CRYSTALLINE FORM OF (S)-7-(1-ACRYLOYLPIPERIDIN-4-YL)-2-(4-PHENOXYPHENYL)-4,5,6,7-TETRA-HYDROPYRAZOLO[1,5-A]PYRIMIDINE-3-CARBOXAMIDE, PREPARATION, AND USES THEREOF

FIELD OF THE INVENTION

[0001] The present invention relates to a crystalline form of (S)-7-(1-acryloylpiperidin-4-yl)-2-(4-phenoxyphenyl)-4,5,6,7-tetra-hydropyrazolo[1,5-a]pyrimidine-3-carboxamide. The present invention also relates to methods of preparing the crystalline form and methods of using the crystalline form as a Btk inhibitor.

BACKGROUND OF THE INVENTION

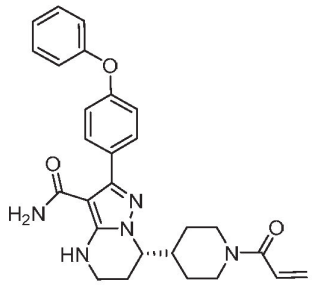
[0002] Bruton's tyrosine kinase (Btk) belongs to the Tec tyrosine kinase family (*Vetrie et al., Nature 361: 226-233, 1993; Bradshaw, Cell Signal. 22: 1175-84, 2010*). Btk is primarily expressed in most hematopoietic cells such as B cells, mast cells and macrophages (*Smith et al., J. Immunol. 152: 557-565, 1994*) and is localized in bone marrow, spleen and lymph node tissue. Btk plays important roles in B-cell receptor (BCR) and FcR signaling pathways, which involve in B-cell development, differentiation (*Khan, Immunol. Res. 23: 147, 2001*). Btk is activated by upstream Src-family kinases. Once activated, Btk in turn phosphorylates PLC gamma, leading to effects on B-cell function and survival (*Humphries et al., J. Biol.Chem. 279: 37651, 2004*).

[0003] These signaling pathways must be precisely regulated. Mutations in the gene encoding Btk cause an inherited B-cell specific immunodeficiency disease in humans, known as X-linked agammaglobulinemia (XLA) (*Conley et al., Annu. Rev. Immunol. 27: 199-227, 2009*). Aberrant BCR-mediated signaling may result in dysregulated B-cell activation leading to a number of autoimmune and inflammatory diseases. Preclinical studies show that Btk deficient mice are resistant to developing collagen- induced arthritis. Moreover, clinical studies of Rituxan, a CD20 antibody to deplete mature B-cells, reveal the key role of B-cells in a number of inflammatory diseases such as rheumatoid arthritis, systemic lupus erythematosus and multiple sclerosis (*Gurcan et al., Int. Immunopharmacol. 9: 10-25, 2009*). Therefore, Btk inhibitors can be used to treat autoimmune and/or inflammatory diseases.

[0004] In addition, aberrant activation of Btk plays an important role in pathogenesis of B-cell lymphomas indicating that inhibition of Btk is useful in the treatment of hematological malignancies (*Davis et al., Nature 463: 88-92, 2010*). Preliminary clinical trial results showed

that the Btk inhibitor PCI-32765 was effective in treatment of several types of B-cell lymphoma (for example, 54thAmerican Society of Hematology (ASH) annual meeting abstract, Dec. 2012: 686 The Bruton's Tyrosine Kinase (Btk) Inhibitor, Ibrutinib (PCI- 32765), Has Preferential Activity in the ABC Subtype of Relapsed/Refractory De Novo Diffuse Large B-Cell Lymphoma (DLBCL): Interim Results of a Multicenter, Open-Label, Phase I Study). Because Btk plays a central role as a mediator in multiple signal transduction pathways, inhibitors of Btk are of great interest as anti-inflammatory and/or anti-cancer agents (*Mohamed et al., Immunol. Rev. 228: 58-73, 2009*; *Pan, Drug News perspect 21: 357-362, 2008*; *Rokosz et al., Expert Opin. Ther. Targets 12: 883-903, 2008*; *Uckun et al., Anti-cancer Agents Med. Chem. 7: 624-632, 2007*; *Lou et al, J. Med. Chem. 55(10): 4539-4550, 2012*).

[0005] International application WO2014173289A disclosed a series of fused heterocyclic compounds as Btk inhibitors. In particular, WO2014173289A disclosed (S)-7-(1-acryloylpiperidin-4-yl)-2-(4-phenoxyphenyl)-4,5,6,7-tetra-hydropyrazolo[1,5-a]pyrimidine-3-carboxamide (hereinafter **Compound 1**)



Compound 1

[0006] **Compound 1** is a potent, specific and irreversible BTK kinase inhibitor. The data generated in preclinical studies using biochemical, cell based and animal studies suggested that **Compound 1** could offer significant benefit in inhibiting tumor growth in B-cell malignancies. As **Compound 1** was shown to be more selective than ibrutinib for inhibition of BTK *vs.* EGFR, FGR, FRK, HER2, HER4, ITK, JAK3, LCK, and TEC, it is expected to give rise to less side-effects than ibrutinib in clinic. In addition, **Compound 1** showed significantly less inhibition of rituximab-induced antigen-dependent cell-mediated cytotoxicity (ADCC) than ibrutinib due to weaker ITK inhibition, and therefore may provide better efficacy when combined with rituximab or other ADCC-dependent antibody in treating B-cell malignancies.

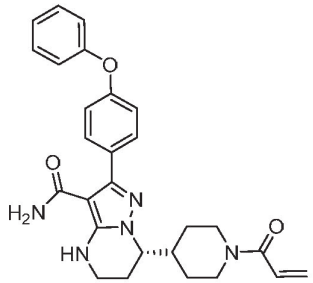
[0007] Preclinical safety evaluation has demonstrated that **Compound 1** was safer than ibrutinib in terms of the overall tolerance and severe toxicities in both rat and dog single and repeat dose toxicity studies up to 28 days. Additionally, **Compound 1** had better bioavailability without accumulation issues observed for ibrutinib. These unique characteristics warrant further evaluation of **Compound 1** in clinical studies.

[0008] However, **Compound 1** was found to be an amorphous form according to the preparation method for Compound 27 in WO 2014173289A, which was further confirmed by the X-Ray Powder Diffraction pattern of **FIG. 7A**. The amorphous form was shown to have a low glass transition temperature as shown in **FIG. 7B**, indicating some difficulties in the drug formulation with the amorphous form, such as low stability and hard to purify. Therefore, it's necessary to develop a new form of **Compound 1** which possesses characteristics such as high melting point and better stability, suitable for drug formulation.

SUMMARY OF THE INVENTION

[0009] The inventors have unexpectedly found a crystalline form of **Compound 1**, which possesses a high melting point and shows an extremely stable profile even when stored at 25°C/60%RH for up to 24 months or stored at 40°C/75%RH condition for up to 6 months.

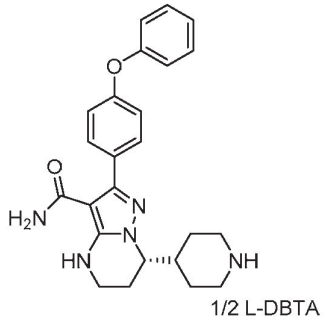
[0010] In a first aspect, disclosed herein is a crystalline form of **Compound 1**,



Compound 1 .

[0011] In some embodiments, the crystalline form of **Compound 1** is a crystalline anhydrate (herein referred to as **"**Crystalline Form A**").**

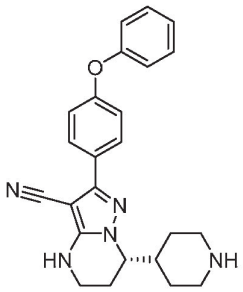
[0012] In a second aspect, disclosed herein is a crystalline form of Compound BG-13, which has an X-ray powder diffraction pattern substantially in accordance with **FIG. 11**.



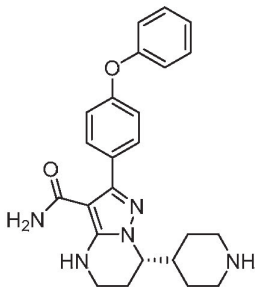
Compound BG-13

[0013] In a third aspect, disclosed herein is a method of preparing **Compound 1**.

[0014] Also disclosed herein is an intermediate compound of Formula Ie or a salt thereof, or Formula If or a salt thereof used to prepare **Compound 1**,



Formula Ie



Formula If

[0015] In a fourth aspect, disclosed herein is a method of preparing Crystalline Form A disclosed herein.

[0016] In a fifth aspect, disclosed herein is a pharmaceutical composition comprising a therapeutically effective amount of Crystalline Form A disclosed herein.

[0017] In a sixth aspect, disclosed herein is a method of treating a disease associated with undesirable Btk activity in a subject by administering to a subject Crystalline Form A disclosed herein.

[0018] In a seventh aspect, disclosed herein is a method of treating a disease selected from an allergic disease, an autoimmune disease, an inflammatory disease, a cancer, or a combination of two or more thereof, in a subject by administering to the subject Crystalline Form A disclosed herein.

[0019] In an eighth aspect, disclosed herein is a method of treating a B-cell proliferative disease, selected from B-cell malignancies, or relapsed / refractory B-cell malignancies, in a subject by administering to the subject Crystalline Form A disclosed herein. In some embodiment of this aspect, disclosed herein is a method of treating a B-cell proliferative disease, selected from chronic lymphocytic, non-Hodgkin's lymphoma, diffuse large B cell lymphoma, mantle cell lymphoma, follicular lymphoma, chronic lymphocytic leukemia, small lymphocytic lymphoma, waldenstrom macroglobulinemia, marginal zone lymphoma, Hairy cell leukemia, Burkitt's-like leukemia or a combination of two or more thereof, in a subject by administering to the subject Crystalline Form A disclosed herein.

[0020] In a ninth aspect, disclosed herein is a use of Crystalline Form A disclosed herein in manufacturing a medicament for treatment of at least one disease associated with undesirable Btk activity, in a subject.

[0021] In a tenth aspect, disclosed herein is a use of Crystalline Form A disclosed herein in manufacturing a medicament for treatment of a disease selected from an allergic disease, an autoimmune disease, an inflammatory disease, a cancer, or a combination of two or more thereof, in a subject.

[0022] In an eleventh aspect, disclosed herein is a use of Crystalline Form A disclosed herein in manufacturing a medicament for treatment of a B-cell proliferative disease selected from B-cell malignancies, or relapsed / refractory B-cell malignancies, in a subject. In some embodiment of this aspect, disclosed herein is a use of Crystalline Form A disclosed herein in manufacturing a medicament for treatment of a B-cell proliferative disease selected from chronic lymphocytic, non-Hodgkin's lymphoma, diffuse large B cell lymphoma, mantle cell lymphoma, follicular lymphoma, chronic lymphocytic leukemia, small lymphocytic lymphoma, waldenstrom macroglobulinemia, marginal zone lymphoma, Hairy cell leukemia, Burkitt's-like leukemia, or a combination of two or more thereof, in a subject.

[0023] In a twelfth aspect, disclosed herein is a process for preparing a crystalline form A of Compound 1, comprising mixing amorphous form of compound 1 with the following solvent system to form a clear solution; keeping the solution at room temperature or heat with or without stirring for a certain period of time to precipitate the crystalline form A, wherein the solvent system is:

ethyl acetate : hexane = 1:0.6-0.7 by volume ratio;

ethyl acetate : heptane = 1:0.6-0.7 by volume ratio;

ethyl acetate : cyclohexane = 1:0.6-1.2 by volume ratio;

methyl acetate: hexane = 1:0.6-1.2 by volume ratio;

toluene : hexane = 1.0:0.2-0.4 by volume ratio;

toluene : cyclohexane = 1.0:0.1-0.2 by volume ratio;

methyl acetate : cyclohexane = 0.6-0.8:1.0 by volume ratio;

IPAC : cyclohexane = 1.0:0.2-1.0 by volume ratio; or

Isobutyl acetate: cyclohexane = 1.0:0.2-1.0 by volume ratio.

[0024] In one embodiment, the amorphous form of compound 1 has an ee value more than 90%. In other embodiment, the amorphous form of compound 1 has an ee value of 97%.

BRIEF DESCRIPTIONS OF THE DRAWINGS

[0025] **FIG. 1** shows the XRPD pattern of Crystalline Form A.

[0026] **FIG. 2** shows the DSC curve of Crystalline Form A.

[0027] **FIG. 3** shows the TGA curve of Crystalline Form A.

[0028] **FIG. 4** shows the ^{1}H-NMR of Crystalline Form A.

[0029] **FIG. 5** shows the ^{13}C-NMR of Crystalline Form A.

[0030] **FIG. 6** shows DVS plot of Crystalline Form A.

[0031] **FIG. 7A** shows the XRPD pattern of the amorphous form of **Compound 1.**

[0032] **FIG. 7B** shows the mDSC curve of the amorphous form of Compound 1, showing the glass transition temperature of the amorphous form is 79.7 ºC (mid-point temperature).

[0033] **FIG. 8** shows the absolute structure of single crystal of BG-13.

[0034] **FIG. 9** illustrates hydrogen bonds of single crystal of BG-13.

[0035] **FIG. 10** shows a crystal packing of single crystal of BG-13.

[0036] **FIG. 11** shows the XRPD pattern of single crystal of BG-13.

DETAILED DESCRIPTION OF THE INVENTION

[0037] The inventors have unexpectedly found that **Compound 1** in a crystalline form**,** named as Crystalline Form A, can only be obtained at a particular conditions, depending on the ee value of the starting materials, and the ratio of the co-solvents and so on. A polymorph study was also performed through methods of slow evaporation, anti-solvent addition, slow cooling, vapor diffusion and polymer-induced crystallization. Most of experiments failed to get crystalline form, which indicates the obtaining of Crystalline Form A is not straight forward.

[0038] Further characterization results have revealed that Crystalline Form A is an anhydrate with a melting point of 139.4 ±2ºC (onset temperature). To evaluate stability, the sample of Crystalline Form A was stored at 80 ºC for 2 days, 25°C/60%RH for up to 24 months or 40°C/75%RH condition for up to 6 months, and characterized by XRPD before, during and after the stability test. Results showed no crystal form change was observed for all the above periods, indicating good physical stability of Crystalline Form A at 80 ºC or stored at 25°C/60%RH for up to 24 months and at 40°C/75%RH condition for up to 6 months.

[0039] In some embodiments, Crystalline Form A has an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values independently selected from: approximately 14.8±0.2°, 16.4±0.2° and 21.4±0.2°.

[0040] In some embodiments, Crystalline Form A has an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values independently selected from: approximately 14.8±0.2°, 15.6±0.2°, 16.4±0.2° and 21.4±0.2°.

[0041] In some embodiments, Crystalline Form A has an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values independently selected from: approximately 12.2±0.2°, 12.9±0.2°, 14.8±0.2°, 15.6±0.2°, 16.4±0.2° and 21.4±0.2°.

[0042] In some embodiments, Crystalline Form A has an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values independently selected from:

approximately 12.2±0.2°, 12.9±0.2°, 14.8±0.2°, 15.6±0.2°, 16.4±0.2°, 17.7±0.2°, 18.5±0.2°, 20.7±0.2° and 21.4±0.2°.

[0043] In some embodiments, Crystalline Form A has an X-ray powder diffraction pattern substantially in accordance with **FIG. 1**.

[0044] In some embodiments, Crystalline Form A has an X-ray powder diffraction pattern summarized in **Table 1**.

[0045] Table 1 X-ray Diffraction Pattern of Crystalline Form A

Peak#	Diffraction angle (2-theta)	Spacing	Relative intensity
1	5.432	16.26908	7.37
2	10.799	8.19295	2.40
3	12.188	7.26191	13.19
4	12.942	6.84040	13.51
5	14.820	5.97780	28.09
6	15.587	5.68534	19.63
7	16.350	5.42177	29.30
8	17.662	5.02158	13.62
9	18.452	4.80853	11.39
10	18.689	4.74791	8.26
11	20.729	4.28515	11.07
12	21.420	4.14847	100.00
13	22.035	4.03409	7.59
14	22.864	3.88958	6.70
15	23.684	3.75673	5.24
16	25.111	3.54646	2.43
17	26.525	3.36044	5.13
18	26.906	3.31381	6.41
19	27.126	3.28741	6.92
20	29.641	3.01393	4.61
21	30.755	2.90724	2.58
22	36.421	2.46692	1.29

[0046] In some preferred embodiments, Crystalline Form A has a melting point of 139 ±2°C (onset temperature).

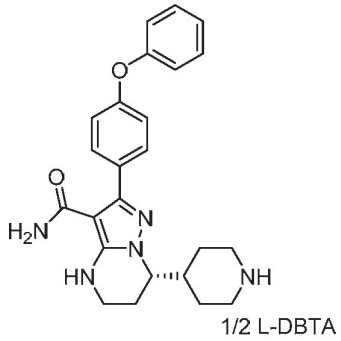
[0047] In some preferred embodiments, Crystalline Form A has a DSC substantially in accordance with **FIG. 2**.

[0048] In some preferred embodiments, Crystalline Form A has a TGA substantially in accordance with **FIG. 3.**

[0049] In some embodiments, the crystalline Form A is slightly hygroscopic. In some embodiments, the crystalline Form A is unsolvated.

[0050] In some embodiments, the crystalline Form A has substantially the same X-ray powder diffraction (XRPD) pattern post storage at 40°C and 75% RH for up to 6 months. In some embodiments, the crystalline Form A has substantially the same X-ray powder diffraction (XRPD) pattern post storage at 25°C and 60% RH for up to 24 months.

[0051] Also disclosed herein is a crystalline form of Compound **BG-13**, which has an X-ray powder diffraction pattern substantially in accordance with **FIG. 11**,



Compound BG-13 .

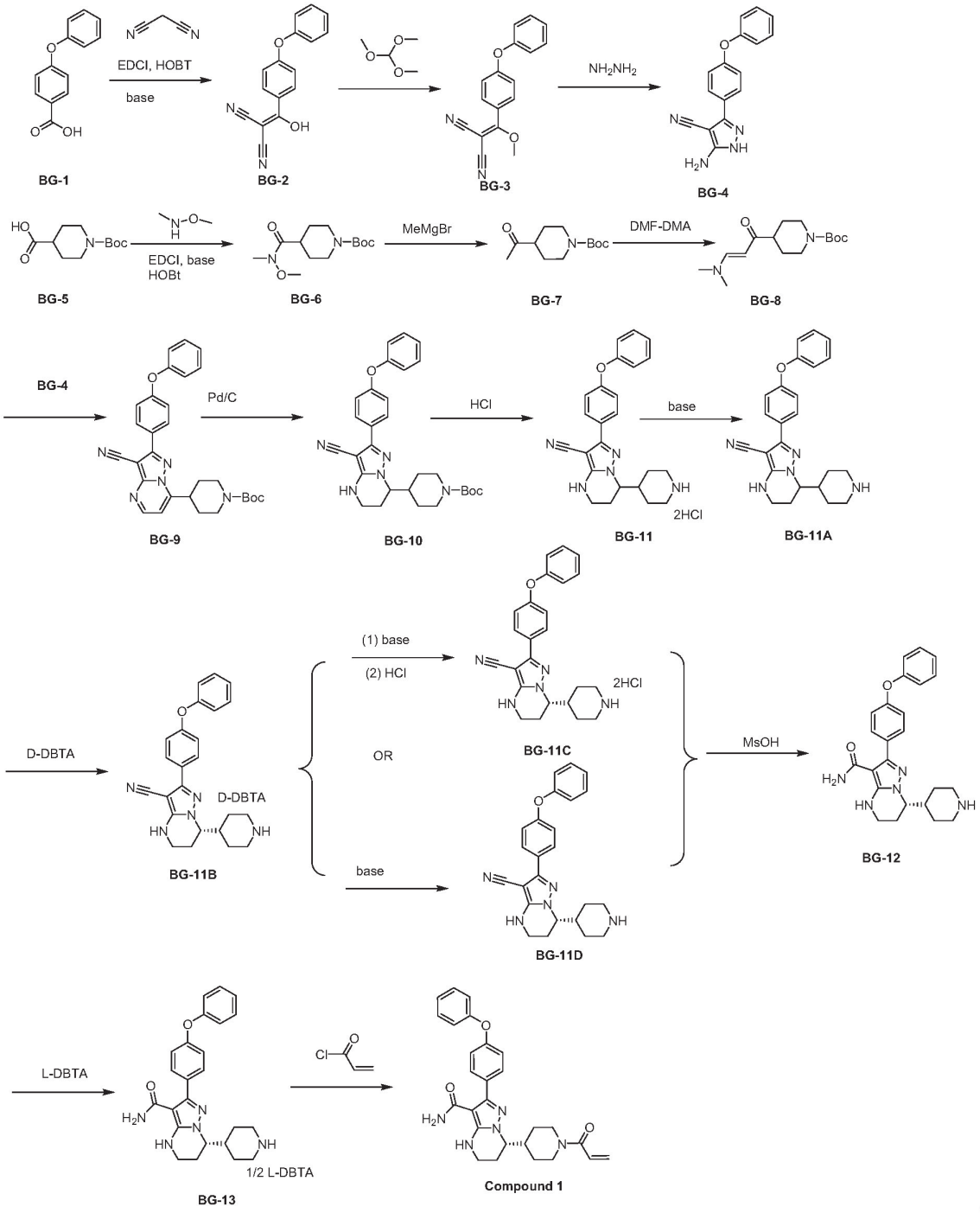
[0052] In some of embodiments, the crystalline form of **BG-13** is a single crystal, which has a unit cell dimensions comprising a=16.7939(4)Å, b=7.9871(2)Å, c=23.5438(5)Å, alpha=90.00deg., beta=108.0460(10)deg., gamma=90.00deg.

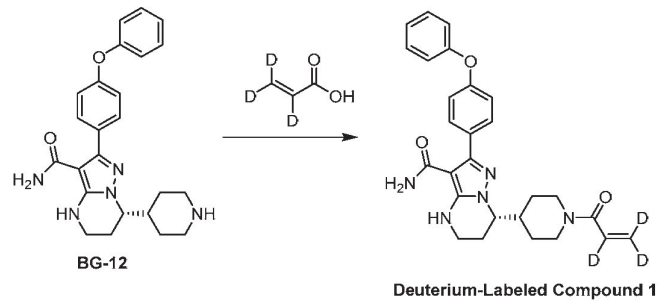
[0053] The inventors have deduced the absolute configurations of **Compound 1** to be S from the single crystal X-ray structural analysis of intermediate **BG-13**.

[0054] Also disclosed herein is a method for preparing **Compound 1** and deuterium-labeled **Compound 1**, such as the procedures depicted in **Scheme 1**. The new synthetic methods and the crystallization/recrystallization procedures of **Compound 1** via crystalline Form A disclosed herein overcome many issues associated with the processes reported previously, such as preparation of the key chiral intermediate with >98% optical purity, improve the purity of **Compound 1** to reach the acceptance criteria in the specification, control the impurities in **Compound 1** and provide many advantages over the existing processes. Notably, the methods disclosed herein are especially suitable for reproducible, commercial-scale manufacture of **Compound 1** in high quality and good yields. In an alternative process, BG-9 or its analogs in

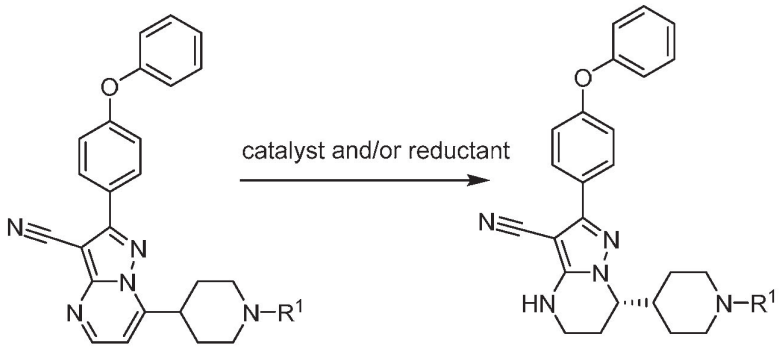
Scheme 1 could be asymmetrically reduced with low to excellent enantioselectivities (5% ee. to 95% ee). The process of other steps are similar to those listed in Scheme 1.

[0055] Scheme 1: Preparation of Compound 1 and deuterium-labeled **Compound 1**





[0056] Also disclosed herein is a method for preparing the compound of Formula **Ia**, comprising asymmetrically reducing the compound of Formula **I** in the presence of the catalyst and/or reductant to produce the compound of Formula **Ia**,



Formula **I** Formula **Ia**

wherein R^1 is hydrogen or an amino protecting group.

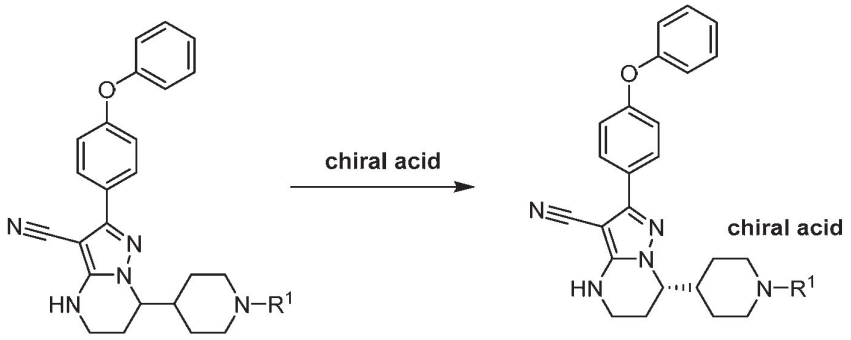
[0057] In some embodiments, the amino protecting group includes, but not limit to, acetyl, propionyl, butyryl, phenylacetyl, benzoyl, toluyl, Phenoxyacetyl (POA), methoxycarbonyl, ethoxycarbonyl, 2,2,2-trichloroethoxycarbonyl, tert-butyloxycarbonyl (BOC), 2-iodoethoxycarbonyl, carbobenzoxy (CBZ), 4-methoxybenzyloxycarbonyl, (Fluoren-9-ylmethoxy)carbonyl (Fmoc), 4-methoxy-2,3,6-trimethylbenzenesulphonyl (Mtr), benzyl, methyl or 4-methoxybenzyl.

[0058] In some embodiments, wherein the catalyst is a neutral catalyst system or a cationic catalyst system. In some preferred embodiments, the catalyst is a iridium catalyst system including, but not limited to, $[Ir(COD)Cl]_2$/(R or S)-MeO-Biphep, $[Ir(COD)Cl]_2$/(R or S)-Binap, $[Ir(COD)Cl]_2$/(R or S)-Tol-Binap, $[Ir(COD)Cl]_2$/(R or S)-xyl-Binap, $[Ir(COD)Cl]_2$/(S,S or R,R)-Diop, $[Ir(COD)Cl]_2$/(R or S)-P-Phos, $[Ir(COD)Cl]_2$/(R or S)-Tol-P-Phos, $[Ir(COD)Cl]_2$/(R or S)-Xyl-P-Phos, $[Ir(COD)Cl]_2$/(R,R or S,S)-Me-DuPhos, $[Ir(COD)Cl]_2$/(R or S)-SegPhos, $[Ir(\mu\text{-}Cl)(cod)]_2$/(R or S)-Ship, $[Ir(\mu\text{-}Cl)(cod)]_2$/(R or S)-Siphos, $[Ir(\mu\text{-}Cl)(cod)]_2$/(R or S)-Siphos-PE, $[Ir(\mu\text{-}Cl)(cod)]_2$/(R or S)-MonoPhos, $[Ir(\mu\text{-}Cl)(cod)]_2$/(R or S)-tol-SDP, $[Ir(\mu\text{-}Cl)(cod)]_2$/(S,S or R,R)-Diop, $[Ir(\mu\text{-}Cl)(cod)]_2$/(S,R or R,S)-Josiphos, $[Ir(\mu\text{-}Cl)(cod)]_2$/(R or S)-Binap, $[Ir(\mu\text{-}Cl)(cod)]_2$/(R or S)-MeO-Biphep,

[Ir(μ-Cl)(cod)]$_2$/(R or S)-Synphos, or [Ir(μ-Cl)(cod)]$_2$/(R or S)-Difluorphosor [Ir(cod)$_2$]$^+$X$^-$ (X: e.g. BF_4, NO_3, OTf, PF_6, SbF_6 and BarF) plus related ligands as described above (*Wen-Bo et al., J. AM. CHEM. SOC. 125, 10536-10537 2003. Damien et al., J. Org. Chem. 77, 4544−4556, 2012. Milos et al., Org. Process Res. Dev. 16, 1293−1300, 2012.*); a rhodium catalyst system including, but not limited to, [Rh(COD)$_2$]BF_4 plus ligands described above *(Xiang-Ping et al.,Top Organomet Chem 36, 313–354,2011)*; or, a ruthenium catalyst system including, but not limited to, $RuCl_2$(R or S)-BINAP/(R or S)-DAIPEN, $RuCl_2$(R or S)-BINAP/(R,R or S,S)-DPEN, $RuCl_2$(S or R)-BINAP (S,S or R,R)-DACH, $RuCl_2$[(R or S)-Tol-BINAP][(S,S or R,R)-DPEN], $RuCl_2$(R,R or S,S)-Me-DuPHOS/(R,R or S,S)-DPEN, $RuCl_2$(R,R or S,S)-Et-DuPHOS/(R,R or S,S)-DPEN, $RuCl_2$(R,R or S,S)-Et-DuPHOS/(R,R or S,S)-DACH, $RuCl_2$(S,S or R,R)-i-Pr-DuPHOS/(R,R or S,S)-DPEN, $RuCl_2$(R or S)-HexaPHEMP/(R,R or S,S)-DPEN, $RuCl_2$(R or S)-MeO-BIPHEP/(R,R or S,S)-DPEN *(Christopher et al., Adv. Synth. Catal. 345, 195-201, 2003. Julian et al., Adv. Synth. Catal. 345, 300-307, 2003.*).

[0059] The above method was found to produce excellent enantioselectivities up to 95% ee by using the above catalyst, especially the neutral or cationic iridium catalyst system.

[0060] Also disclosed herein is a method for resolving the compound of Formula **IIa** to produce the compound of Formula **IIb,** or improving the chiral purity of the compound of Formula **IIb**, comprising treating the racemic compound of Formula **IIa** with a chiral acid,

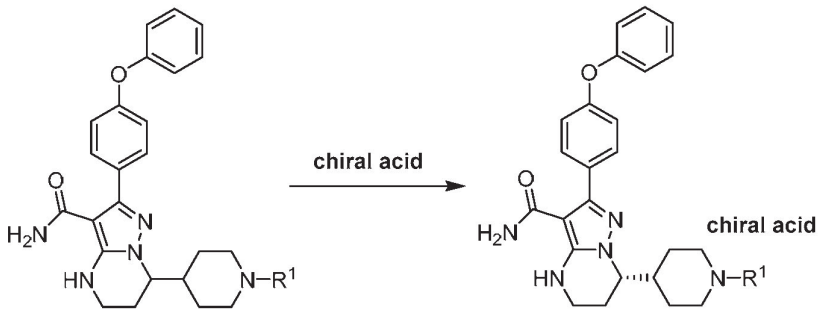


Formula **IIa** Formula **IIb**

wherein R^1 is hydrogen, methyl, benzyl, 4-methoxybenzyl or the other conventional amino protecting groups as mentioned above.

[0061] In some embodiments, the chiral acid includes, but not limited to, L-malic acid, D-malic acid, L-Mandelic acid, D-Mandelic acid, L-camphorsulfonic acid, D-camphorsulfonic acid, L-tartaric acid, D-tartaric acid, L-DBTA, D-DBTA, L-DTTA, or D-DTTA.

[0062] Also disclosed herein is a method for resolving a compound of Formula **Ic** to produce a compound of Formula **Id** or improving the chiral purity of formula **Id**, comprising treating the racemic compound of Formula **Ic** with a chiral acid,

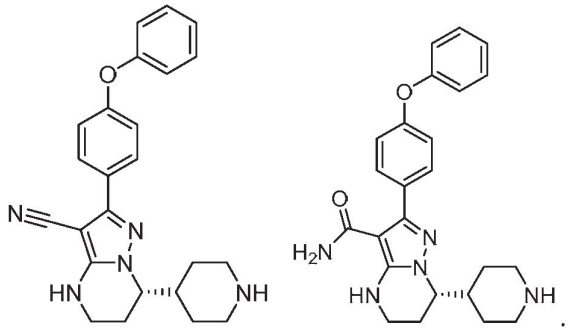


Formula **Ic** Formula **Id**

wherein R^1 is hydrogen, methyl, benzyl, 4-methoxybenzyl or the other conventional amino protecting groups as mentioned above.

[0063] In some embodiments, the chiral acid includes, but not limited to, L-malic acid, D-malic acid, L-Mandelic acid, D-Mandelic acid, L-camphorsulfonic acid, D-camphorsulfonic acid, L-tartaric acid, D-tartaric acid, L-DBTA, D-DBTA, L-DTTA, or D-DTTA.

[0064] Also disclosed herein is a compound of Formula **Ie** or a salt thereof, or Formula **If** or a salt thereof used to prepare **Compound 1**,



Formula **Ie** Formula **If**

[0065] Further, the present also provides methods of preparing Crystalline Form A. The crystalline form disclosed herein can be prepared by crystallizing the compound disclosed herein from a suitable solvent system comprising at least one solvent, which can be achieved by methods of spontaneous precipitation (evaporation), cooling, and/or adding anti-solvent (in which the compound disclosed herein has relatively lower solubility), in order to achieve oversaturation in a solvent system. Crystallization can also be achieved by using or not using crystal seeds which is suitable for crystallizing the crystalline forms disclosed herein.

[0066] In some embodiments, the method of preparing Crystalline Form A comprises the steps of dissolving (S)-7-(1-acryloylpiperidin-4-yl)-2-(4-phenoxyphenyl)-4,5,6,7-tetrahydropyrazolo[1,5-a]pyrimidine-3-carboxamide (**Compound 1**) in DCM, swapping to solvent EA, recrystallizing from EA/MTBE, to obtain the target crystalline form.

[0067] In some embodiments, the method of preparing Crystalline Form A comprises the steps of dissolving Compound 1 in EA, adding hexane, to obtain the target crystalline form.

[0068] In some embodiments, the method of preparing Crystalline Form A is achieved by adding an anti-solvent into the solution of the solid **Compound 1** or crude Form A in a solvent for dissolving the solid, wherein the anti-solvent including, but not limited to, H_2O and n-heptane, and the solvent for dissolving the solid including, but not limited to, acetone, DMAc, EtOAc, DCM, Toluene, and 2-MeTHF.

[0069] In some embodiments, the method of preparing Crystalline Form A is achieved by adding the solution of the solid **Compound 1** or crude Form A in a solvent into an anti-solvent, and allow sufficient time for organic vapor to interact with the solution in a sealed reactor, wherein the solvent including, but not limited to, acetone, and EtOAc, and the anti-solvent including, but not limited to, n-heptane.

[0070] Also disclosed herein is a pharmaceutical composition comprises a therapeutically effective amount of Crystalline Form A, and a pharmaceutically acceptable excipient. In some embodiments, the pharmaceutical composition is used in an oral administration. In some preferred embodiments, the pharmaceutical composition comprises 1 wt% to 99 wt% of Crystalline Form A. In some more preferred embodiments, the pharmaceutical composition comprises 1 wt% to 70 wt% of Crystalline Form A. In some most embodiments, the pharmaceutical composition comprises 10 wt% to 30 wt% of Crystalline Form A.

[0071] The present invention also provide a method of treating or preventing a disease associated with undesirable Btk activity in a subject by administering to a subject Crystalline Form A.

[0072] The present invention also provide a method of treating or preventing a disease selected from an allergic disease, an autoimmune disease, an inflammatory disease, a cancer, or a combination of two or more thereof in a subject by administering to the subject Crystalline Form A.

[0073] The present invention also provide a method of treating or preventing a B-cell proliferative disease in a subject by administering Crystalline Form A to the subject.

[0074] In some embodiments, the B-cell proliferative disease is B-cell malignancies including but not limited to, lymphoma, non-Hodgkin's lymphoma (NHL), diffuse large B cell lymphoma (DLBCL), mantle cell lymphoma (MCL), follicular lymphoma (FL), chronic lymphocytic leukemia (CLL), small lymphocytic lymphoma (SLL), Waldenstrom macroglobulinemia (WM), marginal zone lymphoma (MZL), Hairy cell leukemia (HCL), Burkitt's-like leukemia (BL).

[0075] In some embodiments, the B-cell proliferative disease is relapsed / refractory (R/R) B-cell malignancies including, but limited to, R/ R MCL, R/R CLL, R/R SLL, R/R WM.

[0076] The Crystalline Form A disclosed herein can be used in manufacturing a medicament for treatment of at least one disease associated with undesirable Btk activity, in a subject.

[0077] The Crystalline Form A disclosed herein can be used in manufacturing a medicament for the treatment of a disease selected from an allergic disease, an autoimmune disease, an inflammatory disease, a cancer, or a combination of two or more thereof, in a subject.

[0078] The Crystalline Form A disclosed herein can be used in manufacturing a medicament for the treatment of a B-cell proliferative disease selected from B-cell malignancies, or relapsed / refractory B-cell malignancies, in a subject.

[0079] The updated clinical trials continue to demonstrate that Compound 1 is well tolerated in treatment naïve (TN) and relapsed/refractory (R/R) B-cell malignancies, eg., in WM, with a very good partial response (VGPR) rate of over 40% in an evaluable population of 42 patients and with an overall response rate (ORR) of 90% in 42 efficacy-evaluable patients with a median follow-up time of 12.3 months, and in CLL/SLL, with a high overall response rate (94%) and a very low treatment discontinuation rate (3%) at a median follow-up of 10.5 months for efficacy evaluation.

Definitions

[0080] Unless specifically defined elsewhere in this document, all other technical and scientific terms used herein have the meaning commonly understood by one of ordinary skill in the art to which this invention belongs.

[0081] As used herein, including the appended claims, the singular forms of words such as "**a**", "**an**", and "**the**", include their corresponding plural references unless the context clearly dictates otherwise. Thus, for example, reference to "a crystalline form" includes one or more of such different crystalline forms and reference to "the method" includes reference to equivalent steps and methods know to those of ordinary skill in the art that could be modified or substituted for the methods described herein.

[0082] As disclosed herein, the crystalline form is an approximately pure crystalline. The term "**approximately pure**" as herein used refers to at least 85 wt%, preferably at least 95 wt%, more preferably at least 99 wt% of Crystalline Form A disclosed herein.

[0083] For crystalline forms disclosed herein, only the **main peaks** (i.e, the most characteristic, significant, unique and/or reproducible peaks) are summarized; additional peaks may be obtained from the diffraction spectra by conventional methods. The main peaks

described above can be reproduced within the margin of error (±2 at the last given decimal place, or ±0.2 at the stated value).

[0084] As disclosed herein, "**an X-ray powder diffraction pattern substantially in accordance with FIG. 1**" refers to the X-ray powder diffraction pattern that show major peaks as in **FIG. 1**, wherein major peaks refer to those with the relative intensity greater than 10%, preferably greater than 20%, relative to the highest peak (with its relative intensity designated to be 100%) in **FIG. 1**.

[0085] 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 integer or step. When used herein the term "comprising" can be substituted with the term "containing" or sometimes when used herein with the term "having".

[0086] The term "**therapeutically effective amount**" as herein used, refers to the amount of a compound that, when administered to a subject for treating a disease, or at least one of the clinical symptoms of a disease or disorder, is sufficient to affect such treatment for the disease, disorder, or symptom. The "therapeutically effective amount" can vary with the compound, the disease, disorder, and/or symptoms of the disease or disorder, severity of the disease, disorder, and/or symptoms of the disease or disorder, the age of the subject to be treated, and/or the weight of the subject to be treated. An appropriate amount in any given instance can be apparent to those skilled in the art or can be determined by routine experiments. In the case of combination therapy, the "**therapeutically effective amount**" refers to the total amount of the combination objects for the effective treatment of a disease, a disorder or a condition.

[0087] The pharmaceutical composition comprising the compound disclosed herein can be administrated via oral, inhalation, rectal, parenteral or topical administration to a subject in need thereof. For oral administration, the pharmaceutical composition may be a regular solid formulation such as tablets, powder, granule, capsules and the like, a liquid formulation such as water or oil suspension or other liquid formulation such as syrup, solution, suspension or the like; for parenteral administration, the pharmaceutical composition may be solution, water solution, oil suspension concentrate, lyophilized powder or the like. Preferably, the formulation of the pharmaceutical composition is selected from tablet, coated tablet, capsule, suppository, nasal spray or injection, more preferably tablet or capsule. The pharmaceutical composition can be a single unit administration with an accurate dosage. In addition, the pharmaceutical composition may further comprise additional active ingredients.

[0088] All formulations of the pharmaceutical composition disclosed herein can be produced by the conventional methods in the pharmaceutical field. For example, the active ingredient can be mixed with one or more excipients, then to make the desired formulation. The "**pharmaceutically acceptable excipient**" refers to conventional pharmaceutical carriers suitable for the desired pharmaceutical formulation, for example: a diluent, a vehicle such as water, various organic solvents, etc, a filler such as starch, sucrose, etc a binder such as cellulose derivatives, alginates, gelatin and polyvinylpyrrolidone (PVP); a wetting agent such as glycerol; a disintegrating agent such as agar, calcium carbonate and sodium bicarbonate; an absorption enhancer such as quaternary ammonium compound; a surfactant such as hexadecanol; an absorption carrier such as Kaolin and soap clay; a lubricant such as talc, calcium stearate, magnesium stearate, polyethylene glycol, etc. In addition, the pharmaceutical composition further comprises other pharmaceutically acceptable excipients such as a decentralized agent, a stabilizer, a thickener, a complexing agent, a buffering agent, a permeation enhancer, a polymer, aromatics, a sweetener, and a dye.

[0089] The term "**disease**" refers to any disease, discomfort, illness, symptoms or indications, and can be interchangeable with the term "**disorder**" or "**condition**".

[0090] Abbreviations:

AcOH	Acetic acid
AEs	Adverse events
BID	Twice a day
CLL	Chronic lymphocytic leukemia
Con.	Concentrated
D-DBTA	(2S, 3S)-Dibenzoyl tartaric acid
DDQ	2,3-Dichloro-5,6-dicyano-1,4-benzoquinone
DCM	Dichloromethane
DIEA	*N,N*-diisopropylethylamine
DLBCL	Diffuse large B cell lymphoma
DMAc	N,N-dimethylacetaminde
DMF	*N,N*-dimethylformamide
DMF-DMA	*N,N*-dimethylformamide dimethyl acetal
DMSO	Dimethylsulfoxide
DSC	Differential Scanning Calorimetry
DVS	Dynamic Vapor Sorption
EA	Ethyl Acetate, EtOAc
EDCI	1-Ethyl-3-(3-dimethylaminopropyl)carbodiimide
EtOH	Ethanol
FL	Follicular lymphoma
GC	Gas Chromatograph
GCMS	Gas Chromatography–Mass Spectrometry
HOAc	Acetic Acid
HOBt	Hydroxybenzotriazole
HPLC	High Performance Liquid Chromatography
IPA	Isopropyl alcohol
IPAc	Isopropyl acetate
IPC	In Process Control
KF	Karl-Fischer
L-DBTA	(2R, 3R)-Dibenzoyl tartaric acid
LOQ	Limit of Quantification

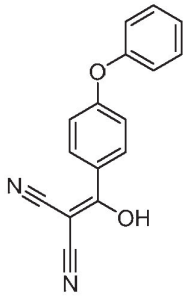
MCL	Mantle cell lymphoma
MeCN or ACN	Acetonitrile
MeMgBr	Methyl Magnesium Bromide
MeOH	Methanol
2-MeTHF	2-Methyltetrahydrofuran
MIBE	4-mehtyl-2-pentanone
MsOH	Methanesulfonic Acid
MTBE	Methyl tertiary butyl ether
NHL	non-Hodgkin's lymphoma
NLT	not less than
NMP	1-Methyl-2-pyrrolidone
NMR	Nuclear Magnetic Resonance
NMT	Not more than
ORR	Overall response rate
Pd	Palladium
pH	Hydrogen ion concentration
POA	Phenoxyacetyl
QD	Once a day
RH	Relative Humidity
SLL	Small lymphocytic lymphoma
RT	Room Temperature
TEA	Triethylamine
TGA	Thermo-gravimetric Analysis
THF	Tetrahydrofuran
TN	Treatment naïve
VGPR	very good partial response
XRPD	X-ray Powder Diffraction
WM	Waldenstrom macroglobulinemia

EXAMPLE

[0091] The present invention is further exemplified, but not limited, by the following examples that illustrate the invention.

Example 1 Preparation of (S)-7-(1-acryloylpiperidin-4-yl)-2-(4-phenoxyphenyl) -4,5,6,7-tetrahydropyrazolo[1,5-a]pyrimidine-3-carboxamide (Compound 1) and Crystalline Form A Thereof

Step 1: Synthesis of BG-2

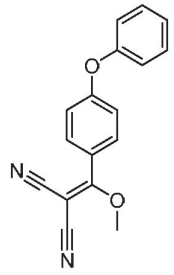


BG-2

[0092] Under nitrogen atmosphere, to a solution of EA (5 v), HOBT (1.2 eq.), EDCI (1.2 eq.), 4-phenoxybenzoic acid (BG-1, 80 Kg, 1.0 eq.) and malononitrile (1.2 eq.) was added TEA (2.4 eq.) at 10°C. The mixture was then stirred at RT until the reaction was completed. The mixture was then centrifuged and the cake was washed with EA. The filtrate was washed with aqueous

$NaHCO_3$ twice and NH_4Cl. The organic phase was washed with 1.5 N H_2SO_4 twice and stirred. Concentrated, precipitated from methanol and purified water. The solid was collected by centrifugation and dried under vacuum. This gave 79.9 Kg of BG-2. ^{1}H NMR (DMSO-d_6) δ 7.62 (d, J = 8.6 Hz, 2H), 7.46-7.38 (m, 2H), 7.18 (t, J = 7.4 Hz, 1H), 7.06 (d, J = 8.0 Hz, 2H), 6.94 (d, J = 8.6 Hz, 2H).

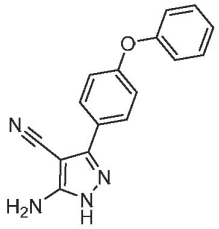
Step 2: Synthesis of BG-3



BG-3

[0093] Under nitrogen atmosphere, a solution of BG-2 (79.9 kg, 1.0 eq.) in MeCN (5.0 v) was added into trimethoxymethane (12.0 v) at 85°C. The resultant mixture was stirred until the reaction was completed. Sampled for HPLC analysis. Concentrated under vacuum. The residue was precipitated from *i*-PrOH and hexane. The mixture was centrifuged, and the cake was washed with hexane and dried under vacuum. This gave 71.7 Kg of product. ^{1}H NMR (400 MHz, DMSO-d_6) δ 7.70 (d, J = 8.4 Hz, 2H), 7.52-7.45 (m, 2H), 7.28 (t, J = 7.6 Hz, 1H), 7.22-7.06 (m, 4H), 3.93 (s, 3H).

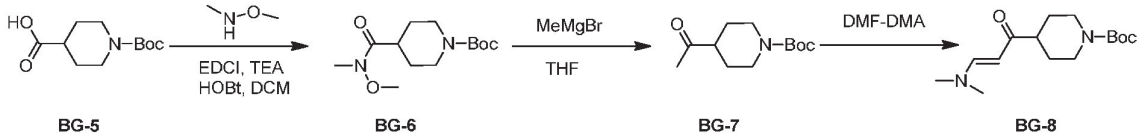
Step 3: Synthesis of BG-4



BG-4

[0094] Under nitrogen atmosphere, to a solution of BG-3 (71.6 kg, 1.0 eq.) in ethanol (2.5 v) hydrazinium hydroxide (1.0 eq) in ethanol (0.6 v) was charged dropwise to the reactor below 15°C. The solution was heated to RT and stirred until the reaction was completed. Water (4.0 v) was added to the reactor. The solution was then cooled to 5°C, centrifuged and the cake was washed with water (1.0 v). The cake was dried under vacuum. This gave 66.9 Kg of product. ^{1}H NMR (DMSO-d_6) δ 12.11 (br s, 1H), 7.80 (d, J = 8.8 Hz, 2H), 7.46-7.39 (m, 2H), 7.18 (t, J = 7.6 Hz, 1H), 7.12-7.04 (m, 4H), 6.43 (br s, 2H).

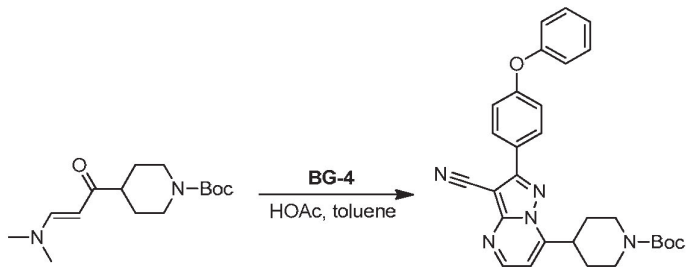
Steps 4 to 6: Synthesis of BG-8



BG-5 BG-6 BG-7 BG-8

[0095] To a mixture of DCM (8.0 v), BG-5 (80.0 Kg, 1.0 eq.), *N,O*-dimethylhydroxylamine hydrochloride (1.2 eq.), HOBt (1.2 eq.) and EDCI (1.2 eq.), TEA (2.6 eq.) was charged dropwise below 15°C. the mixture was stirred at RT until the reaction was completed, centrifuged and the cake was washed with DCM (1.0 v) twice. The filtrate was washed with 20% aqueous NH_4Cl (3 × 4.0 v). The filtrate was concentrated under vacuum to give the crude product BG-6, which was used in the next step without further purification. The residue was dissolved in toluene (5.0 v) and THF (1.0 v), cooled to 10 °C, charged dropwise MeMgBr (1.4 eq.) at 10°C and then stirred at RT until the reaction was completed. The solution was cooled below 10°C. Saturated aqueous NH_4Cl was charged dropwise below 10°C. The mixure was centrifuged, separated, filtrated, and the organic phase was washed with aqueous NaCl twice. The organic phase was concentrated to give the crude product, which was used in the next step without further purification. The residue in DMF (2.5 v) and DMF-DMA (2.5 v) was stirred at 110°C until the reaction was completed. The reaction mixture was cooled, concentrated and then DCM was added. The final mixture was washed with saturated aqueous NH_4Cl. The organic layer was cconcentrated and precipitated by charging hexane. The mixture was ccentrifuged and the cake was collected. The cake was dried under vacuum. This gave 82.2 Kg of the desired product. ^{1}H NMR (DMSO-d_6) δ 7.49 (d, J = 12.6 Hz, 1H), 5.01 (d, J = 12.6 Hz, 1H), 3.99-3.82 (m, 2H), 3.14-2.94 (m, 2H), 2.89-2.61 (m, 6H), 2.49-2.37 (m, 1H), 1.66-1.56 (m, 2H), 1.39 (s, 9H), 1.39-1.20 (m, 2H).

Step 7: Synthesis of BG-9

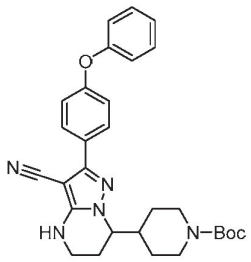


BG-8 BG-9

[0096] Under nitrogen atmosphere, a mixture of toluene (8.0 v), AcOH (0.5 v), BG-8 (1.2 eq.) and BG-4 (66.9 Kg 1.0 eq.) was heated to 95°C and stirred until the reaction was completed. The mixture was cooled, concentrated and precipitated from methanol. The mixture was centrifuged and the cake was washed with methanol. The cake was dried under vacuum. This gave 107.8 Kg of product.^{1}H NMR (DMSO-d_6) δ 8.78 (d, J = 4.6 Hz, 1H), 8.15-8.07 (m, 2H),

7.51-7.41 (m, 2H), 7.34 (d, J = 4.6 Hz, 1H), 7.27-7.19 (m, 3H), 7.17-7.10 (m, 2H), 4.24-4.02 (m, 2H), 3.81-3.69 (m, 1H), 3.12-3.82 (m, 2H), 2.15-2.04 (m, 2H), 1.76-1.60 (m, 2H), 1.43 (s, 9H).

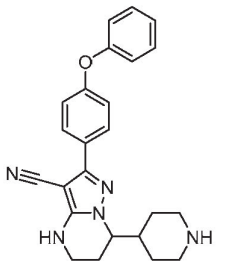
Step 8: Synthesis of BG-10



BG-10

[0097] To a mixture of THF (10.0 v), BG-9 (13.0 Kg, 1.0 eq.) and D-DBTA (1.0 eq) under N_2 was charged Pd/C (10% w/w), hydrogen gas was introduced into the reactor and the hydrogen pressure was maintained to 1.8 MPa. The reactor was heated to 40°C slowly and stirred until the reaction was completed. The mixture was then cooled, filtered, and the cake was washed with THF. The filtrate was collected, and concentrated under vacuum. DCM was added. The residue was washed with aq. $NaHCO_3$, concentrated and precipitated from MTBE and hexane, then centrifuged. The cake was collected and dried under vacuum to give the desired compound (yield:94.8% and purity:98.5%). ^{1}H-NMR (DMSO-d_6) δ 7.82-7.76 (m, 2H), 7.56-7.51 (m, 1H), 7.45-7.37 (m, 2H), 7.21-7.14 (m, 1H), 7.12-7.03 (m, 4H), 4.09-3.91 (m, 3H), 3.30-3.22 (m, 2H), 2.82-2.55 (m, 2H), 2.18-1.99 (m, 2H), 1.98-1.86 (m, 1H), 1.69-1.58 (m, 1H), 1.56-1.45 (m, 1H), 1.38 (s, 9H), 1.32-1.13 (m, 2H).

Step 9: Synthesis of BG-11

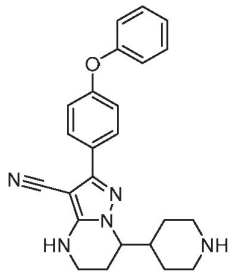


BG-11

[0098] To a solution of BG-10 (100.0 Kg 1.0 eq.) in DCM (6.0 v) was added dropwise HCl in EtOH (20.9% w/w, 2.0 v) under nitrogen atmosphere. The mixture is stirred until the reaction was completed. MTBE (4.0 v) was added to the solution, cooled. The cakes was collected by centrifugation and washed with hexane (2.0 V), then the cake was slurried in hexane (5 v), and centrifuged again. The cake was washed with hexane (2.0 V) and dried under vacuum. This gave 85.2 Kg product. ^{1}H-NMR (DMSO-d_6) δ 9.25-8.85 (m, 2H), 7.84-7.70 (m, 2H), 7.47-7.37 (m, 2H), 7.18 (t, J = 7.4 Hz, 1H), 7.12-7.03 (m, 4H), 5.73 (br s, 2H), 4.12-4.03 (m, 1H),

3.25-3.19 (m, 4H), 2.90-2.73 (m, 2H), 2.28-2.12 (m, 1H), 2.10-2.00 (m, 1H), 1.99-1.86 (m, 1H), 1.84-1.52 (m, 4H).

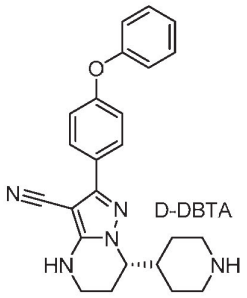
Step 10: Synthesis of BG-11A



BG-11A

[0099] A mixture of BG-11 (85.0 Kg, 1.0 eq) in water (6.0 v) and NaOH (3.0 eq) was stirred until the reaction was completed at RT. The cake was collected and slurried in MTBE (6.0 v). The mixture was then centrifuged to collect the cake. The cake was dried under vacuum. This gave 71.3 Kg product. ^{1}H-NMR (DMSO-d_6) δ 7.82-7.74 (m, 2H), 7.54-7.49 (m, 1H), 7.45-7.38 (m, 2H), 7.21-7.14 (m, 1H), 7.12-7.04 (m, 4H), 4.03-3.95 (m, 1H), 3.29-3.21 (m, 2H), 3.00-2.87 (m, 2H), 2.46-2.31 (m, 2H), 2.11-1.83 (m, 3H), 1.58-1.12 (m, 4H).

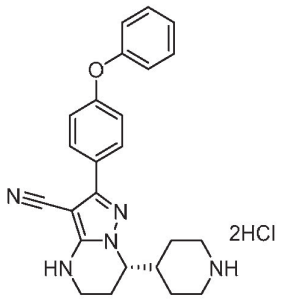
Step 11: Synthesis of BG-11B



BG-11B

[0100] A mixture of enthanol/water/acetic acid (7:3:1, 46 v) and BG-11A (30 kg, 1.0 eq.) in a reactor was heated to 70±5 °C under nitrogen atmosphere, then a solution of D-DBTA (1.20 eq.) in ethanol/water/acetic acid (7:3:1, 4 v) was added dropwise with the temperature not less than 65°C. The resulting solution was stirred for 16 hrs at 60-65 °C, then cooled to RT. The solid was collected by centrifugation and washed with ethanol (2.0 v). The cake was slurried in the mixed solvent of ethanol/water/AcOH (7:3:1, 20 v) for 16 hrs at 55 °C and cooled to RT. The solid was collected by centrifugation, washed with ethanol (2.0 v). The cake was dried under vacuum (Yield: 37.9%).^{1}H-NMR (DMSO-d_6) δ 8.76 (br s, 2H), 7.99-7.89 (m, 4H), 7.83-7.75 (m, 2H), 7.66-7.57 (m, 3H), 7.52-7.45 (m, 4H), 7.45-7.39 (m, 2H), 7.21-7.14 (m, 1H), 7.13-7.03 (m, 4H), 5.64 (s, 2H), 4.08-4.00 (m, 1H), 3.29-3.19 (m, 4H), 2.85-2.72 (m, 2H), 2.21-1.40 (m, 7H).

Step 12: Synthesis of BG-11C



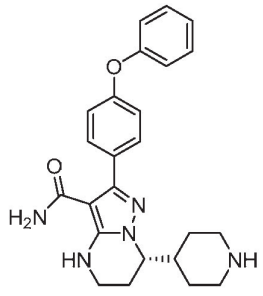
BG-11C

[0101] To a mixture of dichloromethane (15.0 v) and 20.0% aqueous KOH (3.0 v) was added bachwise BG-11B (48.0 kg, 1.0 eq.) under nitrogen atmosphere at RT. After the reaction was completed, the organic layer was collected and the water layer was extracted with dichloromethane (5.0 v). The organic layers were combined. Con. HCl (0.36 v) was added to the above organic layers at RT. The resulting mixture was stirred until the reaction was completed. The solid was collected by centrifugation and washed with dichloromethane (1.0 v). The collected solid was slurried with MTBE (6.0 v). The solid was collected by centrifugation and washed with MTBE (1.0 v), then was dried under vacuum. This gave 31.5 Kg product (Yield:100 %).

Step 12: Synthesis of BG-11D (Alternative intermediate)

[0102] ACN (5.0 v), soft water (10.0 v), KOH (5.0 eq) was charged to a reactor and stirred for at least 15 min. BG-11B (1.0 eq) was charge to the reactor in portion-wise. The mixture was stirred until the reaction was completed. The cake was collected by centrifugation, slurried in ACN (1.0 v) and soft water (5.0 v), and dried under vacuum to give the product.

Step 13: Synthesis of BG-12

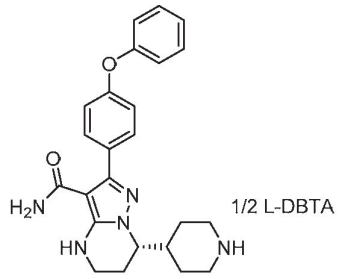


BG-12

[0103] A solution of BG-11C (15.0 Kg 1.0 eq.) in MsOH (2.5 v) was stirred at 85°C under nitrogen atmosphere until the reaction was completed. After cooling to 5 °C. purified water (4.0 v) was added dropwise to the system and kept the temperature not more than 35°C (temperature increased obviously). The resulting solution was stirred for 16 hrs at 30°C, and then washed with DCM (2×3.0 v). The aqueous phase was collected. DCM (6.0 v) was added to the aqueous phase, the mixture was cooled to 5°C. The pH value was adjusted to 11~12 with

20% aqueous NaOH (temperature increased obviously) with stirring with the temperature not more than 30 °C. The organic phase was separated and collected. The aqueous was extracted with DCM (3.0 v). The organic layers were combined and concentrated. MTBE (4.0 v) was added to the residue. The mixture was then concentrated and precipitated from *n*-heptane. The solid was collected by centrifugation and dried in a vacuum oven. This gave 12.55 Kg product (Yield: 94.9%). ^{1}H-NMR (DMSO-d_6) δ 7.52-7.46 (m, 2H), 7.45-7.38 (m, 2H), 7.21-7.13 (m, 1H), 7.12-7.03 (m, 4H), 6.64 (s, 1H), 3.99-3.90 (m, 1H), 3.29-3.22 (m, 2H), 3.03-2.90 (m, 2H), 2.48-2.36 (m, 2H), 2.03 (dd, J = 13.9, 5.6 Hz, 2H), 2.14-1.99 (m, 1H), 1.97-1.85 (m, 1H), 1.65-1.15 (m, 3H).

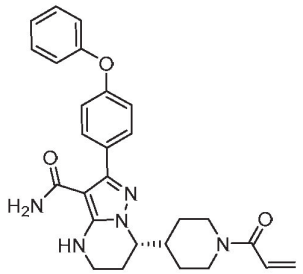
Step 14: Synthesis of BG-13



BG-13

[0104] A mixture of MeOH (13.5 v), purified water (4.5 v) and BG-12 (8.5 Kg, 1.0 eq.) in a reactor was heated to 50°C under N_2 atmosphere. To the mixture was charged dropwise a solution of L-DBTA (0.7 eq) in MeOH/purified water (1.5 v/0.5 v) while keeping the temperature at 50 °C. After addition, the mixture was stirred for at least 2 hrs at 50 °C, and then cooled to RT and stirred for at least 16 hrs at RT. The cake was collected by Centrifugation and was washed with MeOH (2.0 v). The cake was dried in a vacuum oven. This gave 9.08 Kg product (Yield: 74.8%, ee value ＞98%).

Step 15: Synthesis of (S)-7-(1-acryloylpiperidin-4-yl)-2-(4-phenoxyphenyl)-4,5,6,7-tetrahydropyrazolo[1,5-a]pyrimidine-3-carboxamide (**Compound 1**)

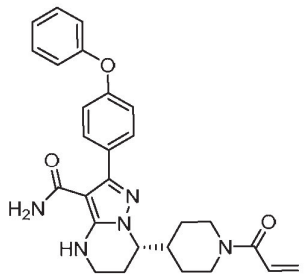


[0105] Under N_2 atmosphere, ACN (12.0 v), water (12.5 v), BG-13 (8.0 Kg, 1.0 eq), and $NaHCO_3$ (2.5 eq.) were added to a reactor. The mixture was then cooled to -5~0 °C. To the mixture, the solution of acryloyl chloride (1.1 eq.) in MeCN (0.5 v) was added dropwise and

stirred until the reaction was completed. EA (6.0 v) was then added to the reactor, and stirred. The organic phase was collected. The aqueous layer was further extracted with EA (3.0 v). The organic phases were combined and washed with brine. The organic layer was collected and concentrated.

[0106] The residue was purified by silica gel (2 wt) column, eluted with 3% w/w methanol in DCM (21.0 v). The **Compound 1** solution was collected and concentrated under vacuum. The residue was precipitated from EA/MTBE (2.0 v). The cake was collected by centrifugation as the product.

Step 15: Synthesis of (S)-7-(1-acryloylpiperidin-4-yl)-2-(4-phenoxyphenyl) -4,5,6,7-tetrahydropyrazolo[1,5-a]pyrimidine-3-carboxamide (**Compound 1**, alternative method)



[0107] A mixture of CH_3CN (10.0 v), purified water (5.0 v), NaOH (1.5 eq.) and BG-13 (1.0 eq.) was stirred to get a clear solution. EtOAc (6.0 v) was then charged to the reaction and separated. The organic phase was collected and washed with 15% brine (3.0 v) twice. The organic phase prepared above was concentrated and the solvent was swapped to CH_3CN (residue volume: NMT 5.0 v). CH_3CN (7.5 v) and purified water (12.5 v) were charged and cooled to 15-20°C. L-(+)-tartaric acid (0.5 eq) and $NaHCO_3$ (2.5 eq.) were charged to the reaction mixture. A solution of acryloyl chloride (1.1 eq.) in CH_3CN (0.5 v) was charged drop-wise to the reaction mixture. After the reaction was completed, EtOAc (6.0 v) was charged to the reaction mixture and organic layer was collected. Aqueous phase was further extracted with EA (3.0 v). The organic layers were combined, washed with 15% brine (5.0 v) and concentrated. The solvent was swapped to DCM (volume of residue: 1.5-2.0 v) and purified by silica gel column (silica gel: 100-200 mush, 2.0 w/ w; eluent: 3% w/ w MeOH in DCM (about 50 v). The collected solution was concentrated and swapped to EtOAc (4.0 v). MTBE (6.4 v) was charged drop-wise to residue at 50°C. The mixture was then cooled to 5°C and the cake was collected centrifugation.

Step 16: Preparation of Crystalline Form A of **Compound 1**

[0108] The above cake of **Compound 1** was dissolved in 7.0 volumes of DCM, and then swapped to solvent EA. After recrystallization from EA/MTBE, the cakes was collected by centrifugation, and was dried under vacuum. This gave 4.44 Kg product (Yield: 70.2%).

[0109] The product was then characterized by X-ray powder diffraction (XRPD) pattern method, which was generated on a PANalytical Empyrean X-ray powder diffractometer with the XRPD parameters as follows: X-Ray wavelength (Cu, kα, Kα1 (Å): 1.540598, Kα2(Å): 1.544426; Kα2/Kα1 intensity ratio: 0.50); X-Ray tube setting (45 Kv, 40mA); divergence slit (automatic); scan mode (Continuous); scan range (°2TH) (3°-40); step size (°2TH) (0.0131); scan speed (°/min) (about 10). The XRPD result found the resultant product as a crystalline shown in **FIG. 1.**

[0110] The differential scanning calorimetry (DSC) curves shown as in **FIG. 2** was generated on a TA Q2000 DSC from TA Instruments. The DSC parameters used includes: temperature (25°C-desired temperature); heating rate (10°C/min) ; method (ramp); sample pan (aluminum, crimped); purge gas (N_2). DSC result showed a sharp melting point at 139.4°C (onset temperature).

[0111] The thermo-gravimetric analysis (TGA) curves shown as in **FIG. 3** was generated on a TA Q5000 TGA from TA Instruments. The TGA parameters used includes: temperature (RT-desired temperature); heating rate (10°C/min); method (ramp); sample pan (platinum, open); purge gas (N_2). TGA result showed is anhydrous with no weight loss even up to 110 °C.

[0112] The proton nuclear magnetic resonance (^{1}H-NMR) shown as in **FIG. 4** was collected on a Bruker 400M NMR Spectrometer in DMSO-d_6. ^{1}H-NMR (DMSO-d_6) δ 7.50 (d, J = 8.6 Hz, 2H), 7.46-7.38 (m, 2H), 7.17 (t, J = 7.6 Hz, 1H), 7.08 (d, J = 7.6 Hz, 2H), 7.05 (d, J = 8.8 Hz, 2H), 6.85-6.72 (m, 1H), 6.67 (s, 1H), 6.07 (dd, J = 16.8, 2.2 Hz, 1H), 5.64 (dd, J = 10.4 Hz, 2.2 Hz, 1H), 4.55-4.38 (m, 1H), 4.17-3.94 (m, 2H), 3.33-3.22 (m, 2H), 3.08-2.88 (m, 1H), 2.67-2.51 (m, 1H), 2.36-2.15 (m, 1H), 2.12-1.82 (m, 2H), 1.79-1.65 (m, 1H), 1.63-1.49 (m, 1H), 1.38-1.08 (m, 2H).

[0113] The carbon nuclear magnetic resonance (^{13}C-NMR) shown as in **FIG. 5** was collected on a Bruker 400M NMR Spectrometer in DMSO-d_6. ^{13}C-NMR spectra for Crystalline Form A of **Compound 1**.

Example 2 Preparation of Crystalline Form A of Compound 1

[0114] (S)-7-(1-acryloylpiperidin-4-yl)-2-(4-phenoxyphenyl)-4,5,6,7-tetrahydropyrazolo[1,5-a]pyrimidine-3-carboxamide (Compound 1) was prepared by the method disclosed in WO2014173289A, and further lyophilized to obtain amorphous form of Compound 1. A solution of **Compound 1** (200mg, ee value ＞ 97%) in EA (8 mL) was heated to 50℃, to the above solution was added dropwise hexane (8 mL) at 50℃. The mixture was cooled to RT and

stirred for 16 hr then was filtered to give 110 mg as a white solid. The solid obtained were characterized by XRPD to be Form A.

Example 3 Preparation of Crystalline Form A of Compound 1 (Anti-solvent Addition)

[0115] About 15 mg of sample (Crystalline Form A) was weighed into a 20-mL glass vial, followed by the addition of 0.4-1.2 mL corresponding solvent (see **Table 2**) to dissolve all the solid. The mixture was then magnetically stirred at the speed of 800 rpm to get a clear solution at RT. Subsequently, the relative anti-solvent (see **Table 2**) was added to the solution to induce precipitation or until the total amount of anti-solvent reached 15.0 mL. If no precipitation occurs, the solution was then transferred to slow evaporation at RT. The solids obtained were characterized by XRPD to be Form A.

[0116] Table 2 Anti-Solvent Addition Experiments

Experiment ID	Solvent	Anti-solvent
1	Acetone	H_2O
2	DMAc	H_2O
3	EtOAc	n-heptane
4	DCM	n-heptane
5	Toluene	n-heptane
6	2-MeTHF	n-heptane

Example 4 Preparation of Crystalline Form A of Compound 1 (Solution Vapor Diffusion)

[0117] About 15 mg of sample (Crystalline Form A) was dissolved in 0.5-1.5 mL of the corresponding solvent (acetone or EtOAc) to obtain a clear solution in a 3-mL vial. Subsequently, the solution was placed into a 20-mL vial with 3 mL of relative anti-solvent (n-heptane). The 20-mL vial was sealed with a cap and kept at RT, allowing sufficient time for organic vapor to interact with the solution. At the end of 11 days, clear solutions were transferred to evaporation at RT. The solid obtained were characterized by XRPD to be Form A.

Example 5 Stability Test of Crystalline Form A of Compound 1 and Purity of Compound 1

(1) Physical Stability Test

[0118] The Crystalline Form A of **Compound 1** was stored at 80 ℃ for two days as a thermo-stability test, and the XRPD patterns before and after the test showed no crystal form change.

[0119] The long term stability studies of Crystalline Form A of **Compound 1** showed there was no significant chemical purity change occurred when stored at 25°C /60%RH for up to 24 months (%area: T0=99.2% and T12=99.2%) and at 40°C / 75%RH condition for up to 6 months (%area: T0=99.1% and T6=99.4%). In addition, no crystal form and optical purity changes were observed when stored at 25°C/60%RH for up to 24 months and at 40°C/75%RH condition for up to 6 months.

(2) Hygroscopic Test

[0120] The dynamic vapor sorption (DVS) plots shown as in **FIG. 6** was collected a SMS (Surface Measurement Systems) DVS Intrinsic. The DVS parameters used includes: temperature (25°C); dm/dt (0.002%/min); Min. dm/dt stability duration (10 min); Max. equilibrium time (180 min); RH range (0%RH to 95%RH); RH step size(10%RH from 0%RH to 90%RH, 5%RH from 90%RH to 95%RH). As shown in **FIG. 6**, there is a very slight increase of mass at 80%RH, which was about 0.8% for Crystalline Form A of **Compound 1**.

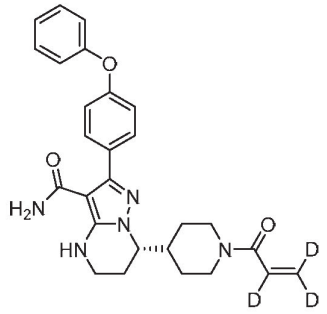
(3) Crystallization/Recrystallization via Form A to improve the purity of **Compound 1**

[0121] Crystallization/Recrystallization via Form A is an efficient way to improve the purity of **Compound 1** and control the impurities in **Compound 1** to reach the acceptance criteria in the specification. See an example as shown in **Table 3**.

[0122] Table 3 Purity Changing after Crystallization/Recrystallization via Form A

Conditions	Purity of Compound 1
After Silica Gel Chromatography Purification	98.5% area
After First Recrystallization	99.3% area
After Second Recrystallization	99.5% area

Example 6 Preparation of deuterium-labeled (S)-7-(1-acryloylpiperidin-4-yl)-2-(4-phenoxyphenyl)-4,5,6,7-tetrahydropyrazolo[1,5-a]pyrimidine-3-carboxamide (Deuterium-labeled Compound 1)



[0123] To a solution of acrylic-2,3,3-d3 acid (50 mg, 0.67 mmol) and DMF (one drop) in DCM (20 mL) was added dropwise oxalyl chloride (1.6 N, 40.9 mL, 65.5 mmol) at 0~5℃

then stirred for 2 hours at RT. The mixture was concentrated under reduced pressure to give the crude acryloyl-d_3 chloride.

[0124] To a solution of (S)-2-(4-phenoxyphenyl)-7-(piperidin-4-yl)-4,5,6,7-tetrahydropyrazolo[1,5-a] pyrimidine-3-carboxamide (dissociated from BG-13, see step 15, **Compound 1**, alternative method; 278 mg, 0.67 mmol) in DCM (20 mL) and aqu. $NaHCO_3$ (10 mL) was added dropwise a solution of the above acryloyl-d_3 chloride in DCM (5 mL) at 0~5℃ and stirred for 2 hours at RT. The organic combined layers were dried over anhydrous sodium sulfate, filtered, concentrated under reduced pressure and purified by prep-TLC to afford 55 mg (17.5%) of (S)-7-(1-(acryloyl-d3)piperidin-4-yl) -2-(4-phenoxyphenyl)-4,5,6,7-tetrahydropyrazolo[1,5-a]pyrimidine-3-carboxamide as an off-white solid. ^{1}H NMR (400 MHz, DMSO) δ 7.50-7.44 (m, 2H), 7.42-7.35 (m, 2H), 7.17-7.10 (m, 1H), 7.09-6.99 (m, 4H), 6.64 (s, 1H), 4.52-4.40 (m, 1H), 4.10-3.95 (m, 2H), 2.29-3.25 (m, 2H), 3.04-2.86 (m, 1H), 2.63-2.50 (m, 1H), 2.32-2.13 (m, 1H), 2.06-1.81 (m, 2H), 1.75-1.45 (m, 2H), 1.35-1.08 (m, 2H). MS (ESI, m/e) $[M+1]^+$ 475.2.

Example 7 Polymorph Study of Compound 1

(1) Polymorph Study from Amorphous Form—Preparation of Form A from an amorphous form of Compound 1

[0125] (S)-7-(1-acryloylpiperidin-4-yl)-2-(4-phenoxyphenyl)-4,5,6,7-tetrahydropyrazolo[1,5-a]pyrimidine-3-carboxamide **(Compound 1)** was prepared by the method disclosed in WO2014173289A, and further lyophilized to obtain amorphous form of **Compound 1**.

[0126] For each experiment in Tables 4a to 4k, Tables 5a to 5e and Table 6, about 20 mg of **Compound 1** as amorphous form was weighed into a glass vial, followed by the addition of corresponding solvent. The mixture was heated to give a clear solution if needed. Then the mixture was kept at RT without stirring for 1-2 days to see any solid generated from the clear solution. The solid was monitored by Polarized light microscopy.

[0127] Table 4 Compound 1 (ee value=90%) as Starting Material

Table 4a

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	EA (mL)	Hexane (mL)			
1-1	0.5	0.1	Y	----	No solid
1-2	0.5	0.2	Y	----	Little solid
1-3	0.5	0.3	N	Y	Oil

1-4	0.5	0.4	N	Y	Oil
1-5	1	0.2	Y	----	No solid
1-6	1	0.3	Y	----	No solid
1-7	1	0.4	Y	----	No solid
1-8	1	0.5	Y	----	No solid
1-9	1	0.6	Y	----	Little solid
1-10	1	0.7	Y	----	Little solid
1-11	1	0.8	N	Y	Oil
1-12	1	0.9	N	Y	Oil

Table 4b

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	EA (mL)	Heptane (mL)			
2-1	0.5	0.1	Y	----	No solid
2-2	0.5	0.2	Y	----	Little solid
2-3	0.5	0.3	N	Y	Oil
2-4	0.5	0.4	N	N	Oil
2-5	1	0.2	Y	----	No solid
2-6	1	0.3	Y	----	No solid
2-7	1	0.4	Y	----	No solid
2-8	1	0.5	Y	----	No solid
2-9	1	0.6	Y	----	Little solid
2-10	1	0.7	Y	----	Little solid
2-11	1	0.8	Y	----	Oil
2-12	1	0.9	N	Y	Oil

Table 4c

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	EA (mL)	Cyclohexane (mL)			
3-1	0.5	0.2	Y	----	No solid
3-2	0.5	0.3	Y	----	Little solid
3-3	0.5	0.4	Y	----	Oil
3-4	0.5	0.5	Y	----	Oil
3-5	0.5	0.6	N	Y	Oil
3-6	1	0.6	Y	----	Little solid

3-7	1	0.8	Y	----	Little solid
3-8	1	1.0	Y	----	Little solid
3-9	1	1.2	Y	----	Little solid
3-10	1	1.4	Y	----	Oil

Table 4d

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	DCM (mL)	Hexane (mL)			
4-1	0.5	0.4	Y	----	No solid
4-2	0.5	0.6	Y	----	No solid
4-3	0.5	0.8	Y	----	No solid
4-4	0.5	1.0	N	Y	Oil
4-5	1.0	1.4	Y	----	No solid
4-6	1.0	1.6	Y	----	No solid
4-7	1.0	1.8	Y	----	No solid
4-8	1.0	2.0	N	Y	Oil

Table 4e

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	1,2-Dichloroethane (mL)	Hexane (mL)			
5-1	0.5	0.6	Y	----	No solid
5-2	0.5	0.8	Y	----	No solid
5-3	0.5	1.0	Y	----	No solid
5-4	0.5	1.1	N	Y	Oil
5-5	1.0	1.4	Y	----	No solid
5-6	1.0	1.6	Y	----	No solid
5-7	1.0	1.8	Y	----	No solid
5-8	1.0	2.0	Y	----	No solid
5-9	1.0	2.2	N	Y	Oil

Table 4f

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	MeOAc (mL)	Hexane (mL)			
6-1	0.5	0.3	Y	----	Little solid
6-2	0.5	0.4	Y	----	Oil
6-3	0.5	0.5	Y	----	Oil
6-4	0.5	0.6	N	Y	Oil

6-5	1.0	0.6	Y	----	Little solid
6-6	1.0	0.8	Y	----	Little solid
6-7	1.0	1.0	Y	----	Little solid
6-8	1.0	1.2	Y	----	Little solid
6-9	1.0	1.4	N	Y	Oil

Table 4g

Experiment ID	Solvent		RT	heat	Result (1-2d)
	Toluene (mL)	Hexane (mL)			
7-1	1.0	0.2	Y	----	Little solid
7-2	1.0	0.3	Y	----	Little solid
7-3	1.0	0.4	Y	----	Little solid
7-4	1.0	0.5	N	Y	Oil
7-5	1.0	0.6	N	Y	Oil

Table 4h

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	Toluene (mL)	Cyclohexane (mL)			
8-1	1.0	0.1	Y	----	Little solid
8-2	1.0	0.2	Y	----	Little solid
8-3	1.0	0.3	Y	----	Oil
8-4	1.0	0.4	N	Y	Oil
8-5	1.0	0.5	N	Y	Little solid
8-6	1.5	0.4	Y	----	Little solid
8-7	1.5	0.5	Y	----	Little solid

Table 4i

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	MeOAc (mL)	Cyclohexane (mL)			
9-1	0.4	1.0	Y	----	Little solid
9-2	0.5	1.0	Y	----	Little solid
9-3	0.6	1.0	Y	----	Little solid
9-4	0.8	1.0	Y	----	Little solid
9-5	1.0	1.0	Y	----	Little solid

Table 4j

Experiment ID	Solvent		RT	Heat	Result (2-3d)
	IPAC (ml)	Cyclohexane (ml)			

10-1	1.0	0.2	Y	----	Little solid
10-2	1.0	0.4	Y	----	Little solid
10-3	1.0	0.6	Y	----	Little solid
10-4	1.0	0.8	Y	----	Little solid
10-5	1.0	1.0	Y	----	Little solid
10-6	1.0	1.2	N	Y	Oil

Table 4k

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	Isobutyl acetate (mL)	Cyclohexane (mL)			
11-1	1.0	0.2	Y	----	Little solid
11-2	1.0	0.4	Y	----	Little solid
11-3	1.0	0.6	Y	----	Little solid
11-4	1.0	0.8	Y	----	Little solid
11-5	1.0	1.0	Y	----	Little solid
11-6	1.0	1.2	N	Y	Oil

Y=Yes, and N=No.

Table 5 Compound 1 (ee value=97%) as Starting Material

Table 5a

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	EA (mL)	Hexane (mL)			
12-1	1	0.2	Y	----	No solid
12-2	1	0.3	Y	----	No solid
12-3	1	0.4	Y	----	No solid
12-4	1	0.5	Y	----	No solid
12-5	1	0.6	Y	----	Solid
12-6	1	0.7	Y	----	Solid
12-7	1	0.8	N	Y	Oil
12-8	1	0.9	N	Y	Oil

Table 5b

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	EA (mL)	Heptane (mL)			
13-1	1	0.2	Y	----	No solid
13-2	1	0.3	Y	----	No solid

13-3	1	0.4	Y	----	No solid
13-4	1	0.5	Y	----	No solid
13-5	1	0.6	Y	----	Solid
13-6	1	0.7	Y	----	Solid
13-7	1	0.8	Y	----	Oil
13-8	1	0.9	N	Y	Oil

Table 5c

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	MeOAc（ml）	Cyclohexane (ml)			
14-1	0.4	1.0	Y	----	No solid
14-2	0.5	1.0	Y	----	No solid
14-3	0.6	1.0	Y	----	Solid
14-4	0.8	1.0	Y	----	Solid
14-5	1.0	1.0	Y	----	No solid
14-6	1.0	1.5	Y	----	Solid
14-7	1.0	2.0	Y	----	Solid
14-8	1.0	2.2	N	Y	Oil

Table 5d

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	EA (ml)	Cyclohexane (ml)			
15-1	0.5	0.2	Y	----	No solid
15-2	0.5	0.3	Y	----	solid
15-3	0.5	0.4	Y	----	Oil
15-4	0.5	0.5	Y	----	Oil
15-5	0.5	0.6	N	Y	Oil
15-6	1	0.6	Y	----	solid
15-7	1	0.8	Y	----	solid
15-8	1	1.0	Y	----	solid
15-9	1	1.2	Y	----	solid
15-10	1	1.4	Y	----	Oil

Table 5e

Experiment ID	Solvent		RT	Heat	Result (1-2d)
	MeOAc（ml）	Hexane (ml)			

16-1	0.5	0.3	Y	----	solid
16-2	0.5	0.4	Y	----	No solid
16-3	0.5	0.5	Y	----	No solid
16-4	0.5	0.6	N	Y	No solid
16-5	1.0	0.6	Y	----	solid
16-6	1.0	0.8	Y	----	solid
16-7	1.0	1.0	Y	----	solid
16-8	1.0	1.2	Y	----	solid
16-9	1.0	1.4	N	Y	Oil

Y=Yes, and N=No.

[0128] Experiments in Tables 4a to 4k and Tables 5a to 5e were conducted on the same scale (i.e., the amount of the starting material—amorphous **Compound 1** is about 20 mg). However, the ee value of the starting material appeared to have significant influence in the amount of the solid to be formed in each experiment. As shown in the experiments in Tables 4a to 4k starting from 90% ee of amorphous **Compound 1**, the solids thus formed are of little amount. The experiments in Tables 5a to 5e starting from 97% ee of amorphous **Compound 1** resulted in noticeable amount of solid. Also, the obtained solid in the experiments in Tables 4a to 4k showed low ee value when crystallization from starting material with 90% ee. One solid sample from Tables 4a to 4k using EA/Hexane as crystallization system only showed 45% ee value.

[0129] The results of Table 5a were further confirmed by a scale-up experiment similar to those in Example 2, which confirmed that the resultant solid was in the desired crystalline form (Form A).

[0130] As shown in the above Tables 4a to 4k and Tables 5a to 5e, the formation of the crystalline solid may vary depending on the specific solvents, the ratio of the solvents, and so on.

[0131] The results in Table 6 further confirms that the formation of the crystalline solid depends on the specific ratio of the solvent.

Table 6

Solvent-2 / Solvent-1 (0.5 mL)	Hexane		MTBE		Heptane		Cyclohexane		H_2O		Ether	
	V /mL	Results	V /mL	Results	V /mL	Results	V /mL	Results	V /mL	Results	V /mL	Results

THF	0.4	Little solid	2.0	Little solid	0.4	Little solid	0.4	Little solid	----	----	2.0	No solid
Me-THF	0.4	Little solid	1.5	No solid	0.4	No solid	----	----	----	----	----	----
DME	0.6	Little solid	1.5	No solid	0.6	Little solid	0.8	Little solid	----	----	1.5	No solid
EtOH	2.0	No solid	5.0	No solid	2.5	oil	2.0	No solid	5.0	No solid	5.0	No solid
i-PrOH	1.5	No solid	2.5	No solid	----	----	2.0	No solid	2.0	Little solid	----	----
pyridine	1.0	No solid	4.0	No solid	----	----	1.0	No solid	2.0	No solid	----	----
Propyl acetate	0.3	No solid	0.8	No solid	----	----	----	----	----	----	----	----
Isobutyl acetate	0.2	No solid	2.0	No solid	----	----	----	----	----	----	----	----
n-BuOH	0.5	No solid	2.0	No solid	----	----	----	----	0.5	No solid	----	----
1,2-Dichloroethane	1.0	No solid	5.0	No solid	----	----	1.2	No solid	----	----	----	----
DCM	1.0	oil	5.0	No solid	----	----	1.2	No solid	----	----	----	----
Toluene	0.2	Oil and Little solid	0.5	No solid	0.2	No solid	0.2	Oil and Little solid	----	----	0.5	No solid

(2) Polymorph Study from Crystalline Form—Preparation of Form A from Crystalline Form

Slow evaporation

[0132] About15 mg of sample (Crystalline Form A) was weighed into a 3-mL glass vial, followed by the addition of corresponding solvent or solvent mixture (see **Table 7**) to get a clear solution. Subsequently, the vial was covered with parafilm with 3~4 pinholes, and kept at RT to allow the solution to evaporate slowly. The solids were isolated for XRPD analysis. However, no crystal form was produced, as summarized in **Table 7**.

[0133] Table 7 Slow Evaporation Experiments

Experiment ID	Solvent (v/v)	Solid Form
1	MeOH	Amorphous
2	EtOH	Amorphous
3	IPA	Amorphous
4	ACN	Amorphous
5	Acetone	Oil

6	EtOAc	Oil
7	THF	Oil
8	DCM	Amorphous
9	Toluene	Oil
10	Acetic acid	Oil
11	EtOH/H_2O (4:1)	Amorphous
12	Acetone/H_2O (4:1)	Amorphous
13	THF/H_2O (4:1)	Amorphous
14	DCM/n-heptane (4:1)	Amorphous
15	EtOH/n-heptane (4:1)	Amorphous
16	EtOAc/n-heptane (6.5:1)	Oil
17	ACN/MTBE (4:1)	Oil

Anti-solvent addition

[0134] About 15 mg of sample (Crystalline Form A) was weighed into a 20-mL glass vial, followed by the addition of 0.4-1.2 mL corresponding solvent (see **Table 8**). The mixture was then magnetically stirred at the speed of 800 rpm to get a clear solution at RT. Subsequently, the relative anti-solvent (see **Table 8**) was added to the solution to induce precipitation or until the total amount of anti-solvent reached 15.0 mL. If no precipitation occurs, the solution was then transferred to slow evaporation at RT. Results summarized in **Table 8**.

[0135] Table 8 Anti-solvent Addition Experiments

Experiment ID	Anti-Solvent	Solvent	Solid Form
1	H_2O	EtOH	Oil
2	H_2O	THF	Oil
3	H_2O	Acetic acid	Oil
4	n-heptane	1,4-dioxane	Oil
5	MTBE	ACN	Oil
6	MTBE	NMP	N/A
7	MTBE	EtOH	Oil
8	MTBE	DCM	Oil

N/A: no solid was obtained.

Slow cooling

[0136] About 20 mg of sample (Crystalline Form A) was suspended in 1.0 mL of corresponding solvent (see **Table 9**) in a 3- mL glass vial at RT. The suspension was

transferred to slurry at 50 ºC using magnetic stirring with the speed of 800 rpm. The sample was equilibrated at 50 ºC for 2 hrs and filtered using a 0.45 μm Nylon membrane. Subsequently, the filtrate was slowly cooled down from 50 ºC to 5 ºC at a rate of 0.1 ºC/min. The obtained solids were kept isothermal at 5 ºC before isolated for XRPD analysis. No crystal form was obtained, as summarized in **Table 9**.

[0137] Table 9 Slow Cooling Experiments

Experiment ID	Solvent (v/v)	Solid Form
1	IPA	N/A
2	MIBK	N/A
3	IPAc	N/A
4	Toluene	N/A
5	EtOH/H_2O (1:2)	Gel
6	Acetone/H_2O (1:2)	Gel
7	EtOAc/n-heptane (1:2)	Amorphous
8	$CHCl_3$/n-heptane (1:2)	N/A
9	THF/n-heptane (1:2)	Oil*
10	ACN/MTBE (1:2)	Oil*

N/A: no solid was obtained.

*: clear solution was transferred to evaporate at RT.

Solution Vapor Diffusion

[0138] About 15 mg of sample (Crystalline Form A) was dissolved in 0.5-1.5 mL of corresponding solvent (see **Table 10**) to obtain a clear solution in a 3-mL vial. Subsequently, the solution was placed into a 20-mL vial with 3 mL of relative anti-solvent. The 20-mL vial was sealed with a cap and kept at RT, allowing sufficient time for organic vapor to interact with the solution. At the end of 11 days, clear solutions were transferred to evaporation at RT. The solids obtained were characterized by XRPD. The results summarized in **Table 10**.

[0139] Table 10 Solution Vapor Diffusion Experiments

Experiment ID	Solvent	Anti-solvent	Solid Form
1	EtOH	H_2O	Amorphous*
2	ACN	H_2O	N/A
3	Acetone	H_2O	Amorphous*
4	THF	H_2O	Amorphous*
5	Acetic acid	H_2O	Oil
6	EtOH	n-heptane	N/A

7	THF	n-heptane	Amorphous*
5	DCM	n-heptane	Amorphous*
8	DMAc	MTBE	N/A
9	IPA	MTBE	N/A
10	1,4-Dioxane	MTBE	N/A
11	Toluene	MTBE	N/A
12	NMP	MTBE	N/A

N/A: no solid was obtained.

*: solid was generated via slow evaporation.

Polymer-induced crystallization experiments

[0140] About 15 mg of sample (Crystalline Form A) was dissolved in 1.0 mL of corresponding solvent (see **Table 11**) to obtain a clear solution in a 3-mL vial. The solution was then filtered using 0.45 μm Nylon membrane. About 2 mg of polymer mixture was added into the filtrate. The mixture was stirred at RT to induce precipitation. The solids were isolated for XRPD analysis. No crystal form was obtained, as summarized in **Table 11**.

[0141] Table 11 Polymer-induced crystallization Experiments

Experiment ID	Solvent (v/v)	Polymer Mixture	Solid Form
1	EtOH	A	Amorphous
2	ACN	A	Amorphous
3	Acetone	A	Amorphous
4	THF	A	Amorphous
5	DCM	A	Amorphous
6	EtOAc	A	Amorphous
7	EtOH	B	Amorphous
8	ACN	B	Amorphous
9	Acetone	B	Amorphous
10	THF	B	Amorphous
11	DCM	B	Amorphous
12	EtOAc	B	Amorphous

Polymer mixture A: polyvinyl pyrrolidone (PVP), polyvinyl alcohol (PVA), polyvinylchloride (PVC), polyvinyl acetate (PVAC), hypromellose (HPMC), methyl cellulose (MC) (mass ratio of 1:1:1:1:1:1)
Polymer mixture B: polycaprolactone (PCL), polyethylene glycol (PEG), poly(methyl methacrylate) (PMMA) sodium alginate (SA), and hydroxyethyl cellulose (HEC) (mass ratio of 1:1:1:1:1).

Example 8 Determination of Absolute Configuration of Compound 1

Preparation of BG-13 Single Crystal

[0142] Six single crystal growth experiments (see **Table 12**) were performed via slow cooling. Suitable single crystals of BG-13 were obtained by slow cooling in MeOH/H_2O (1:1, v/v). The crystal data and structure refinement are listed in **Table 13**.

[0143] Table 12 single Crystal Growth Experiments

Experiment ID	Weight (mg)	Solvent (1 mL, v/v)	Method	Temperature (°C)	Dissolved (Y/N*)	Observation
1	5.6	IPA/H_2O (3/1)	cooling	60	N	Block-like crystal
2	5.5	IPA/H_2O (3/1)	cooling	60	N	Block -like crystal
3	5.4	IPA/H_2O (3/1)	cooling	60	N	Block -like crystal
4	5.5	IPA/H_2O (3/1)	cooling	60	N	Block -like crystal
5	4.7	MeOH/H_2O (2/1)	cooling	60	N	Crystal
6	5.5	MeOH/H_2O (1/1)	cooling	60	N	Crystal

Table 13 Single Crystal Data and Structure Refinement of BG-13

[0144] The data of single crystal were generated on a Bruker APEX DUO single-crystal diffractometer with CCD detector (Cu Kα，λ=1.54178 Å, 173.15 K).

Empirical formula	$C_{33}H_{34}N_5O_6$	-
Formula weight	596.65	
Temperature	173.15	-
Wavelength	1.54178 Å	-
Crystal system, space group	monoclinic	C2
Unit cell dimensions	a = 16.7939(4) Å b = 7.9871(2) Å c = 23.5438(5) Å	alpha = 90.00 deg. beta = 108.0460(10) deg. gamma = 90.00 deg.
Volume	3002.69(12)Å^3	-
Z, Calculated density	4	1.320 mg/mm^3
Absorption coefficient	0.756 mm^{-1}	-
F(000)	1260.0	-
Crystal size	0.3 ×0.21 ×0.08 mm^3	-

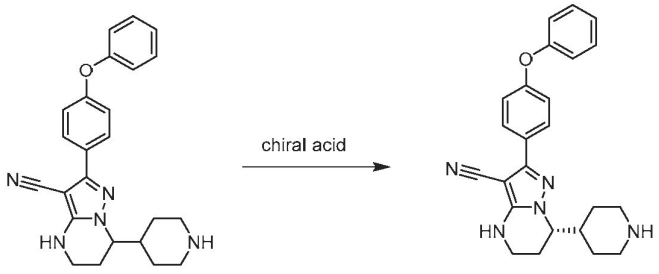
Theta range for data collection	1.97 to 64.96 deg.	-
Limiting indices	-19<=h<=17, -7<=k<=9, -27<=l<=24	- - -
Reflections collected / unique	5073 / 3756[R(int) = 0.1062]	-
Completeness	92.8%	-
Refinement method	Full matrix least squares on F^2	-
Data / restraints / parameters	3756/1/398	-
Goodness-of-fit on F^2	1.192	-
Final R indices [I>2sigma(I)]	R_1 =0.0819	wR_2 =0.2294
Absolute structure Flack	0.0(3)	
Largest diff. peak and hole	0.50 and -0.57 e.A^{-3}	-

[0145] BG-13 was confirmed to be a (2R, 3R)-dibenzoyl tartaric acid (L-DBTA) salt and the molar ratio of freebase to L-DBTA is 2:1. Configuration of both carbons (C32 and C32') in L-DBTA was confirmed to be R. Configuration of C6 in freebase was determined to be S, as shown in **FIG. 8** to **FIG. 10**. A powder X-ray diffraction pattern method was also used to characterize the structure of the single crystals, as shown in **FIG. 11**.

Absolute Configuration of Compound 1

[0146] The absolute configurations of **Compound 1** was deduced to be S from the single crystal X-ray structural analysis of intermediate **BG-13**.

Example 9 Chiral resolution of BG-11A



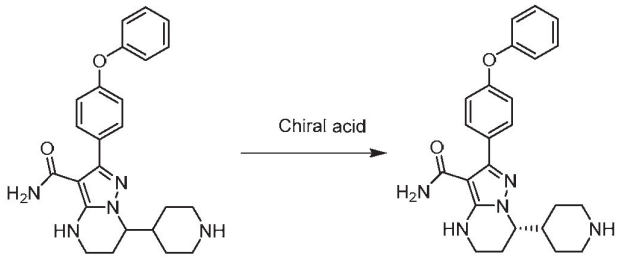
BG-11A

[0147] General procedure: To a solution of compound **BG-11A** in a prepared solvent system was added a chrial acid at elevated temperature. After stirring at this temperature, it was cooled to RT and stirred overnight at RT. The solid was filtered and washed with the prepared solvent system. The ee value was tested by chiral HPLC directly from the related salt or its Boc-derivative (see **Table 14**). Other chiral acids or solvent system gave no ee value, low ee value or not desired chiral compound.

[0148] Table 14 Chiral Resolution of BG-11A

Solvent System	Amount of 11A	Chiral acid	temperature	ee value	Yield
EtOH/H_2O/AcOH 7/3/1 (1.9 L)	40.0 g	D-DBTA (0.5 eq.)	70 °C to RT	>85% ee	42.2%
i-PrOH/H_2O/AcOH 7/3/1 (25 mL)	500 mg	D-DBTA (1.0 eq.)	70 °C to RT	77% ee	38.5%
i-PrOH/H_2O/AcOH 7/3/1 (25 mL)	500 mg	D-DBTA (0.5 eq.)	70 °C to RT	85% ee	38.9%
EtOH/H_2O/AcOH 7/3/1 (25 mL)	500 mg	D-DBTA (0.5 eq.)	70 °C to RT	86% ee	39.8%
MeOH/H_2O/AcOH 7/3/1 (25 mL)	500 mg	D-DBTA (0.5 eq.)	70 °C to RT	82% ee	42.2%
AcOH/H_2O 3/1 (40 mL)	1 g	D-DBTA (0.55 eq.)	60 °C to RT	83% ee	27.6%
1,4-dioxane/H2O 1/1 (2.5 mL)	25 mg	D-DBTA (2.0 eq.)	60 °C to RT	No Solid	No Solid
MeOH/H_2O 1/1 (2.5 mL)	25 mg	D-DBTA (2.0 eq.)	60 °C to RT	36% ee	Not weigh
CH_3CN/H_2O 9/1 (2.5 mL)	25 mg	D-DBTA (2.0 eq.)	60 °C to RT	14% ee	Not weigh
CH_3CN/H_2O 6/1 (2.5 mL)	25 mg	D-DBTA (2.0 eq.)	60 °C to RT	89% ee	Not weigh
i-PrOH/H_2O 1/1 (2.5 mL)	25 mg	D-DBTA (2.0 eq.)	60 °C to RT	79% ee	Not weigh
CH_3CN/H_2O 4/1 (1 mL)	50 mg	D-DBTA (1.0 eq.)	60 °C to RT	24% ee	46%
CH_3CN/H_2O 4/1 (1.5 mL)	50 mg	D-DBTA (1.0 eq.)	60 °C to RT	91% ee	33.7%

Example 10 Chiral resolution of BG-12A and improve the chiral purity



BG-12A

[0149] General procedure: To a solution of compound BG-**12A** in a prepared solvent system was added chrial acid in at elevated temperature. After stirring at this temperature, it was cooled to RT and stirred overnight at RT. The solid was filtered and washed with the prepared

solvent system. The chiral purity was tested by chiral HPLC directly from the related salt or free base (see **Table 15**). Other chiral acids or solvent system gave no ee value, low ee value or not desired chiral compound.

[0150] Table 15 Chiral Resolution of BG-12A

Solvent System	Amount of BG-12A	Chiral acid	Temperature	ee value	Yield
MeOH/H_2O 3/1 (1500 mL)	50 g	L-DBTA (0.35 eq.)	50 °C to RT	85.6% ee	43.1%
EtOH/H_2O 6/1 (250 mL)	14.4 g	L-DBTA (0.55 eq.)	78 °C to RT	79.1% ee	41.8%
n-BuOH/H_2O 6/1 (20 mL)	1 g	L-DBTA (0.8 eq.)	80 °C to RT	95% ee	20%
MeOH (4 mL)	500 mg	L-DBTA (1.1 eq.)	Reflux to RT	No solid	
EtOH (17 mL)	1.0 g	L-DBTA (1.1 eq.)	Reflux to RT	40%ee	Not weigh
EtOH (30 mL)	500 mg	L-DBTA (2.2 eq.)	Reflux to RT	No ee	Not weigh

[0151] The obtained L-DBTA salt (31 g, 85.6% ee) was added to THF/H_2O (1/1, 1034 mL), the suspension was warmed to 70 °C and stirred until all solid dissolved. Then 517 mL of water was added. The solution was then slowly cooed to 40 °C and added seed crystal (10 mg). After stirring for about 2 hrs, the solution was slowly cooled to ambient temperature and stirred for 2 days. Filtered, the solid was washed with THF/H_2O=1/1 (20 mL) and dried over under reduced pressure to give the product as a white solid (22.5 g, 72% yield, >98.5 ee value).

[0152] The obtained free base (6.02 g, 79.1% ee) was dissolved in (1g/15 mL) EtOH/H_2O (6/1, 90 mL), stirred at 78 ^{0}C allowing all the starting material to be dissolved. Then, a solution of L-DBTA (2.84 g, 7.9 mmol, 0.55 eq) in EtOH/H_2O (6/1, 7 mL) was added. The solid quickly formed, the mixture was stirred at this temperature for 1 h before removing the heating system. The mixture was allowed to cool to RT. Filtered, the solid was washed with EtOH/H_2O (6/1, 10 mL). The collected solid was converted to free base using in NaOH aqueous solution and DCM to get the product (4.7 g, yield: 32.6%, 93% ee) as a white foam.

[0153] A suspension of the obtained free base (70.0 g, 90.5% ee) in CH_3CN/H_2O (1/1, 700 mL) was heated to 60 °C to give a clear solution. To the above solution was then addeded L-DBTA (33 g, 0.55 eq). After stirring at 60 °C for about 2 hr, the mixture was slowly cooled to RT and stirred for overnight. Filtered, the solid was washed with CH_3CN/H_2O (1/1, 50 mL), dried over under reduced pressure to give the product as a off-white solid (80 g, yield: 80% ee value > 98%).

Example 11 Efficacy Tests

[0154] (S)-7-(1-acryloylpiperidin-4-yl)-2-(4-phenoxyphenyl)-4,5,6,7-tetrahydropyrazolo[1,5-a]pyrimidine-3-carboxamide was tested hereinafter by using its Crystalline Form A.

Test 1: Inhibition and Selectivity of the Kinases

Methods:

(1) BTK kinase enzymatic assays

[0155] Crystalline Form A of **Compound 1** was tested for inhibition of BTK kinase (aa2-659, Carna Biosciences) in assays based on the time-resolved fluorescence-resonance energy transfer (TR-FRET) methodology. The assays were carried out in 384-well low volume black plates in a reaction mixture containing BTK kinase, 5μM ATP, 2μM peptide substrate and 0-10 μM compound in buffer containing 50 mM Tris pH7.4, 10 mM $MgCl_2$, 2 mM $MnCl_2$, 0.1 mM EDTA, 1 mM DTT, 0.005% Tween-20, 20 nM SEB and 0.01% BSA. The kinase was incubated with compound for 60 minutes at room temperature and the reaction was initiated by the addition of ATP and peptide substrate. After reaction at room temperature for 60 minutes, an equal volume of stop/detection solution was added according to the manufacture's instruction (CisBio Bioassays). The stop/detection solution contained Eu^{3+} cryptate-conjugated mouse monoclonal antibody (PT66) anti-phosphotyrosine and XL665-conjugated streptavidin in buffer containing 50 mM HEPES pHn7.0, 800 mM KF, 20 mM EDTA, and 0.1% BSA. Plates were sealed and incubated at room temperature for 1 hour, and the TR-FRET signals (ratio of fluorescence emission at 665 nm over emission at 620 nm with excitation at 337 nm wavelength) were recorded on a PHERAstar FS plate reader (BMG Labtech). Phosphorylation of peptide substrate led to the binding of anti-phosphotyrosine antibody to the biotinylated peptide substrate, which places fluorescent donor (Eu^{3+} crypate) in close proximity to the accepter (Streptavidin-XL665), thus resulting in a high degree of fluorescence resonance energy transfer from the donor fluorophore (at 620 nm) to the acceptor fluorophore (at 665 nm). Inhibition of BTK kinase activity resulted in decrease of the TR-FRET signal. The IC_{50} for **Compound 1** was derived from fitting the data to the four-parameter logistic equation by Graphpad Prism software.

(2) Biochemical Kinase Selectivity

[0156] Selectivity of Crystalline Form A was profiled against a panel of 342 kinases at 1 M at Reaction Biology Corp.. Crystalline Form A displayed less than 70% inhibition against 329 kinases, and greater than 70% inhibition against 13 kinases including BTK. IC_{50s} of Crystalline Form A (see **Table 13**), including ITK, TEC, JAK3 and EGFR assays carried out in-house at BeiGene by using a TR-FRET assay and corresponding peptides as the substrate.

[0157] IC_{50} determination of ITK: The protocol of ITK assay is similar to BTK assay except for the following modification: 3 μM ATP and 2 μM TK substrate were used in the kinase reaction.

[0158] IC_{50} determination of TEC**:** The protocol of Tec assay is similar to BTK assay except for the following modifications: 1) 280 μM ATP and 2nM Poly-GT substrate were used in the kinase reaction; 2) the reaction buffer doesn't contain SEB.

[0159] IC_{50} determination of JAK3: The protocol of JAK3 assay is similar to BTK assay except for the following modifications: 1) 3.4 μM ATP and 3 μM peptide substrate (B-EE-15, Biotin-EQEDEPEGDYFEWLE) were used in the kinase reaction; 2) the reaction buffer contains 50 mM Tris pH7.8, 10 mM $MgCl_2$, 5 mM DTT, 0.01% Triton X-100 and 0.01% BSA.

[0160] IC_{50} determination of EGFR: The protocol of EGFR assay is similar to BTK assay except for the following modifications: 1) 20 μM ATP， 1.44 μM TK substrate-biotin (one universal substrate for tyrosine kinases) and 0-1000 nM compound (the final concentration of 1% DMSO) were used in the kinase reaction; 2) the reaction buffer contains 50 mM HEPES pH7.5, 10 mM $MgCl_2$, 1 mM EGTA, 0.01% Brij-35, 2.5 mM DTT and 0.1% BSA; 3) the stop/detection solution buffer contains 25 mM HEPES pH7.5, 400 mM KF, 50 mM EDTA， 0.01%Triton-X100 and 0.1% BSA.

Results:

[0161] IC_{50} of Crystalline From A for BTK kinase was 0.27 nM. Crystalline Form A was shown to be a potent, specific and irreversible BTK kinase inhibitor. In terms of its selectivity, Crystalline Form A inhibited only 13 other kinases more than 70% when profiled against a panel of 342 human kinases at 1 μM.

[0162] Table 16 Enzymatic Inhibition Activities of Crystalline Form A

Enzyme	IC_{50} (nM)
BTK	0.27
ITK	53
TEC	1.9
JAK3	600
EGFR	3.6
BLK	1.13
BMX/ETK	0.62
BRK	33
ERBB4/HER4	1.58

FGR	155
FRK/PTK5	379
LCK	187
TXK	2.95

Note: BTK, EGFR, ITK, TEC and JAK3 assays were carried out by using a TR-FRET assay and corresponding peptides as substrate. IC_{50}s of Crystalline Form A were measured at K_M of ATP for the five kinases and with 1-hour pre-incubation. HER4, BMX, TXK, BLK FGR, LCK, FRK/PTK5 assays were carried out at Reaction Biology Corp. using ^{33}P-ATP and filter-binding assay. IC_{50}s of Crystalline Form A were measured at 1 M ATP and with 1-hour pre-incubation.

Test 2: BTKpY223 cellular assay by Crystalline Form A

Methods:

[0163] BTKpY223 cellular assay is a HTRF based assay intended to quantitatively determine the endogenous levels of phosphorylationat BTK Tyr223. Phosphorylated Tyr223 is necessary for full activation of BTK. The assay was performed in Ramos cells (CRL-1596, ATCC) with a BTKpY223 assay kit (63IDC000, Cisbio).

[0164] Briefly, Ramos cells were serum starved in 0.5% FBS-containing RPMI1640 for 2 hours. Following starvation, the cells were incubated with Crystalline Form A to be detected at various concentrations in a CO_2 incubator for 1 hour. After incubation, cells were stimulated with 1mM pervanadate (PV) or Na_3VO_4 (OV) for 20 min. Then, the cells were spun down and lysed with 1x lysis buffer at RT for 10 min (4x lysis buffer supplied in the kit). During incubation, 1x antibody mix was prepared by diluting anti-BTK-d2 and anti-pBTK-K in detection buffer (supplied in the kit). 2 ul/well of 1 x antibody mixture was dispensed into the OptiPlate-384 assay plate (6005620, Perkin Elmer). After that, 18 μL of cell lysate was transferred to the assay plate pre-loaded with antibody solution. After mixing gently and spinning briefly, the plate was sealed up and kept in dark at RT for 18 hours. The fluorescence emission was measured at two different wavelengths (665 nm and 620 nm) on a compatible HTRF reader (PHERAstar FS, BMG). The potency of **Compound 1** was calculated basing on the inhibition of ratio between signal intensities at 665 nm and 620 nm. IC_{50} values were calculated with GraphPad Prism software using the sigmoidal doseresponse function.

Results:

[0165] Crystalline Form A inhibited the phosphorylation of BTK in the B cell lymphoma cell line, Ramos, at concentration as low as 1.8±0.2 nM (n=3).

Test 3: Effects of Crystalline Form A on Tumor Cell Proliferation in Haematological Cancer Lines (Rec-1, Mino, JEKO-1 and TMD-8)

Methods:

[0166] 3 MCL cell lines (Rec-1, Mino and JEKO-1) and an ABC type diffuse large B-cell lymphoma cell line (TMD8) were used in this study. Cell lines were maintained in RPMI-1640 supplemented with 10% fetal bovine serum/FBS (Thermo Scientific); 100 units/ml penicillin (Gibco) and 0.1mg/ml streptomycin (Gibco) and kept at 37°C in a humidified atmosphere of 5% CO_2 in air. Cell lines were reinstated from frozen stocks that were laid down within 30 passages from the original cells purchased.

[0167] The growth-inhibitory activity of compounds in Rec-1, Mino, JEKO-1 and TMD-8 cells was determined using CellTiter-Glo luminescent cell viability assay (Promega). The number of cells seeded per well of a 96-well plate was optimized for each cell line to ensure logarithmic growth over 6 days treatment period. Cells were treated in triplicate with a 10-point dilution series. Following a 6-day exposure to the compound, a volume of CellTiter-Glo reagent equal to the volume of cell culture medium present in each well was added. Mixture was mixed on an orbital shaker for 2 minutes to allow cell lysis, followed by 10 minutes incubation at room temperature to allow development and stabilization of luminescent signal, which corresponded to quantity of ATP and thus the quantity of metabolically active cells. Luminescent signal was measured using PHERAstar FS reader (BMG Labtech). IC_{50} values for cell viability were determined with GraphPad Prism software and were the mean of 3 independent assays.

Results:

[0168] Crystalline Form A of **Compound 1** exhibited specific and potent inhibitory effect on cellular proliferation in 3 MCL cell lines and an ABC type diffuse large B-cell lymphoma cell line (TMD8) (**Table 17**).

Table 17 Inhibition of Crystalline Form A on hematic tumor cell proliferation

Cell line	Cell Type	Potency IC50(nM)	Standard deviation(nM)
Rec-1	MCL	0.36	0.03
Mino	MCL	3.8	1.8
JEKO-1	MCL	20.0	NA
TMD-8	DLBCL(ABC)	0.54	0.3

Test 4: Pharmacokinetics study of Crystalline Form A in mouse

Methods:

[0169] For time course study, mice were randomly assigned into 7 groups with 4 mice per group. Mice were treated with single dose of Crystalline Form A of **Compound 1** and euthanized using carbon dioxide at different time points (30 minutes, 1, 2, 4, 12, 24 hrs) after dosing. For dose dependency study, mice were randomly assigned into 9 groups with 4 mice per group. Mice were treated with different dose levels of Crystalline Form A of **Compound 1** and euthanized using carbon dioxide at 4 hrs after dosing. Treatments were administered by oral gavage (p.o.) in a volume of 10 ml/kg body weight. Body weight was assessed immediately before dosing and volume dosed was adjusted accordingly.

[0170] PK SAMPLE PREPARATION: For time course study, blood samples (50 μL per mouse) were collected from the retro-orbital sinus under isoflurane/oxygen anesthesia at 15 min after dosing (this group of mice were also used for 24 hr time point) or heart puncture after euthanization for the other time points. For dose dependency study, blood samples were collected from the retro-orbital sinus under isoflurane/oxygen anesthesia at 30 minutes after dosing. Plasma was collected by centrifugation at 3,000 g for 10 minutes and was kept frozen in -80 ºC until analysis.

[0171] PK Analysis: maximum plasma concentration (Cmax) and time to reach Cmax (Tmax) were taken directly from the plasma concentration versus time profiles.

Results:

[0172] Crystalline Form A was quickly absorbed and eliminated in ICR mice.

Test 5: Efficacy study of Crystalline Form A for in TMD-8 xenograft model

Tumor implantation Methods:

[0173] Animals were pre-treated with cyclophosphamide (prepared in saline, 150 mg/kg i.p.) and disulfiram (prepared in 0.8% Tween 80 in saline, 125 mg/kg p.o., one hour after each dose of cyclophosphamide) once daily for two days. Animals were then inoculated with TMD-8 cells 24 hours after the second dose of cyclophosphamide. On the day of implantation, cell culture medium was replaced with fresh medium. Four hours later, media was removed and cells were collected as described above. Cells were re-suspended in cold (4 ºC) PBS and same volume of matrigel (BD, Cat# 356237) was added to give a final concentration of 2.5×10^7 cells/ml. Resuspended cells were placed on ice prior to inoculation The right axilla region of each mouse was cleaned with 75% ethanol prior to cell inoculation. Each animal was injected subcutaneously with 5×10^6 cells in 200 μl of cell suspension in the right front flank via a 26-gauge needle.

[0174] For in vivo efficacy studies, starting from day 3 after cell inoculation, animals were randomly assigned into desired number of groups with 10 mice per group. Mice were treated twice daily (BID) with vehicle (0.5% carboxymethylcellulose (CMC) + 0.2% Tween 80), and

different dose levels of Crystalline Form A of **Compound 1** for 39 days. Treatments were administered by oral gavage (p.o.) in a volume of 10 ml/kg body weight. Body weight was assessed immediately before dosing and volume dosed was adjusted accordingly. Tumor volume was measured twice weekly in two dimensions using a calliper (measureable from day 11 post inoculation in this study). Tumor volume was calculated using the formula: $V = 0.5 \times (a \times b^2)$ where a and b are the long and short diameters of the tumor, respectively. Statistical analysis was conducted using the student T-test. $P < 0.05$ was considered statistically significant. One individual was responsible for tumor measurement for the entire duration of the study. Body weights were also recorded twice weekly. Mice were also being monitored daily for clinical signs of toxicity for the duration of the study.

Results:

[0175] *In vivo* efficacy of Crystalline Form A was examined in TMD-8 DLBCL xenografts grown subcutaneously in NOD/SCID mice. Following daily oral administration at well tolerated at different dose levels twice daily (BID), Crystalline Form A of **Compound 1** induced dose-dependent anti-tumor effects. Crystalline Form A of **Compound 1** at lowest dose tested already showed strong anti-tumor activity. All treatment groups had no significant impact on animal body weight throughout the study.

Test 6: Efficacy study of Crystalline Form A in systemic REC-1 xenograft model

Tumor implantation Methods:

[0176] Animals were pre-treated with cyclophosphamide (prepared in saline, 150 mpk i.p.) and disulfiram (prepared in 0.8% TW-80 in saline, 125 mpk p.o., one hour after each dose of cyclophosphamide) once daily for two days. Animals were then inoculated with REC-1 cells 24 hours after the second dose of cyclophosphamide. On the day of implantation, cell culture medium was replaced with fresh medium. Four hours later, media was removed and cells were collected as described above. Cells were re-suspended in cold (4 ºC) PBS to give a final concentration of 1×10^8 cells/ml. Resuspended cells were placed on ice prior to implantation. Each animal was injected intravenously via tail vein with 1×10^7 cells in 100 l of cell suspension.

[0177] For in vivo efficacy studies, starting from day 8 after cell inoculation, animals were randomly assigned into desired number of groups with 10 mice per group. Mice were treated either twice daily (BID) with vehicle (0.5% carboxymethylcellulose (CMC) + 0.2% Tween 80), different dose levels of Crystalline Form A of **Compound 1** for 71 days. All dosing was stopped on day 78 after inoculation. Treatments were administered by oral gavage (p.o.) in a volume of 10 ml/kg body weight. Body weight was assessed immediately before dosing and volume dosed was adjusted accordingly. Body weight was recorded twice weekly (changed to

three times per week from day 33). Mice were also watched daily for clinical signs of sickness for the duration of the study. The endpoint of the study is overall survival. In the case of severe toxic effect, such as loss of movement, mice were euthanized and scored as death.

[0178] For Data Analysis: Survival analysis was performed by Kaplan-Meier method. The survival time was defined as the time from the day of tumor cell inoculation to the date of animal death or being euthanized. For each group, median survival time (MST), range of survival time (RST) with 95% confidence interval and increase in life-span (ILS) were calculated. Median survival is defined as the time when 50% of mice have died. ILS was calculated using the following formula:

$\%ILS = (MST - MST_{(vehicle)})/MST_{(vehicle)} X100$

Statistical analysis was conducted between each group using Gehan-Breslow-Wilcoxon Test. $P < 0.05$ was considered as statistically significant.

Results:

[0179] Crystalline Form A of **Compound 1** demonstrated dose-dependent anti-tumor activity against systemic REC-1 MCL engrafts in NOD/SCID mice. Crystalline Form A of **Compound 1** was significantly effective in this xenograft model.

Test 7: Toxicology of Crystalline Form A

[0180] A comprehensive nonclinical toxicity study program, including 28-day GLP studies in rats and dogs and several investigational studies, was conducted for the evaluation of the preclinical safety of Crystalline Form A of **Compound 1** at different doses. These studies took account the available regulatory guidance for preclinical development of anticancer drugs. In these studies, **Compound 1** demonstrated a favorable toxicology and safety pharmacology profile. No test article-related mortality occurred at any dose levels throughout the study. No toxicologically significant changes in clinical chemistry or coagulation were noted throughout the study. None of these changes were noted after the recovery phase.

Test 8: Pharmacokinetics of Crystalline Form A

[0181] The fully-validated LC-MS/MS method was well used for the pharmacokinetic (PK) studies of Crystalline Form A of **Compound 1** in Sprague-Dawley rats and beagle dogs following single- and multiple-dose administrations.

[0182] Crystalline Form A of **Compound 1** has good oral bioavailability in rats. It was quickly absorbed and exhibited high plasma clearance (CL) in rats. The kinetics was linear over the dose range in female rats. The linearity in male rats was not as good. There was no statistically significant accumulation of **Compound 1** following multiple oral dosing in both male and female rats. Crystalline Form A of **Compound 1** exhibited moderate clearance (CL),

reasonably good bioavailability (F%), linear PK over the dose range and no accumulation of **Compound 1** following multiple oral dosing in dogs.

Test 9: ADME of Crystalline Form A

[0183] **Compound 1** was widely distributed to various tissues, but was low in brain tissue, indicating the drug does not easily cross the blood-brain barrier.

[0184] IC_{50} values of Crystalline Form A of **Compound 1** for seven major drug metabolizing CYP isozymes (CYP1A2, CYP2B6, CYP2C8, CYP2C9, CYP2C19, CYP2D6, and CYP3A) were determined in human liver microsomes and the time-dependent inhibition potential on major CYP isozymes of **Compound 1** was also evaluated. It showed weak inhibition on CYP2C8 (IC_{50} = 4.03 μM), CYP2C9 (IC_{50} = 5.69 μM) and CYP2C19 (IC_{50} = 7.58 μM), but lower inhibition on other CYP isozymes. **Compound 1** is unlikely to be time dependent CYP inhibitors on these 7 major human CYPs. CYP3A is the major CYP isoform responsible for the metabolism in human liver microsomes.

Example 12 Clinical Trail Study

(1) Ongoing Clinical Trial phase 1 Result on **Compound 1** in Patients with advanced B cell malignancies

[0185] The first-in-human multi-center, open-label phase 1 trial of **Compound 1** is being conducted in Australia and New Zealand and is comprised of two parts – a dose-escalation phase involving 25 patients and a dose-expansion phase, in which we plan to enroll a total of 100 patients. A total of 39 patients, including all 25 patients from the initial dose-escalation component and 14 patients from the ongoing dose-expansion component were enrolled. Based on the pharmacokinetics, pharmacodynamics, safety and efficacy of Compound 1 in the dose-escalation phase, 320mg once daily (QD) and 160 mg twice daily (BID) are being further explored in the ongoing dose-expansion trial.

[0186] As of October 19, 2015, the cutoff date for data analysis, 29 objective responses have been observed, including 3 complete responses (CRs), 1 very good partial response (VGPR), and 25 partial responses (PRs). Responses by histology are summarized in **Table 18**. 31 of the 39 patients remain on study treatment, free of progression, including all patients to date who have achieved an objective response.

[0187] Table 18 Responses by histology of Patients

	Follow-up Days Median (Range)	Best Response				ORR (CR + PR)
		CR	PR	SD	PD	
Chronic Lymphocytic Leukemia	220 (83-329)	0/14 (0%)	13/14[1] (93%)	1/14 (7%)	0 (0%)	13/14 (93%)
Mantle Cell Lymphoma	148 (84-392)	2/10 (20%)	6/10 (60%)	1/10 (10%)	1/10 (10%)	8/10 (80%)
Waldenström's Macroglobulinemia	271 (11-398)	0/7 (0%)	6/7[2] (86%)	0/7 (0%)	1/7 (14%)	6/7 (86%)
DLBCL	29 (20-236)	1/4 (25%)	0/4 (0%)	0/4 (0%)	3/4 (75%)	1/4 (25%)
Indolent NHL	233 (215-250)	0/2 (0%)	0/2 (0%)	2/2 (100%)	0/2 (0%)	0/2 (0%)
Hairy Cell Leukemia	362	0/1 (0%)	1/1 (100%)	0/1 (0%)	0/1 (0%)	1/1 (100%)
Burkitt's-like Lymphoma	84	0/1 (0%)	0/1 (0%)	0/1 (0%)	1/1 (100%)	0/1 (0%)

[1] Includes five patients with lymphocytosis at latest assessment; [2] Includes one patient with VGPR

Note: CR = complete response; PR = partial response; SD = stable disease; PD =progressive disease; ORR = objective response rate

[0188] 8 patients discontinued **Compound 1**, including 6 due to disease progression and 2 due to adverse events related to their underlying malignancy. 3 patients died during study as a result of disease progression or complications of disease progression. There were no drug-related serious adverse events (SAEs). The vast majority of adverse events, regardless of relationship to treatment, were Grade 1 or 2 in severity and not treatment-limiting. Of the 19 ≥Grade 3 AEs, 4 were assessed by investigators as possibly drug-related – all were self-limited neutropenia, not requiring treatment discontinuation. There was one case of major hemorrhage, defined as a bleeding event grade 3 or higher or an intracranial bleeding event of any grade: GI hemorrhage in a mantle cell lymphoma patient with lymphomatous involvement of the GI tract; this bleeding event occurred during drug hold, and resolved rapidly with re-initiation of **Compound 1** treatment, and therefore is not considered to be drug-related. 6 patients had a baseline history of atrial fibrillation/flutter (AF), and no exacerbation or new event of AF was reported.

(2) Ongoing Clinical Trial Phase 1 result on **Compound 1** in Patients with Waldenström's Macroglobulinemia (WM)

[0189] The multi-center, open-label Phase 1 trial of **Compound 1** in B-cell malignancies is being conducted in Australia, New Zealand, South Korea, and the United States and consists of a dose-escalation phase and a dose-expansion phase in disease-specific cohorts, which include treatment naïve and relapsed/refractory waldenström's macroglobulinemia (R/R WM). The dose-escalation component of the trail tested total daily doses ranging from 40 mg to 320 mg,

and the ongoing dose-expansion phase is testing doses of 160 mg twice a day (BID) or 320 mg once a day (QD). As of March 31, 2017, 48 patients with WM were enrolled in the study. Responses were determined according to the modified Sixth International Workshop on WM (IWWM) criteria.

[0190] **Compound 1** was shown to be well tolerated with no discontinuation for **Compound 1**-related toxicity to date. Adverse events (AEs) were generally mild in severity and self-limited. The most frequent AEs (>10%) of any attribution among 48 patients evaluable for safety were petechiae/purpura/contusion (35%), upper respiratory tract infection (31%), constipation (25%), diarrhea (19%), epistaxis (19%), nausea (17%), cough (15%), anemia (15%), headache (15%), neutropenia (13%), and rash (13%), all of which were grade 1 or 2 in severity except for grade 3 or 4 anemia and neutropenia (8% each) as well as grade 3 or 4 diarrhea and headache (2% each). Five serious AEs were assessed to be possibly related to **Compound 1**; these included one case each of hemothorax, atrial fibrillation, colitis, febrile neutropenia, and headache. Among AEs of special interest, there were a total of three cases of atrial fibrillation (all grade 1 or 2), and one case of serious hemorrhage (hemothorax), defined as grade 3 or higher hemorrhage or central nervous system hemorrhage of any grade. Three events led to treatment discontinuation: one case each of bronchiectasis, prostate adenocarcinoma, and adenocarcinoma of pylorus.

[0191] At the time of the data cutoff, 42 patients were evaluable for response. Patients not evaluable for efficacy included two patients with less than 12 weeks of follow-up, three patients with IgM < 500mg/dl at baseline, and one patient with inaccurate baseline IgM due to cryoprotein. At a median follow-up of 12.3 months (4.4–30.5 months), the ORR was 90% (38/42 patients) and the major response rate was 76% (32/42 patients), with VGPRs in 43% (18/42) of patients and partial responses in 33% (14/42) of patients.

(3) Ongoing Clinical Trial Phase 1 Result on Compound 1 in Patients with Chronic Lymphocytic Leukemia and Small Lymphocytic Lymphoma (CLL/SLL)

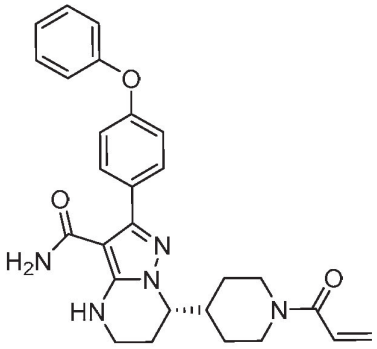
[0192] The multi-center, open-label Phase 1 trial of **Compound 1** in patients with B-cell malignancies is being conducted in Australia, New Zealand, South Korea, and the United States and consists of a dose-escalation phase and a dose-expansion phase in disease-specific cohorts, which include treatment naïve (TN) and relapsed/refractory (R/R) CLL/SLL. The dose-escalation component of the trail tested total daily doses between 40 mg and 320 mg, and the ongoing dose-expansion component is testing doses of 160 mg twice a day (BID) or 320 mg once a day (QD). As of March 31, 2017, 69 patients with CLL or SLL (18 TN, 51 R/R) were enrolled in the study.

[0193] Compound 1 was shown to be well tolerated in CLL/SLL. The most frequent adverse events (AEs) (≥10%) of any attribution were petechiae/purpura/contusion (46%), fatigue (29%), upper respiratory tract infection (28%), cough (23%), diarrhea (22%), headache (19%), hematuria (15%), nausea (13%), rash (13%), arthralgia (12%), muscle spasms (12%), and urinary tract infection (12%); all of these events were grade 1 or 2 except for one case of grade 3 purpura (subcutaneous hemorrhage), which was the only major bleeding event. Additional adverse events of interest included one case of each grade 2 diarrhea and grade 2 atrial fibrillation. A total of 18 serious AEs (SAEs) occurred in 13 patients, with no SAE occurring in more than one patient. Only one patient discontinued treatment due to an AE, a grade 2 pleural effusion.

[0194] At the time of the data cutoff, 66 patients (16 TN and 50 R/R) had more than 12 weeks of follow-up and were evaluable for efficacy, and three other patients had less than 12 weeks of follow-up. After a median follow-up of 10.5 months (2.2-26.8 months), the overall response rate (ORR) was 94% (62/66) with complete responses (CRs) in 3% (2/66), partial responses (PRs) in 82% (54/66), and PRs with lymphocytosis (PR-Ls) in 9% (6/66) of patients. Stable disease (SD) was observed in 5% (3/66) of patients. The patient with pleural effusion discontinued treatment prior to week 12 and was not evaluable for response. There was one instance of Hodgkin's transformation. In TN CLL/SLL, at a median follow-up time of 7.6 months (3.7-11.6 months), the ORR was 100% (16/16) with CRs in 6% (1/16), PRs in 81% (13/16) and PR-Ls in 13% (2/16) of patients. In R/R CLL/SLL, at a median follow-up time of 14.0 months (2.2-26.8 months), the ORR was 92% (46/50) with CRs in 2% (1/50), PRs in 82% (41/50), and PR-Ls in 8% (4/50) of patients. Stable disease was observed in 6% (3/50) patients.

STATEMENTS OF INVENTION

1. A crystalline form of Compound 1,



Compound 1 .

2. The crystalline form of Claim 1, wherein the crystalline form is an anhydrate.

3. The crystalline form of any one of Claims 1 or 2, characterized by an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values independently selected from: approximately 14.8±0.2°, 16.4±0.2° and 21.4±0.2°.

4. The crystalline form of any one of Claims 1 or 2, characterized by an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values independently selected from: approximately 14.8±0.2°, 15.6±0.2°, 16.4±0.2° and 21.4±0.2°.

5. The crystalline form of any one of Claims 1 or 2, characterized by an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values independently selected from: approximately 12.2±0.2°, 12.9±0.2°, 14.8±0.2°, 15.6±0.2°, 16.4±0.2° and 21.4±0.2°.

6. The crystalline form of any one of Claims 1 or 2, characterized by an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values independently selected from: approximately 12.2±0.2°, 12.9±0.2°, 14.8±0.2°, 15.6±0.2°, 16.4±0.2°, 17.7±0.2°, 18.5±0.2°, 20.7±0.2° and 21.4±0.2°.

7. The crystalline form of any one of Claims 1 or 2, wherein the crystalline form has an X-ray powder diffraction pattern substantially in accordance with **FIG. 1**.

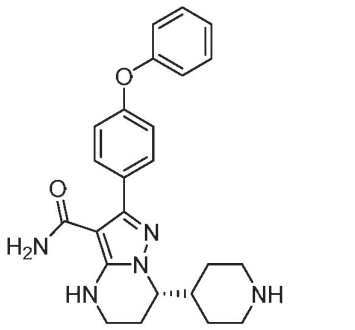
8. The crystalline form of any one of Claims 2-7, wherein the crystalline form is characterized by a melting point of 139±2 ºC (onset temperature).

9. The crystalline form of any one of Claims 2-7, wherein the crystalline form is characterized by having a DSC substantially in accordance with **FIG. 2**.

10. The crystalline form of any one of Claims 2-7, wherein the crystalline form is characterized by having a TGA substantially in accordance with **FIG. 3.**

11. The crystalline form of any one of Claims 1-7, wherein the crystalline form is characterized by a purity of >85% or a purity of >95% or a purity of >99%.

12. A crystalline form of the compound having the following structure,

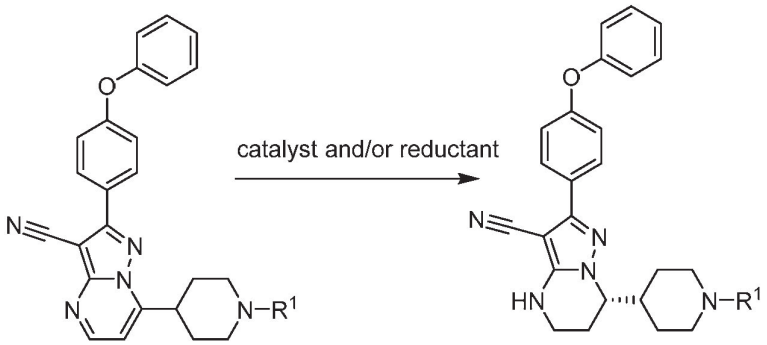


1/2 L-DBTA

wherein the crystalline form has an X-ray powder diffraction pattern substantially in accordance with **FIG. 11.**

13. The crystalline form of Claim 12, wherein the crystalline form is characterized by having a unit cell dimensions comprising a=16.7939(4)Å, b=7.9871(2)Å, c=23.5438(5)Å, alpha=90.00deg., beta=108.0460(10)deg., gamma=90.00deg.

14. A method of preparing the compound of Formula **Ia**, comprising asymmetrically reducing the compound of Formula **I** in the presence of the catalyst and/or reductant to produce the compound of Formula **Ia**,



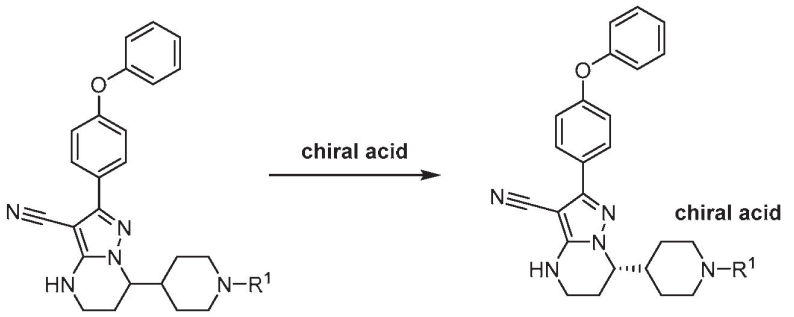
Formula **I** Formula **Ia**

wherein the R^1 is hydrogen or an amino protecting group.

15. The method of Claim14, where in the amino protecting group is selected from acetyl, propionyl, butyryl, phenylacetyl, benzoyl, toluyl, phenoxyacetyl, methoxycarbonyl, ethoxycarbonyl, 2,2,2-trichloroethoxycarbonyl, tert-butyloxycarbonyl, 2-iodoethoxycarbonyl, carbobenzoxy, 4-methoxybenzyloxycarbonyl, (Fluoren-9-ylmethoxy)carbonyl, 4-methoxy-2,3,6-trimethylbenzenesulphonyl, benzyl, methyl or 4-methoxybenzyl.

16. The method of Claim 14, wherein the catalyst is a neutral catalyst system, or a cationic catalyst system.

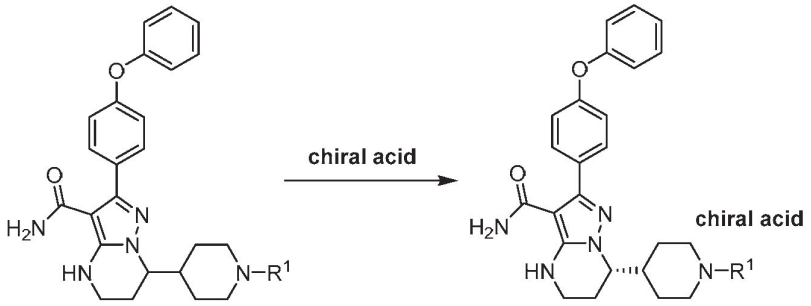
17. A method of resolving a compound of Formula **IIa** to produce the compound of Formula **IIb** or improving the chiral purity of the compound of Formula **IIb**, comprising treating the racemic compound of Formula **IIa** with a chiral acid,



Formula **IIa** Formula **IIb**

wherein the R^1 is hydrogen, methyl, benzyl, 4-methoxybenzyl or the other conventional amino protecting groups.

18. A method of resolving a compound of Formula **Ic** to produce the compound of formula **Id** or improving the chiral purity of the compound of Formula **Id**, comprising treating the racemic compound of Formula **Ic** with a chiral acid,

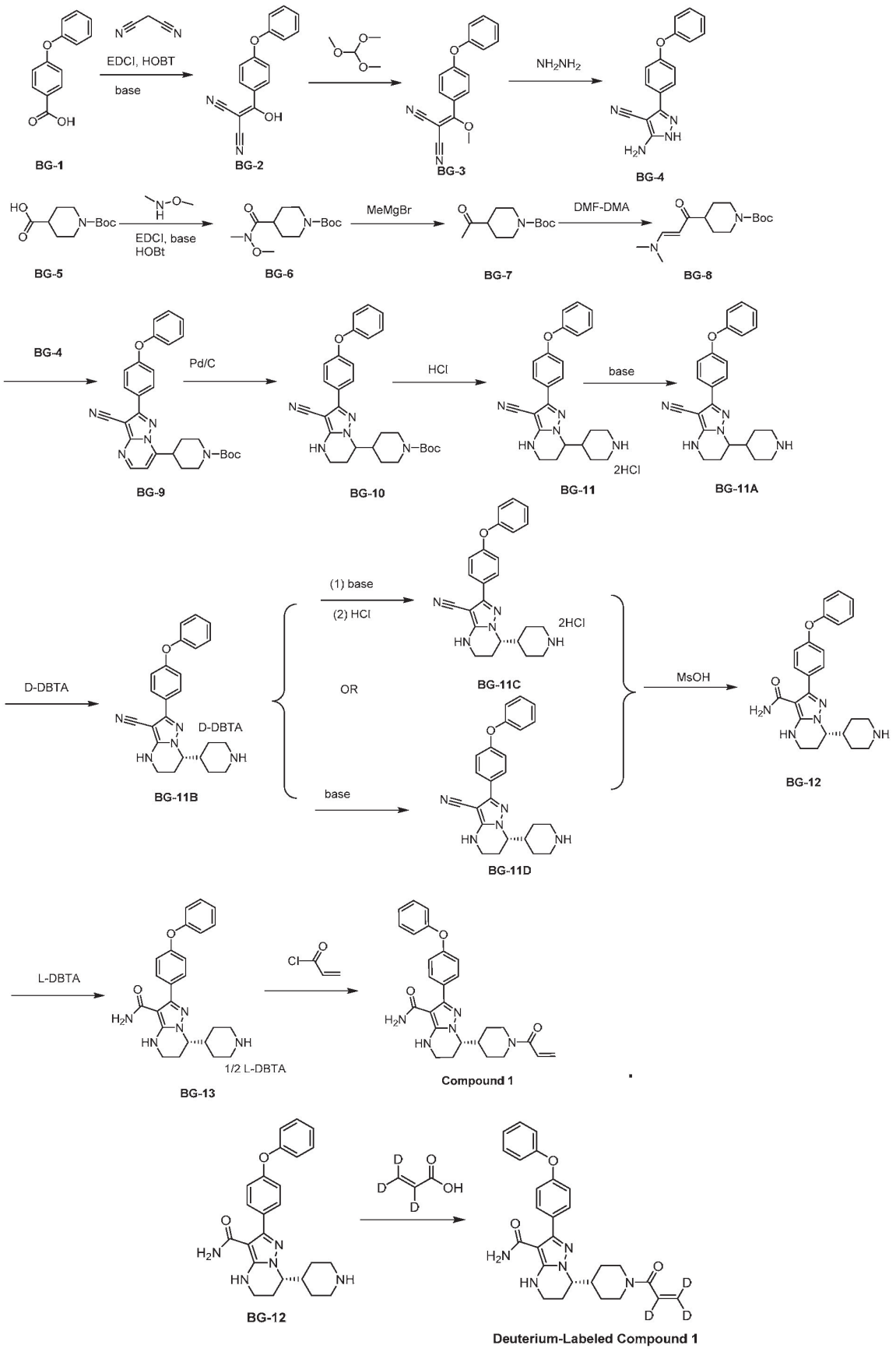


Formula **Ic** Formula **Id**

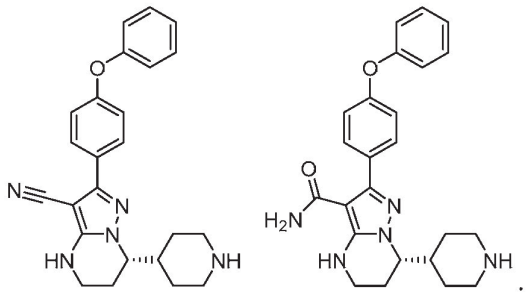
wherein R^1 is hydrogen, methyl, benzyl, 4-methoxybenzyl or the other conventional amino protecting groups.

19. The method of Claim 17 or 18, wherein the chiral acid is selected from L-malic acid, D-malic acid, L-Mandelic acid, D-Mandelic acid, L-camphorsulfonic acid, D-camphorsulfonic acid, L-tartaric acid, D-tartaric acid, L-DBTA, D-DBTA, L-DTTA or D-DTTA.

20. A method of preparing Compound **1** and deuterium-labeled Compound 1, comprising the following:


EDCI, HOBT
base
BG-1
BG-2
BG-3
BG-4
NH2NH2
EDCI, base
HOBt
BG-5
BG-6
MeMgBr
BG-7
DMF-DMA
BG-8
BG-4
Pd/C
BG-9
HCl
BG-10
base
2HCl
BG-11
BG-11A
(1) base
(2) HCl
OR
BG-11C
D-DBTA
BG-11B
base
BG-11D
MsOH
BG-12
L-DBTA
1/2 L-DBTA
BG-13
Compound 1
BG-12
Deuterium-Labeled Compound 1

21. A compound of Formula **Ie** or a salt thereof, or Formula **If** or a salt thereof used to prepare **Compound 1**,



Formula **Ie** Formula **If .**

22. A method of preparing the crystalline form of any one of Claims 2-7, comprising the steps of dissolving Compound 1 in DCM, swapping to solvent EA, recrystallizing from EA/MTBE, to obtain the target crystalline form.

23. A method of preparing the crystalline form of any one of Claims 2-7, comprising the steps of dissolving Compound 1 in EA, adding hexane, to obtain the target crystalline form.

24. A method of preparing the crystalline from of any one of Claims 2-7, comprising the steps of dissolving Compound 1 in an organic solvent, adding H_2O, to obtain the target crystalline form, wherein the organic solvent is selected from acetone or DMAc.

25. A method of preparing the crystalline from of any one of Claims 2-7, comprising the steps of dissolving the crystalline of Claims 1-7 in an organic solvent, adding H_2O, to obtain the target crystalline form, wherein the organic solvent is selected from acetone or DMAc.

26. A method of preparing the crystalline from of any one of Claims 2-7, comprising the steps of dissolving Compound 1 in an organic solvent, adding n-heptane, to obtain the target crystalline form, wherein the organic solvent is selected from EtOAc, DCM, toluene or 2-MeTHF.

27. A method of preparing the crystalline from of any one of Claims 2-7, comprising the steps of dissolving the crystalline of Claims 1-7 in an organic solvent, adding n-heptane, to obtain the target crystalline form, wherein the organic solvent is selected from EtOAc, DCM, toluene or 2-MeTHF.

28. A method of preparing the crystalline from of any one of Claims 2-7, comprising the steps of dissolving Compound 1 in acetone or EtOAc to obtain a solution, placing the solution into n-heptane, evaporating at RT, to obtain the target crystalline form.

29. A method of preparing the crystalline from of any one of Claims 2-7, comprising the steps of dissolving the crystalline of Claims 1-7 in acetone or EtOAc to obtain a solution, placing the solution into n-heptane, evaporating at RT, to obtain the target crystalline form.

30. The method of Claims 22-29, wherein Compound 1 or the crystalline of Claims 1-7 has ee value more than 90%, preferably more than 97%.

31. A pharmaceutical composition comprising a therapeutically effective amount of the crystalline form of any one of Claims 1-7, and a pharmaceutically acceptable excipient.

32. The pharmaceutical composition of Claim 31, wherein the pharmaceutical composition is used in an oral administration.

33. The pharmaceutical composition of any one of Claims 31 or 32, wherein the pharmaceutical composition contains 1 wt%-99 wt% of the crystalline form of any one of Claims 1-7.

34. The pharmaceutical composition of Claim 31 wherein the composition contains 1 wt%-70 wt% of the crystalline form of any one of Claims 1-7.

35. The pharmaceutical composition of Claim 31, wherein the composition contains 10 wt%-30 wt% of the crystalline form of any one of Claims 1-7.

36. A method of treating a disease associated with undesirable Btk activity in a subject by administering to the subject the crystalline form of any one of Claims 1-7.

37. A method of treating a disease selected from an allergic disease, an autoimmune disease, an inflammatory disease, a cancer, or a combination of two or more thereof, in a subject by administering to the subject the crystalline form of any one of Claims 1-7.

38. A method of treating a B-cell proliferative disease, selected from B-cell malignancies, in a subject by administering to the subject the crystalline form of any one of Claims 1-7.

39. The method of Claim 38, wherein the B-cell proliferative disease is B-cell malignancies, selected from lymphoma, non-Hodgkin's lymphoma (NHL), diffuse large B cell lymphoma (DLBCL), mantle cell lymphoma (MCL), follicular lymphoma (FL), chronic lymphocytic leukemia (CLL), small lymphocytic lymphoma (SLL), waldenstrom macroglobulinemia (WM), marginal zone lymphoma (MZL), Hairy cell leukemia (HCL), Burkitt's-like leukemia (BL), or a combination of two or more thereof.

40. The method of Claim 38, wherein the B-cell proliferative disease is relapsed / refractory B-cell malignancies, selected from relapsed / refractory mantle cell lymphoma (R/R MCL), relapsed / refractory chronic lymphocytic leukemia (R/R CLL), relapsed / refractory small lymphocytic lymphoma (R/R SLL), relapsed / refractory Waldenstrom macroglobulinemia (R/R WM), or a combination of two or more thereof.

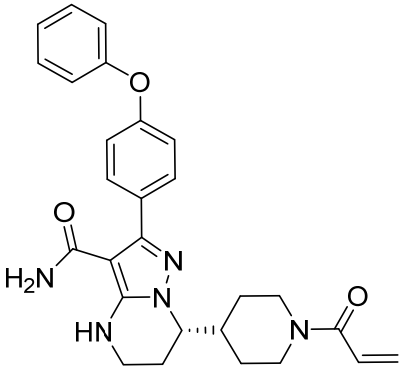
41. The method of Claim 38, wherein the crystalline form of any one of Claims 1-7 was administrated at a dose of 40 mg-320 mg/day.

42. The method of Claim 38, wherein the crystalline form of any one of Claims 1-7 was administrated at a dose of 160 mg twice a day (BID) or 320 mg once a day (QD).

Claims

1. A composition comprising:

(i) a solid amorphous form of Compound 1,



Compound 1,

wherein the solid amorphous form has:

(a) a mid-point temperature of a glass transition temperature of about 79.7 °C; and

(b) an enantiomeric excess value of at least 97%; and

(ii) a crystalline form of Compound 1, wherein the crystalline form exhibits an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values at 14.8 ± 0.2°, 16.4 ± 0.2° and 21.4 ± 0.2°.

2. The composition of claim 1, wherein the crystalline form has a melting point onset temperature of 139 ± 2 °C.

3. The composition of claim 1, wherein the crystalline form has an enantiomeric excess value of at least 45%.

4. The composition of claim 1, wherein the crystalline form has a purity of at least 99.3%.

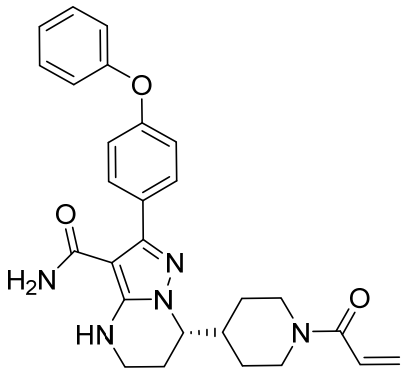
5. The composition of claim 1, wherein the crystalline form has a purity of at least 99.5%.

6. The composition of claim 1, wherein the crystalline form exhibits an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values at 14.8±0.2°, 15.6±0.2°, 16.4±0.2°, and 21.4±0.2°.

7. The composition of claim 1, wherein the crystalline form of Compound 1 is present in about 95% by weight of the composition.

8. The composition of claim 1, wherein the crystalline form of Compound 1 is present in about 99% by weight of the composition.

9. A use of Compound 1 in the manufacture of a medicament for use in a method for treating a B-cell proliferative disease in a subject, comprising administering to the subject in need thereof Compound 1,



Compound 1,

wherein the B-cell proliferative disease is selected from a group consisting of chronic lymphocytic leukemia, small lymphocytic lymphoma, mantle cell lymphoma, Waldenström's macroglobulinemia, marginal zone lymphoma, and follicular lymphoma; and

Compound 1 is to be administrated at a dose of 160 mg twice a day (BID).

10. The use of claim 9, wherein Compound 1 has a purity of at least 99.3%.

11. The use of claim 9, wherein Compound 1 has a purity of at least 99.5%.

12. The use of claim 11, wherein the B-cell proliferative disease is mantle cell lymphoma.

13. The use of claim 12, wherein the subject has received at least one prior therapy.

14. The use of claim 11, wherein the B-cell proliferative disease is Waldenström's macroglobulinemia.

15. The use of claim 11, wherein the B-cell proliferative disease is marginal zone lymphoma.

16. The use of claim 15, wherein the subject has received at least one prior therapy.

17. The use of claim 16, wherein the marginal zone lymphoma is relapsed or refractory marginal zone lymphoma.

18. The use of claim 11, wherein the B-cell proliferative disease is chronic lymphocytic leukemia.

19. The use of claim 11, wherein the B-cell proliferative disease is small lymphocytic lymphoma.

20. The use of claim 11, wherein the B-cell proliferative disease is follicular lymphoma.

21. The use of claim 11, wherein an amorphous form or a crystalline form of Compound 1 is administered.

22. The use of claim 21, wherein a crystalline form of Compound 1 is administered.

23. The use of claim 22, wherein the crystalline form exhibits an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values at 14.8 ± 0.2°, 16.4 ± 0.2° and 21.4 ± 0.2°.

24. The use of claim 23, wherein the crystalline form exhibits an X-ray powder diffraction pattern comprising diffraction peaks having 2θ angle values at 14.8 ± 0.2°, 15.6 ± 0.2°, 16.4 ± 0.2° and 21.4 ± 0.2°.

25. The use of claim 24, wherein the B-cell proliferative disease is mantle cell lymphoma, wherein the subject has received at least one prior therapy.

26. The use of claim 24, wherein the B-cell proliferative disease is Waldenström's macroglobulinemia.

27. The use of claim 24, wherein the B-cell proliferative disease is relapsed or refractory marginal zone lymphoma, wherein the subject has received at least one prior therapy.

28. The use of claim 24, wherein the B-cell proliferative disease is chronic lymphocytic leukemia, or small lymphocytic lymphoma.

29. The use of claim 21, wherein an amorphous form of Compound 1 is administered.

30. The use of claim 29, wherein the amorphous form of Compound 1 has a mid-point temperature of a glass transition temperature at 79.7 °C.

31. The use of claim 30, wherein the amorphous form has an enantiomeric excess value of at least 97%.

32. The use of claim 31, wherein the B-cell proliferative disease is mantle cell lymphoma, wherein the subject has received at least one prior therapy.

33. The use of claim 31, wherein the B-cell proliferative disease is Waldenström's macroglobulinemia.

34. The use of claim 31, wherein the B-cell proliferative disease is relapsed or refractory marginal zone lymphoma, wherein the subject has received at least one prior therapy.

35. The use of claim 31, wherein the B-cell proliferative disease is chronic lymphocytic leukemia, or small lymphocytic lymphoma.

36. The use of claim 11, wherein Compound 1 is administered orally.