated for 24 hours in 5% carbon dioxide at 37°C. The supernatant was removed, serum-free DMEM high glucose medium was added at 90 μL/well, then the compounds contained in the culture medium with INF-γ and tryptophan were added at 10 μL/well (the final concentration: 10000, 1000, 100, 10, 1, 0.1 nM), the mixture was incubated for 48 hours in 5% carbon dioxide at 37°C. 80 μL of the supernate was transferred from the 96-well cell culture plate to a 96 well round-bottomed plate, then 30% (W/V) trichloroacetic acid was added at 16 μL/well, then the mixture was incubated for 25 minutes at 65°C in a incubator. The reaction plate was centrifuged in a centrifuge for for 5 mins at 4700RPM. 50 μL of the supernatant was transferred from the reaction plate to a 96-well flat-bottomed transparent plate by a multi-channel pipette. 2% (W/V) 4-(dimethylamino)benzaldehyde/glacial acetic acid solution was added at 50 μL/well, then the mixture was mixed uniformly for 1 minute on a shaker. After incubation for 2 minutes at room temperature, the absorbance at 480 nm was read on Synergy HT Reader.

The inhibition activity of the compounds of the present invention on IDO in HeLa cells was tested by the assay described above. The IC_{50} values are shown in Table 3 below.

Table 3 IC_{50} of the compounds of the present invention for inhibiting the activity of IDO in HeLa cells

Example No.	IC_{50} (nM)
3	167.1
4	187.6
5	353.1
8	252.9
9	100.9
11	477.3
12	70.57
15	199.2
16	260.3
18	197.8
21	477
22	129.8
23	438.9
28	85.16
29	292.4
30	333.8
32	225
33	47.23

34	29.34
35	69.06
36	27.76
37	113.8
38	150.7
39	198.3
41	47.7
42	253.8
43	171.1
44	174.7
45	231
46	69.1
47	88.3

Conclusion: The compounds of the present invention have significant inhibition effect on the activity of IDO in HeLa cell.

PHARMACOKINETICS ASSAY

Test Example 4. Pharmacokinetics assay of the compounds of Example 3 and Example 9 of the present invention

1. Abstract

Sprague-Dawley (SD) rats were used as test animals. The drug concentration in plasma at different time points was determined by LC/MS/MS after intragastrical administration of the compounds of Example 3 and Example 9 in rats. The pharmacokinetic behavior of the compounds of the present invention was studied and evaluated in rats.

2. Protocol

2.1 Samples

Compounds of Example 3 and Example 9

2.2 Test animals

8 healthy adult SD rats, male and female half in half, which were purchased from SINO-BRITSH SIPPR/BK LAB. ANIMAL LTD., CO, with Certificate No.: SCXK (Shanghai) 2008-0016.

2.3 Preparation of the test compounds

The appropriate amount of the test compounds was weighed, and added with 0.5% CMC-Na to prepare a 0.5 mg/mL suspension by an ultrasonic method.

2.4 Administration

After an overnight fast, 8 SD rats were equally divided into 2 groups, male and female half in half, and administered the test compounds intragastrically at an administration volume of 10 mL/kg.

3. Process

0.2 mL of blood was taken from orbital sinus before administration and at 0.5 h, 1.0 h, 2.0 h, 4.0 h, 6.0 h, 8.0 h, 11.0 h, and 24.0 h after administration. The samples were stored in heparinized test tubes, and centrifuged for 10 minutes at 3,500 rpm to separate blood plasma. The plasma samples were stored at -20°C. The rats were fed 2 hours after administration.

The concentration of the test compounds in rat plasma after intragastrically administration was determined by LC/MS/MS.

4. Results of pharmacokinetic parameters

Pharmacokinetic parameters of the compounds of Example 3 and Example 9 are shown below.

Example No.	Pharmacokinetics Assay (10 mg/kg)					
	Plasma Conc.	Area Under Curve	Half-Life	Mean Residence Time	Clearance	Apparent Distribution Volume
	Cmax (ng /mL)	AUC (ng /mL*h)	T1/2 (h)	MRT (h)	CLz/F (l/h/kg)	Vz/F (l/kg)
3	1067±524	2621±977	2.54±0.91	2.72±0.36	70.9±26.4	14099±1721
9	3117±1600	18901±15997	2.22±0.48	3.85±1.30	15.2±10.9	2621±1592

Conclusion: The compounds of the present invention are well absorbed and have a remarkable pharmacological absorption effect.

Test Example 5. Pharmacokinetics assay of the compounds of Example 28 and Example 41 of the present invention

1. Abstract

c57bl/6 mice were used as test animals. The drug concentration in plasma at different time points was determined by LC/MS/MS after intragastrical administration of the compounds of Example 28 and Example 41 in c57bl/6 mice. The pharmacokinetic behavior of the compounds of the present invention was studied and evaluated in c57bl/6 mice.

2. Protocol

2.1 Samples

Compounds of Example 28 and Example 41

2.2 Test animals

18 female c57bl/6 mice, which were purchased from SINO-BRITSH SIPPR/BK LAB. ANIMAL LTD., CO.

2.3 Preparation of the test compounds

The appropriate amount of the test compounds was weighed, and added with 0.5% CMC-Na to prepare a 1 mg/mL suspension by an ultrasonic method.

2.4 Administration

After an overnight fastt, 18 female c57bl/6 mice were equally divided into 2 groups, 9/group, and administered the test compounds intragastrically at an administration volume of 0.2 mL/kg.

3. Process

0.2 mL of blood was taken from orbital sinus at 0.5 h, 1.0 h, 2.0 h, 4.0 h, 6.0 h, 8.0 h, 11.0 h and 24.0 h after administration. The samples were stored in heparinized test tubes, and centrifuged for 10 minutes at 3,500 rpm to separate blood plasma. The plasma samples were stored at -20°C.

The concentration of the test compounds in rat plasma after intragastrically administration was determined by LC/MS/MS.

4. Results of pharmacokinetic parameters

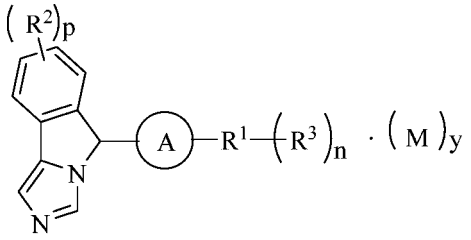
Pharmacokinetic parameters of the compounds of Example 28 and Example 41are shown below.

Example No.	Pharmacokinetics Assay					
	Plasma Conc.	Area Under Curve	Half-Life	Mean Residence Time	Clearance	Apparent Distribution Volume
	Cmax (ng /mL)	AUC (ng /mL*h)	t1/2(h)	MRT(h)	CLz/F (L/h/kg)	Vz/F (L/kg)
28(2mg/kg)	972	5671	4.79	6.99	5.88	2438
41(3mg/kg)	1672	4630	2.06	1.36	10.8	1275

Conclusion: The compounds of the present invention are well absorbed and have a remarkable pharmacological absorption effect

The claims defining the invention are as follows:

1. A compound of formula (I):



(I)

or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,

wherein:

M is inorganic acid or organic acid, preferably trifluoroacetic acid;

A is selected from the group consisting of cycloalkyl, heterocyclyl, aryl and heteroaryl, wherein the cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, amino, nitro, hydroxy, cyano, alkoxy, hydroxyalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl;

R^1 is selected from the group consisting of hydrogen, alkyl, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-OR^4$, $-C(O)R^4$, $-C(O)OR^4$, $-S(O)_mR^4$, $-NR^5R^6$, $-C(O)NR^5R^6$, $-C(O)NHR^5$, $-NR^5C(O)R^6$ and $-NR^5S(O)_mR^6$;

R^2 are identical or different and each independently selected from the group consisting of hydrogen, alkyl, haloalkyl, alkoxy, haloalkoxy, halogen, amino, nitro, hydroxy, cyano, cycloalkyl, heterocyclyl, aryl and heteroaryl;

R^3 are identical or different and each independently selected from the group consisting of hydrogen, alkyl, haloalkyl, alkoxy, haloalkoxy, halogen, amino, nitro, hydroxy, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-OR^4$, $-C(O)R^4$, $-C(O)OR^4$, $-S(O)_mR^4$, $-NR^5R^6$, $-C(O)NR^5R^6$, $-NR^5C(O)R^6$ and $-NR^5S(O)_mR^6$, wherein the alkyl, haloalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, haloalkyl, halogen, amino, nitro, cyano, hydroxy, alkoxy, haloalkoxy, hydroxyalkyl, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-R^a$, $-OR^7$, $-C(O)R^7$, $-C(O)OR^7$, $-S(O)_mR^7$, $-NR^7R^8$, $-C(O)NR^7R^8$, $-NR^7C(O)R^8$ and $-NR^7S(O)_mR^8$;

R^a is selected from the group consisting of alkyl, haloalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl, wherein the alkyl, haloalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, amino, nitro, hydroxy, alkoxy, hydroxyalkyl, cyano, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-OR^4$, $-C(O)R^4$, $-C(O)OR^4$, $-S(O)_mR^4$, $-NR^5R^6$, $-C(O)NR^5R^6$, $-NR^5C(O)R^6$ and $-NR^5S(O)_mR^6$;

R^4 is selected from the group consisting of hydrogen, alkyl, haloalkyl, hydroxy,

amino, alkoxy, haloalkoxy, cycloalkyl, heterocyclyl, aryl and heteroaryl, wherein the alkyl, haloalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, amino, nitro, cyano, hydroxy, hydroxyalkyl, alkoxy, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-R^a$, $-OR^7$, $-C(O)R^7$, $-C(O)OR^7$, $-S(O)_mR^7$, $-NR^7R^8$, $-C(O)NR^7R^8$, $-NR^7C(O)R^8$ and $-NR^7S(O)_mR^8$;

R^5 and R^6 are identical or different and each independently selected from the group consisting of hydrogen, alkyl, hydroxy, amino, cycloalkyl, heterocyclyl, aryl and heteroaryl, wherein the alkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, hydroxy, amino, nitro, cyano, alkoxy, hydroxyalkyl, cycloalkyl, heterocyclyl, aryl, heteroaryl, $-R^a$, $-OR^7$, $-C(O)R^7$, $-C(O)OR^7$, $-S(O)_mR^7$, $-NR^7R^8$, $-C(O)NR^7R^8$, $-NR^7C(O)R^8$ and $-NR^7S(O)_mR^8$;

R^7 and R^8 are identical or different and each independently selected from the group consisting of hydrogen, alkyl, hydroxy, amino, cycloalkyl, heterocyclyl, aryl and heteroaryl, wherein the alkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, hydroxy, amino, nitro, cyano, alkoxy, hydroxyalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl;

p is an integer of 0, 1, 2, 3 or 4;

y is an integer of 0, 1, 2 or 3;

m is an integer of 0, 1 or 2; and

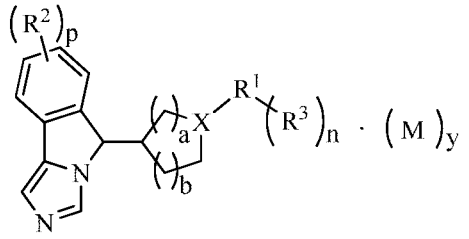
n is an integer of 0, 1, 2, 3, 4 or 5.

2. The compound of formula (I) according to claim 1, wherein y is 0, 1 or 3, particularly 0.

3. The compound of formula (I) according to claim 1 or 2, wherein A is selected from the group consisting of heterocyclyl and cycloalkyl, wherein the heterocyclyl and cycloalkyl are each optionally substituted by one or more groups selected from the group consisting of alkyl, halogen, amino, nitro, hydroxy, cyano, alkoxy, hydroxyalkyl, cycloalkyl, heterocyclyl, aryl and heteroaryl.

4. The compound of formula (I) according to any one of claims 1 to 3, wherein n is 0, 1 or 2.

5. The compound of formula (I) according to claim 1, being a compound of formula (II):



(II)

or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,
wherein:

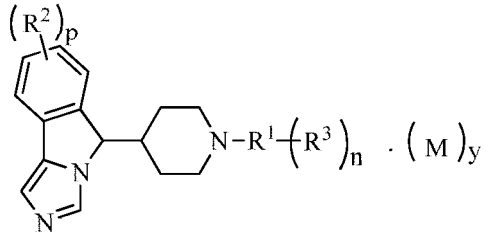
X is CH or N;

R^1 to R^3, M, p, n and y are as defined in claim 1;

a is an integer of 0, 1, 2 or 3; and

b is an integer of 0, 1, 2 or 3.

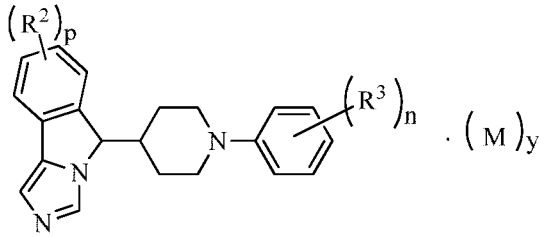
6. The compound of formula (I) according to any one of claims 1 to 5, being a compound of formula (III):



(III)

or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,
wherein R^1 to R^3, M, p, n and y are as defined in claim 1.

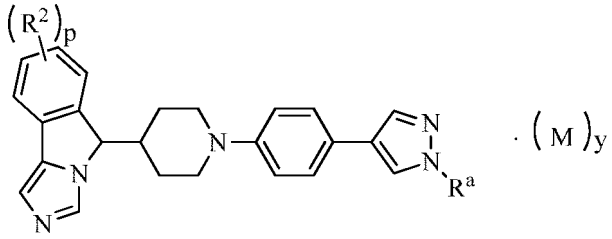
7. The compound of formula (I) according to any one of claims 1, 5 and 6, being a compound of formula (IV):



(IV)

or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,
wherein R^2, R^3, M, p, n and y are as defined in claim 1.

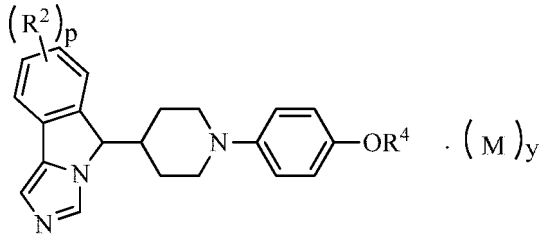
8. The compound of formula (I) according to any one of claims 1, 5, 6 and 7, being a compound of formula (IV-1):



(IV -1)

or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,
wherein R^2, R^a, M, p and y are as defined in claim 1.

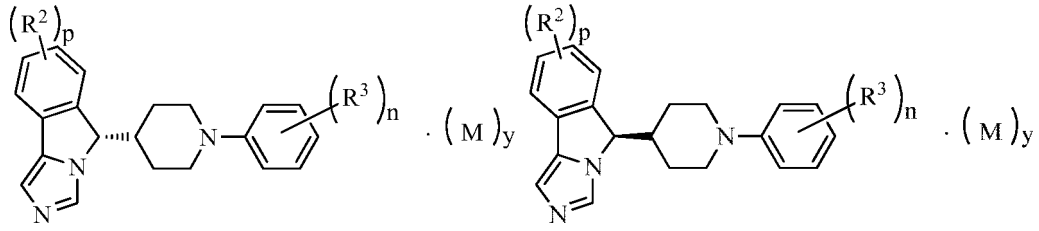
9. The compound of formula (I) according to any one of claims 1, 5, 6 and 7, being a compound of formula (IV-2):



(IV -2)

or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,
wherein R^2, R^4, M, p and y are as defined in claim 1.

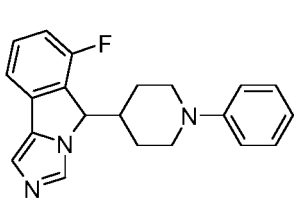
10. The compound of formula (I) according to any one of claims 1, 5, 6 and 7, being a compound of formula (IV-A) or formula (IV-B):



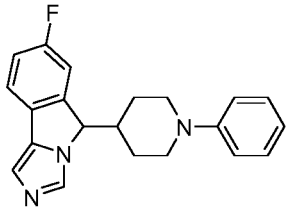
(IV-A) (IV-B)

or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or a pharmaceutically acceptable salt thereof,
wherein R^2, R^3, M, p, n and y are as defined in claim 1.

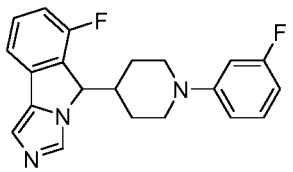
11. The compound of formula (I) according to any one of claims 1 to 10 selected from the group consisting of:



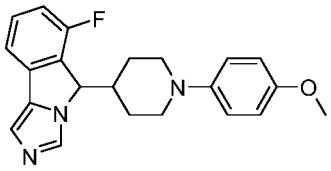
1h



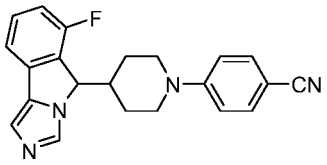
2k



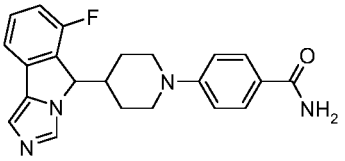
3a



4a



5a



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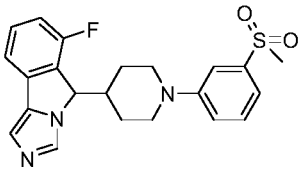

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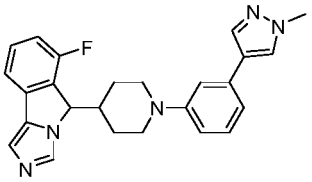

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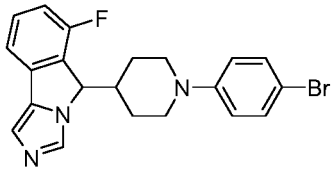

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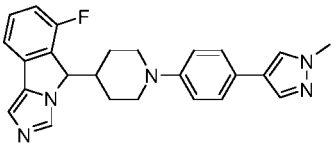

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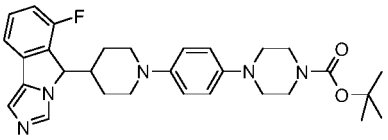

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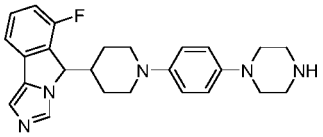

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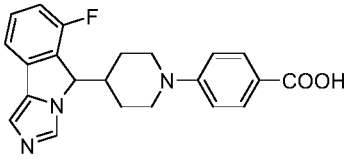

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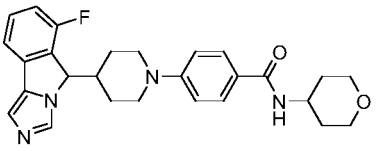

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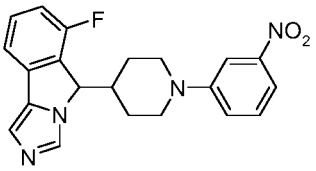

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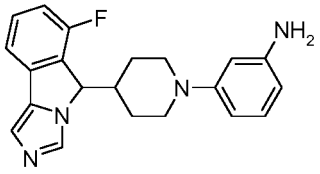

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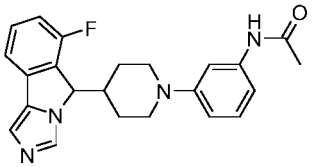

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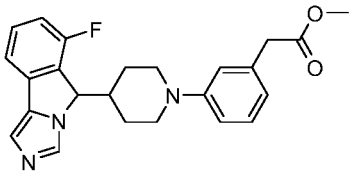

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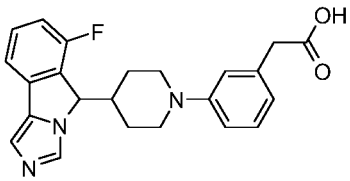

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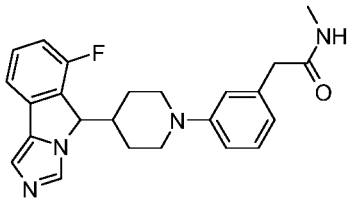

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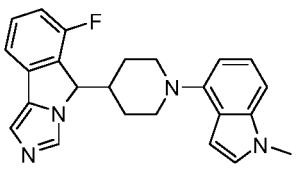

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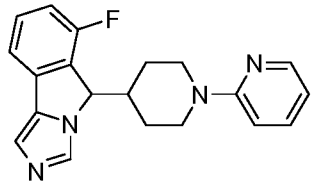

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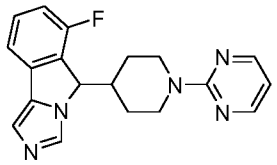

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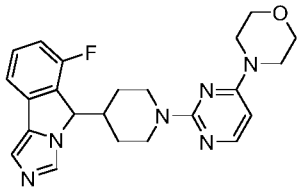

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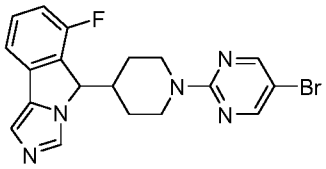

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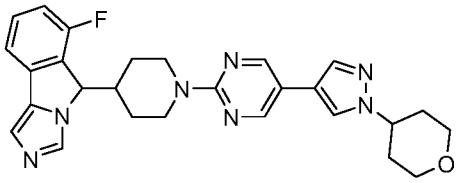

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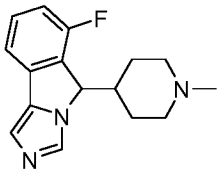

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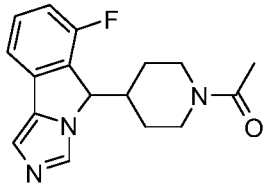

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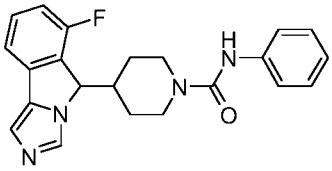

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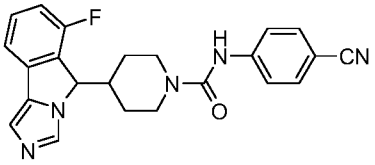

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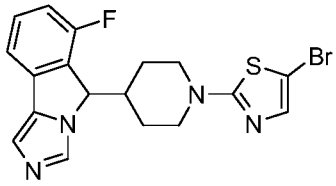

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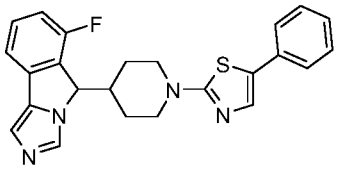

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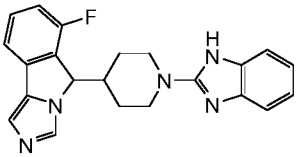

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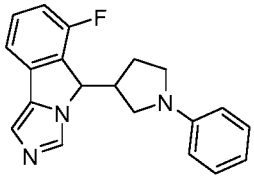

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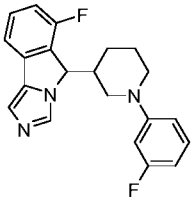

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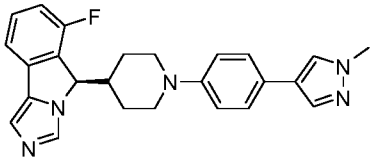

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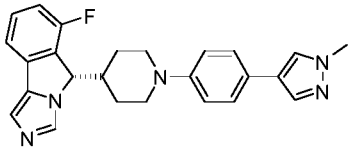

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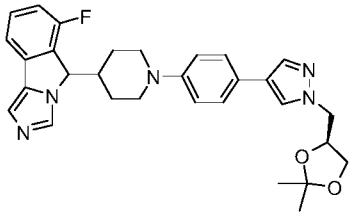

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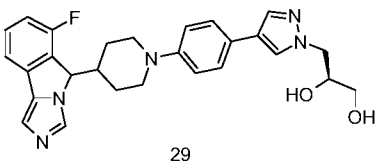

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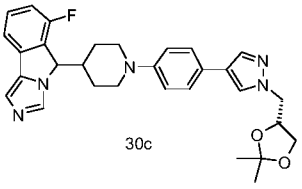

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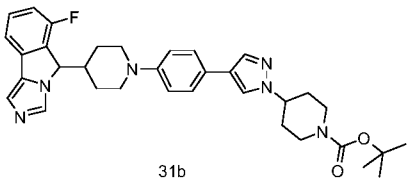

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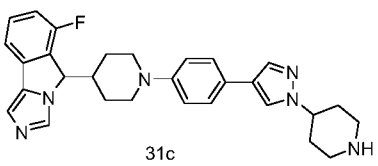

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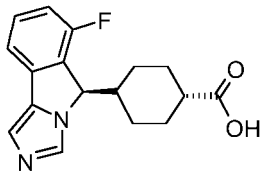

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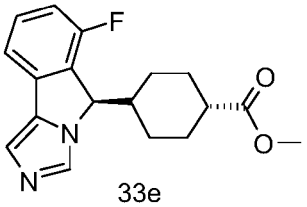

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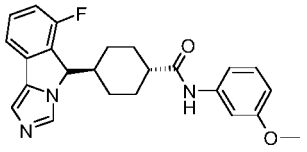

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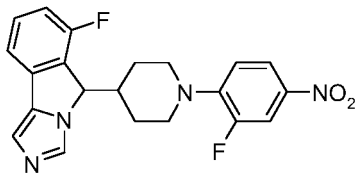

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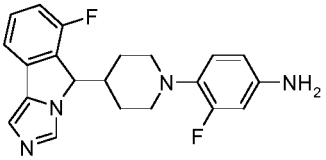

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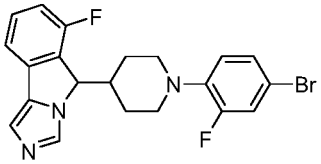

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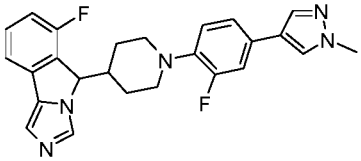

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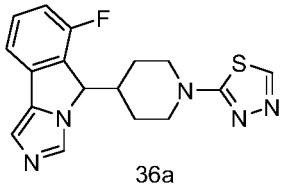

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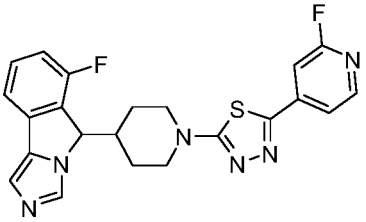

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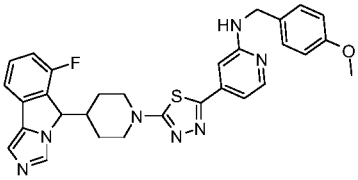

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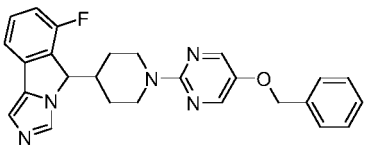

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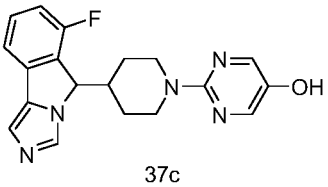

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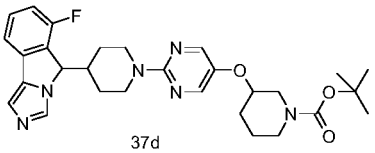

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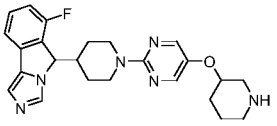

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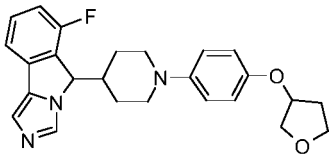

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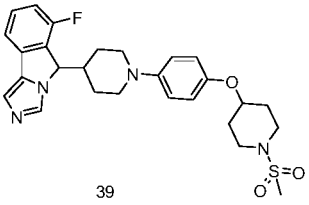

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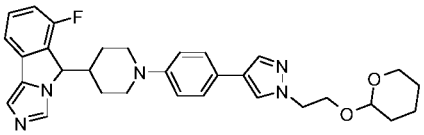

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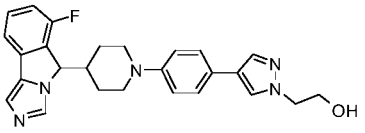

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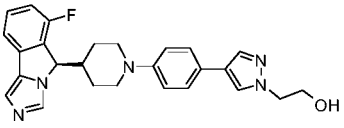

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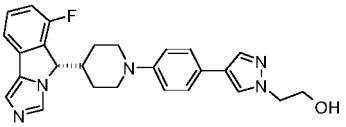

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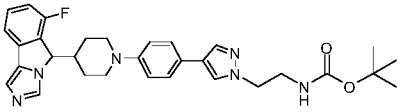

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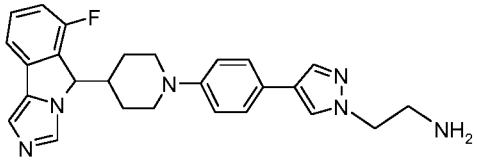
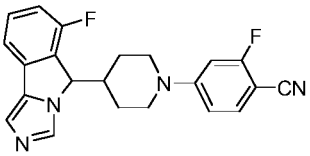


43c



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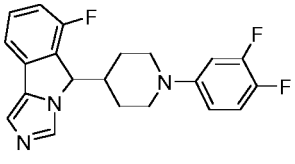

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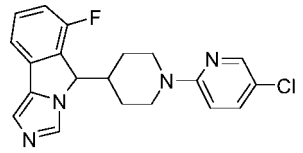
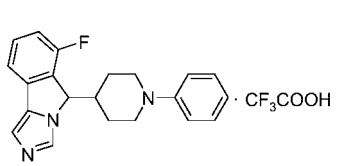


and 47 .

12. The compound of formula (I) according to any one of claims 1 to 10, selected from the group consisting of:



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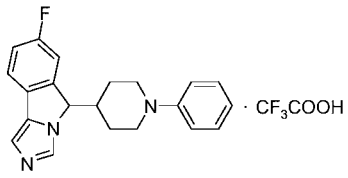

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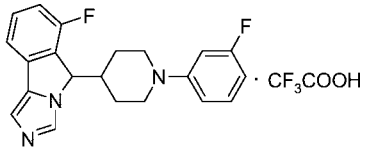

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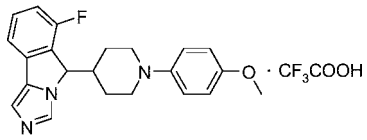

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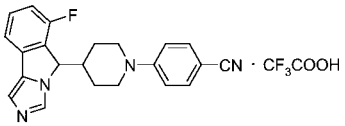

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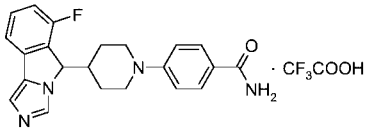

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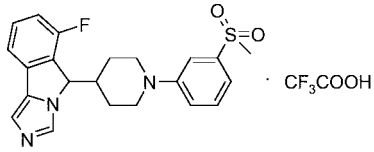

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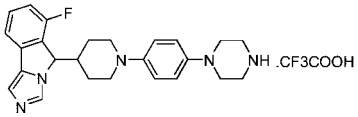

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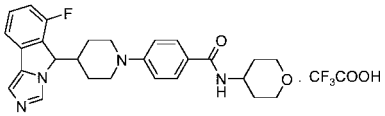

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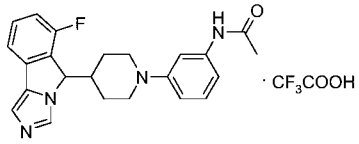

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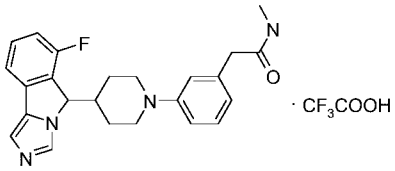

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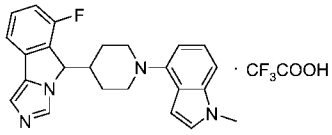

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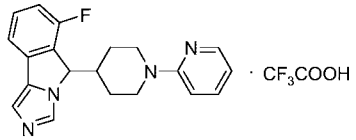

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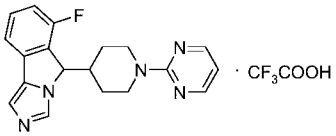

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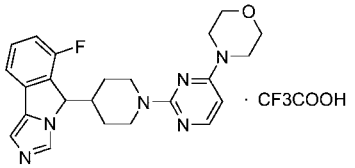

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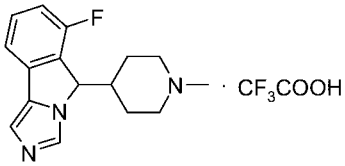

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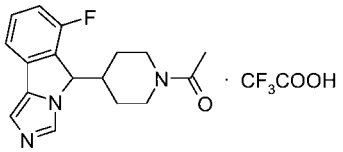

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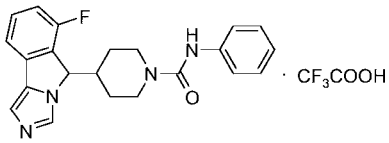

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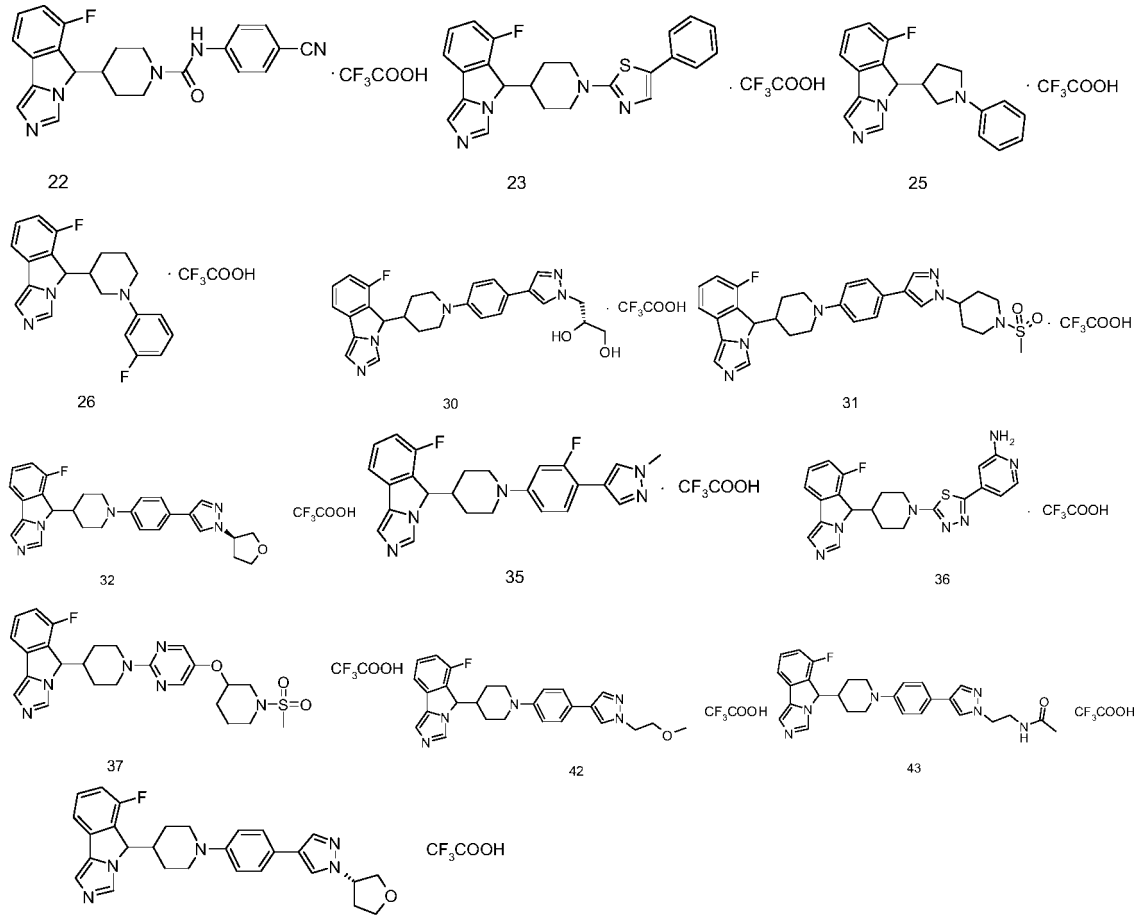
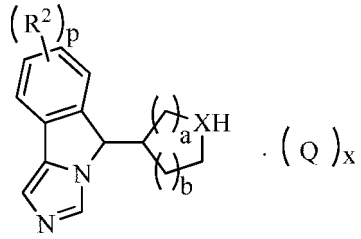


and .

13. A compound of formula (V):



(V)

or a tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof,

wherein,

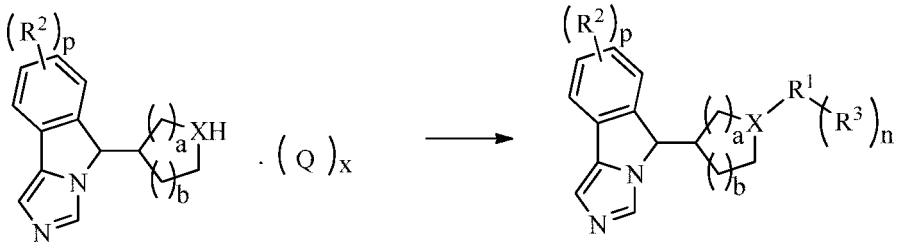
Q is inorganic acid or organic acid, preferably trifluoroacetic acid;

X is CH or N;

R^2, p, a and b are as defined in claim 5; and

x is an integer of 0, 1, 2 or 3.

14. A process for preparing a compound of formula (II-1), comprising the steps of:



(V) (II-1)

coupling a compound of formula (V) with a halide of R^1 under an alkaline condition in the presence of a catalyst, then optionally reacting the resulting product with a boric acid or borate ester of R^3 to obtain the compound of formula (II-1);

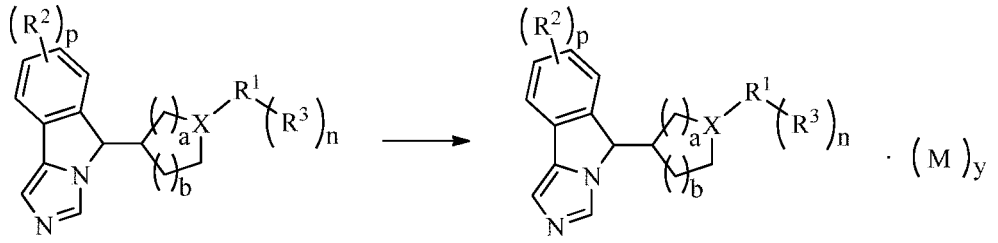
wherein:

X is N;

R^1 to R^3, p, n, a and b are as defined in claim 5; and

Q and x are as defined in claim 13.

15. A process for preparing the compound of formula (II) according to claim 5, comprising a step of:



(II-1) (II)

salifying a compound of formula (II-1) under an acidic condition to obtain the compound of formula (II);

wherein:

X is CH or N;

R^1 to R^3, M, p, y, n, a and b are as defined in claim 5.

16. A pharmaceutical composition comprising a therapeutically effective amount of the compound of formula (I) or the tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or the pharmaceutically acceptable salt thereof according to any one of claims 1 to 12, and a pharmaceutically acceptable carrier, diluent or excipient.

17. Use of the compound of formula (I) or the tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or the pharmaceutically acceptable salt thereof according to any one of claims 1 to 12, or the pharmaceutical composition according to claim 16 in the preparation of a medicament for preventing

and/or treating a disease with the pathological feature of IDO-mediated tryptophan metabolic pathway.

18. The use according to claim 17, wherein the disease with the pathological feature of IDO-mediated tryptophan metabolic pathway is selected from the group consisting of cancer, myelodysplastic syndrome, alzheimer's disease, autoimmune disease, depression, anxiety, cataract, psychological disorder and AIDS, wherein the cancer is preferably selected from the group consisting of breast cancer, cervical cancer, colon cancer, lung cancer, gastric cancer, rectal cancer, pancreatic cancer, brain cancer, skin cancer, oral cancer, prostate cancer, bone cancer, kidney cancer, ovarian cancer, bladder cancer, liver cancer, tubal tumor, ovarian tumor, peritoneal tumor, phase IV melanoma, glioma, neuroblastoma, hepatocellular carcinoma, papillomatosis, head and neck tumor, leukemia, lymphoma, myeloma and non-small cell lung cancer.

19. A method for preventing and/or treating a disease with the pathological feature of IDO-mediated tryptophan metabolic pathway in a subject comprising administering a therapeutically effective amount of the compound of formula (I) or the tautomer, mesomer, racemate, enantiomer, diastereomer thereof, or mixtures thereof, or the pharmaceutically acceptable salt thereof according to any one of claims 1 to 12, or the pharmaceutical composition according to claim 16, to the subject.

20. The method according to claim 19, wherein the disease with the pathological feature of IDO-mediated tryptophan metabolic pathway is selected from the group consisting of cancer, myelodysplastic syndrome, alzheimer's disease, autoimmune disease, depression, anxiety, cataract, psychological disorder and AIDS, wherein the cancer is preferably selected from the group consisting of breast cancer, cervical cancer, colon cancer, lung cancer, gastric cancer, rectal cancer, pancreatic cancer, brain cancer, skin cancer, oral cancer, prostate cancer, bone cancer, kidney cancer, ovarian cancer, bladder cancer, liver cancer, tubal tumor, ovarian tumor, peritoneal tumor, phase IV melanoma, glioma, neuroblastoma, hepatocellular carcinoma, papillomatosis, head and neck tumor, leukemia, lymphoma, myeloma and non-small cell lung cancer.