

IRAK4 DEGRADERS AND SYNTHESIS THEREOF

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority to U.S. Appl. No. 63/263,274, filed October 29, 2021, the entire contents of which is herein incorporated by reference.

TECHNICAL FIELD OF THE INVENTION

[0002] The present invention relates to IRAK4 degrader 5-((1R,4R)-2-oxa-5-azabicyclo[2.2.1]heptan-5-yl)-N-(3-(difluoromethyl)-1-((1r,4R)-4-((4-((3-(1-(2,6-dioxopiperidin-3-yl)-3-methyl-2-oxo-2,3-dihydro-1H-benzo[d]imidazol-4-yl)prop-2-yn-1-yl)oxy)piperidin-1-yl)methyl)cyclohexyl)-1H-pyrazol-4-yl)pyrazolo[1,5-a]pyrimidine-3-carboxamide, synthesis thereof, and compositions thereof.

BACKGROUND OF THE INVENTION

[0003] Ubiquitin-Proteasome Pathway (UPP) is a critical pathway that regulates key regulator proteins and degrades misfolded or abnormal proteins. UPP is central to multiple cellular processes, and if defective or imbalanced, it leads to pathogenesis of a variety of diseases. The covalent attachment of ubiquitin to specific protein substrates is achieved through the action of E3 ubiquitin ligases.

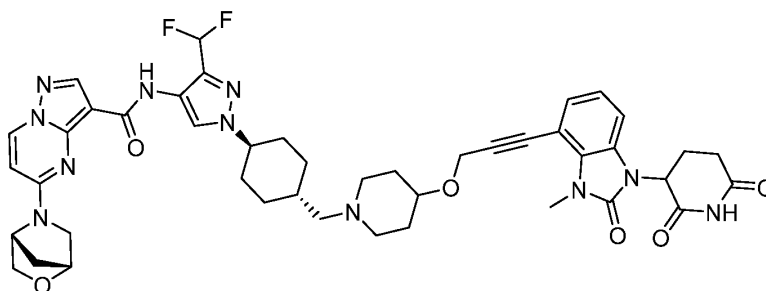
[0004] UPP plays a key role in the degradation of short-lived and regulatory proteins important in a variety of basic cellular processes, including regulation of the cell cycle, modulation of cell surface receptors and ion channels, and antigen presentation. Interleukin-1 receptor-associated kinase-4 (IRAK4) is a key component of the myddosome, a multiprotein complex involved in innate immunity that mediates signaling through toll-like receptors (TLRs) and interleukin (IL)-1 receptors (Patra and Choi, Molecule 2016, 21(11):1529). The IRAK4 protein is ubiquitously expressed across multiple different tissue types, including skin, lymphoid tissue, bone marrow, gastrointestinal (GI) tract and lung. The function of IRAK4 is dependent both on its kinase activity and on its scaffolding properties, which is required for the assembly of the myddosome complex following TLR or IL-1R engagement and myeloid differentiation factor 88 (MyD88) activation (De Nardo et al., J. Bio. Chem. 2018, 293(39):15195; Cushing et al., J. Bio. Chem. 2014, 289(15):10865). The NF-κB activation is particularly dependent on the scaffolding function of IRAK4 and is a key driver of cellular proliferation and proinflammatory cytokine and chemokine production mediated by myddosome activation.

[0005] Various IRAK4 degraders, including 5-((1R,4R)-2-oxa-5-azabicyclo[2.2.1]heptan-5-yl)-N-(3-(difluoromethyl)-1-((1r,4R)-4-((4-((3-(1-(2,6-dioxopiperidin-3-yl)-3-methyl-2-oxo-2,3-dihydro-1H-benzo[d]imidazol-4-yl)prop-2-yn-1-yl)oxy)piperidin-1-yl)methyl)cyclohexyl)-1H-pyrazol-4-yl)pyrazolo[1,5-a]pyrimidine-3-carboxamide, have been described previously, for example, in WO

2019/133531 and WO 2020/010227, the contents of which are incorporated herein by reference in their entireties. There remains an unmet need for improved synthesis of such compounds.

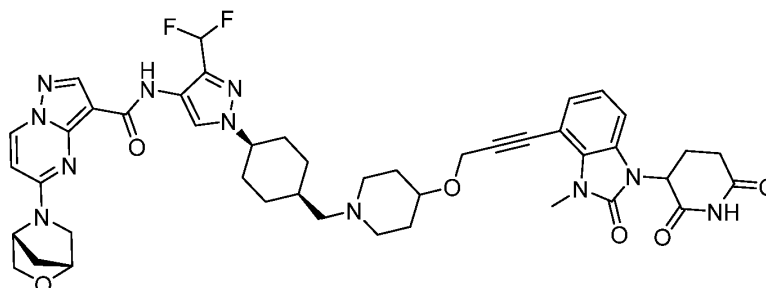
SUMMARY OF THE INVENTION

[0006] It has now been found that a composition of 5-((1R,4R)-2-oxa-5-azabicyclo[2.2.1]heptan-5-yl)-N-(3-(difluoromethyl)-1-((1r,4R)-4-((4-((3-(1-(2,6-dioxopiperidin-3-yl)-3-methyl-2-oxo-2,3-dihydro-1H-benzo[d]imidazol-4-yl)prop-2-yn-1-yl)oxy)piperidin-1-yl)methyl)cyclohexyl)-1H-pyrazol-4-yl)pyrazolo[1,5-a]pyrimidine-3-carboxamide (compound **I-1** herein) or a pharmaceutically acceptable salt thereof may contain a number of impurities.

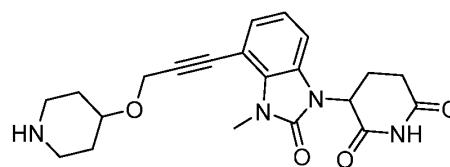
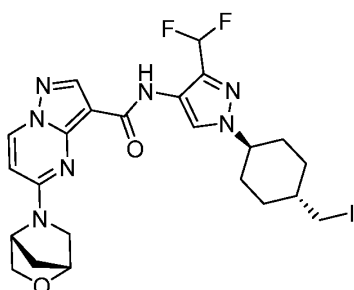


I-1

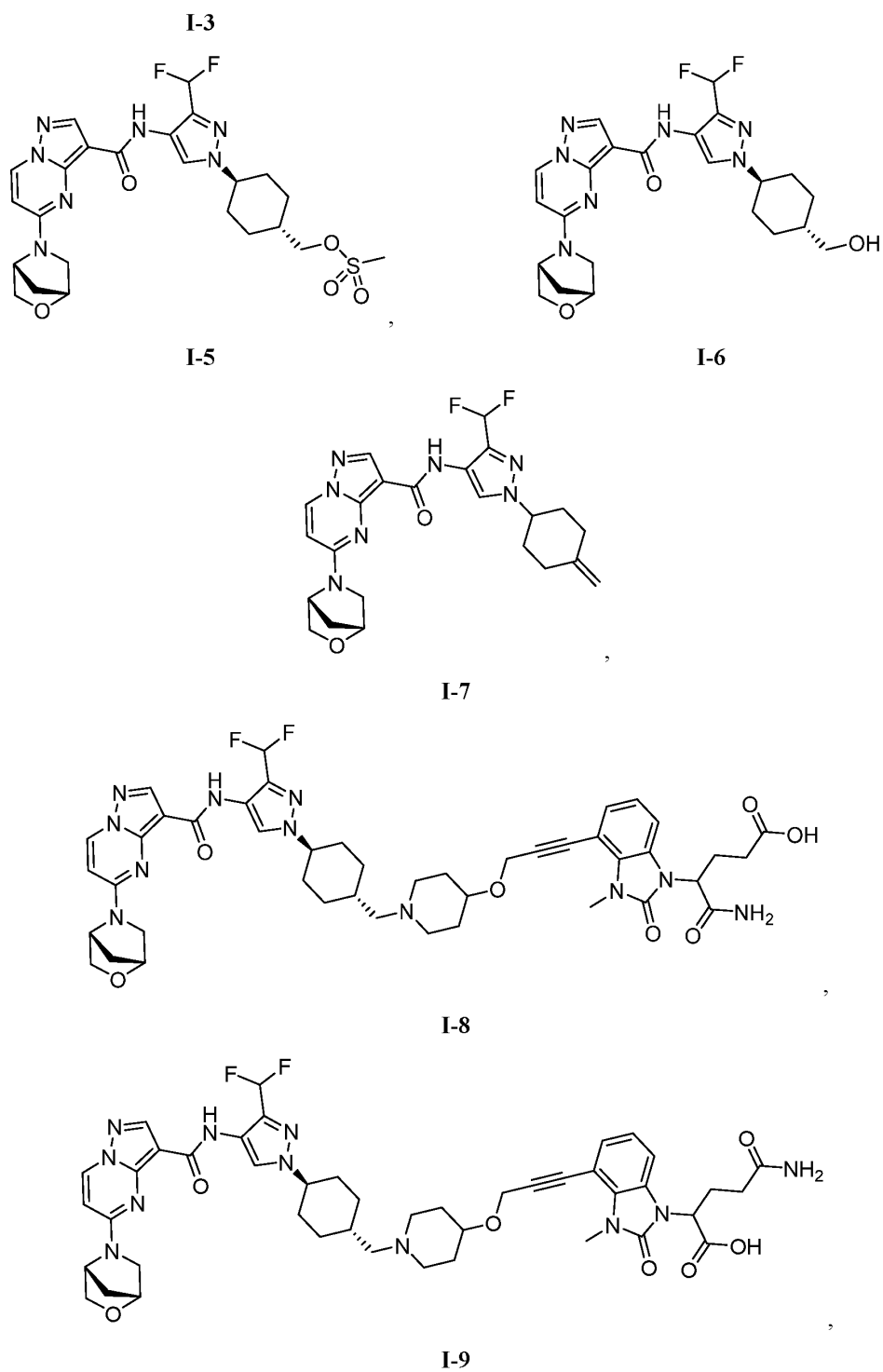
[0007] In one aspect, the present invention provides a composition comprising compound **I-1** and one or more impurity compounds selected from the group consisting of:



I-2



I-4



or a pharmaceutically acceptable salt thereof.

[0008] Compound **I-1** or a pharmaceutically acceptable salts thereof, and pharmaceutical compositions thereof, as described in the instant application, are useful for treating an autoimmune/autoinflammatory disease. In some aspects, the autoimmune/autoinflammatory disease is a cutaneous autoimmune/autoinflammatory disease selected from atopic dermatitis (AD), rheumatoid arthritis (RA), and hidradenitis suppurativa (HS).

[0009] In another aspect, the present invention provides a method for synthesizing compound **I-1**, or a pharmaceutically acceptable salt thereof, and related intermediates.

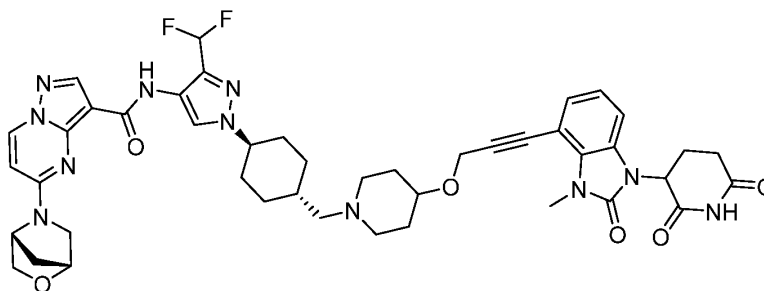
[0010] These and other aspects of this disclosure will be apparent upon reference to the following detailed description. To this end, various references are set forth herein which describe in more detail certain background information and procedures and are each hereby incorporated by reference in their entirety.

DETAILED DESCRIPTION OF THE INVENTION

1. General Description of Certain Embodiments of the Invention

[0011] One of ordinary skill in the art will appreciate that impurity profile of an active pharmaceutical agent (“API” or “drug substance”) is an important aspect of any pharmaceutical drug product. As such, impurities arising from synthesis or degradation are useful in that they allow for the monitoring of API purity and adherence to regulatory standards.

[0012] In certain embodiments, the present invention provides compositions comprising compound **I-1**:



I-1

and one or more impurity compounds (i.e., impurities) therein.

[0013] Compound **I-1** is a potent, highly selective, orally administered heterobifunctional small molecule therapeutic targeting IRAK4 and the E3 ligase CRBN to mediate the selective degradation of IRAK4 via the ubiquitin-proteasome system.

[0014] In some embodiments, compound **I-1** is in crystalline form. In some embodiments, compound **I-1** is in HCl salt form. In some embodiments, compound **I-1** is in a crystalline HCl salt form. In some embodiments, the crystalline HCl salt form of compound **I-1** is polymorph Form A, as described in WO 2021/247899 the content of which is incorporated herein by reference in its entirety. In some embodiments, the polymorph Form A of compound **I-1** is characterized by having one or more main peaks in its X-ray powder diffraction pattern selected from those at about 14.1, about 17.0, about 17.3, about 19.0, about 21.0, about 21.2 and about 23.3 degrees 2-theta.

[0015] In certain embodiments, the present invention provides methods for treating an autoimmune/autoinflammatory disease or a hematological malignancy in a patient comprising administering to the patient a pharmaceutical composition comprising compound **I-1** as described herein. In some embodiments, the composition comprises compound **I-1**, and one or more impurities selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9**, or a pharmaceutically acceptable salt thereof, as described herein.

[0016] In the following disclosure, certain specific details are set forth in order to provide a thorough understanding of various embodiments. However, one skilled in the art will understand that the methods and uses described herein may be practiced without these details. In other instances, well-known structures have not been shown or described in detail to avoid unnecessarily obscuring descriptions of the embodiments. Unless the context requires otherwise, throughout the specification and claims which follow, the word “comprise” and variations thereof, such as, “comprises” and “comprising” are to be construed in an open, inclusive sense, that is, as “including, but not limited to.” Further, headings provided herein are for convenience only and do not interpret the scope or meaning of the claimed invention.

[0017] Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. Also, as used in this specification and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the content clearly dictates otherwise. It should also be noted that the term “or” is generally employed in its sense including “and/or” unless the content clearly dictates otherwise.

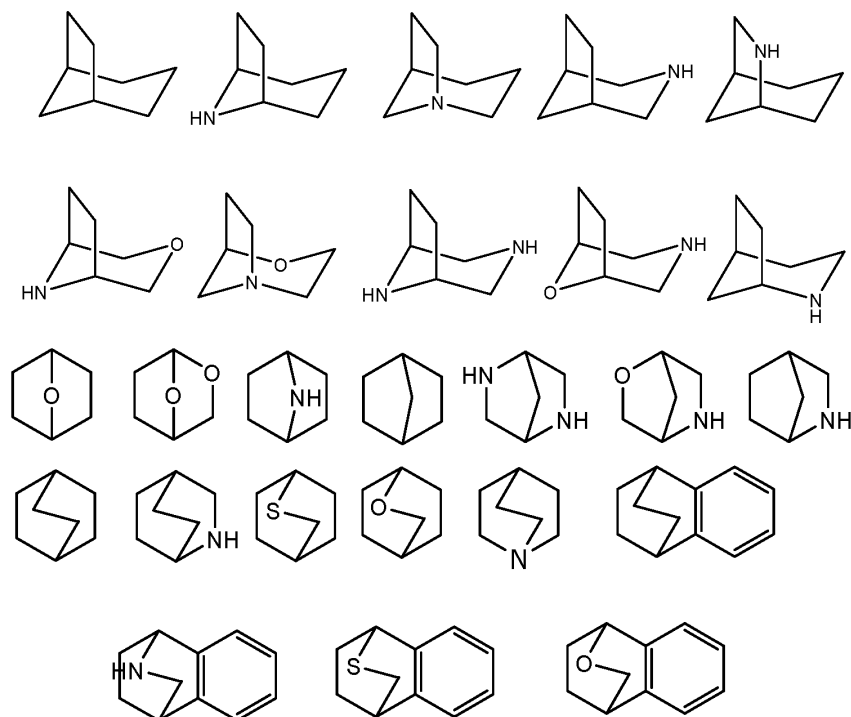
2. *Compounds and Definitions*

[0018] Compounds of the present invention include those described generally herein, and are further illustrated by the classes, subclasses, and species disclosed herein. As used herein, the following definitions

shall apply unless otherwise indicated. For purposes of this invention, the chemical elements are identified in accordance with the Periodic Table of the Elements, CAS version, Handbook of Chemistry and Physics, 75th Ed. Additionally, general principles of organic chemistry are described in "Organic Chemistry", Thomas Sorrell, University Science Books, Sausalito: 1999, and "March's Advanced Organic Chemistry", 5th Ed., Ed.: Smith, M.B. and March, J., John Wiley & Sons, New York: 2001, the entire contents of which are hereby incorporated by reference.

[0019] The term "aliphatic" or "aliphatic group", as used herein, means a straight-chain (i.e., unbranched) or branched, substituted or unsubstituted hydrocarbon chain that is completely saturated or that contains one or more units of unsaturation, or a monocyclic hydrocarbon or bicyclic hydrocarbon that is completely saturated or that contains one or more units of unsaturation, but which is not aromatic (also referred to herein as "carbocycle," "cycloaliphatic" or "cycloalkyl"), that has a single point of attachment to the rest of the molecule. Unless otherwise specified, aliphatic groups contain 1-6 aliphatic carbon atoms. In some embodiments, aliphatic groups contain 1-5 aliphatic carbon atoms. In other embodiments, aliphatic groups contain 1-4 aliphatic carbon atoms. In still other embodiments, aliphatic groups contain 1-3 aliphatic carbon atoms, and in yet other embodiments, aliphatic groups contain 1-2 aliphatic carbon atoms. In some embodiments, "cycloaliphatic" (or "carbocycle" or "cycloalkyl") refers to a monocyclic C₃-C₆ hydrocarbon that is completely saturated or that contains one or more units of unsaturation, but which is not aromatic, that has a single point of attachment to the rest of the molecule. In some embodiments, a carbocyclic ring may be a 5-12 membered bicyclic, bridged bicyclic, or spirocyclic ring. A carbocyclic ring may include one or more oxo (=O) or thioxo (=S) substituent. Suitable aliphatic groups include, but are not limited to, linear or branched, substituted or unsubstituted alkyl, alkenyl, alkynyl groups and hybrids thereof such as (cycloalkyl)alkyl, (cycloalkenyl)alkyl or (cycloalkyl)alkenyl.

[0020] As used herein, the term "bridged bicyclic" refers to any bicyclic ring system, i.e. carbocyclic or heterocyclic, saturated or partially unsaturated, having at least one bridge. As defined by IUPAC, a "bridge" is an unbranched chain of atoms or an atom or a valence bond connecting two bridgeheads, where a "bridgehead" is any skeletal atom of the ring system which is bonded to three or more skeletal atoms (excluding hydrogen). In some embodiments, a bridged bicyclic group has 7-12 ring members and 0-4 heteroatoms independently selected from nitrogen, oxygen, or sulfur. Such bridged bicyclic groups are well known in the art and include those groups set forth below where each group is attached to the rest of the molecule at any substitutable carbon or nitrogen atom. Unless otherwise specified, a bridged bicyclic group is optionally substituted with one or more substituents as set forth for aliphatic groups. Additionally or alternatively, any substitutable nitrogen of a bridged bicyclic group is optionally substituted. Exemplary bridged bicyclics include:



[0021] The term “lower alkyl” refers to a C_{1-4} straight or branched alkyl group. Exemplary lower alkyl groups are methyl, ethyl, propyl, isopropyl, butyl, isobutyl, and tert-butyl.

[0022] The term “lower haloalkyl” refers to a C_{1-4} straight or branched alkyl group that is substituted with one or more halogen atoms.

[0023] The term “heteroatom” means one or more of oxygen, sulfur, nitrogen, phosphorus, or silicon (including, any oxidized form of nitrogen, sulfur, phosphorus, or silicon; the quaternized form of any basic nitrogen or; a substitutable nitrogen of a heterocyclic ring, for example N (as in 3,4-dihydro-2*H*-pyrrolyl), NH (as in pyrrolidinyl) or NR^+ (as in N-substituted pyrrolidinyl)).

[0024] The term “unsaturated,” as used herein, means that a moiety has one or more units of unsaturation.

[0025] As used herein, the term “bivalent C_{1-8} (or C_{1-6}) saturated or unsaturated, straight or branched, hydrocarbon chain”, refers to bivalent alkylene, alkenylene, and alkynylene chains that are straight or branched as defined herein.

[0026] The term “alkylene” refers to a bivalent alkyl group. An “alkylene chain” is a polymethylene group, i.e., $-(CH_2)_n-$, wherein n is a positive integer, preferably from 1 to 6, from 1 to 4, from 1 to 3, from 1 to 2, or from 2 to 3. A substituted alkylene chain is a polymethylene group in which one or more methylene hydrogen atoms are replaced with a substituent. Suitable substituents include those described below for a

substituted aliphatic group.

[0027] The term “alkenylene” refers to a bivalent alkenyl group. A substituted alkenylene chain is a polymethylene group containing at least one double bond in which one or more hydrogen atoms are replaced with a substituent. Suitable substituents include those described below for a substituted aliphatic group.

[0028] As used herein, the term “cyclopropylenyl” refers to a bivalent cyclopropyl group of the



following structure:

[0029] The term “halogen” means F, Cl, Br, or I.

[0030] The term “aryl” used alone or as part of a larger moiety as in “aralkyl,” “aralkoxy,” or “aryloxyalkyl,” refers to monocyclic or bicyclic ring systems having a total of five to fourteen ring members, wherein at least one ring in the system is aromatic and wherein each ring in the system contains 3 to 7 ring members. The term “aryl” may be used interchangeably with the term “aryl ring.” In certain embodiments of the present invention, “aryl” refers to an aromatic ring system which includes, but not limited to, phenyl, biphenyl, naphthyl, anthracyl and the like, which may bear one or more substituents. Also included within the scope of the term “aryl,” as it is used herein, is a group in which an aromatic ring is fused to one or more non-aromatic rings, such as indanyl, phthalimidyl, naphthimidyl, phenanthridinyl, or tetrahydronaphthyl, and the like. The term “arylenyl” refers to bivalent aryl groups (e.g., phenylenyl).

[0031] The terms “heteroaryl” and “heteroar-,” used alone or as part of a larger moiety, e.g., “heteroaralkyl,” or “heteroaralkoxy,” refer to groups having 5 to 10 ring atoms, preferably 5, 6, or 9 ring atoms; having 6, 10, or 14 π electrons shared in a cyclic array; and having, in addition to carbon atoms, from one to five heteroatoms. The term “heteroatom” refers to nitrogen, oxygen, or sulfur, and includes any oxidized form of nitrogen or sulfur, and any quaternized form of a basic nitrogen. Heteroaryl groups include, without limitation, thienyl, furanyl, pyrrolyl, imidazolyl, pyrazolyl, triazolyl, tetrazolyl, oxazolyl, isoxazolyl, oxadiazolyl, thiazolyl, isothiazolyl, thiadiazolyl, pyridyl, pyridazinyl, pyrimidinyl, pyrazinyl, indoliziny, purinyl, naphthyridinyl, and pteridinyl. The terms “heteroaryl” and “heteroar-,” as used herein, also include groups in which a heteroaromatic ring is fused to one or more aryl, cycloaliphatic, or heterocyclyl rings, where the radical or point of attachment is on the heteroaromatic ring. Nonlimiting examples include indolyl, isoindolyl, benzothienyl, benzofuranyl, dibenzofuranyl, indazolyl, benzimidazolyl, benzthiazolyl, quinolyl, isoquinolyl, cinnoliny, phthalazinyl, quinazolinyl, quinoxalinyl, 4*H*-quinoliziny, carbazolyl, acridinyl, phenazinyl, phenothiazinyl, phenoxazinyl, tetrahydroquinoliny, tetrahydroisoquinoliny, and pyrido[2,3-*b*]-1,4-oxazin-3(4*H*)-one. A heteroaryl group may be monocyclic, bicyclic, bridged bicyclic, or spirocyclic. The term “heteroaryl” may be used interchangeably with the terms “heteroaryl ring,” “heteroaryl group,” or “heteroaromatic,” any of which terms include rings that are optionally substituted. The term “heteroaralkyl” refers to an alkyl group substituted by a heteroaryl,

wherein the alkyl and heteroaryl portions independently are optionally substituted. The term “heteroarylenyl” refers to bivalent heteroaryl groups (e.g., pyridylenyl).

[0032] As used herein, the terms “heterocycle,” “heterocyclyl,” “heterocyclic radical,” and “heterocyclic ring” are used interchangeably and refer to a stable 5- to 7-membered monocyclic or 7-10-membered bicyclic heterocyclic moiety that is either saturated or partially unsaturated, and having, in addition to carbon atoms, one or more, preferably one to four, heteroatoms, as defined above. When used in reference to a ring atom of a heterocycle, the term “nitrogen” includes a substituted nitrogen. As an example, in a saturated or partially unsaturated ring having 0-3 heteroatoms selected from oxygen, sulfur or nitrogen, the nitrogen may be N (as in 3,4-dihydro-2*H*-pyrrolyl), NH (as in pyrrolidinyl), or ⁺NR (as in *N*-substituted pyrrolidinyl).

[0033] A heterocyclic ring can be attached to its pendant group at any heteroatom or carbon atom that results in a stable structure and any of the ring atoms can be optionally substituted. Examples of such saturated or partially unsaturated heterocyclic radicals include, without limitation, tetrahydrofuranyl, tetrahydrothiophenyl, pyrrolidinyl, piperidinyl, pyrrolinyl, tetrahydroquinolinyl, tetrahydroisoquinolinyl, decahydroquinolinyl, oxazolidinyl, piperazinyl, dioxanyl, dioxolanyl, diazepinyl, oxazepinyl, thiazepinyl, morpholinyl, and quinuclidinyl. The terms “heterocycle,” “heterocyclyl,” “heterocyclyl ring,” “heterocyclic group,” “heterocyclic moiety,” and “heterocyclic radical,” are used interchangeably herein, and also include groups in which a heterocyclyl ring is fused to one or more aryl, heteroaryl, or cycloaliphatic rings, such as indolinyl, 3*H*-indolyl, chromanyl, phenanthridinyl, or tetrahydroquinolinyl. In some embodiments, a heterocyclic ring may be a 5-12 membered bicyclic, bridged bicyclic, or spirocyclic ring. A heterocyclic ring may include one or more oxo (=O) or thioxo (=S) substituent. The term “heterocyclylalkyl” refers to an alkyl group substituted by a heterocyclyl, wherein the alkyl and heterocyclyl portions independently are optionally substituted.

[0034] As used herein, the term “partially unsaturated” refers to a ring moiety that includes at least one double or triple bond. The term “partially unsaturated” is intended to encompass rings having multiple sites of unsaturation, but is not intended to include aryl or heteroaryl moieties, as herein defined.

[0035] As described herein, compounds of the disclosure may contain “substituted” moieties. In general, the term “substituted” means that one or more hydrogens of the designated moiety are replaced with a suitable substituent. Unless otherwise indicated, an “optionally substituted” group may have a suitable substituent at each substitutable position of the group, and when more than one position in any given structure may be substituted with more than one substituent selected from a specified group, the substituent may be either the same or different at every position. Combinations of substituents envisioned by this invention are preferably those that result in the formation of stable or chemically feasible compounds. The term “stable,” as used herein, refers to compounds that are not substantially altered when

subjected to conditions to allow for their production, detection, and, in certain embodiments, their recovery, purification, and use for one or more of the purposes disclosed herein.

[0036] Suitable monovalent substituents on a substitutable carbon atom of an “optionally substituted” group are independently halogen; $-(CH_2)_{0-4}R^\circ$; $-(CH_2)_{0-4}OR^\circ$; $-O(CH_2)_{0-4}R^\circ$; $-O-(CH_2)_{0-4}C(O)OR^\circ$; $-(CH_2)_{0-4}CH(OR^\circ)_2$; $-(CH_2)_{0-4}SR^\circ$; $-(CH_2)_{0-4}Ph$, which may be substituted with R° ; $-(CH_2)_{0-4}O(CH_2)_{0-1}Ph$ which may be substituted with R° ; $-CH=CHPh$, which may be substituted with R° ; $-(CH_2)_{0-4}O(CH_2)_{0-1}$ -pyridyl which may be substituted with R° ; $-NO_2$; $-CN$; $-N_3$; $-(CH_2)_{0-4}N(R^\circ)_2$; $-(CH_2)_{0-4}N(R^\circ)C(O)R^\circ$; $-N(R^\circ)C(S)R^\circ$; $-(CH_2)_{0-4}N(R^\circ)C(O)NR^\circ_2$; $-N(R^\circ)C(S)NR^\circ_2$; $-(CH_2)_{0-4}N(R^\circ)C(O)OR^\circ$; $-N(R^\circ)N(R^\circ)C(O)R^\circ$; $-N(R^\circ)N(R^\circ)C(O)NR^\circ_2$; $-N(R^\circ)N(R^\circ)C(O)OR^\circ$; $-(CH_2)_{0-4}C(O)R^\circ$; $-C(S)R^\circ$; $-(CH_2)_{0-4}C(O)OR^\circ$; $-(CH_2)_{0-4}C(O)SR^\circ$; $-(CH_2)_{0-4}C(O)OSiR^\circ_3$; $-(CH_2)_{0-4}OC(O)R^\circ$; $-OC(O)(CH_2)_{0-4}SR^\circ$; $-(CH_2)_{0-4}SC(O)R^\circ$; $-(CH_2)_{0-4}C(O)NR^\circ_2$; $-C(S)NR^\circ_2$; $-C(S)SR^\circ$; $-SC(S)SR^\circ$; $-(CH_2)_{0-4}OC(O)NR^\circ_2$; $-C(O)N(OR^\circ)R^\circ$; $-C(O)C(O)R^\circ$; $-C(O)CH_2C(O)R^\circ$; $-C(NOR^\circ)R^\circ$; $-(CH_2)_{0-4}SSR^\circ$; $-(CH_2)_{0-4}S(O)_2R^\circ$; $-(CH_2)_{0-4}S(O)_2OR^\circ$; $-(CH_2)_{0-4}OS(O)_2R^\circ$; $-S(O)_2NR^\circ_2$; $-(CH_2)_{0-4}S(O)R^\circ$; $-N(R^\circ)S(O)_2NR^\circ_2$; $-N(R^\circ)S(O)_2R^\circ$; $-N(OR^\circ)R^\circ$; $-C(NH)NR^\circ_2$; $-P(O)_2R^\circ$; $-P(O)R^\circ$; $-OP(O)R^\circ$; $-OP(O)(OR^\circ)_2$; SiR°_3 ; $-(C_{1-4}$ straight or branched alkylene) $O-N(R^\circ)_2$; or $-(C_{1-4}$ straight or branched alkylene) $C(O)O-N(R^\circ)_2$, wherein each R° may be substituted as defined below and is independently hydrogen, C_{1-6} aliphatic, $-CH_2Ph$, $-O(CH_2)_{0-1}Ph$, $-CH_2$ -(5-6 membered heteroaryl ring), or a 5-6-membered saturated, partially unsaturated, or aryl ring having 0-4 heteroatoms independently selected from nitrogen, oxygen, or sulfur, or, notwithstanding the definition above, two independent occurrences of R° , taken together with their intervening atom(s), form a 3-12-membered saturated, partially unsaturated, or aryl mono- or bicyclic ring having 0-4 heteroatoms independently selected from nitrogen, oxygen, or sulfur, which may be substituted as defined below.

[0037] Suitable monovalent substituents on R° (or the ring formed by taking two independent occurrences of R° together with their intervening atoms), are independently halogen, $-(CH_2)_{0-2}R^\bullet$, $-(haloR^\bullet)$, $-(CH_2)_{0-2}OH$, $-(CH_2)_{0-2}OR^\bullet$, $-(CH_2)_{0-2}CH(OR^\bullet)_2$, $-O(haloR^\bullet)$, $-CN$, $-N_3$, $-(CH_2)_{0-2}C(O)R^\bullet$, $-(CH_2)_{0-2}C(O)OH$, $-(CH_2)_{0-2}C(O)OR^\bullet$, $-(CH_2)_{0-2}SR^\bullet$, $-(CH_2)_{0-2}SH$, $-(CH_2)_{0-2}NH_2$, $-(CH_2)_{0-2}NHR^\bullet$, $-(CH_2)_{0-2}NR^\bullet_2$, $-NO_2$, $-SiR^\bullet_3$, $-OSiR^\bullet_3$, $-C(O)SR^\bullet$, $-(C_{1-4}$ straight or branched alkylene) $C(O)OR^\bullet$, or $-SSR^\bullet$ wherein each $R^\bullet$ is unsubstituted or where preceded by “halo” is substituted only with one or more halogens, and is independently selected from C_{1-4} aliphatic, $-CH_2Ph$, $-O(CH_2)_{0-1}Ph$, or a 5-6-membered saturated, partially unsaturated, or aryl ring having 0-4 heteroatoms independently selected from nitrogen, oxygen, or sulfur. Suitable divalent substituents on a saturated carbon atom of R° include $=O$ and $=S$.

[0038] Suitable divalent substituents on a saturated carbon atom of an “optionally substituted” group include the following: $=O$, $=S$, $=NNR^*_2$, $=NNHC(O)R^*$, $=NNHC(O)OR^*$, $=NNHS(O)_2R^*$, $=NR^*$, $=NOR^*$, $-$

$\text{O}(\text{C}(\text{R}^*))_{2-3}\text{O}-$, or $-\text{S}(\text{C}(\text{R}^*))_{2-3}\text{S}-$, wherein each independent occurrence of R^* is selected from hydrogen, C_{1-6} aliphatic which may be substituted as defined below, or an unsubstituted 5–6-membered saturated, partially unsaturated, or aryl ring having 0–4 heteroatoms independently selected from nitrogen, oxygen, or sulfur. Suitable divalent substituents that are bound to vicinal substitutable carbons of an “optionally substituted” group include: $-\text{O}(\text{C}(\text{R}^*))_{2-3}\text{O}-$, wherein each independent occurrence of R^* is selected from hydrogen, C_{1-6} aliphatic which may be substituted as defined below, or an unsubstituted 5–6-membered saturated, partially unsaturated, or aryl ring having 0–4 heteroatoms independently selected from nitrogen, oxygen, or sulfur.

[0039] Suitable substituents on the aliphatic group of R^* include halogen, $-\text{R}^\bullet$, $-(\text{haloR}^\bullet)$, $-\text{OH}$, $-\text{OR}^\bullet$, $-\text{O}(\text{haloR}^\bullet)$, $-\text{CN}$, $-\text{C}(\text{O})\text{OH}$, $-\text{C}(\text{O})\text{OR}^\bullet$, $-\text{NH}_2$, $-\text{NHR}^\bullet$, $-\text{NR}^\bullet_2$, or $-\text{NO}_2$, wherein each $\text{R}^\bullet$ is unsubstituted or where preceded by “halo” is substituted only with one or more halogens, and is independently C_{1-4} aliphatic, $-\text{CH}_2\text{Ph}$, $-\text{O}(\text{CH}_2)_{0-1}\text{Ph}$, or a 5–6-membered saturated, partially unsaturated, or aryl ring having 0–4 heteroatoms independently selected from nitrogen, oxygen, or sulfur.

[0040] Suitable substituents on a substitutable nitrogen of an “optionally substituted” group include $-\text{R}^\dagger$, $-\text{NR}^\dagger_2$, $-\text{C}(\text{O})\text{R}^\dagger$, $-\text{C}(\text{O})\text{OR}^\dagger$, $-\text{C}(\text{O})\text{C}(\text{O})\text{R}^\dagger$, $-\text{C}(\text{O})\text{CH}_2\text{C}(\text{O})\text{R}^\dagger$, $-\text{S}(\text{O})_2\text{R}^\dagger$, $-\text{S}(\text{O})_2\text{NR}^\dagger_2$, $-\text{C}(\text{S})\text{NR}^\dagger_2$, $-\text{C}(\text{NH})\text{NR}^\dagger_2$, or $-\text{N}(\text{R}^\dagger)\text{S}(\text{O})_2\text{R}^\dagger$; wherein each $\text{R}^\dagger$ is independently hydrogen, C_{1-6} aliphatic which may be substituted as defined below, unsubstituted $-\text{OPh}$, or an unsubstituted 5–6-membered saturated, partially unsaturated, or aryl ring having 0–4 heteroatoms independently selected from nitrogen, oxygen, or sulfur, or, notwithstanding the definition above, two independent occurrences of $\text{R}^\dagger$, taken together with their intervening atom(s) form an unsubstituted 3–12-membered saturated, partially unsaturated, or aryl mono- or bicyclic ring having 0–4 heteroatoms independently selected from nitrogen, oxygen, or sulfur.

[0041] Suitable substituents on the aliphatic group of $\text{R}^\dagger$ are independently halogen, $-\text{R}^\bullet$, $-(\text{haloR}^\bullet)$, $-\text{OH}$, $-\text{OR}^\bullet$, $-\text{O}(\text{haloR}^\bullet)$, $-\text{CN}$, $-\text{C}(\text{O})\text{OH}$, $-\text{C}(\text{O})\text{OR}^\bullet$, $-\text{NH}_2$, $-\text{NHR}^\bullet$, $-\text{NR}^\bullet_2$, or $-\text{NO}_2$, wherein each $\text{R}^\bullet$ is unsubstituted or where preceded by “halo” is substituted only with one or more halogens, and is independently C_{1-4} aliphatic, $-\text{CH}_2\text{Ph}$, $-\text{O}(\text{CH}_2)_{0-1}\text{Ph}$, or a 5–6-membered saturated, partially unsaturated, or aryl ring having 0–4 heteroatoms independently selected from nitrogen, oxygen, or sulfur.

[0042] As used herein, the term “pharmaceutically acceptable salt” refers to those salts which are, within the scope of sound medical judgment, suitable for use in contact with the tissues of humans and lower animals without undue toxicity, irritation, allergic response and the like, and are commensurate with a reasonable benefit/risk ratio. Pharmaceutically acceptable salts are well known in the art. For example, S. M. Berge *et al.*, describe pharmaceutically acceptable salts in detail in J. Pharmaceutical Sciences, 1977, 66, 1–19, incorporated herein by reference. Pharmaceutically acceptable salts of the compounds of this disclosure include those derived from suitable inorganic and organic acids and bases. Examples of pharmaceutically acceptable, nontoxic acid addition salts are salts of an amino group formed with inorganic

acids such as hydrochloric acid, hydrobromic acid, phosphoric acid, sulfuric acid and perchloric acid or with organic acids such as acetic acid, oxalic acid, maleic acid, tartaric acid, citric acid, succinic acid or malonic acid or by using other methods used in the art such as ion exchange. Other pharmaceutically acceptable salts include adipate, alginate, ascorbate, aspartate, benzenesulfonate, benzoate, bisulfate, borate, butyrate, camphorate, camphorsulfonate, citrate, cyclopentanepropionate, digluconate, dodecylsulfate, ethanesulfonate, formate, fumarate, glucoheptonate, glycerophosphate, gluconate, hemisulfate, heptanoate, hexanoate, hydroiodide, 2-hydroxy-ethanesulfonate, lactobionate, lactate, laurate, lauryl sulfate, malate, maleate, malonate, methanesulfonate, 2-naphthalenesulfonate, nicotinate, nitrate, oleate, oxalate, palmitate, pamoate, pectinate, persulfate, 3-phenylpropionate, phosphate, pivalate, propionate, stearate, succinate, sulfate, tartrate, thiocyanate, p-toluenesulfonate, undecanoate, valerate salts, and the like.

[0043] Salts derived from appropriate bases include alkali metal, alkaline earth metal, ammonium and $N^+(C_{1-4}alkyl)_4$ salts. Representative alkali or alkaline earth metal salts include sodium, lithium, potassium, calcium, magnesium, and the like. Further pharmaceutically acceptable salts include, when appropriate, nontoxic ammonium, quaternary ammonium, and amine cations formed using counterions such as halide, hydroxide, carboxylate, sulfate, phosphate, nitrate, loweralkyl sulfonate and aryl sulfonate.

[0044] As used herein, the terms “about” or “approximately” have the meaning of within 20% of a given value or range. In some embodiments, the term “about” refers to within 20%, 19%, 18%, 17%, 16%, 15%, 14%, 13%, 12%, 11%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or 1% of a given value.

[0045] Unless otherwise stated, structures depicted herein are also meant to include all isomeric (e.g., enantiomeric, diastereomeric, and geometric (or conformational)) forms of the structure; for example, the R and S configurations for each asymmetric center, Z and E double bond isomers, and Z and E conformational isomers. Therefore, single stereochemical isomers as well as enantiomeric, diastereomeric, and geometric (or conformational) mixtures of the present compounds are within the scope of the invention. Unless otherwise stated, all tautomeric forms of the compounds of the invention are within the scope of the invention.

[0046] As used herein, the phrase “leaving group” refers to a functional group that is displaced from a molecule during a chemical reaction. Leaving groups include halogens, as well sulfonate groups, such as tosylate, triflate, and mesylate.

[0047] As used herein, the term “patient” or “subject” means a mammal, preferably a human.

[0048] As used herein, a “therapeutically effective amount” means an amount of a substance (e.g., a therapeutic agent, composition, and/or formulation) that elicits a desired biological response. In some embodiments, a therapeutically effective amount of a substance is an amount that is sufficient, when administered as part of a dosing regimen to a subject suffering from or susceptible to a disease, condition,

or disorder, to treat, diagnose, prevent, and/or delay the onset of the disease, condition, or disorder. As will be appreciated by those of ordinary skill in this art, the effective amount of a substance may vary depending on such factors as the desired biological endpoint, the substance to be delivered, the target cell or tissue, etc. For example, the effective amount of compound in a formulation to treat a disease, condition, or disorder is the amount that alleviates, ameliorates, relieves, inhibits, prevents, delays onset of, reduces severity of and/or reduces incidence of one or more symptoms or features of the disease, condition, or disorder. In some embodiments, a “therapeutically effective amount” is at least a minimal amount of a compound, or composition containing a compound, which is sufficient for treating one or more symptoms associated with autoimmune/autoinflammatory disease in a patient.

[0049] The terms “treat” or “treating,” as used herein, refers to partially or completely alleviating, inhibiting, delaying onset of, preventing, ameliorating and/or relieving a disease or disorder, or one or more symptoms of the disease or disorder. As used herein, the terms “treatment,” “treat,” and “treating” refer to partially or completely alleviating, inhibiting, delaying onset of, preventing, ameliorating and/or relieving a disease or disorder, or one or more symptoms of the disease or disorder, as described herein. In some embodiments, treatment may be administered after one or more symptoms have developed. In some embodiments, the term “treating” includes preventing or halting the progression of a disease or disorder. In other embodiments, treatment may be administered in the absence of symptoms. For example, treatment may be administered to a susceptible individual prior to the onset of symptoms (e.g., in light of a history of symptoms and/or in light of genetic or other susceptibility factors). Treatment may also be continued after symptoms have resolved, for example to prevent or delay their recurrence. Thus, in some embodiments, the term “treating” includes preventing relapse or recurrence of a disease or disorder.

[0050] The expression “unit dosage form” as used herein refers to a physically discrete unit of therapeutic formulation appropriate for the subject to be treated. It will be understood, however, that the total daily usage of the compositions of the present invention will be decided by the attending physician within the scope of sound medical judgment. The specific effective dose level for any particular subject or organism will depend upon a variety of factors including the disorder being treated and the severity of the disorder; activity of specific active agent employed; specific composition employed; age, body weight, general health, sex and diet of the subject; time of administration, and rate of excretion of the specific active agent employed; duration of the treatment; drugs and/or additional therapies used in combination or coincidental with specific compound(s) employed, and like factors well known in the medical arts.

[0051] As used herein, the term “area percent of the HPLC” or “area percent HPLC” refers to the area percentage of a peak in a HPLC chromatogram. The terms “area percent of the HPLC” or “area percent HPLC” are used to indicate the amount of a compound in a composition. In some embodiments, an area percent of the HPLC, or an area percentage HPLC, of compound I-1 refers to the area of the compound I-

1 peak(s) relative to the total area of the compound **I-1** and impurity compounds peaks in the composition in a HPLC chromatogram. In some embodiments, an area percent of the HPLC, or an area percentage HPLC, of an impurity compound refers to the area of the impurity compound peak(s) relative to the total area of the compound **I-1** and impurity compounds peaks in the composition in a HPLC chromatogram. In some embodiments, an area percent of the HPLC, or an area percentage HPLC, of total impurity compounds refers to the area of all impurity compounds peak(s) relative to the total area of the compound **I-1** and impurity compounds peaks in the composition in a HPLC chromatogram. In some embodiments, an area percentage is relative to the area of compound **I-1** in a HPLC chromatogram. In some embodiments, a HPLC method is as described in the examples, e.g., column: Zorbax Eclipse Plus C18, 150 x 3.0 mm, 3.5 µm; mobile phases: 0.04% TFA in water and 0.02% TFA in acetonitrile; detection: UV at 225 nm; column temperature: 40 °C; pump program: gradient; flow rate: 0.9 mL/min; and sample preparation: 0.4 mg/mL in diluent = 50:50:0:2 acetonitrile:water:TFA. In some embodiments, a HPLC method is as described in Table 7 in the examples.

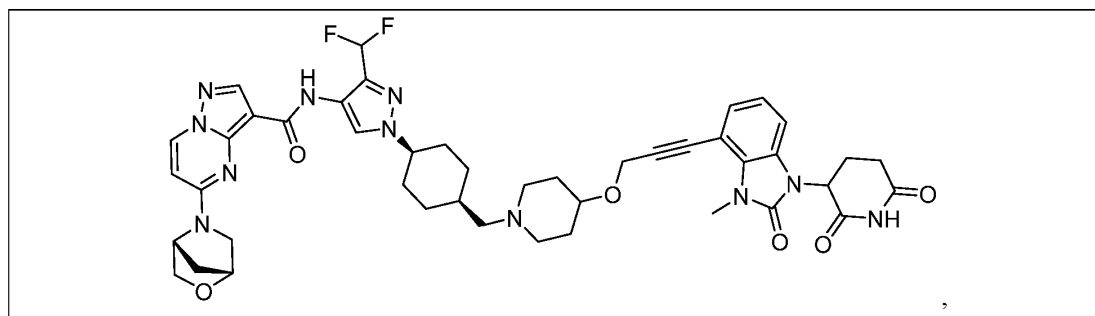
[0052] The term “weight percent” or “wt%” as used herein refers to the weight percentage of a component calculated based on the non salt form. A weight percentage of compound **I-1** refers to the weight percent of compound **I-1** relative to the total weight of a composition. In some embodiments, a weight percentage of an impurity, or total organic impurities, refers to the weight percent of the impurity, or total organic impurities, relative to the total weight of a composition. In some embodiments, a weight percentage of an impurity, or total organic impurities, refers to the weight percent of the impurity, or total organic impurities, relative to the weight of compound **I-1** in a composition.

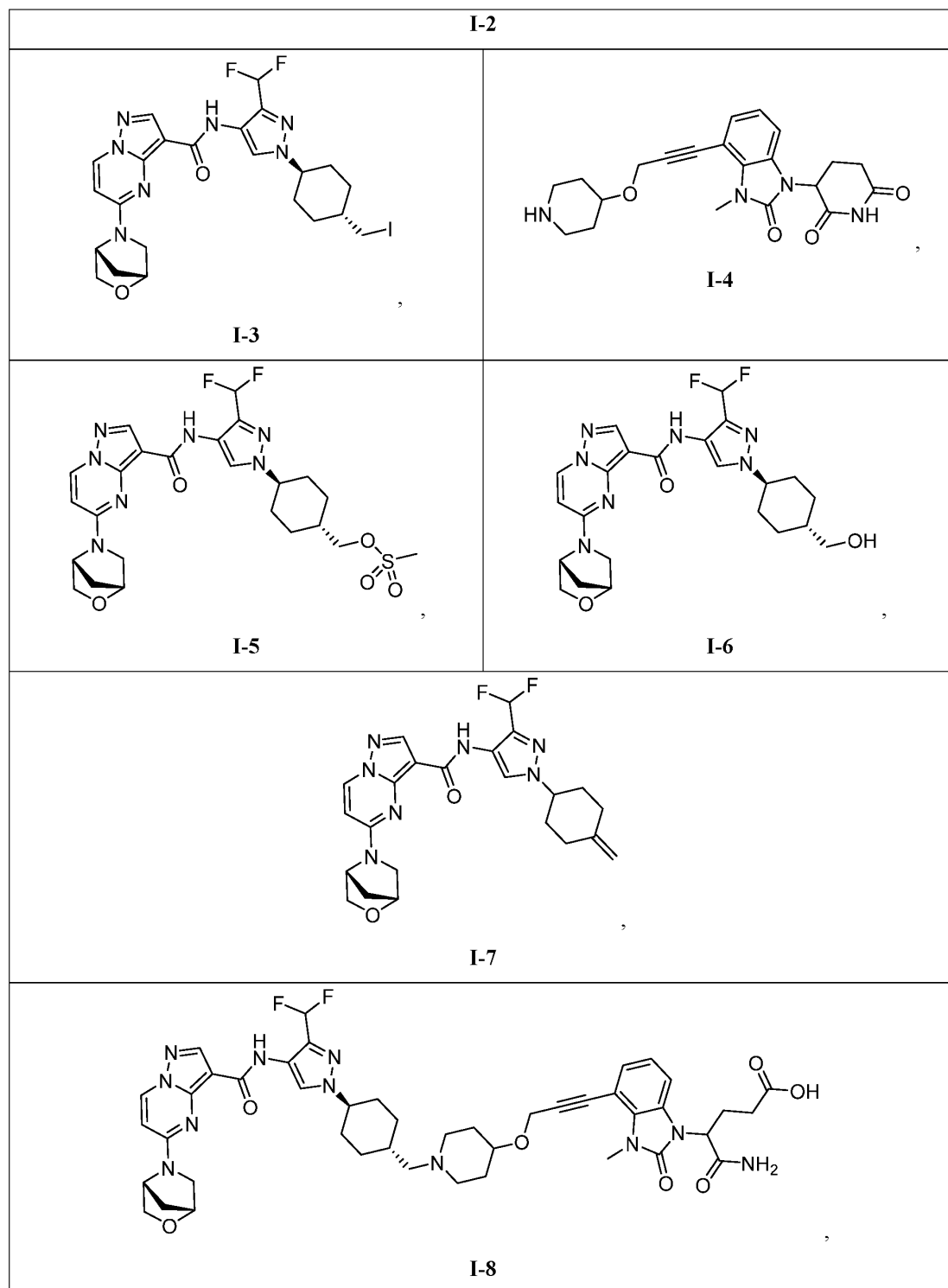
3. Description of Exemplary Compounds

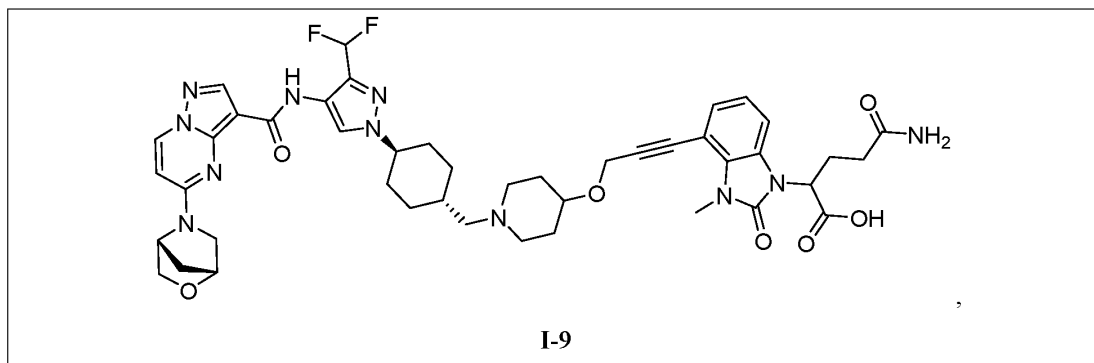
[0053] It has now been found that certain impurity compounds may be present in a composition comprising compound **I-1**.

[0054] According to one aspect, the present invention provides an impurity compound, which is any one of the following below in **Table 1**.

Table 1. Exemplary Compounds

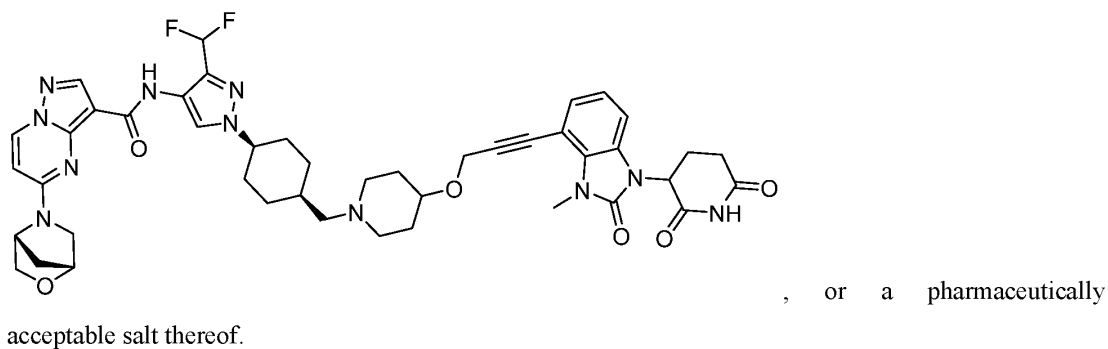




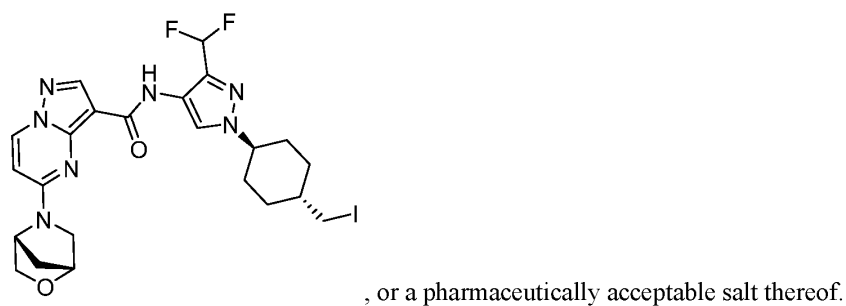


or a pharmaceutically acceptable salt thereof.

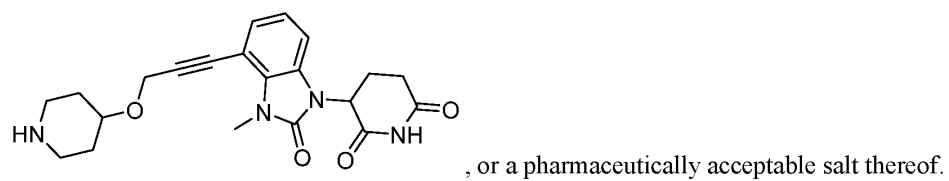
[0055] In some embodiments, the present invention provides compound **I-2**:



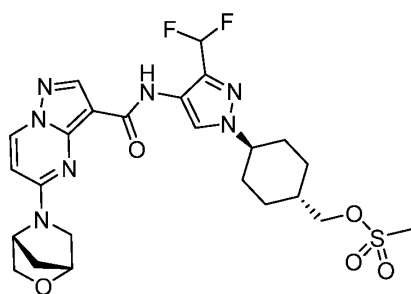
[0056] In some embodiments, the present invention provides compound **I-3**:



[0057] In some embodiments, the present invention provides compound **I-4**:

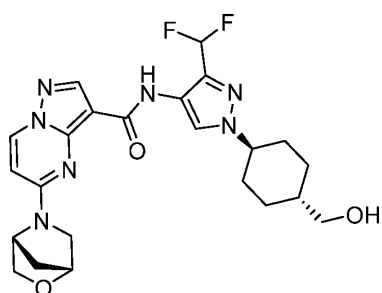


[0058] In some embodiments, the present invention provides compound I-5:



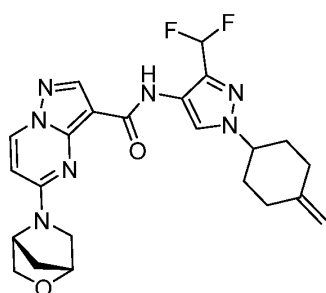
, or a pharmaceutically acceptable salt thereof.

[0059] In some embodiments, the present invention provides compound I-6:



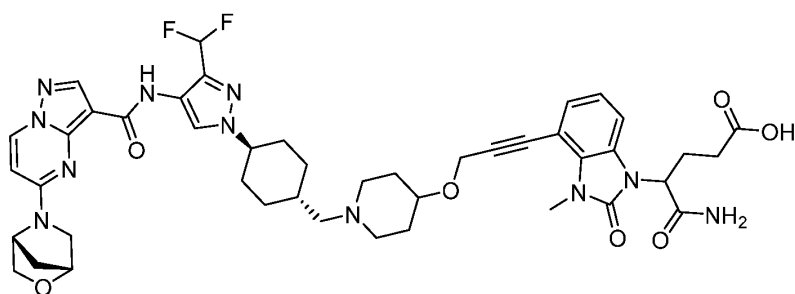
, or a pharmaceutically acceptable salt thereof.

[0060] In some embodiments, the present invention provides compound I-7:



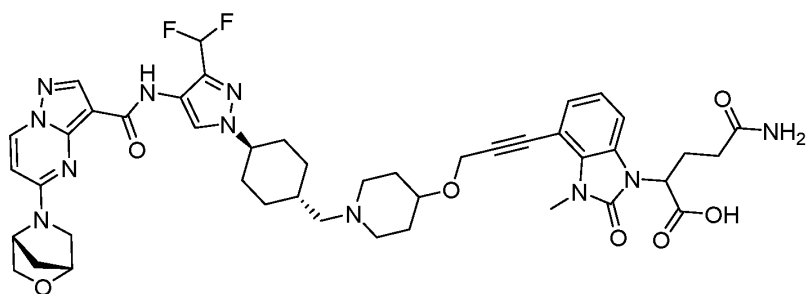
, or a pharmaceutically acceptable salt thereof.

[0061] In some embodiments, the present invention provides compound I-8:



, or a pharmaceutically acceptable salt thereof.

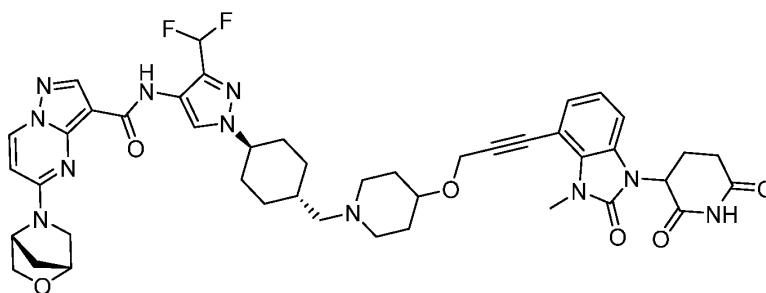
[0062] In some embodiments, the present invention provides compound **I-9**:



, or a pharmaceutically acceptable salt thereof.

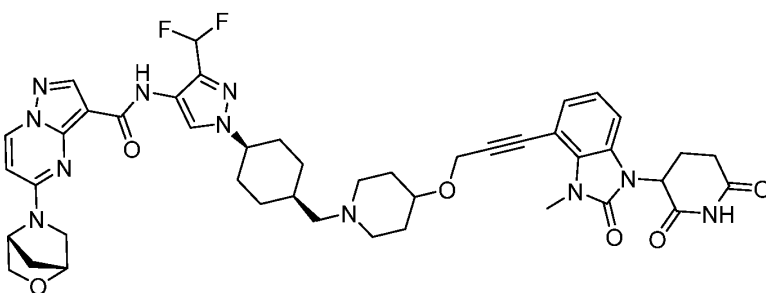
4. Description of Exemplary Compositions

[0063] In another aspect, the present invention provides a composition comprising compound **I-1**:

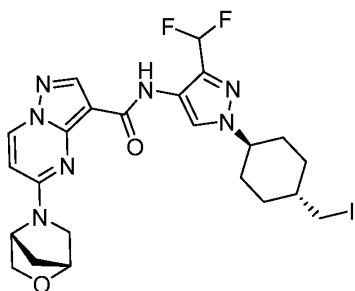


I-1

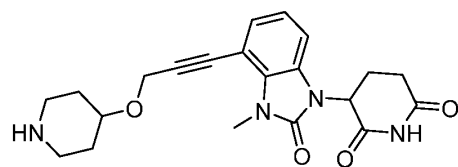
or a pharmaceutically acceptable salt thereof, and one or more impurity compounds selected from the group consisting of:



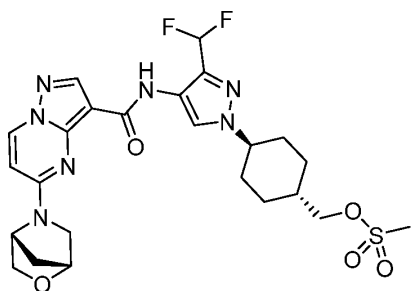
I-2



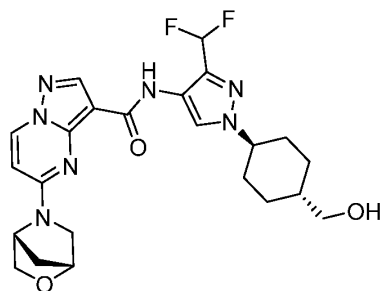
I-3



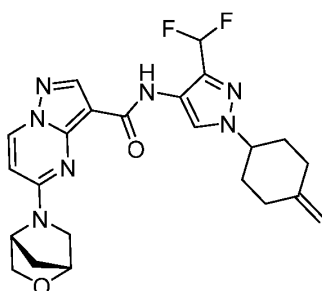
I-4



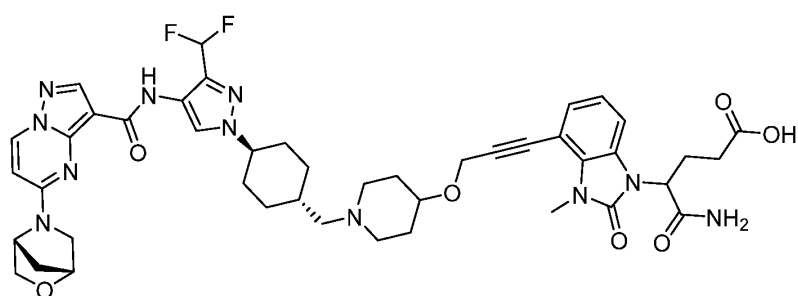
I-5



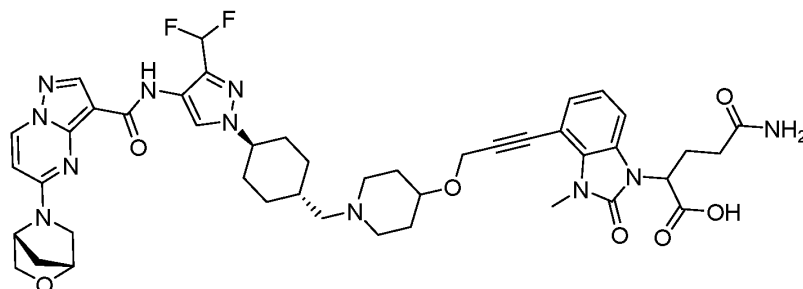
I-6



I-7



I-8



I-9

or a pharmaceutically acceptable salt thereof.

[0064] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and one impurity compound selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[0065] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and two impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[0066] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and three impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[0067] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and four impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[0068] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and five impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[0069] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and six impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[0070] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and seven impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[0071] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and each of impurity compounds I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[0072] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and one or more impurity compounds selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof.

[0073] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and one impurity compound selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof.

[0074] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and two impurity compounds selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof.

[0075] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and three impurity compounds selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof.

[0076] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and four impurity compounds selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof.

[0077] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and each of impurity compounds **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof.

[0078] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and one or more impurity compounds selected from the group consisting of **I-2**, **I-3**, or **I-5**, or a pharmaceutically acceptable salt thereof.

[0079] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and one impurity compound selected from the group consisting of **I-2**, **I-3**, or **I-5**, or a pharmaceutically acceptable salt thereof.

[0080] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and two impurity compounds selected from the group consisting of **I-2**, **I-3**, or **I-5**, or a pharmaceutically acceptable salt thereof.

[0081] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and each of impurity compounds **I-2**, **I-3**, or **I-5**, or a pharmaceutically acceptable salt thereof.

[0082] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and impurity compound **I-2**, or a pharmaceutically acceptable salt thereof.

[0083] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and impurity compound **I-3**, or a pharmaceutically acceptable salt thereof.

[0084] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and impurity compound **I-4**, or a pharmaceutically acceptable salt thereof.

[0085] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and impurity compound **I-5**, or a pharmaceutically acceptable salt thereof.

[0086] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and impurity compound **I-6**, or a pharmaceutically acceptable salt thereof.

[0087] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and impurity compound **I-7**, or a pharmaceutically acceptable salt thereof.

[0088] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and impurity compound **I-8**, or a pharmaceutically acceptable salt thereof.

[0089] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and impurity compound **I-9**, or a pharmaceutically acceptable salt thereof.

[0090] In some embodiments, a composition of the present invention comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, in an amount of at least about 95, 95.5, 96, 96.5, 97, 97.5, 98, 98.5, 99.0, 99.5, 99.8, 99.9, 99.95, or 99.99 wt% of the total weight of the composition. In some embodiments, a composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, in an amount of at least about 97 wt% of the total weight of the composition. In some embodiments, a composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, in an amount of at least about 98 wt% of the total weight of the composition.

[0091] In some embodiments, a composition of the present invention comprises compound **I-1** HCl, in an amount of at least about 95, 95.5, 96, 96.5, 97, 97.5, 98, 98.5, 99.0, 99.5, 99.8, 99.9, 99.95, or 99.99 wt% of the total weight of the composition. In some embodiments, a composition comprises compound **I-1** HCl, in an amount of at least about 97 wt% of the total weight of the composition. In some embodiments, a composition comprises compound **I-1** HCl, in an amount of at least about 98 wt% of the total weight of the composition.

[0092] In some embodiments, a composition of the present invention comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, in an amount of at least about 95, 95.5, 96, 96.5, 97, 97.5, 98, 98.5, 99.0, 99.5, 99.8, 99.9, or 99.95 area percent HPLC. In some embodiments, a composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, in an amount of at least about 97 area percent HPLC. In some embodiments, a composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, in an amount of at least about 98 area percent HPLC. In some embodiments, a HPLC method is as described in the examples.

[0093] In some embodiments, a composition of the present invention comprises compound **I-1** HCl, in an amount of at least about 95, 95.5, 96, 96.5, 97, 97.5, 98, 98.5, 99.0, 99.5, 99.8, 99.9, or 99.95 area

percent HPLC. In some embodiments, a composition comprises compound **I-1** HCl, in an amount of at least about 97 area percent HPLC. In some embodiments, a composition comprises compound **I-1** HCl, in an amount of at least about 98 area percent HPLC. In some embodiments, a HPLC method is as described in the examples.

[0094] In some embodiments, a composition comprising compound **I-1**, or a pharmaceutically acceptable salt thereof, contains an amount of impurities no more than about 5.0, 4.0, 3.0, 2.0, 1.9, 1.8, 1.7, 1.6, 1.5, 1.25, 1, 0.75, 0.5, 0.25, 0.2, 0.1, 0.01, 0.005, or 0.001 wt% of the total weight of the composition. In some embodiments, the amount of total organic impurities is no more than about 3.0 wt% of the total weight of the composition. In some embodiments, the amount of total organic impurities is about 0.05-3.0, 0.05-2.9, 0.05-2.8, 0.05-2.7, 0.05-2.6, 0.05-2.5, 0.05-2.4, 0.05-2.3, 0.05-2.2, 0.05-2.1, 0.05-2.0, 0.1-3.0, 0.15-3.0, 0.2-3.0, 0.25-3.0, 0.3-3.0, 0.4-3.0, 0.5-3.0, 0.6-3.0, 0.7-3.0, 0.8-3.0, 0.9-3.0, or 1.0-3.0 wt% of the total weight of the composition. In some embodiments, the amount of total organic impurities is no more than about 2.0 wt% of the total weight of the composition. In some embodiments, the amount of total organic impurities is no more than about 1.0 wt% of the total weight of the composition.

[0095] In some embodiments, a composition comprising compound **I-1**, or a pharmaceutically acceptable salt thereof, the amount of total organic impurities is no more than about 5.0, 4.0, 3.0, 2.0, 1.9, 1.8, 1.7, 1.6, 1.5, 1.25, 1, 0.75, 0.5, 0.25, 0.2, 0.15, 0.1, or 0.05 area percent HPLC. In some embodiments, the amount of total organic impurities is no more than about 5.0 area percent HPLC. In some embodiments, the amount of total organic impurities is about 2.0-5.0, 2.0-4.5, 2.0-4.0, 2.0-3.8, 2.0-3.6, 2.0-3.5, 2.0-3.2, 2.0-3.0, 2.0-2.9, 2.0-2.8, 2.0-2.7, 2.0-2.6, 2.0-2.5, 2.0-2.4, 2.0-2.3, 2.0-2.2, or 2.0-2.1 area percent HPLC. In some embodiments, the amount of total organic impurities is no more than about 3.0 area percent HPLC. In some embodiments, the amount of total organic impurities is about 0.05-3.0, 0.05-2.9, 0.05-2.8, 0.05-2.7, 0.05-2.6, 0.05-2.5, 0.05-2.4, 0.05-2.3, 0.05-2.2, 0.05-2.1, 0.05-2.0, 0.1-3.0, 0.15-3.0, 0.2-3.0, 0.25-3.0, 0.3-3.0, 0.4-3.0, 0.5-3.0, 0.6-3.0, 0.7-3.0, 0.8-3.0, 0.9-3.0, or 1.0-3.0 area percent HPLC. In some embodiments, a HPLC method is as described in the examples.

[0096] In some embodiments, total organic impurities comprise one or more compounds selected from **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9**. In some embodiments, total organic impurities comprise one or more compounds selected from **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**. In some embodiments, total organic impurities comprise one or more compounds selected from **I-2**, **I-3**, and **I-5**.

[0097] In some embodiments, each organic impurity is, independently, no more than about 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.15, 0.1, or 0.05 wt% of the total weight of the composition. In some embodiments, each of organic impurities **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9** is, independently, no more than about 0.7 wt% of the total weight of the composition. In some embodiments, each of organic impurities **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9** is, independently, no more than about 0.5 wt% of the total weight of

the composition. In some embodiments, an organic impurity selected from **I-2**, **I-4**, **I-6**, **I-7**, **I-8**, and **I-9** is, independently, absent or about 0.2-0.7, 0.25-0.7, 0.3-0.7, 0.35-0.7, 0.4-0.7, 0.2-0.65, 0.2-0.6, 0.2-0.55, 0.2-0.5, 0.05-0.5, 0.1-0.5, 0.15-0.5, 0.2-0.5, or 0.25-0.5 wt% of the total weight of the composition.

[0098] In some embodiments, each organic impurity is, independently, no more than about 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.15, 0.1, or 0.05 area percent HPLC. In some embodiments, each of organic impurities **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9** is, independently, no more than about 0.7 area percent HPLC. In some embodiments, each of organic impurities **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9** is, independently, no more than about 0.5 area percent HPLC. In some embodiments, an organic impurity selected from **I-2**, **I-4**, **I-6**, **I-7**, **I-8**, and **I-9** is, independently, absent or about 0.2-0.7, 0.25-0.7, 0.3-0.7, 0.35-0.7, 0.4-0.7, 0.2-0.65, 0.2-0.6, 0.2-0.55, 0.2-0.5, 0.05-0.5, 0.1-0.5, 0.15-0.5, 0.2-0.5, or 0.25-0.5 area percent HPLC. In some embodiments, a HPLC method is as described in the examples.

[0099] In some embodiments, the amount of compound **I-2**, or a pharmaceutically acceptable salt thereof, is about 0.05-2.0, 0.1-2.0, or 0.5-2.0 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-2**, or a pharmaceutically acceptable salt thereof, is about 0.1, 0.5, 1.0, or 1.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-2**, or a pharmaceutically acceptable salt thereof, is no more than about 2.0 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-2**, or a pharmaceutically acceptable salt thereof, is about 0.5-1.0 or 1.0-1.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-2**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-2**, or a pharmaceutically acceptable salt thereof, is about 0.05-2.0, 0.1-2.0, or 0.5-2.0 area percent HPLC. In some embodiments, the amount of compound **I-2**, or a pharmaceutically acceptable salt thereof, is about 0.1, 0.5, 1.0, or 1.5 area percent HPLC. In some embodiments, the amount of compound **I-2**, or a pharmaceutically acceptable salt thereof, is no more than about 2.0 area percent HPLC. In some embodiments, the amount of compound **I-2**, or a pharmaceutically acceptable salt thereof, is about 0.5-1.0 or 1.0-1.5 area percent HPLC. In some embodiments, the amount of compound **I-2**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 area percent HPLC. In some embodiments, compound **I-2** is absent (as determined by HPLC) from the composition. In some embodiments, a HPLC method is as described in the examples.

[00100] In some embodiments, the amount of compound **I-4**, or a pharmaceutically acceptable salt thereof, is about 0.05-0.7, 0.1-0.7, or 0.2-0.7 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-4**, or a pharmaceutically acceptable salt thereof, is about 0.01, 0.05, 0.1, or 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-4**, or a pharmaceutically acceptable salt thereof, is no more than about 0.7 wt% of the total

weight of the composition. In some embodiments, the amount of compound **I-4**, or a pharmaceutically acceptable salt thereof, is about 0.01-0.1 or 0.05-0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-4**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-4**, or a pharmaceutically acceptable salt thereof, is about 0.05-0.7, 0.1-0.7, or 0.2-0.7 area percent HPLC. In some embodiments, the amount of compound **I-4**, or a pharmaceutically acceptable salt thereof, is 0.01, 0.05, 0.1, or 0.5 area percent HPLC. In some embodiments, the amount of compound **I-4**, or a pharmaceutically acceptable salt thereof, is no more than about 0.7 area percent HPLC. In some embodiments, the amount of compound **I-4**, or a pharmaceutically acceptable salt thereof, is about 0.01-0.1 or 0.05-0.5 area percent HPLC. In some embodiments, the amount of compound **I-4**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 area percent HPLC. In some embodiments, compound **I-4** is absent (as determined by HPLC) from the composition. In some embodiments, a HPLC method is as described in the examples.

[00101] In some embodiments, the amount of compound **I-6**, or a pharmaceutically acceptable salt thereof, is about 0.05-0.7, 0.1-0.7, or 0.2-0.7 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-6**, or a pharmaceutically acceptable salt thereof, is about 0.01, 0.05, 0.1, or 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-6**, or a pharmaceutically acceptable salt thereof, is no more than about 0.7 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-6**, or a pharmaceutically acceptable salt thereof, is about 0.01-0.1 or 0.05-0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-6**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-6**, or a pharmaceutically acceptable salt thereof, is about 0.05-0.7, 0.1-0.7, or 0.2-0.7 area percent HPLC. In some embodiments, the amount of compound **I-6**, or a pharmaceutically acceptable salt thereof, is 0.01, 0.05, 0.1, or 0.5 area percent HPLC. In some embodiments, the amount of compound **I-6**, or a pharmaceutically acceptable salt thereof, is no more than about 0.7 area percent HPLC. In some embodiments, the amount of compound **I-6**, or a pharmaceutically acceptable salt thereof, is about 0.01-0.1 or 0.05-0.5 area percent HPLC. In some embodiments, the amount of compound **I-6**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 area percent HPLC. In some embodiments, compound **I-6** is absent (as determined by HPLC) from the composition. In some embodiments, a HPLC method is as described in the examples.

[00102] In some embodiments, the amount of compound **I-7**, or a pharmaceutically acceptable salt thereof, is about 0.05-0.7, 0.1-0.7, or 0.2-0.7 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-7**, or a pharmaceutically acceptable salt thereof, is about 0.01,

0.05, 0.1, or 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-7**, or a pharmaceutically acceptable salt thereof, is no more than about 0.7 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-7**, or a pharmaceutically acceptable salt thereof, is about 0.01-0.1 or 0.05-0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-7**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-7**, or a pharmaceutically acceptable salt thereof, is about 0.05-0.7, 0.1-0.7, or 0.2-0.7 area percent HPLC. In some embodiments, the amount of compound **I-7**, or a pharmaceutically acceptable salt thereof, is 0.01, 0.05, 0.1, or 0.5 area percent HPLC. In some embodiments, the amount of compound **I-7**, or a pharmaceutically acceptable salt thereof, is no more than about 0.7 area percent HPLC. In some embodiments, the amount of compound **I-7**, or a pharmaceutically acceptable salt thereof, is about 0.01-0.1 or 0.05-0.5 area percent HPLC. In some embodiments, the amount of compound **I-7**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 area percent HPLC. In some embodiments, compound **I-7** is absent (as determined by HPLC) from the composition. In some embodiments, a HPLC method is as described in the examples.

[00103] In some embodiments, the amount of compound **I-8**, or a pharmaceutically acceptable salt thereof, is about 0.05-0.7, 0.1-0.7, or 0.2-0.7 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-8**, or a pharmaceutically acceptable salt thereof, is about 0.01, 0.05, 0.1, or 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-8**, or a pharmaceutically acceptable salt thereof, is no more than about 0.7 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-8**, or a pharmaceutically acceptable salt thereof, is about 0.01-0.1 or 0.05-0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-8**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-8**, or a pharmaceutically acceptable salt thereof, is about 0.05-0.7, 0.1-0.7, or 0.2-0.7 area percent HPLC. In some embodiments, the amount of compound **I-8**, or a pharmaceutically acceptable salt thereof, is 0.01, 0.05, 0.1, or 0.5 area percent HPLC. In some embodiments, the amount of compound **I-8**, or a pharmaceutically acceptable salt thereof, is no more than about 0.7 area percent HPLC. In some embodiments, the amount of compound **I-8**, or a pharmaceutically acceptable salt thereof, is about 0.01-0.1 or 0.05-0.5 area percent HPLC. In some embodiments, the amount of compound **I-8**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 area percent HPLC. In some embodiments, compound **I-8** is absent (as determined by HPLC) from the composition. In some embodiments, a HPLC method is as described in the examples.

[00104] In some embodiments, the amount of compound **I-9**, or a pharmaceutically acceptable salt thereof, is about 0.05-0.7, 0.1-0.7, or 0.2-0.7 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-9**, or a pharmaceutically acceptable salt thereof, is about 0.01, 0.05, 0.1, or 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-9**, or a pharmaceutically acceptable salt thereof, is no more than about 0.7 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-9**, or a pharmaceutically acceptable salt thereof, is about 0.01-0.1 or 0.05-0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-9**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 wt% of the total weight of the composition. In some embodiments, the amount of compound **I-9**, or a pharmaceutically acceptable salt thereof, is about 0.05-0.7, 0.1-0.7, or 0.2-0.7 area percent HPLC. In some embodiments, the amount of compound **I-9**, or a pharmaceutically acceptable salt thereof, is 0.01, 0.05, 0.1, or 0.5 area percent HPLC. In some embodiments, the amount of compound **I-9**, or a pharmaceutically acceptable salt thereof, is no more than about 0.7 area percent HPLC. In some embodiments, the amount of compound **I-9**, or a pharmaceutically acceptable salt thereof, is about 0.01-0.1 or 0.05-0.5 area percent HPLC. In some embodiments, the amount of compound **I-9**, or a pharmaceutically acceptable salt thereof, is no more than about 0.5 area percent HPLC. In some embodiments, compound **I-9** is absent (as determined by HPLC) from the composition. In some embodiments, a HPLC method is as described in the examples.

[00105] In some embodiments, a composition comprising compound **I-1**, or a pharmaceutically acceptable salt thereof, contains one or more genotoxic impurity. In some embodiments, the potential genotoxicity of selected impurities are evaluated *in silico* by means of DEREK 6.0.0 Nexus 2.2.0 (mutagenicity only) and LSMA Version 2.4.5-7 (mutagenicity suite), e.g., as shown in the Examples section below. In some embodiments, each of the genotoxic impurities in a composition is, independently, no more than about 30 ppm. In some embodiments, each of genotoxic impurities in a composition is, independently, no more than about 20 ppm. In some embodiments, each of genotoxic impurities in a composition is, independently, about 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 ppm, or less than 1 ppm. In some embodiments, a composition comprises no more than about 15 ppm total genotoxic impurities. In some embodiments, a composition comprises no more than about 10 ppm total genotoxic impurities. In some embodiments, a composition comprises about 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 ppm, or less than about 1 ppm, total genotoxic impurities. In some embodiments, a genotoxic impurity is compound **I-3** and compound **I-5**. In some embodiments, a genotoxic impurity is compound **I-3**. In some embodiments, a genotoxic impurity is compound **I-5**.

[00106] In some embodiments, the composition comprises compound **I-1** HCl and impurity compound **I-2**, wherein compound **I-1** HCl is at an amount of at least about 97 area percent HPLC, and impurity

compound **I-2** is at an amount of no more than about 2 area percent HPLC. In some embodiments, the composition comprises compound **I-1** HCl, impurity compound **I-2**, and impurity compound **I-3** or **I-5**, wherein compound **I-1** HCl is at an amount of at least about 97 area percent HPLC, impurity compound **I-2** is at an amount of no more than about 2 area percent HPLC, and impurity compound **I-3** or **I-5** is at an amount of no more than about 30 ppm. In some embodiments, the composition comprises compound **I-1** HCl, impurity compounds **I-2**, **I-3**, and **I-5**, wherein compound **I-1** HCl is at an amount of at least about 97 area percent HPLC, impurity compound **I-2** is at an amount of no more than about 2 area percent HPLC, and each of impurity compounds **I-3** and **I-5** is at an amount of no more than about 30 ppm. In some embodiments, the HPLC method is as described in the example.

[00107] In some embodiments, a composition comprises a residual solvent in an amount of no more than about 9000, 8000, 7000, 6000, 5000, 4000, 3000, 2000, 1000, or 500 ppm. In some embodiments, a residual solvent is about 100, 200, 300, 400, 500, 600, 700, 800, 900, or 1000 ppm. In some embodiments, a residual solvent is no more than about 500 ppm. In some embodiments, residual solvent content is measured by capillary GC.

[00108] In some embodiments, a composition comprises residual solvent dichloromethane in an amount of no more than about 600 ppm. In some embodiments, residual solvent dichloromethane is no more than about 600, 500, 400, 300, or 200 ppm. In some embodiments, residual solvent dichloromethane is no more than about 100 ppm. In some embodiments, residual solvent dichloromethane is about 10-100, 50-200, 100-300, 150-400, 200-500, 250-600, or 300-700 ppm. In some embodiments, residual solvent dichloromethane is absent (as determined by GC) from the composition.

[00109] In some embodiments, a composition comprises residual solvent N,N-dimethylacetamide in an amount of no more than about 1090 ppm. In some embodiments, residual solvent N,N-dimethylacetamide is no more than about 1000, 900, 800, 700, 600, 500, 400, 300, or 200 ppm. In some embodiments, residual solvent N,N-dimethylacetamide is no more than about 100 ppm. In some embodiments, residual solvent N,N-dimethylacetamide is about 10-100, 50-200, 100-300, 150-400, 200-500, 250-600, 300-700, 400-800, 500-900, or 600-1000 ppm. In some embodiments, residual solvent N,N-dimethylacetamide is absent (as determined by GC) from the composition.

[00110] In some embodiments, a composition comprises residual solvent tetrahydrofuran in an amount of no more than about 720 ppm. In some embodiments, residual solvent tetrahydrofuran is no more than about 700, 600, 500, 400, 300, or 200 ppm. In some embodiments, residual solvent tetrahydrofuran is no more than about 100 ppm. In some embodiments, residual solvent tetrahydrofuran is about 10-100, 50-200, 100-300, 150-400, 200-500, 250-600, or 300-700 ppm. In some embodiments, residual solvent tetrahydrofuran is absent (as determined by GC) from the composition.

[00111] In some embodiments, a composition comprises residual solvent 2-propanol in an amount of no more than about 5000 ppm. In some embodiments, residual solvent 2-propanol is no more than about 4000, 3000, 2000, 1000, or 500 ppm. In some embodiments, residual solvent 2-propanol is no more than about 100 ppm. In some embodiments, residual solvent 2-propanol is about 100-1000, 500-2000, 1000-3000, 1500-4000, or 2000-5000 ppm. In some embodiments, residual solvent 2-propanol is absent (as determined by GC) from the composition.

[00112] In some embodiments, a composition comprises residual solvent 2-methyltetrahydrofuran in an amount of no more than about 5000 ppm. In some embodiments, residual solvent 2-methyltetrahydrofuran is no more than about 4000, 3000, 2000, 1000, or 500 ppm. In some embodiments, residual solvent 2-methyltetrahydrofuran is no more than about 100 ppm. In some embodiments, residual solvent 2-methyltetrahydrofuran is about 100-1000, 500-2000, 1000-3000, 1500-4000, or 2000-5000 ppm. In some embodiments, residual solvent 2-methyltetrahydrofuran is absent (as determined by GC) from the composition.

[00113] In some embodiments, the present invention provides a composition comprising **I-1** HCl, and one or more additional component of the acceptance criteria as described in Table 2 in Example 2. In some embodiments, the present invention provides a composition comprising **I-1** HCl, and all components of the acceptance criteria as described in Table 2 in Example 2.

[00114] In some embodiments, the present invention provides any compound described above and disclosed herein in isolated form. As used herein, the term “isolated” means that a compound is provided in a form that is separated from other components that might be present in that compound’s usual environment. In certain embodiments, an isolated compound is in solid form. In some embodiments, an isolated compound is at least about 50% pure as determined by a suitable HPLC method. In certain embodiments, an isolated compound is at least about 60%, 70%, 80%, 90%, 95%, 98%, 99%, 99.5%, 99.6%, 99.7%, 99.8%, 99.9%, 99.95%, 99.99%, or 99.999% pure as determined by a suitable HPLC method. Percent purity may be measured by weight percent of the desired compound (% w/w), by area % relative to the total area of the HPLC chromatogram, or by other methods known in the art.

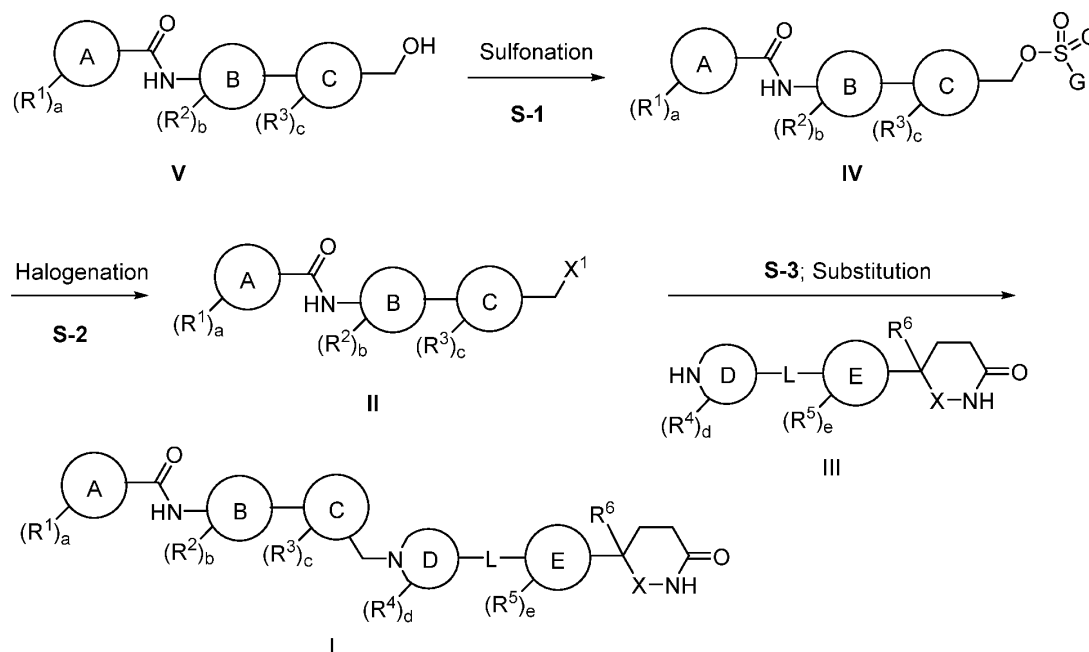
[00115] In some embodiments, a composition is a tablet. In some embodiments, compound **I-1**, or a pharmaceutically acceptable salt thereof, in a tablet is in an amount of at least about 97 area percent of the HPLC relative to the total area of the compound **I-1** and impurity compounds peaks in the HPLC chromatogram. In some embodiments, the amount of an organic impurity, as described above, in a tablet is no more than about 0.7% area percent of the HPLC relative to the total area of the compound **I-1** and impurity compounds peaks in the HPLC chromatogram. In some embodiments, a HPLC method is as described in the examples.

[00116] Disclosed compounds may be purified by any means known in the art. Such means include, e.g. silica gel column chromatography; medium pressure liquid chromatography (MPLC); high pressure liquid chromatography (HPLC); preparative HPLC (prep-HPLC); flash chromatography (FC); liquid chromatography (LC); supercritical fluid chromatography (SFC); thin layer chromatography (TLC); preparative TLC (prep-TLC); liquid chromatography-mass spectrometry (LC-MS, LCMS or LC/MS); recrystallization; precipitation; trituration; distillation; derivatization; acid-base extraction; and the like.

[00117] The term “purified”, “in purified form” or “in isolated and purified form” for a compound refers to the physical state of said compound after being isolated from a synthetic process (e.g., from a reaction mixture), or natural source or combination thereof. Thus, the term “purified”, “in purified form” or “in isolated and purified form” for a compound refers to the physical state of said compound (or a tautomer or stereoisomer thereof, or pharmaceutically acceptable salt or solvate of said compound, said stereoisomer, or said tautomer) after being obtained from a purification process or processes described herein or well known to the skilled artisan (e.g., chromatography, recrystallization and the like), in sufficient purity to be suitable for in vivo or medicinal use and/or characterizable by standard analytical techniques described herein or well known to the skilled artisan.

5. Description of Synthesis of Compound Formula I and Relevant Intermediates

[00118] In some embodiments, compound of formula I, or a pharmaceutically acceptable salt thereof, is synthesized according to Scheme 1:



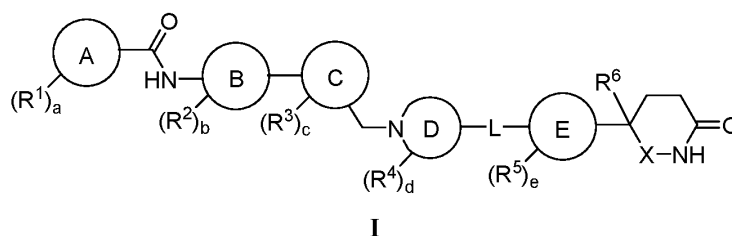
[00119] At step S-1, the primary hydroxyl of compound of formula V, or a salt thereof, is sulfonated using an appropriate sulfonation reagent to provide a sulfonate ester compound of formula IV. Suitable sulfonation reagents and reaction conditions are well known to one of ordinary skill in the art, see for example, Greene's Protective Groups in Organic Synthesis, P. G. M. Wuts and T. W. Greene, 4th Edition, John Wiley & Sons, 2007. In some embodiments, step S-1 comprises a reaction between compound of formula V and methanesulfonyl chloride (MsCl) or methanesulfonic anhydride (Ms₂O). In some embodiments, step S-1 comprises a solvent tetrahydrofuran (THF). In some embodiments, step S-1 comprises a tertiary base (e.g., triethylamine, diisopropylethylamine, etc.).

[00120] At step S-2, the sulfonate ester of the compound of formula IV, or a salt thereof, is halogenated using an appropriate halogenation reagent to provide a primary halogen compound of formula II. Suitable halogenation reagents and reaction conditions are well known to one of ordinary skill in the art, see for example, Greene's Protective Groups in Organic Synthesis, P. G. M. Wuts and T. W. Greene, 4th Edition, John Wiley & Sons, 2007. In some embodiments, step S-2 comprises a reaction between compound of formula IV and lithium iodide. In some embodiments, step S-2 comprises a solvent 2-methyltetrahydrofuran (2-MeTHF).

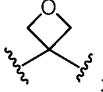
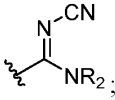
[00121] At step S-3, the primary halogen of the compound of formula II, or a salt thereof, is reacted with a compound of formula III under appropriate substitution conditions to provide the compound of formula I. Suitable reaction conditions for substitution reactions are well known to one of ordinary skill in the art, see for example, Greene's Protective Groups in Organic Synthesis, P. G. M. Wuts and T. W. Greene, 4th Edition, John Wiley & Sons, 2007. In some embodiments, step S-3 comprises a solvent N-N-dimethylacetamide (DMAc). In some embodiments, step S-3 comprises a tertiary base (e.g., triethylamine, diisopropylethylamine, etc.).

[00122] One of ordinary skill in the art will appreciate that compound formula I, or a salt thereof, may be prepared in a crystal polymorph form through one or more acidifying, basifying, slurrying, warming, cooling, filtering, precipitating, and seeding steps.

[00123] In some embodiment, the present invention provides a process for preparing a compound of formula I:



or a pharmaceutically acceptable salt thereof, wherein:

X is a bivalent moiety selected from a covalent bond, $-\text{CH}_2-$, $-\text{C}(\text{O})-$, $-\text{C}(\text{S})-$, or  ;
 R^1 , R^2 , R^3 , R^4 , and R^5 , independently, are selected from hydrogen, deuterium, R^A , halogen, $-\text{CN}$, $-\text{NO}_2$, $-\text{OR}$, $-\text{SR}$, $-\text{NR}_2$, $-\text{SO}_2\text{R}$, $-\text{SO}_2\text{NR}_2$, $-\text{S}(\text{O})\text{R}$, $-\text{CFR}_2$, $-\text{CF}_2\text{R}$, $-\text{CF}_3$, $-\text{CR}_2\text{OR}$, $-\text{CR}_2(\text{NR}_2)$, $-\text{C}(\text{O})\text{R}$, $-\text{C}(\text{O})\text{OR}$, $-\text{C}(\text{O})\text{NR}_2$, $-\text{C}(\text{S})\text{NR}_2$, $-\text{C}(\text{O})\text{NROR}$, $-\text{OC}(\text{O})\text{R}$, $-\text{OC}(\text{O})\text{NR}_2$, $-\text{NRC}(\text{O})\text{OR}$, $-\text{NRC}(\text{O})\text{R}$, $-\text{NRC}(\text{O})\text{NR}_2$, $-\text{NRSO}_2\text{R}$, $-\text{N}^+(\text{O}^-)\text{R}_2$, $-\text{OP}(\text{O})\text{R}_2$, $-\text{OP}(\text{O})(\text{OR})_2$, $-\text{OP}(\text{O})(\text{OR})\text{NR}_2$, $-\text{OP}(\text{O})(\text{NR}_2)_2$, $-\text{P}(\text{O})\text{R}_2$, $-\text{SiR}_3$, $-\text{Si}(\text{OR})\text{R}_2$, or  ;

each R, independently, is hydrogen, or an optionally substituted group selected from C_{1-6} aliphatic, phenyl, a 3-7 membered saturated or partially unsaturated heterocyclic having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, and a 5-6 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or:
 two R groups on the same carbon or nitrogen are optionally taken together with their intervening atoms to form a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or a 5-9 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur;

each R^A , independently, is an optionally substituted group selected from C_{1-6} aliphatic, phenyl, a 4-7 membered saturated or partially unsaturated heterocyclic ring having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, and a 5-6 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur;

a, b, c, d, and e, independently, are selected from 0, 1, 2, 3, or 4;

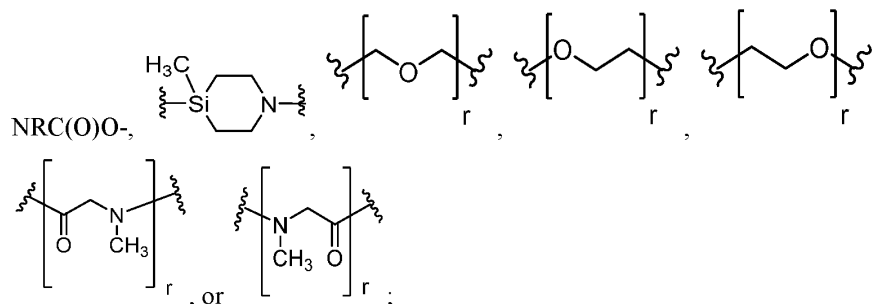
R^6 is hydrogen or C_{1-6} aliphatic;

Ring A, Ring B, and Ring E, independently, are selected from phenyl, naphthyl, a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or a 5-10 membered monocyclic or bicyclic heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur;

Ring C is a 4-6 membered saturated or partially unsaturated carbocyclic or heterocyclic ring having 1-2 heteroatoms selected from nitrogen, oxygen, and sulfur;

Ring D is a 4-6 membered saturated or partially unsaturated heterocyclic ring having, in addition to the nitrogen present, 0-2 heteroatoms selected from nitrogen, oxygen, and sulfur;

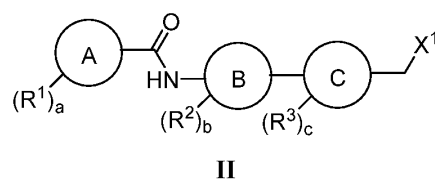
L is a covalent bond or a bivalent, saturated or unsaturated, straight or branched C₁₋₁₀ hydrocarbon chain, wherein 0-6 methylene units of L are independently replaced by -CDH-, -CD₂-, -CRF-, -CF₂-, -Cy-, -O-, -NR-, -SiR₂-, -Si(OH)R-, -Si(OH)₂-, -P(O)OR-, -P(O)R-, -P(O)NR₂-, -S-, -OC(O)-, -C(O)O-, -C(O)-, -S(O)-, -SO₂-, -NRSO₂-, -SO₂NR-, -NRC(O)-, -C(O)NR-, -OC(O)NR-, -



each -Cy-, independently, is an optionally substituted bivalent ring selected from phenylenyl, an 8-10 membered bicyclic arylenyl, a 4-7 membered saturated or partially unsaturated carbocyclylenyl, a 4-12 membered saturated or partially unsaturated spiro carbocyclylenyl, an 8-10 membered bicyclic saturated or partially unsaturated carbocyclylenyl, a 4-7 membered saturated or partially unsaturated heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, a 4-12 membered saturated or partially unsaturated spiro heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, an 8-10 membered bicyclic saturated or partially unsaturated heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, a 5-6 membered heteroarylenyl having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or an 8-10 membered bicyclic heteroarylenyl having 1-5 heteroatoms independently selected from nitrogen, oxygen, or sulfur; and

r is 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10,

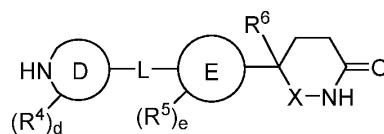
comprising treating a compound of formula II:



or pharmaceutically acceptable salt thereof, wherein:

X¹ is a suitable leaving group,

with a compound of formula III:

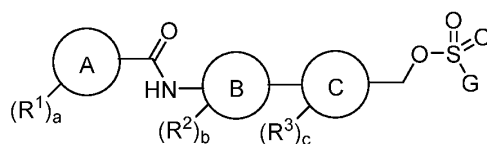


III

under suitable conditions to form the compound of formula **I** or a pharmaceutically acceptable salt thereof.

[00124] In some embodiments, a compound of formula **I** is compound **I-1**. In some embodiments, a compound of formula **II** is compound **I-3**. In some embodiments, a compound of formula **III** is compound **I-4**.

[00125] In some embodiments, the present invention provides a process for preparing a compound of formula **II**, wherein X^1 is a halogen, the process comprising halogenating a compound of formula **IV**:



IV

or a pharmaceutically acceptable salt thereof, wherein:

each of variables R^1 , R^2 , R^3 , a, b, c, Ring A, Ring B, and Ring C is independently as defined and described in embodiments herein; and

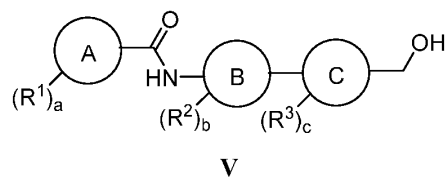
G is an optionally substituted group selected from a C_{1-6} aliphatic, phenyl, naphthyl, a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or a 5-10 membered monocyclic or bicyclic heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur;

under suitable conditions to form the compound of formula **II** or a pharmaceutically acceptable salt thereof.

[00126] In some embodiments, the present invention provides a process to prepare a compound of formula **I**, the process comprising treating a compound of formula **IV** with a compound of formula **III** under suitable conditions to form the compound of formula **I** or a pharmaceutically acceptable salt thereof.

[00127] In some embodiments, a compound of formula **IV** is compound **I-5**.

[00128] In some embodiments, the present invention provides a process for preparing a compound of formula **IV**, the process comprising sulfonating a compound of formula **V**:



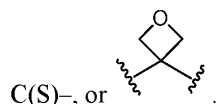
or a pharmaceutically acceptable salt thereof, under suitable conditions to form the compound of formula **IV** or a pharmaceutically acceptable salt thereof, wherein each variable is independently as defined and described in embodiments herein.

[00129] In some embodiments, the present invention provides a process to prepare a compound of formula **I**, the process comprising treating a compound of formula **V** with a compound of formula **III** under suitable conditions to form the compound of formula **I** or a pharmaceutically acceptable salt thereof.

[00130] In some embodiments, a compound of formula **V** is compound **I-6**.

[00131] How about incorporate by reference the definitions of the variables of formula **I**, followed by the simplified version below?

[00132] As described above, **X** is a bivalent moiety selected from a covalent bond, $-\text{CH}_2-$, $-\text{C}(\text{O})-$, $-\text{C}(\text{S})-$, or



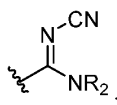
[00133] In some embodiments, **X** is a covalent bond. In some embodiments, **X** is $-\text{CH}_2-$. In some

embodiments, **X** is $-\text{C}(\text{O})-$. In some embodiments, **X** is $-\text{C}(\text{S})-$. In some embodiments, **X** is



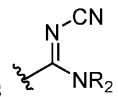
[00134] As described above, R^1 , R^2 , R^3 , R^4 , and R^5 , independently, are selected from hydrogen, deuterium, R^A , halogen, $-\text{CN}$, $-\text{NO}_2$, $-\text{OR}$, $-\text{SR}$, $-\text{NR}_2$, $-\text{SO}_2\text{R}$, $-\text{SO}_2\text{NR}_2$, $-\text{S}(\text{O})\text{R}$, $-\text{CFR}_2$, $-\text{CF}_2\text{R}$, $-\text{CF}_3$, $-\text{CR}_2\text{OR}$, $-\text{CR}_2(\text{NR}_2)$, $-\text{C}(\text{O})\text{R}$, $-\text{C}(\text{O})\text{OR}$, $-\text{C}(\text{O})\text{NR}_2$, $-\text{C}(\text{S})\text{NR}_2$, $-\text{C}(\text{O})\text{NROR}$, $-\text{OC}(\text{O})\text{R}$, $-\text{OC}(\text{O})\text{NR}_2$, $-\text{NRC}(\text{O})\text{OR}$, $-\text{NRC}(\text{O})\text{R}$, $-\text{NRC}(\text{O})\text{NR}_2$, $-\text{NRSO}_2\text{R}$, $-\text{N}^+(\text{O}^-)\text{R}_2$, $-\text{OP}(\text{O})\text{R}_2$, $-\text{OP}(\text{O})(\text{OR})_2$, $-\text{OP}(\text{O})(\text{OR})\text{NR}_2$,

$-\text{OP}(\text{O})(\text{NR}_2)_2$, $-\text{P}(\text{O})\text{R}_2$, $-\text{SiR}_3$, $-\text{Si}(\text{OR})\text{R}_2$, or

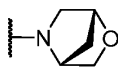


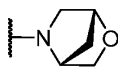
[00135] In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is hydrogen. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is deuterium. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is R^A . In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is halogen. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{CN}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{NO}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{OR}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{SR}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{NR}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{SO}_2\text{R}$. In

some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{SO}_2\text{NR}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{S(O)R}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{CFR}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{CF}_2\text{R}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{CF}_3$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{CR}_2\text{OR}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{CR}_2(\text{NR}_2)$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{C(O)R}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{C(O)OR}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{C(O)NR}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{C(S)NR}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{C(O)NROR}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{OC(O)R}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{OC(O)NR}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{NRC(O)OR}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{NRC(O)R}$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{NRC(O)NR}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{NRSO}_2\text{R}$, $-\text{N}^+(\text{O})\text{R}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{OP(O)R}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{OP(O)(OR)}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{OP(O)(OR)NR}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{OP(O)(NR}_2)_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{P(O)R}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{SiR}_3$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is $-\text{Si(OR)R}_2$. In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is



Si(OR)R_2 . In some embodiments, one or more of R^1 , R^2 , R^3 , R^4 , and R^5 , is



[00136] In some embodiments, R^1 is . In some embodiments, R^2 is $-\text{CHF}_2$. In some embodiments, R^5 is methyl.

[00137] As described above, each R, independently, is hydrogen, or an optionally substituted group selected from C_{1-6} aliphatic, phenyl, a 3-7 membered saturated or partially unsaturated heterocyclic having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, and a 5-6 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or two R groups on the same carbon or nitrogen are optionally taken together with their intervening atoms to form a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or a 5-9 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

[00138] In some embodiments, R is hydrogen. In some embodiments, R is an optionally substituted C₁₋₆ aliphatic. In some embodiments, R is an optionally substituted phenyl. In some embodiments, R is an optionally substituted 3-7 membered saturated or partially unsaturated heterocyclic having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur. In some embodiments, R is an optionally substituted 5-6 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur. In some embodiments, two R groups on the same carbon or nitrogen are optionally taken together with their intervening atoms to form a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or a 5-9 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

[00139] As described above, each R^A, independently, is an optionally substituted group selected from C₁₋₆ aliphatic, phenyl, a 4-7 membered saturated or partially unsaturated heterocyclic ring having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, and a 5-6 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

[00140] In some embodiments, R^A is an optionally substituted C₁₋₆ aliphatic. In some embodiments, R^A is an optionally substituted phenyl. In some embodiments, R^A is an optionally substituted 4-7 membered saturated or partially unsaturated heterocyclic ring having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur. In some embodiments, R^A is an optionally substituted 5-6 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

[00141] As described above, a, b, c, d, and e, independently, are selected from 0, 1, 2, 3, or 4.

[00142] In some embodiments, one or more of a, b, c, d, and e, is 0. In some embodiments, one or more of a, b, c, d, and e, is 1. In some embodiments, one or more of a, b, c, d, and e, is 2. In some embodiments, one or more of a, b, c, d, and e, is 3. In some embodiments, one or more of a, b, c, d, and e, is 4.

[00143] As described above, R⁶ is hydrogen or C₁₋₆ aliphatic.

[00144] In some embodiments, R⁶ is hydrogen. In some embodiments, R⁶ is C₁₋₆ aliphatic.

[00145] As described above, Ring A, Ring B, and Ring E, independently, are selected from phenyl, naphthyl, a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or a 5-10 membered monocyclic or bicyclic heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

[00146] In some embodiments, one or more of Ring A, Ring B, and Ring E is phenyl. In some embodiments, one or more of Ring A, Ring B, and Ring E is naphthyl. In some embodiments, one or more of Ring A, Ring B, and Ring E is a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently

selected from nitrogen, oxygen, and sulfur. In some embodiments, one or more of Ring A, Ring B, and Ring E is a 5-10 membered monocyclic or bicyclic heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

[00147] In some embodiments, Ring A is pyridinyl. In some embodiments, Ring B is pyrazolyl. In some embodiments, Ring E is 1,3-dihydro-2H-benzo[d]imidazol-2-onyl.

[00148] As described above, Ring C is a 4-6 membered saturated or partially unsaturated carbocyclic or heterocyclic ring having 1-2 heteroatoms selected from nitrogen, oxygen, and sulfur.

[00149] In some embodiments, Ring C is a 4-6 membered saturated or partially unsaturated carbocyclic or heterocyclic ring having 1-2 heteroatoms selected from nitrogen, oxygen, and sulfur.

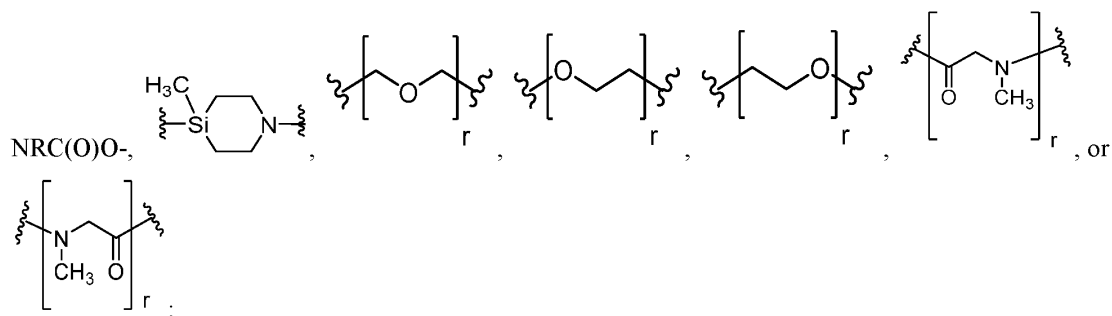
[00150] In some embodiments, Ring C is cyclohexyl.

[00151] As described above, Ring D is a 4-6 membered saturated or partially unsaturated heterocyclic ring having, in addition to the nitrogen present, 0-2 heteroatoms selected from nitrogen, oxygen, and sulfur.

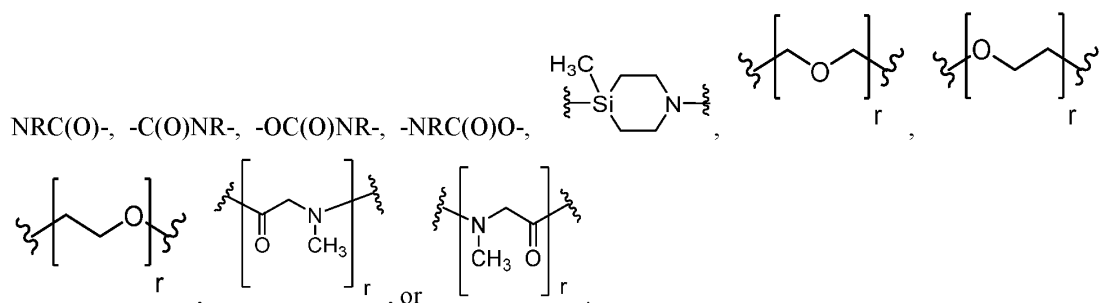
[00152] In some embodiments, Ring D is a 4-6 membered saturated or partially unsaturated heterocyclic ring having, in addition to the nitrogen present, 0-2 heteroatoms selected from nitrogen, oxygen, and sulfur.

[00153] In some embodiments, Ring D is piperidinyl.

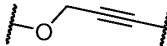
[00154] As described above, L is a covalent bond or a bivalent, saturated or unsaturated, straight or branched C₁₋₁₀ hydrocarbon chain, wherein 0-6 methylene units of L are independently replaced by -CDH-, -CD₂-, -CRF-, -CF₂-, -Cy-, -O-, -NR-, -SiR₂-, -Si(OH)R-, -Si(OH)₂-, -P(O)OR-, -P(O)R-, -P(O)NR₂-, -S-, -OC(O)-, -C(O)O-, -C(O)-, -S(O)-, -SO₂-, -NRSO₂-, -SO₂NR-, -NRC(O)-, -C(O)NR-, -OC(O)NR-, -



[00155] In some embodiments, L is a covalent bond. In some embodiments, L is a bivalent, saturated or unsaturated, straight or branched C₁₋₁₀ hydrocarbon chain, wherein 0-6 methylene units of L are independently replaced by -CDH-, -CD₂-, -CRF-, -CF₂-, -Cy-, -O-, -NR-, -SiR₂-, -Si(OH)R-, -Si(OH)₂-, -P(O)OR-, -P(O)R-, -P(O)NR₂-, -S-, -OC(O)-, -C(O)O-, -C(O)-, -S(O)-, -SO₂-, -NRSO₂-, -SO₂NR-, -



[00156] In some embodiments, L is $-\text{O}(\text{CH}_2)_{1-4}-$. In some embodiments, L is $-(\text{CH}_2)_{1-5}-$

[00157] In some embodiments, L is .

[00158] As described above, each $-\text{Cy}-$, independently, is an optionally substituted bivalent ring selected from phenylenyl, an 8-10 membered bicyclic arylene, a 4-7 membered saturated or partially unsaturated carbocyclylenyl, a 4-12 membered saturated or partially unsaturated spiro carbocyclylenyl, an 8-10 membered bicyclic saturated or partially unsaturated carbocyclylenyl, a 4-7 membered saturated or partially unsaturated heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, a 4-12 membered saturated or partially unsaturated spiro heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, an 8-10 membered bicyclic saturated or partially unsaturated heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, a 5-6 membered heteroarylenyl having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or an 8-10 membered bicyclic heteroarylenyl having 1-5 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

[00159] In some embodiments, $-\text{Cy}-$ is an optionally substituted phenylenyl. In some embodiments, $-\text{Cy}-$ is an optionally substituted 8-10 membered bicyclic arylene. In some embodiments, $-\text{Cy}-$ is an optionally substituted 4-7 membered saturated or partially unsaturated carbocyclylenyl. In some embodiments, $-\text{Cy}-$ is an optionally substituted 4-12 membered saturated or partially unsaturated spiro carbocyclylenyl. In some embodiments, $-\text{Cy}-$ is an optionally substituted 8-10 membered bicyclic saturated or partially unsaturated carbocyclylenyl. In some embodiments, $-\text{Cy}-$ is an optionally substituted 4-7 membered saturated or partially unsaturated heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur. In some embodiments, $-\text{Cy}-$ is an optionally substituted 4-12 membered saturated or partially unsaturated spiro heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur. In some embodiments, $-\text{Cy}-$ is an optionally substituted 8-10 membered bicyclic saturated or partially unsaturated heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur. In some embodiments, $-\text{Cy}-$ is an optionally substituted 5-6 membered heteroarylenyl having 1-4 heteroatoms independently selected from nitrogen,

oxygen, and sulfur. In some embodiments, –Cy– is an optionally substituted 8-10 membered bicyclic heteroarylenyl having 1-5 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

[00160] As described above, *r* is 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10,

[00161] In some embodiments, *r* is 0. In some embodiments, *r* is 1. In some embodiments, *r* is 2. In some embodiments, *r* is 3. In some embodiments, *r* is 4. In some embodiments, *r* is 5. In some embodiments, *r* is 6. In some embodiments, *r* is 7. In some embodiments, *r* is 8. In some embodiments, *r* is 9. In some embodiments, *r* is 10.

[00162] As described above, X^1 is a suitable leaving group.

[00163] In some embodiments, X^1 is a suitable leaving group. In some embodiments, the leaving group is halogen. In some embodiments, the leaving group is iodide.

[00164] As described above, *G* is an optionally substituted group selected from a C_{1-6} aliphatic, phenyl, naphthyl, a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or a 5-10 membered monocyclic or bicyclic heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

[00165] In some embodiments, *G* is an optionally substituted C_{1-6} aliphatic. In some embodiments, *G* is an optionally substituted phenyl. In some embodiments, *G* is an optionally substituted naphthyl. In some embodiments, *G* is an optionally substituted 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur. In some embodiments, *G* is an optionally substituted 5-10 membered monocyclic or bicyclic heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

[00166] In some embodiments, *G* is methyl.

[00167] In some embodiments, the present invention provides a compound of formula II, or a salt thereof, wherein each variable is independently as defined and described in embodiments herein.

[00168] In some embodiments, the present invention provides a compound of formula III, or a salt thereof, wherein each variable is independently as defined and described in embodiments herein.

[00169] In some embodiments, the present invention provides a compound of formula IV, or a salt thereof, wherein each variable is independently as defined and described in embodiments herein.

[00170] In some embodiments, the present invention provides a compound of formula V, or a salt thereof, wherein each variable is independently as defined and described in embodiments herein.

6. *Analysis, Formulation, and Administration*

6.1. *Analysis*

[00171] It has been discovered that certain impurities arise during the synthesis of compound **I-1**, such as the compounds shown in **Table 1**, above, or a stereoisomer or pharmaceutically acceptable salt thereof. Isolation and characterization of each impurity is useful for a number of purposes. Generally, pharmaceutical compositions require a high level of purity to meet regulated standards for drug quality and purity. For example, in the synthesis of compound **I-1**, impurities are often formed, including degradants or by-products of manufacture, which may hinder the therapeutic effects of compound **I-1** and/or may be toxic if present in high enough quantities. As such, it is desirable to have the ability to determine the presence and amounts of such impurities and to monitor the chemical purity, including stereochemical purity, of compound **I-1**. To do this, it is important to identify, isolate, and chemically characterize impurities, which can be used in chromatographic procedures as standards to confirm the purity of compound **I-1**.

[00172] Accordingly, in one aspect the present invention provides a method of preparing a disclosed compound, or a pharmaceutically acceptable salt thereof, comprising contacting an appropriate starting material or materials under conditions shown, e.g., in the Examples below, to prepare the compound or pharmaceutically acceptable salt thereof. In some embodiments, the compound or a pharmaceutically acceptable salt thereof is useful as a reference standard and/or in methods of determining the presence of an impurity in a sample, such as a sample of compound **I-1**, or a pharmaceutically acceptable salt thereof.

[00173] The present invention also provides methods for determining an impurity, comprising injecting a reference compound (e.g., compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**) or a pharmaceutically acceptable salt thereof, into an HPLC column under a set of conditions to obtain a first HPLC chromatogram, wherein the amount and/or chemical identity of the compound present in the reference solution is known; injecting a sample solution comprising compound **I-1**, or a pharmaceutically acceptable salt thereof, into the HPLC column under said set of conditions to obtain a second HPLC chromatogram; and determining the presence and/or the amount of the compound in the sample solution. In some embodiments, the reference solution is injected multiple times. In some embodiments, the determining comprises comparing retention times of peaks in the first HPLC chromatogram and peaks in the second HPLC chromatogram to determine the presence of the compound in the sample solution. In other embodiments, the determining comprises quantifying peak areas of the sample solution and peak areas of the reference solution on the HPLC chromatograms and estimating from these the amount of the compound in the sample solution. In some embodiments, the HPLC column is a reverse phase column and the column is eluted using a mobile phase (e.g., water, acetonitrile, and a mineral or organic acid).

[00174] The present invention also provides methods for determining an impurity in a material consisting essentially of compound **I-1**, or a pharmaceutically acceptable salt thereof, comprising injecting into an HPLC column, in a single or series of injections, a sample solution containing the material and

spiked with a reference compound having a known chemical structure (e.g., compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9) or a pharmaceutically acceptable salt thereof; obtaining an HPLC chromatogram; and determining the presence and/or the amount of the compound in the material. In some embodiments, the HPLC column is a reverse phase column and the column is eluted using a mobile phase (e.g., water, acetonitrile, and a mineral or organic acid). The method may further comprise documenting in a written form the chemical identity of the compound and the amount of the compound as an impurity.

[00175] The present invention also provides methods for determining an impurity in a material consisting essentially of compound I-1, or a pharmaceutically acceptable salt thereof, comprising injecting, in a single or series of injections, a solution in which the material is dissolved into an HPLC column and obtaining an HPLC chromatogram; determining the amount in the material of a compound having a known structure (e.g., compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9) or a pharmaceutically acceptable salt thereof; and documenting in a written form the chemical identity of the compound and the amount of the compound as an impurity in the material. In some cases, the amount in the material of the compound is determined by (i) identifying a peak on the chromatogram that corresponds to a peak on a control chromatogram of a compound having the known structure, (ii) identifying a peak on the chromatogram that corresponds to a relative retention time of a compound having the known structure, and/or (iii) identifying a peak on the chromatogram that corresponds to a known amount of a spike of the compound having the known structure. In some embodiments, the HPLC column is a reverse phase column and the column is eluted using a mobile phase (e.g., water, acetonitrile, and a mineral or organic acid).

[00176] In some embodiments, the present invention provides compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9, or a pharmaceutically acceptable salt thereof, in sufficient purity to enable its use as a reference or standard compound in various analytical methods (e.g., HPLC, HPTLC, GC, SFC, LCMS), as described more fully below. In some embodiments, the compound or pharmaceutically acceptable salt thereof may be isolated with at least 50% purity, at least 75% purity, at least 95% purity, or with at least 97% purity. In some embodiments, the compound or pharmaceutically acceptable salt thereof is isolated and/or packaged as a solid.

[00177] In another aspect, the present invention provides methods for determining the presence and/or amount of compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9, or a pharmaceutically acceptable salt thereof. For example, compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9, or a pharmaceutically acceptable salt thereof, may be formed as an impurity during the synthesis of compound I-1. As used herein, the term “impurity” may refer to degradants which arise during storage of compound I-1 and/or by-products formed during the chemical manufacturing of compound I-1. In one embodiment, the method comprises injecting a reference solution comprising compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9, or a pharmaceutically acceptable salt thereof, into an HPLC column under a set of conditions to obtain a first HPLC chromatogram wherein the

amount and/or chemical identity of compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof, present in the reference solution is known, injecting a sample solution comprising compound **I-1** into the HPLC column under the same set of conditions to obtain a second HPLC chromatogram, and comparing the first HPLC chromatogram with the second HPLC chromatogram to determine the presence and/or amount of the impurity (compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof). The reference solution may be formed by dissolving a sample (e.g., solid sample) of a compound of Formula **I-1**, or a pharmaceutically acceptable salt thereof, in a first solvent, and the sample solution may be formed by dissolving a solid sample in a second solvent. In some embodiments, the reference solution may contain an additional compound(s), wherein the amount and/or identity of the additional compound(s) is also known. In one embodiment, the sample (e.g., sample solution) may comprise compound **I-1**. It should be understood that the invention may encompass other samples suspected of containing compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof.

[00178] In some embodiments, the presence of compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof, in the sample solution may be determined by comparing retention times of peaks in the first HPLC chromatogram with the retention times of peaks in the second HPLC chromatogram. For example, the standard solution comprising compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof, may produce a chromatogram with a peak corresponding to compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof, and having a particular retention time. A sample solution may then be injected into the HPLC column under the same conditions as the standard solution, and the resulting chromatogram may be studied to determine if a peak exists at the same retention time as the peak corresponding to compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof, in the HPLC chromatogram of the standard solution. The existence of such a peak can indicate that compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof, is present in the sample. In another embodiment, the amount of a compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof, in the sample solution may be determined by comparing the area of peaks in the first HPLC chromatogram with the area of peaks in the second HPLC chromatogram, and calculating from these the content of compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof, in the sample solution.

[00179] In some embodiments, the present invention provides methods for determining an impurity in a material consisting essentially of compound **I-1**, wherein a sample solution containing the material and spiked with a reference compound having a known chemical structure of compound **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, or **I-9**, or a pharmaceutically acceptable salt thereof, as described herein, is injected into an HPLC

column and an HPLC chromatogram is obtained to determine the presence and/or the amount of the compound in the material.

[00180] Methods of the invention may further comprise documenting in a written form the chemical identity of the compound and the amount of the compound as an impurity in the material.

[00181] In some embodiments, the present invention provides methods for determining an impurity in a material consisting essentially of compound I-1, wherein a solution in which the material is dissolved is injected into an HPLC column and an HPLC chromatogram is obtained to determine the amount in the material of a compound known to have the structure of compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9, or a pharmaceutically acceptable salt thereof, as described herein. The chemical identity of the compound and the amount of the compound as an impurity in the material may then be documented. The amount in the material of the compound may be determined by (i) identifying a peak on the chromatogram that corresponds to a peak on a control chromatogram, (ii) identifying a peak on the chromatogram that corresponds to a relative retention time of a compound known to have the structure of compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9, or pharmaceutically acceptable salt thereof, and/or (iii) identifying a peak on the chromatogram that corresponds to a known amount of a spike of the compound known to have the structure of compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9, or a pharmaceutically acceptable salt thereof.

[00182] Some embodiments of the invention may be useful in determining the amount and/or presence of compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9, or a pharmaceutically acceptable salt thereof, in a sample comprising compound I-1. The sample may be a sample of freshly manufactured material or the sample may be one stored for a given period of time. In one embodiment, a sample of compound I-1 may be stored and periodically analyzed using methods described herein to determine the presence and/or amount of compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9, or a pharmaceutically acceptable salt thereof, in the sample which may have been formed by, for example, degradation of compound I-1. In some cases, the sample may be placed under stressed conditions, i.e. conditions to intentionally promote degradation of compound I-1 such as elevated temperatures and/or elevated humidity, wherein the sample is periodically analyzed using methods described herein to determine the presence and/or amount of compound I-2, I-3, I-4, I-5, I-6, I-7, I-8, or I-9, or a pharmaceutically acceptable salt thereof, in the sample.

6.2. *Pharmaceutically acceptable compositions*

[00183] In some embodiments, the invention provides a pharmaceutical composition comprising a provided composition as described in detail herein, *infra*, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00184] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and one impurity compound selected from the group consisting of I-2, I-3, I-4, I-5,

I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00185] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and two impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00186] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and three impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00187] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and four impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00188] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and five impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00189] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and six impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00190] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and seven impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00191] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and each of impurity compounds I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00192] In some embodiments, the composition comprises compound I-1, or a pharmaceutically acceptable salt thereof, and one or more impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, and I-6, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00193] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and one impurity compound selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00194] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and two impurity compounds selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00195] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and three impurity compounds selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00196] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and four impurity compounds selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00197] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and each of impurity compounds **I-2**, **I-3**, **I-4**, **I-5**, and **I-6**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00198] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and one or more impurity compounds selected from the group consisting of **I-2**, **I-3**, or **I-5**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00199] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and one impurity compound selected from the group consisting of **I-2**, **I-3**, or **I-5**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00200] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and two impurity compounds selected from the group consisting of **I-2**, **I-3**, or **I-5**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00201] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and each of impurity compounds **I-2**, **I-3**, or **I-5**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00202] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and compound **I-2**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00203] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and compound **I-3**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00204] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and compound **I-4**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00205] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and compound **I-5**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00206] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and compound **I-6**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00207] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and compound **I-7**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00208] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and compound **I-8**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00209] In some embodiments, the composition comprises compound **I-1**, or a pharmaceutically acceptable salt thereof, and compound **I-9**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier, adjuvant, or vehicle.

[00210] In some embodiments, the composition of the present invention comprising compound **I-1**, or a pharmaceutically acceptable salt thereof, and one or more of impurity compounds selected from **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9**, or a pharmaceutically acceptable salt thereof, is present in the pharmaceutically acceptable carrier, adjuvant, or vehicle from 1-90 wt% of the total weight of the pharmaceutical composition. In some embodiments, the composition of the present invention is present in about 5, about 10, about 15, about 20, about 25, about 30, about 35, about 40, about 45, about 50, about 55, about 60, about 65, about 70, about 75, about 80, about 85, or about 90 wt% of the total weight of the pharmaceutical composition. In some embodiments, the composition of the present invention is present in 20-40, 30-50, 40-60, or 50-70 wt% of the total weight of the pharmaceutical composition.

[00211] The term “pharmaceutically acceptable carrier, adjuvant, or vehicle” refers to a non-toxic carrier, adjuvant, or vehicle that does not destroy the pharmacological activity of the compound with which it is formulated. Pharmaceutically acceptable carriers, adjuvants or vehicles that may be used in the compositions of this disclosure include, but are not limited to, ion exchangers, alumina, aluminum stearate, lecithin, serum proteins, such as human serum albumin, buffer substances such as phosphates, glycine, sorbic acid, potassium sorbate, partial glyceride mixtures of saturated vegetable fatty acids, water, salts or electrolytes, such as protamine sulfate, disodium hydrogen phosphate, potassium hydrogen phosphate, sodium chloride, zinc salts, colloidal silica, magnesium trisilicate, polyvinyl pyrrolidone, cellulose-based substances, polyethylene glycol, sodium carboxymethylcellulose, polyacrylates, waxes, polyethylene-polyoxypropylene-block polymers, polyethylene glycol and wool fat.

6.3. Administration

[00212] In some embodiments, a pharmaceutical composition herein is administered in a single composition as a single dosage form. As described herein, a pharmaceutical composition herein may comprise compound I-1, or a pharmaceutically acceptable salt thereof, and one or more of impurity compounds selected from I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof. In some embodiments, the amounts of one or more impurity compounds I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof is as described herein. In some embodiments, a pharmaceutical composition comprising compound I-1, or a pharmaceutically acceptable salt thereof, further comprises one or more of compounds selected from I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof. In some embodiments, a pharmaceutical composition herein further comprises water, and/or one or more residual solvent. As also described herein, in some embodiments, the present invention provides a pharmaceutical composition comprising compound I-1 as the active ingredient, or a pharmaceutically acceptable salt thereof.

[00213] Compositions of the present disclosure may be administered orally, parenterally, by inhalation spray, topically, rectally, nasally, buccally, vaginally or via an implanted reservoir. The term “parenteral” as used herein includes subcutaneous, intravenous, intramuscular, intra-articular, intra-synovial, intrasternal, intrathecal, intrahepatic, intralesional and intracranial injection or infusion techniques. Preferably, the compositions are administered orally, intraperitoneally or intravenously. Sterile injectable forms of the compositions of this disclosure may be aqueous or oleaginous suspension. These suspensions may be formulated according to techniques known in the art using suitable dispersing or wetting agents and suspending agents. The sterile injectable preparation may also be a sterile injectable solution or suspension in a non-toxic parenterally acceptable diluent or solvent, for example as a solution in 1,3-butanediol. Among the acceptable vehicles and solvents that may be employed are water, Ringer's solution and isotonic

sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium.

[00214] For this purpose, any bland fixed oil may be employed including synthetic mono- or diglycerides. Fatty acids, such as oleic acid and its glyceride derivatives are useful in the preparation of injectables, as are natural pharmaceutically-acceptable oils, such as olive oil or castor oil, especially in their polyoxyethylated versions. These oil solutions or suspensions may also contain a long-chain alcohol diluent or dispersant, such as carboxymethyl cellulose or similar dispersing agents that are commonly used in the formulation of pharmaceutically acceptable dosage forms including emulsions and suspensions. Other commonly used surfactants, such as Tweens, Spans and other emulsifying agents or bioavailability enhancers which are commonly used in the manufacture of pharmaceutically acceptable solid, liquid, or other dosage forms may also be used for the purposes of formulation.

[00215] Pharmaceutically acceptable compositions of this disclosure may be orally administered in any orally acceptable dosage form including, but not limited to, capsules, tablets, aqueous suspensions or solutions. In the case of tablets for oral use, carriers commonly used include lactose and corn starch. Lubricating agents, such as magnesium stearate, are also typically added. For oral administration in a capsule form, useful diluents include lactose and dried cornstarch. When aqueous suspensions are required for oral use, the active ingredient is combined with emulsifying and suspending agents. If desired, certain sweetening, flavoring or coloring agents may also be added.

[00216] Alternatively, pharmaceutically acceptable compositions of this disclosure may be administered in the form of suppositories for rectal administration. These can be prepared by mixing the agent with a suitable non-irritating excipient that is solid at room temperature but liquid at rectal temperature and therefore will melt in the rectum to release the drug. Such materials include cocoa butter, beeswax and polyethylene glycols.

[00217] Pharmaceutically acceptable compositions of this disclosure may also be administered topically, especially when the target of treatment includes areas or organs readily accessible by topical application, including diseases of the eye, the skin, or the lower intestinal tract. Suitable topical formulations are readily prepared for each of these areas or organs.

[00218] Topical application for the lower intestinal tract can be effected in a rectal suppository formulation (see above) or in a suitable enema formulation. Topically-transdermal patches may also be used.

[00219] For topical applications, provided pharmaceutically acceptable compositions may be formulated in a suitable ointment containing the active component suspended or dissolved in one or more carriers. Carriers for topical administration of compounds of this disclosure include, but are not limited to, mineral oil, liquid petrolatum, white petrolatum, propylene glycol, polyoxyethylene, polyoxypropylene

compound, emulsifying wax and water. Alternatively, provided pharmaceutically acceptable compositions can be formulated in a suitable lotion or cream containing the active components suspended or dissolved in one or more pharmaceutically acceptable carriers. Suitable carriers include, but are not limited to, mineral oil, sorbitan monostearate, polysorbate 60, cetyl esters wax, cetearyl alcohol, 2-octyldodecanol, benzyl alcohol and water.

[00220] For ophthalmic use, provided pharmaceutically acceptable compositions may be formulated as micronized suspensions in isotonic, pH adjusted sterile saline, or, preferably, as solutions in isotonic, pH adjusted sterile saline, either with or without a preservative such as benzylalkonium chloride. Alternatively, for ophthalmic uses, the pharmaceutically acceptable compositions may be formulated in an ointment such as petrolatum.

[00221] Pharmaceutically acceptable compositions of this disclosure may also be administered by nasal aerosol or inhalation. Such compositions are prepared according to techniques well-known in the art of pharmaceutical formulation and may be prepared as solutions in saline, employing benzyl alcohol or other suitable preservatives, absorption promoters to enhance bioavailability, fluorocarbons, and/or other conventional solubilizing or dispersing agents.

[00222] In certain embodiments, pharmaceutically acceptable compositions of this disclosure are formulated for oral administration. Such formulations may be administered with or without food. In some embodiments, pharmaceutically acceptable compositions of this disclosure are administered without food. In other embodiments, pharmaceutically acceptable compositions of this disclosure are administered with food.

[00223] Pharmaceutically acceptable compositions of this disclosure can be administered to humans and other animals orally, rectally, parenterally, intracisternally, intravaginally, intraperitoneally, topically (as by powders, ointments, or drops), buccally, as an oral or nasal spray, or the like, depending on the severity of the infection being treated. In certain embodiments, compound **I-1** or a pharmaceutically acceptable salt thereof, may be administered orally at a dose of about 10 mg/kg to about 200 mg/kg, particularly at a dose of selected from about 30 mg/kg, about 35 mg/kg, about 40 mg/kg, about 45 mg/kg, about 50 mg/kg, about 55 mg/kg, about 60 mg/kg, about 65 mg/kg, about 70 mg/kg, about 75 mg/kg, about 80 mg/kg, about 85 mg/kg, and about 90 mg/kg, of subject body weight per day, one or more times a day, to obtain the desired therapeutic effect.

[00224] Liquid dosage forms for oral administration include, but are not limited to, pharmaceutically acceptable emulsions, microemulsions, solutions, suspensions, syrups and elixirs. In addition to the active compounds, the liquid dosage forms may contain inert diluents commonly used in the art such as, for example, water or other solvents, solubilizing agents and emulsifiers such as ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene

glycol, dimethylformamide, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor, and sesame oils), glycerol, tetrahydrofurfuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof. Besides inert diluents, the oral compositions can also include adjuvants such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, and perfuming agents.

[00225] Injectable preparations, for example, sterile injectable aqueous or oleaginous suspensions may be formulated according to the known art using suitable dispersing or wetting agents and suspending agents. The sterile injectable preparation may also be a sterile injectable solution, suspension or emulsion in a nontoxic parenterally acceptable diluent or solvent, for example, as a solution in 1,3-butanediol. Among the acceptable vehicles and solvents that may be employed are water, Ringer's solution, U.S.P. and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose any bland fixed oil can be employed including synthetic mono- or diglycerides. In addition, fatty acids such as oleic acid are used in the preparation of injectables.

[00226] Injectable formulations can be sterilized, for example, by filtration through a bacterial-retaining filter, or by incorporating sterilizing agents in the form of sterile solid compositions which can be dissolved or dispersed in sterile water or other sterile injectable medium prior to use.

[00227] In order to prolong the effect of compound **I-1** or a pharmaceutically acceptable salt thereof, it may be desirable to slow the absorption of the compound from subcutaneous or intramuscular injection. This may be accomplished by the use of a liquid suspension of crystalline or amorphous material with poor water solubility. The rate of absorption of the compound then depends upon its rate of dissolution that, in turn, may depend upon crystal size and crystalline form. Alternatively, delayed absorption of a parenterally administered compound form is accomplished by dissolving or suspending the compound in an oil vehicle. Injectable depot forms are made by forming microencapsule matrices of the compound in biodegradable polymers such as polylactide-polyglycolide. Depending upon the ratio of compound to polymer and the nature of the particular polymer employed, the rate of compound release can be controlled. Examples of other biodegradable polymers include poly(orthoesters) and poly(anhydrides). Depot injectable formulations are also prepared by entrapping the compound in liposomes or microemulsions that are compatible with body tissues.

[00228] Compositions for rectal or vaginal administration are preferably suppositories which can be prepared by mixing the compounds of this disclosure with suitable non-irritating excipients or carriers such as cocoa butter, polyethylene glycol or a suppository wax which are solid at ambient temperature but liquid at body temperature and therefore melt in the rectum or vaginal cavity and release the active compound.

[00229] Solid dosage forms for oral administration include capsules, tablets, pills, powders, and granules. In such solid dosage forms, the active compound is mixed with at least one inert, pharmaceutically acceptable excipient or carrier such as sodium citrate or dicalcium phosphate and/or a) fillers or extenders

such as starches, lactose, sucrose, glucose, mannitol, and silicic acid, b) binders such as, for example, carboxymethylcellulose, alginates, gelatin, polyvinylpyrrolidinone, sucrose, and acacia, c) humectants such as glycerol, d) disintegrating agents such as agar--agar, calcium carbonate, potato or tapioca starch, alginic acid, certain silicates, and sodium carbonate, e) solution retarding agents such as paraffin, f) absorption accelerators such as quaternary ammonium compounds, g) wetting agents such as, for example, cetyl alcohol and glycerol monostearate, h) absorbents such as kaolin and bentonite clay, and i) lubricants such as talc, calcium stearate, magnesium stearate, solid polyethylene glycols, sodium lauryl sulfate, and mixtures thereof. In the case of capsules, tablets and pills, the dosage form may also comprise buffering agents.

[00230] Solid compositions of a similar type may also be employed as fillers in soft and hard-filled gelatin capsules using such excipients as lactose or milk sugar as well as high molecular weight polyethylene glycols and the like. The solid dosage forms of tablets, dragees, capsules, pills, and granules can be prepared with coatings and shells such as enteric coatings and other coatings well known in the pharmaceutical formulating art. They may optionally contain opacifying agents and can also be of a composition that they release the active ingredient(s) only, or preferentially, in a certain part of the intestinal tract, optionally, in a delayed manner. Examples of embedding compositions that can be used include polymeric substances and waxes. Solid compositions of a similar type may also be employed as fillers in soft and hard-filled gelatin capsules using such excipients as lactose or milk sugar as well as high molecular weight polyethylene glycols and the like.

[00231] Compound I-1, or a pharmaceutically acceptable salt thereof, can also be in micro-encapsulated form with one or more excipients as noted above. The solid dosage forms of tablets, dragees, capsules, pills, and granules can be prepared with coatings and shells such as enteric coatings, release controlling coatings and other coatings well known in the pharmaceutical formulating art. In such solid dosage forms the active compound may be admixed with at least one inert diluent such as sucrose, lactose or starch. Such dosage forms may also comprise, as is normal practice, additional substances other than inert diluents, e.g., tableting lubricants and other tableting aids such as magnesium stearate and microcrystalline cellulose. In the case of capsules, tablets and pills, the dosage forms may also comprise buffering agents. They may optionally contain opacifying agents and can also be of a composition that they release the active ingredient(s) only, or preferentially, in a certain part of the intestinal tract, optionally, in a delayed manner. Examples of embedding compositions that can be used include polymeric substances and waxes.

[00232] Dosage forms for topical or transdermal administration of a compound of this disclosure include ointments, pastes, creams, lotions, gels, powders, solutions, sprays, inhalants or patches. The active component is admixed under sterile conditions with a pharmaceutically acceptable carrier and any needed preservatives or buffers as may be required. Ophthalmic formulation, ear drops, and eye drops are also

contemplated as being within the scope of this disclosure. Additionally, the present disclosure contemplates the use of transdermal patches, which have the added advantage of providing controlled delivery of a compound to the body. Such dosage forms can be made by dissolving or dispensing the compound in the proper medium. Absorption enhancers can also be used to increase the flux of the compound across the skin. The rate can be controlled by either providing a rate controlling membrane or by dispersing the compound in a polymer matrix or gel.

7. *Methods and Uses for Treating Disease*

[00233] In some embodiments, the present disclosure provides a method of administering compound **I-1**, or a pharmaceutically acceptable salt thereof (in a composition comprising one or more impurity compound selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9**, or a pharmaceutically acceptable salt thereof), to a patient in need thereof, wherein the patient suffers from an autoimmune/autoinflammatory disease or a hematological malignancy. In some embodiments, the autoimmune/autoinflammatory disease is a cutaneous autoimmune/autoinflammatory disease. In some embodiments, the present disclosure provides a method of treating an autoimmune/autoinflammatory disease and/or a hematological malignancy, comprising administering to a patient in need thereof a therapeutically effective amount of Compound **I-1**, or a pharmaceutically acceptable salt thereof (in a composition comprising one or more impurity compound selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9**, or a pharmaceutically acceptable salt thereof). In some embodiments, an autoimmune/autoinflammatory disease is selected from atopic dermatitis (AD), rheumatoid arthritis (RA), and hidradenitis suppurativa (HS).

[00234] In some embodiments, the autoimmune/autoinflammatory disease includes inflammatory or allergic conditions of the skin, for example psoriasis, generalized pustular psoriasis (GPP), psoriasis vulgaris, contact dermatitis, atopic dermatitis, alopecia areata, erythema multiforma, dermatitis herpetiformis, scleroderma, vitiligo, hypersensitivity angiitis, urticaria, bullous pemphigoid, lupus erythematosus, systemic lupus erythematosus, pemphigus vulgaris, pemphigus foliaceus, paraneoplastic pemphigus, epidermolysis bullosa acquisita, acne vulgaris, hidradenitis suppurativa, Sweet Syndrome, pyoderma gangrenosum, and other inflammatory or allergic conditions of the skin. In some embodiments, the inflammatory disease of the skin is selected from contact dermatitis, atopic dermatitis, alopecia areata, erythema multiforma, dermatitis herpetiformis, scleroderma, vitiligo, hypersensitivity angiitis, urticaria, bullous pemphigoid, pemphigus vulgaris, pemphigus foliaceus, paraneoplastic pemphigus, epidermolysis bullosa acquisita, or hidradenitis suppurativa.

[00235] In some embodiments, a composition comprising compound **I-1**, or a pharmaceutically acceptable salt thereof, and one or more impurity compound selected from the group consisting of **I-2**, **I-3**,

I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof may also be used for the treatment of other diseases or conditions, such as diseases or conditions having an inflammatory component, for example, treatment of diseases and conditions of the eye such as ocular allergy, conjunctivitis, keratoconjunctivitis sicca, and vernal conjunctivitis, diseases affecting the nose including allergic rhinitis, and inflammatory disease in which autoimmune reactions are implicated or having an autoimmune component or etiology, including autoimmune hematological disorders (e.g. hemolytic anemia, aplastic anemia, pure red cell anemia and idiopathic thrombocytopenia), systemic lupus erythematosus, rheumatoid arthritis, polychondritis, scleroderma, Wegener granulomatosis, dermatomyositis, chronic active hepatitis, myasthenia gravis, Steven-Johnson syndrome, idiopathic sprue, autoimmune inflammatory bowel disease (e.g. ulcerative colitis and Crohn's disease), irritable bowel syndrome, celiac disease, periodontitis, hyaline membrane disease, kidney disease, glomerular disease, alcoholic liver disease, multiple sclerosis, endocrine ophthalmopathy, Grave's disease, sarcoidosis, alveolitis, chronic hypersensitivity pneumonitis, multiple sclerosis, primary biliary cirrhosis, uveitis (anterior and posterior), Sjogren's syndrome, keratoconjunctivitis sicca and vernal keratoconjunctivitis, interstitial lung fibrosis, psoriatic arthritis, systemic juvenile idiopathic arthritis, cryopyrin-associated periodic syndrome, nephritis, vasculitis, diverticulitis, interstitial cystitis, glomerulonephritis (with and without nephrotic syndrome, e.g. including idiopathic nephrotic syndrome or minimal change nephropathy), chronic granulomatous disease, endometriosis, leptospirosis renal disease, glaucoma, retinal disease, ageing, headache, pain, complex regional pain syndrome, cardiac hypertrophy, musclewasting, catabolic disorders, obesity, fetal growth retardation, hypercholesterolemia, heart disease, chronic heart failure, mesothelioma, anhidrotic ectodermal dysplasia, Behcet's disease, incontinentia pigmenti, Paget's disease, pancreatitis, hereditary periodic fever syndrome, asthma (allergic and non-allergic, mild, moderate, severe, bronchitic, and exercise-induced), acute lung injury, acute respiratory distress syndrome, eosinophilia, hypersensitivities, anaphylaxis, nasal sinusitis, ocular allergy, silica induced diseases, COPD (reduction of damage, airways inflammation, bronchial hyperreactivity, remodeling or disease progression), pulmonary disease, cystic fibrosis, acid-induced lung injury, pulmonary hypertension, polyneuropathy, cataracts, muscle inflammation in conjunction with systemic sclerosis, inclusion body myositis, myasthenia gravis, thyroiditis, Addison's disease, lichen planus, Type 1 diabetes, or Type 2 diabetes, appendicitis, atopic dermatitis, asthma, allergy, blepharitis, bronchiolitis, bronchitis, bursitis, cervicitis, cholangitis, cholecystitis, chronic graft rejection, colitis, conjunctivitis, Crohn's disease, cystitis, dacryoadenitis, dermatitis, dermatomyositis, encephalitis, endocarditis, endometritis, enteritis, enterocolitis, epicondylitis, epididymitis, fasciitis, fibrositis, gastritis, gastroenteritis, Henoch-Schonlein purpura, hepatitis, hidradenitis suppurativa, immunoglobulin A nephropathy, interstitial lung disease, laryngitis, mastitis, meningitis, myelitis myocarditis, myositis, nephritis, oophoritis, orchitis, osteitis, otitis, pancreatitis, parotitis,

pericarditis, peritonitis, pharyngitis, pleuritis, phlebitis, pneumonitis, pneumonia, polymyositis, proctitis, prostatitis, pyelonephritis, rhinitis, salpingitis, sinusitis, stomatitis, synovitis, tendonitis, tonsillitis, ulcerative colitis, uveitis, vaginitis, vasculitis, or vulvitis.

[00236] In some embodiments the inflammatory disease which can be treated according to the methods of this disclosure is selected from acute and chronic gout, chronic gouty arthritis, psoriasis, psoriatic arthritis, rheumatoid arthritis, juvenile rheumatoid arthritis, systemic juvenile idiopathic arthritis (SJIA), cryopyrin associated periodic syndrome (CAPS), adult onset Still's disease, macrophage activation syndrome (MAS), primary and secondary hemophagocytic lymphohistiocytosis (HLH), familial Mediterranean fever, NLRP12 autoinflammatory syndrome, and osteoarthritis.

[00237] In some embodiments the inflammatory disease which can be treated is a TH17 mediated disease. In some embodiments the TH17 mediated disease is selected from systemic lupus erythematosus, multiple sclerosis, psoriasis vulgaris, hidradenitis suppurativa, and inflammatory bowel disease (including Crohn's disease or ulcerative colitis).

[00238] In some embodiments the inflammatory disease which can be treated according to the methods of this disclosure is selected from Sjogren's syndrome, allergic disorders, osteoarthritis, conditions of the eye such as ocular allergy, conjunctivitis, keratoconjunctivitis sicca and vernal conjunctivitis, and diseases affecting the nose such as allergic rhinitis or chronic rhinosinusitis with nasal polyps (CRSwNP).

[00239] In some embodiments, the present disclosure provides a method for treating a cutaneous autoimmune/autoinflammatory disease in a patient, such as atopic dermatitis (AD) and hidradenitis suppurativa (HS), comprising administering to the patient a therapeutically effective amount of a composition comprising compound **I-1**, or a pharmaceutically acceptable salt thereof, and one or more impurity compound selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9**, or a pharmaceutically acceptable salt thereof.

[00240] In some embodiments, the present disclosure provides a method for treating AD in a patient, comprising administering to the patient a therapeutically effective amount of a composition comprising compound **I-1**, or a pharmaceutically acceptable salt thereof, and one or more impurity compound selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9**, or a pharmaceutically acceptable salt thereof.

[00241] In some embodiments, the present disclosure provides a method for treating AD in a patient, comprising administering to the patient a therapeutically effective amount of a composition comprising compound **I-1 HCl**, and one or more impurity compound selected from the group consisting of **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9**, or a pharmaceutically acceptable salt thereof.

[00242] In some embodiments, the present disclosure provides a method for treating HS in a patient, comprising administering to the patient a therapeutically effective amount of a composition comprising

compound I-1, or a pharmaceutically acceptable salt thereof, and one or more impurity compound selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[00243] In some embodiments, the present disclosure provides a method for treating HS in a patient, comprising administering to the patient a therapeutically effective amount of a composition comprising compound I-1 HCl, and one or more impurity compound selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[00244] In some embodiments, the present disclosure provides a method for treating RA in a patient, comprising administering to the patient a therapeutically effective amount of a composition comprising compound I-1, or a pharmaceutically acceptable salt thereof, and one or more impurity compound selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[00245] In some embodiments, the present disclosure provides a method for treating RA in a patient, comprising administering to the patient a therapeutically effective amount of a composition comprising compound I-1 HCl, and one or more impurity compound selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

[00246] In some embodiments, the present disclosure provides a method for treating hematological malignancy in a patient, comprising administering to the patient a therapeutically effective amount of a composition comprising compound I-1, or a pharmaceutically acceptable salt thereof, and one or more impurity compound selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof. In some embodiments, the present disclosure provides a method for treating hematological malignancy in a patient, comprising administering to the patient a therapeutically effective amount of a composition comprising compound I-1 HCl, and one or more impurity compound selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof. In some embodiments, the hematological malignancy is leukemia, diffuse large B-cell lymphoma (DLBCL), ABC DLBCL, chronic lymphocytic leukemia (CLL), chronic lymphocytic lymphoma, primary effusion lymphoma, Burkitt lymphoma/leukemia, acute lymphocytic leukemia, B-cell prolymphocytic leukemia, lymphoplasmacytic lymphoma, Waldenström's macroglobulinemia (WM), splenic marginal zone lymphoma, multiple myeloma, plasmacytoma, intravascular large B-cell lymphoma, AML, or MDS.

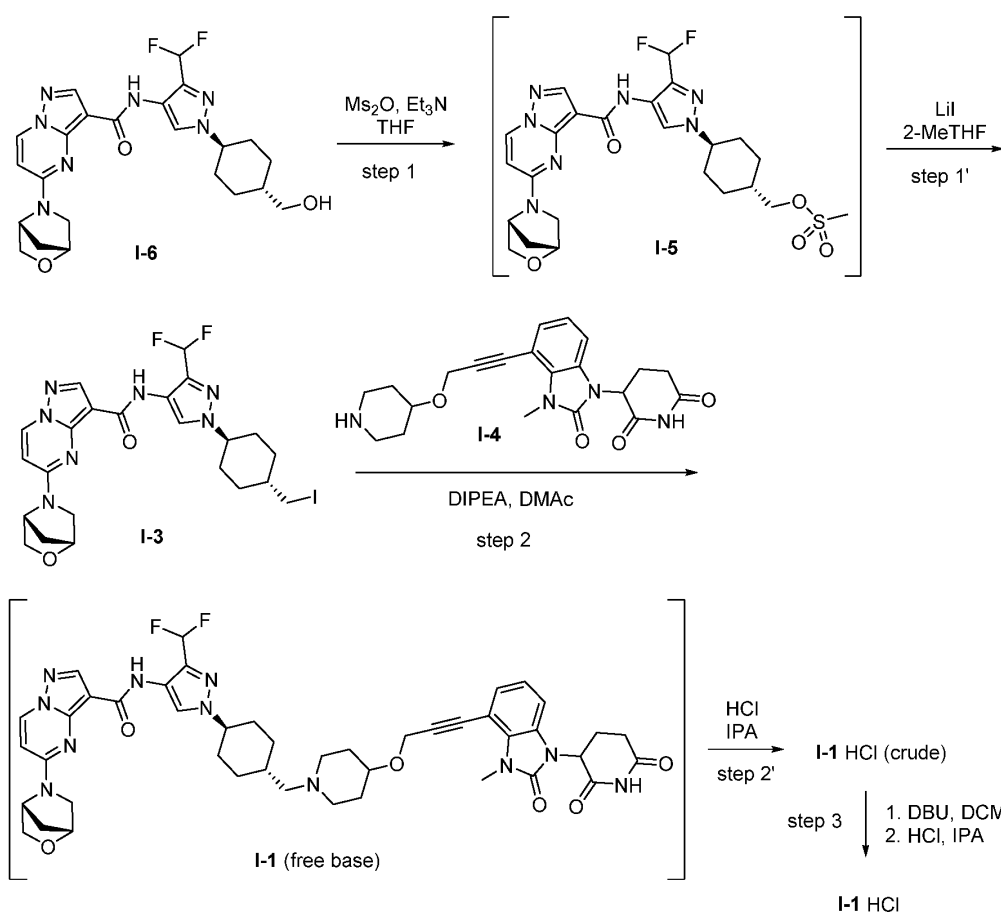
[00247] The following examples are merely illustrative of the present invention and should not be construed as limiting the scope of the invention in any way as many variations and equivalents that are encompassed by the present invention will become apparent to those skilled in the art upon reading the present disclosure. For example, some reactions described below may be carried out under a range of

conditions, such as at a different temperature (4° C., 10° C., 25° C., etc.), substitution with other reagents and different amounts or concentration of reagents.

EXEMPLIFICATION

[00248] As depicted in the Examples below, in certain exemplary embodiments, **I-1 HCl** is prepared and characterized according to the following procedures. Synthesis of starting materials can be found, for example, in WO 2019/133531 and WO 2020/010227, the contents of which are incorporated herein by reference in their entireties.

Example 1. Synthesis of **I-1 HCl**



[00249] Step 1: Synthesis of **I-3**. A solution of the starting alcohol (**I-6**) and methanesulfonic anhydride (Ms_2O) in tetrahydrofuran (THF) was prepared in a reaction vessel and cooled to -15 °C. Triethylamine (Et_3N) was then charged to the vessel, and the reaction mixture was aged until complete

conversion of **I-6** to **I-5** was achieved (IPC, reaction monitoring by HPLC). The reaction mixture was warmed to room temperature, and an excess of lithium iodide (LiI) was added with stirring at 50 °C until complete conversion of **I-5** to **I-3** was observed (IPC, reaction monitoring by HPLC). The reaction mixture was then cooled and quenched with sodium bisulfite (NaHSO₃) solution. The batch was extracted with 2-methyltetrahydrofuran (2-MeTHF), and the 2-MeTHF stream was azeotropically dried by atmospheric distillation to an acceptable level (IPC, moisture by Karl Fischer) prior to a solvent switch to N,N-dimethylacetamide (DMAc). The crude solution of **I-3** was discharged from the reaction vessel through an in-line filter and assayed (IPC, weight % by HPLC) before being introduced directly into Step 2 of the process.

[00250] Step 2: Synthesis of **I-1** HCl (crude). The DMAc solution of **I-3** (from Step 1) and **I-4** were charged to a reaction vessel and reacted at 75 °C with N,N-diisopropylethylamine (DIPEA) to form **I-1** free base. Upon reaction completion (IPC, reaction monitoring by HPLC), the mixture was cooled to 50 °C before addition of hydrochloric acid (HCl) in 2-propanol (IPA). Seed crystals of **I-1** HCl were then added, and the reaction mixture was aged at 50 °C. Additional 2-propanol (IPA) was charged to the vessel. The crystallization slurry was further aged at 50 °C before cooling to room temperature to precipitate **I-1** HCl from solution. The material was isolated by filtration, and the cake was washed with 2-propanol (IPA) and dried. The solid **I-1** HCl (crude) was assayed (IPC, weight % by HPLC) and introduced directly into Step 3 of the process. It was noted that the Step 2 reaction mixture and crude API were determined to maintain ~ 50:50 ratio of diastereomers.

[00251] Step 3: Preparation of **I-1** HCl. The **I-1** HCl (crude) material from Step 2 was suspended in dichloromethane (DCM) in a reaction vessel, and 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) was added while maintaining the contents of the vessel below 25 °C. The mixture was agitated to form a solution, and then an aqueous solution of potassium phosphate monobasic (KH₂PO₄) was added. The organic phase was discharged, and the vessel was cleaned with rinses of N,N-dimethylacetamide (DMAc), water, 2-propanol (IPA), and dichloromethane (DCM) before charging the organic phase back into the vessel via an in-line filter. Dichloromethane (DCM) was added, washing the in-line filter, followed by addition of 2-propanol (IPA) and heating to 35 °C. Sequentially, hydrochloric acid (HCl) in IPA and **I-1** HCl seed crystals are charged to the vessel, and **I-1** HCl precipitates as the mixture ages and cools to 20 °C. The batch is filtered, and the cake was washed with dichloromethane (DCM) and 2-propanol (IPA) before drying in a vacuum oven at 60 °C. In-process measurements of crystallinity (XRPD) and residual solvent levels (GC) of the dried **I-1** HCl are completed prior to packaging.

Example 2. Characterization of I-1 HCl Drug Substance

Justification of Specification

[00252] The release specification for I-1 HCl drug substance and the justification of the limit for each drug substance attribute shown in **Table 2** and is discussed in the sections below.

Table 2. I-1 HCl Drug Substance Specification

Test	Acceptance Criteria	Analytic Method
Description	White to off-white to beige powder	Visual
Identification (FTIR)	Conforms to reference spectrum	USP <197A>
Identification (HPLC)	Conforms to reference spectrum	HPLC
Assay (on anhydrous solvent-free basis, % wt/wt) as HCl salt	95-105%	HPLC
HPLC Purity (area percent)	≥ 97.0%	HPLC
Impurities (Area %)	Report ≥ 0.05%	HPLC
Specified Impurity, I-2	≤ 2.0%	
Individual Unspecified Impurities	≤ 0.7%	
Total Impurities	≤ 3.0%	
Diastereomeric Ratio	Report Results	HPLC
Residual Solvents		GC
Dichloromethane	≤ 600 ppm	
N,N-Dimethylacetamide	≤ 1090 ppm	
Tetrahydrofuran	≤ 720 ppm	
Isopropanol	≤ 5000 ppm	
2-Methyltetrahydrofuran	≤ 5000 ppm	
Elemental Impurities		USP <233>
Cadmium	≤ 5 ppm	
Lead	≤ 5 ppm	
Arsenic	≤ 15 ppm	
Mercury	≤ 30 ppm	
Cobalt	≤ 50 ppm	
Vanadium	≤ 100 ppm	
Nickel	≤ 200 ppm	
Palladium	≤ 100 ppm	
Lithium	≤ 550 ppm	
Copper	≤ 3000 ppm	
Water Content (% wt/wt)	Report Results	USP <921>
Counterion Analysis (% wt/wt)		Titration
Chloride	3.3-4.5%	
Residue of Ignition	≤ 0.5%	USP <281>
Crystallinity	Conforms to reference pattern	USP <941>
Particle Size Distribution (µm)	Report D10, D50, D90 and MV	USP <429>
Isopropyl Chloride Content	≤ 3000 ppm	GC

Specified Impurities I-3 I-5	≤ 30 ppm ≤ 30 ppm	HPLC-MS
Microbial Enumeration Tests Total Aerobic Microbial Count (TAMC) Total Combined Yeasts and Molds Count (TYMC) <i>E. coli</i>	$\leq 10^3$ cfu/g $\leq 10^2$ cfu/g Absence in 1 g	USP<61> USP<62>

Description

[00253] Batches of **I-1** HCl are visually inspected for color and physical characteristics. The description of the drug substance is “white to off-white to beige powder” based on observations from **I-1** HCl produced in development batches.

Identification by FTIR

[00254] Infrared (IR) spectroscopy was used to verify the identity of the drug substance. Identification was based on comparison of the sample IR spectrum to the spectrum of **I-1** HCl reference standard.

Identification by HPLC

[00255] High Performance Liquid Chromatography (HPLC) was used to verify the identity of the drug substance. Identification was based on comparison of the sample retention time to the retention time of the **I-1** HCl reference standard, using method parameters are listed in **Table 3**.

Table 3. Assay and Impurities Method Parameters

Technique	Reversed-phase HPLC
Column	Zorbax Eclipse Plus C18, 150 x 3.0 mm, 3.5 μ m
Mobile phases	A: 0.04% TFA in water B: 0.02% TFA in acetonitrile
Detection	UV detection at 225 nm
Column temperature	40 °C
Pump program	Gradient
Flow rate	0.9 mL/min
Sample Preparation	0.4 mg/mL Diluent = 50:50:0:2 acetonitrile:water:TFA

Purity and Assay by HPLC

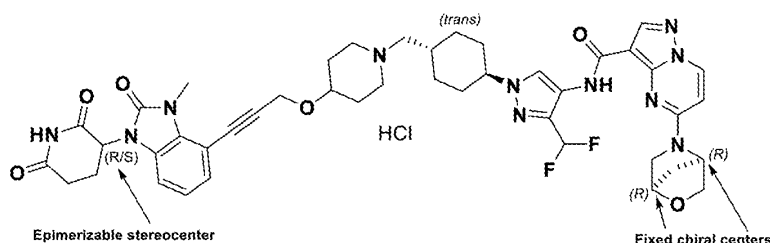
[00256] The HPLC Purity limit ($\geq 97.0\%$ area) of **I-1** HCl was based on results obtained from development lots and conforms to limits normally established for early-phase development. The **Table 3** method was used to identify impurities of **I-1** HCl. The gradient method resolves all known related impurity

peaks and was shown to be stability indicating in forced degradation studies. The limit for assay (on anhydrous solvent-free basis) as HCl salt by HPLC is established as 95 – 105% (w/w). The limit is based on results obtained from development lots and conforms to limits normally established for early-phase development.

Stereochemical Control

[00257] I-1 HCl was manufactured as an approximately 50:50 mixture of diastereomers, (S)-I-1 and (R)-I-1. The molecular structure of I-1 HCl contains three chiral centers, including two fixed/stable centers around the morpholine ring (*R,R*) and one epimerizable chiral center (*R/S*). Additionally, the *trans* configuration at the cyclohexyl ring is desired. All of the stereogenic features are introduced through the starting materials. Table 4 lists the compound identifiers of the potential isomers which may be present in I-1 HCl.

Table 4. Stereochemical Isomers



I-#	Configuration		
	Epimerization Center	Cyclohexyl Ring	Morpholine Ring
(S)-I-1	S	trans	R,R
(R)-I-1	R	trans	R,R
I-2	S/R	cis	R,R
S,S-morph-I-1	S/R	trans	S,S
S,S-morph-I-2	S/R	cis	S,S

Diastereomeric Ratio

[00258] The diastereomeric ratio of (S)-I-1:(R)-I-1 is determined by chiral HPLC. The method parameters are listed in Table 5.

Table 5. Diastereomeric Ratio Method Parameters

Technique	Reversed-phase HPLC
Column	Agilent Poroshell 120 Chiral-V, 100 x 4.6 mm, 2.7 μ m
Mobile phases	A: 20 mM Ammonium acetate, pH 4.0 B: Acetonitrile

Detection	UV detection at 225 nm
Column temperature	40 °C
Pump program	Gradient
Flow rate	0.7 mL/min
Sample Preparation	1.0 mg/mL Diluent = 50:50:0:2 acetonitrile:water:TFA

Unspecified Impurities by HPLC

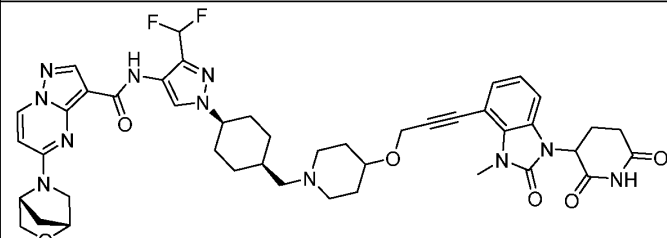
[00259] Impurities above the reporting threshold will be reported ($\geq 0.05\%$ area). The limit for individual unspecified impurities in **I-1** HCl drug substance is derived from literature guidance, e.g., Harvey, et al., “Management of organic impurities in small molecule medicinal products: Deriving safe limits for use in early development”, *Regul. Toxicol. Pharmacol.* 2017, 84:116-23, to justify an acceptable limit of 5 mg/day or 0.7% (whichever is lower) for non-mutagenic impurities in early clinical studies (< 6 months). The planned Multiple Ascending Dose clinical study has an estimated maximum daily dose (MDD) of 500 mg (as freebase). The upper impurity limit corresponding to this MDD is calculated to be 1.0%, according to Eqn 1. However, this is superseded by the upper limit of 0.7%, as required by Harvey, *et al.*

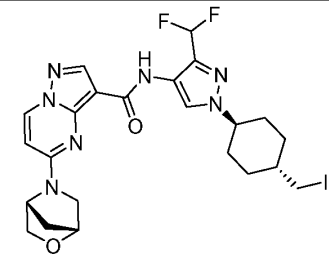
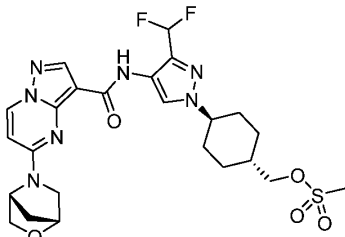
$$\frac{\text{daily impurity limit}}{\text{daily dose}} \times 100 = \frac{5 \text{ mg/day}}{500 \text{ mg/day}} \times 100 = 1.0\% \quad \text{Eqn 1}$$

Specified Impurities by HPLC-MS

[00260] Several impurities may be found in **I-1** HCl using the synthesis depicted in Example 1. Specified impurities are listed in **Table 6**.

Table 6. Specified Impurities

I - #	Structure	MW (Da)	Origin of Impurity	Analytical Method
I - 2		865.94	Process Impurity	HPLC (RRT 1.03)

I-3		565.60	Process Intermediate	LCMS
I-5		597.41	Process Intermediate	LCMS

[00261] The *trans* configuration at the cyclohexyl ring of I-1 is a result of the synthesis. Additionally, the crystallization process steps upgrade the *trans* purity. The *cis* configuration (I-2) in the I-1 HCl was detected using the HPLC method in Table 3. The limit for specified impurity I-2 is $\leq 2\%$. I-3 and I-5 are measured by the reversed-phase HPLC method with mass spectrometry detection (MS) in Table 7 and are potential genotoxic impurities discussed below.

Table 7. Specified Impurities Method Parameters

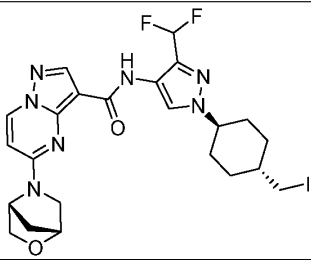
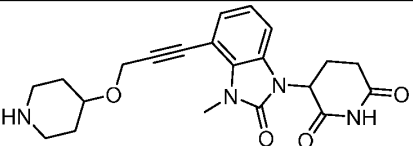
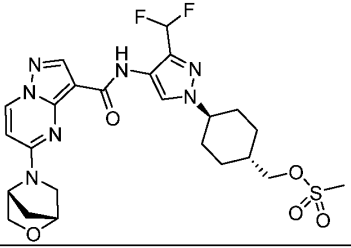
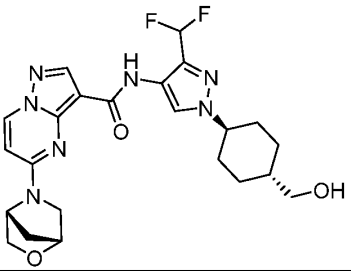
Technique	Reversed-phase HPLC
Column	Agilent Zorbax SB-C18, 50 x 2.1 mm, 1.8 μ m
Mobile phases	A: Water B: 0.1% Formic acid in acetonitrile
Column temperature	40 °C
Pump program	Gradient
Flow rate	0.4 mL/min
Sample Preparation	1.0 mg/mL Diluent = 4:1 acetonitrile:water
Detection System	Single Quadrupole Mass Spectrometer
Ionization	Electrospray Positive
Mode	SIM (m/z 566, 598)

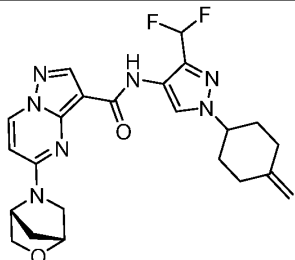
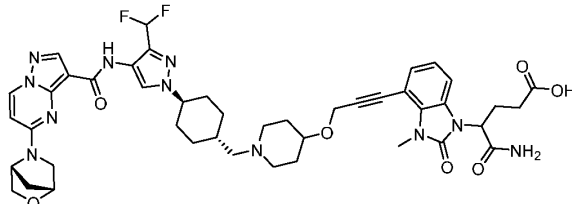
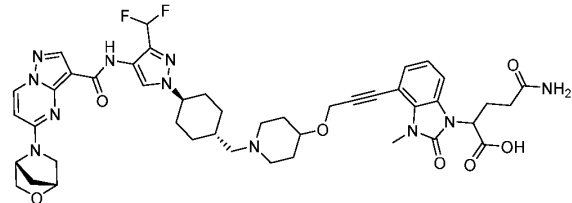
Potential Genotoxic Impurities

[00262] An assessment of the possible formation of potential genotoxic impurities (PGIs) during the manufacture of I-1 HCl was conducted according to ICH M7(R1) – *Assessment and Control of DNA Reactive (Mutagenic) Impurities in Pharmaceuticals to Limit Potential Carcinogenic Risk* (published 31

March 2017). The potential mutagenicity of the starting materials, intermediates, and potential impurities and degradation products was evaluated *in silico* by means of DEREK 6.0.0 Nexus 2.2.0 (mutagenicity only) and LSMA Version 2.4.5-7 (mutagenicity suite). The results are summarized in **Table 8**.

Table 8. Summary of In Silico Mutagenicity Findings

I-#	Structure	Origin of Impurity	DEREK Results ^a	LSMA Results ^b (Bacterial Mut.)	M7 Class
I-3		Process Intermediate	Plausible	Positive Pp = 0.866	3
I-4		Starting Material	Inactive	Not in Domain Pp = 0.165	5
I-5		Process Intermediate	Plausible	Positive Pp = 0.988	3
I-6		Starting Material	Inactive	Starting Material	5

I-7		Potential Degradation Product	Inactive	Negative Pp = 0.238	5
I-8		Potential Degradation Product	Inactive	Not in Domain Pp = 0.0151	5
I-9		Potential Degradation Product	Inactive	Not in Domain Pp = 0.0151	5

^a Mutagenicity in vitro in: bacterium; *E. coli*; and *S. typhimurium*. ^b LSMA Positive Mutagenicity Prediction Probability (Pp) < 0.4 is negative; > is positive; and 0.4-0.6 is indeterminate.

[00205] I-3 was predicted to be plausible for *in vitro* mutagenicity in DEREK and positive in LSMA, due to the presence of an alkyl iodide feature. This feature is known to be an alkylating agent with several examples showing positive results in the Ames test. Methyl iodide has also shown positive results in rodent carcinogenicity assays. Therefore, I-3 is considered potentially mutagenic and classified as Class 3, per ICH M7.

[00206] I-5 was predicted to be plausible for *in vitro* mutagenicity in DEREK and positive in LSMA due to the presence of an alkyl sulfonate ester feature. This feature is known to be an alkylating agent with several examples showing positive results in the Ames test. There are also compounds that have shown positive results in rodent carcinogenicity assays. Therefore, I-5 is considered potentially mutagenic and classified as Class 3, per ICH M7.

[00207] Since I-3 and I-5 were considered potentially mutagenic (Class 3), the content of these impurities was tested by HPLC-MS. The limit of each impurity was derived from ICH M7(R1). For a planned Multiple Ascending Dose clinical study that has an estimated maximum daily dose of 500 mg (520 mg as HCl salt) and duration of treatment for not more than 12 months, the M7 (R1) guidance indicates a daily intake of 20 µg/day for treatment duration of up to 12 months. From these values, the calculated limit

for **I-3** and **I-5** each is ≤ 38 ppm, as shown in Eqn 2. The specified limit for each compound was rounded down to ≤ 30 ppm.

$$\frac{\text{daily impurity limit}}{\text{daily dose}} \times 100 = \frac{20 \text{ ug/day}}{0.520 \text{ g/day}} \times 100 = 38 \text{ ppm} \quad \text{Eqn 2}$$

[00208] **I-4** was predicted to be inactive for *in vitro* mutagenicity in DEREK, with no misclassified or unclassified features, and not in domain in LSMA, due to a lack of analogues. None of the features present in the impurity are significantly associated with positive mutagenicity results. All of the features present in the impurity are accounted for in the API, which was negative in the preliminary Ames test. Therefore, **I-4** was considered non-mutagenic and classified as Class 5, per ICH M7.

[00209] **I-6** was predicted to be inactive for *in vitro* mutagenicity in DEREK, with no misclassified or unclassified features, and negative in LSMA. None of the features present in the impurity are significantly associated with positive mutagenicity results. All of the relevant features are present on the API, which was negative in a preliminary Ames test. Therefore, **I-6** was considered non-mutagenic and classified as Class 5, per ICH M7.

[00210] Elimination impurity **I-7** was predicted to be inactive for *in vitro* mutagenicity in DEREK, with no misclassified or unclassified features, and negative in LSMA. None of the features present in the impurity are significantly associated with positive mutagenicity results. Additionally, most of the features in this compound are present on the **I-1** in a similar chemical space. The only differing feature between the impurity and **I-1** is the methylenecyclohexane, which is not expected to contribute toward positive mutagenicity. Therefore, elimination impurity **I-7** was considered nonmutagenic and classified as Class 5, per ICH M7.

[00211] Ring open impurity isomer **I-8** and isomer **I-9** were predicted to be inactive for *in vitro* mutagenicity in DEREK, with no misclassified or unclassified features, and not in domain in LSMA, due to a lack of analogues. None of the features present in the impurities are significantly associated with positive mutagenicity results. These impurities are very similar in structure to **I-1**. None of the differing features are associated with positive mutagenicity results. Therefore, ring open impurity isomer **I-8** and isomer **I-9** are considered non-mutagenic and classified as Class 5, per ICH M7.

Residual Solvents

[00212] Residual solvents used in the process to prepare **I-1** HCl are listed in **Table 9**, with the Option 1 limits established by ICH Q3C(R6) – *Impurities: Guideline for Residual Solvents*, adopted 20 October 2016. Additionally, the limit for 2-methyltetrahydrofuran is based on the Class 3 designation suggested by ICH draft guidance Q3C(R8) – *Impurities: Guideline for Residual Solvents, PDE for 2-Methyltetrahydrofuran, Cyclopentyl methyl ether, and tertiary-Butyl alcohol*, endorsed on 25 March 2020.

Table 9. Residual Solvents

Solvent	Process Step	ICH Limit (ppm)
Dichloromethane	3	≤ 600 ppm
N,N-Dimethylacetamide	1, 2, 3	≤ 1090 ppm
Tetrahydrofuran	2, 3	≤ 720 ppm
Isopropanol	2, 3	≤ 5000 ppm
2-Methyltetrahydrofuran		≤ 5000 ppm ^a

^a Based on the Class 3 designation suggested by ICH draft guidance Q3C(R8) – *Impurities: Guideline for Residual Solvents, PDE for 2-Methyltetrahydrofuran, Cyclopentyl methyl ether, and tertiary-Butyl alcohol*, endorsed 25 March 2020.

[00213] Residual solvent content is determined by gas chromatography (GC) with a flame ionization detector (FID). The method parameters are listed in **Table 10**.

Table 10. Residual Solvents Method Parameters

Technique	Gas Chromatography
Column	DB-624, 30 m x 0.32 mm x 1.8 μm
Carrier gas	Hydrogen at 1.0 mL/min, constant flow
Detection	FID at 240 °C
Sample introduction	Liquid injection
Oven program	Thermal gradient
Sample Preparation	100 mg/mL Diluent = 1-methyl-2-pyrrolidinone

Isopropyl Chloride

[00214] Isopropyl chloride is a potential byproduct of the manufacturing process. Isopropyl chloride is a Class 2 compound per ICH M7(R1) – *Assessment and Control of DNA Reactive (Mutagenic) Impurities in Pharmaceuticals to Limit Potential Carcinogenic Risk*, dated 31 March 2017. The default Threshold of Toxicological Concern (TTC) for monofunctional alkyl chlorides can be raised ten times the default TTC listed in the M7(R1) guidance. Therefore, based on the duration of treatment of not more than 12 months, the TTC limit for isopropyl chloride is 200 μg/day. A planned Multiple Ascending Dose clinical study that has an estimated maximum daily dose of 500 mg (520 mg as HCl salt), the calculated limit for isopropyl chloride is ≤ 385 ppm. The specified limit was rounded down to ≤ 300 ppm. The content of isopropyl chloride was determined by the method of **Table 10**.

Inorganic Impurities

[00215] I-1 HCl was tested using inductively coupled plasma mass spectrometry (ICP-MS) according to USP <233> to detect all Class 1 and Class 2A elements. The elements used in the process (palladium,

copper, and lithium) are controlled at oral limits (up to 1 g/day dosing of I-1 HCl) established by ICH Q3D(R1) – *Guideline for Elemental Impurities*, adopted 22 March 2019. **Table 11** lists the elemental impurities.

Table 11. Elemental Impurities

Element	Class	Limit (ppm)
Cd	1	≤ 5 ppm
Pb	1	≤ 5 ppm
As	1	≤ 15 ppm
Hg	1	≤ 30 ppm
Co	2A	≤ 50 ppm
V	2A	≤ 100 ppm
Ni	2A	≤ 200 ppm
Pd	2B	≤ 100 ppm
Li	3	≤ 550 ppm
Cu	3	≤ 3000 ppm

Counterion Analysis

[00216] The counterion is chloride. The chloride ion content limit is set to $3.9 \pm 0.6\%$. The counterion content was determined by titration. The measurement is performed using a silver electrode against silver nitrate titrant. The limit is based on the results obtained for development batches and is consistent with a mono-HCl salt.

Residue on Ignition

[00217] Residue on Ignition was tested according to USP <281>. The limit for Residue on Ignition (ROI) was $\leq 0.5\%$. The limit is based on results obtained from development lots and conforms to limits normally established for early-phase development.

Crystallinity

[00218] The polymorphic form of the drug substance was determined by X-Ray Powder Diffraction (XRPD) according to USP <941>. Confirmation of form was based on comparison of the sample XRPD diffraction pattern to the diffraction pattern of I-1 HCl reference standard.

Water Content

[00219] Water content are measured by coulometric Karl Fischer titration according to USP <921>.

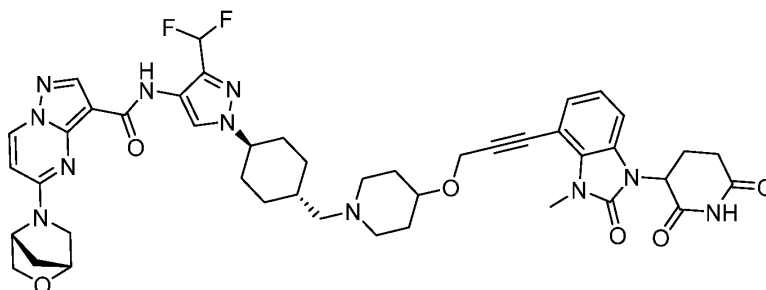
Microbial Enumeration Tests

[00220] Total Aerobic Microbial Count (TAMC), Total Combined Yeasts and Molds Count (TYMC), and E. coli are tested according to USP <61> and USP <62>.

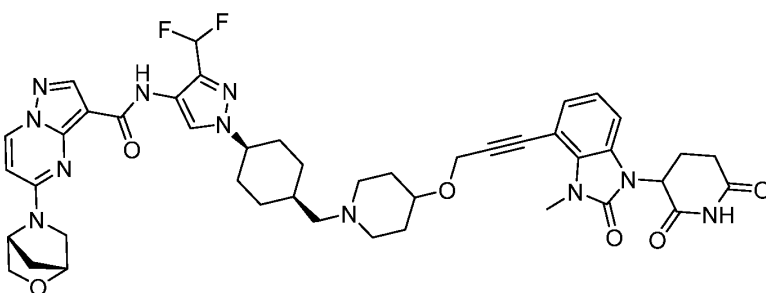
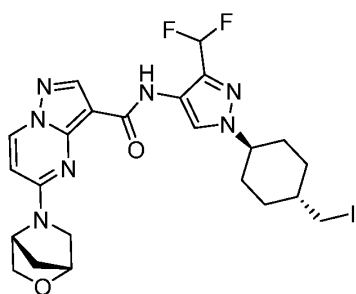
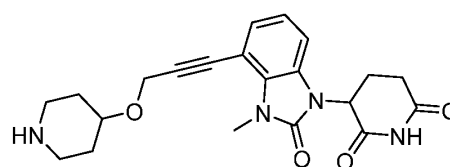
[00221] While we have described a number of embodiments of this invention, it is apparent that our basic examples may be altered to provide other embodiments that utilize the compounds and methods of this invention. Therefore, it will be appreciated that the scope of this invention is to be defined by the application and claims rather than by the specific embodiments that have been represented by way of example.

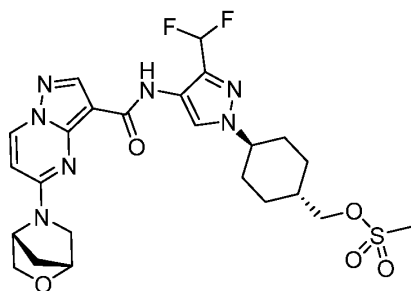
CLAIMS

1. A composition comprising compound **I-1**:

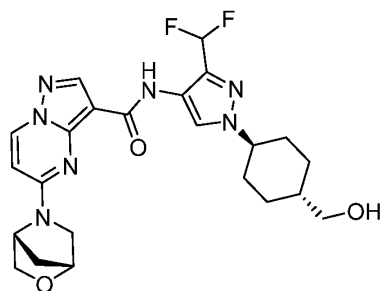
**I-1**

or a pharmaceutically acceptable salt thereof, and one or more impurity compounds selected from the group consisting of:

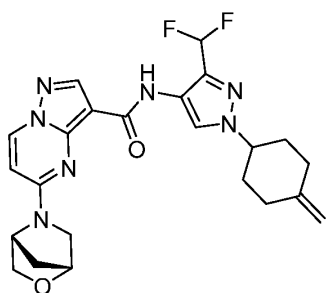
**I-2****I-3****I-4**



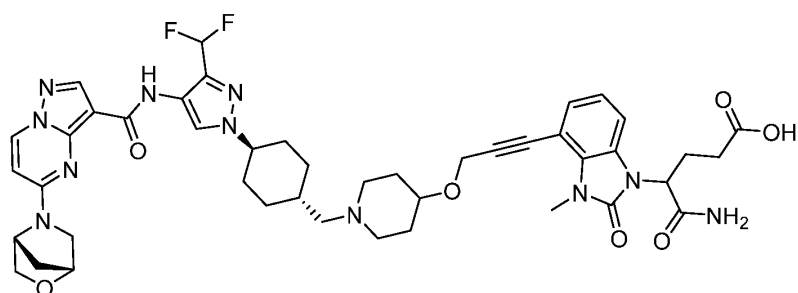
I-5



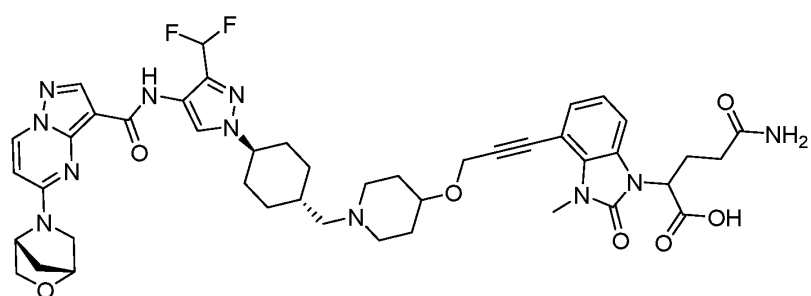
I-6



I-7



I-8



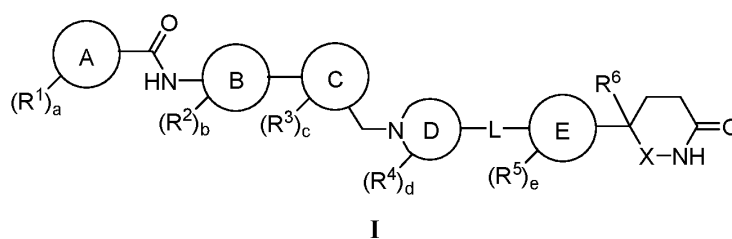
I-9

or a pharmaceutically acceptable salt thereof.

2. The composition of claim 1, wherein the composition comprises one impurity compound selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.
3. The composition of claim 1, wherein the composition comprises two impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.
4. The composition of claim 1, wherein the composition comprises three impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.
5. The composition of claim 1, wherein the composition comprises four impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.
6. The composition of claim 1, wherein the composition comprises five impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.
7. The composition of claim 1, wherein the composition comprises six impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.
8. The composition of claim 1, wherein the composition comprises seven impurity compounds selected from the group consisting of I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.
9. The composition of claim 1, wherein the composition comprises each of impurity compounds I-2, I-3, I-4, I-5, I-6, I-7, I-8, and I-9, or a pharmaceutically acceptable salt thereof.

10. The composition of any one of claims 1-9, wherein the composition comprises one or more impurity compound selected from the group consisting of **I-2**, **I-3**, and **I-5**, or a pharmaceutically acceptable salt thereof.
11. The composition of any one of claims 1-10, wherein the composition comprises one or more impurity compound selected from the group consisting of **I-3** and **I-5**, or a pharmaceutically acceptable salt thereof.
12. The composition of any one of claims 1-11, wherein each of impurity compounds **I-4**, **I-6**, **I-7**, **I-8**, and **I-9**, or a pharmaceutically acceptable salt thereof, is, independently, no more than about 0.7 area percent HPLC of the total weight of the composition.
13. The composition of any one of claims 1-12, wherein impurity compound **I-2** or a pharmaceutically acceptable salt thereof is no more than about 2.0 area percent HPLC of the total weight of the composition.
14. The composition of any one of claims 1-13, wherein each of impurity compounds **I-3** and **I-5**, or a pharmaceutically acceptable salt thereof, is, independently, no more than about 30 ppm.
15. The composition of any one of claims 1-14, wherein the total impurity compounds of **I-2**, **I-3**, **I-4**, **I-5**, **I-6**, **I-7**, **I-8**, and **I-9**, or a pharmaceutically acceptable salt thereof, present in the composition is no more than about 3.0 area percent HPLC.
16. The composition of any one of claims 1-15, wherein the purity of compound **I-1**, or a pharmaceutically acceptable salt thereof, in the composition is at least about 97.0 area percent HPLC.
17. The composition of any one of claims 1-16, further comprising dichloromethane in the composition in an amount of no more than about 600 ppm.
18. The composition of any one of claims 1-17, further comprising N,N-dimethylacetamide in the composition in an amount of no more than about 1090 ppm.
19. The composition of any one of claims 1-18, further comprising tetrahydrofuran in the composition in an amount of no more than about 720 ppm.

20. The composition of any one of claims 1-19, further comprising isopropanol in the composition in an amount of no more than about 5000 ppm.
21. The composition of any one of claims 1-20, further comprising 2-methyltetrahydrofuran in the composition in an amount of no more than about 5000 ppm.
22. The composition of any one of claims 1-21, further comprising isopropyl chloride in the composition in an amount of no more than about 300 ppm.
23. A pharmaceutical composition comprising a composition of any one of claims 1-22, and a pharmaceutically acceptable adjuvant, carrier, or vehicle.
24. A method for treating an autoimmune/autoinflammatory disease and/or a hematological malignancy in a patient, comprising administering to the patient the pharmaceutical composition of claim 23.
25. The method of claim 24, wherein the autoimmune/autoinflammatory disease is selected from a cutaneous, rheumatic, and gastrointestinal autoimmune/autoinflammatory disease.
26. The method of claim 24, wherein the autoimmune/autoinflammatory disease is a cutaneous autoimmune/autoinflammatory disease selected from atopic dermatitis (AD) and hidradenitis suppurativa (HS).
27. A process for preparing a compound of formula I:



or a pharmaceutically acceptable salt thereof, wherein:

X is a bivalent moiety selected from a covalent bond, $-\text{CH}_2-$, $-\text{C}(\text{O})-$, $-\text{C}(\text{S})-$, or  ;

R^1 , R^2 , R^3 , R^4 , and R^5 , independently, are selected from hydrogen, deuterium, R^A , halogen, $-\text{CN}$, $-\text{NO}_2$, $-\text{OR}$, $-\text{SR}$, $-\text{NR}_2$, $-\text{SO}_2\text{R}$, $-\text{SO}_2\text{NR}_2$, $-\text{S}(\text{O})\text{R}$, $-\text{CFR}_2$, $-\text{CF}_2\text{R}$, $-\text{CF}_3$, $-\text{CR}_2\text{OR}$, $-\text{CR}_2(\text{NR}_2)$, $-\text{C}(\text{O})\text{R}$, $-\text{C}(\text{O})\text{OR}$, $-\text{C}(\text{O})\text{NR}_2$, $-\text{C}(\text{S})\text{NR}_2$, $-\text{C}(\text{O})\text{NROR}$, $-\text{OC}(\text{O})\text{R}$, $-\text{OC}(\text{O})\text{NR}_2$, $-\text{NRC}(\text{O})\text{OR}$, $-\text{NRC}(\text{O})\text{R}$, $-\text{NRC}(\text{O})\text{NR}_2$, $-\text{NRSO}_2\text{R}$, $-\text{N}^+(\text{O}^-)\text{R}_2$, $-\text{OP}(\text{O})\text{R}_2$, $-\text{OP}(\text{O})(\text{OR})_2$, $-\text{OP}(\text{O})(\text{OR})\text{NR}_2$, $-\text{OP}(\text{O})(\text{NR}_2)_2$, $-\text{P}(\text{O})\text{R}_2$, $-\text{SiR}_3$, $-\text{Si}(\text{OR})\text{R}_2$, or



each R , independently, is hydrogen, or an optionally substituted group selected from C_{1-6} aliphatic, phenyl, a 3-7 membered saturated or partially unsaturated heterocyclic having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, and a 5-6 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or:

two R groups on the same carbon or nitrogen are optionally taken together with their intervening atoms to form a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or a 5-9 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur;

each R^A , independently, is an optionally substituted group selected from C_{1-6} aliphatic, phenyl, a 4-7 membered saturated or partially unsaturated heterocyclic ring having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, and a 5-6 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur;

a , b , c , d , and e , independently, are selected from 0, 1, 2, 3, or 4;

R^6 is hydrogen or C_{1-6} aliphatic;

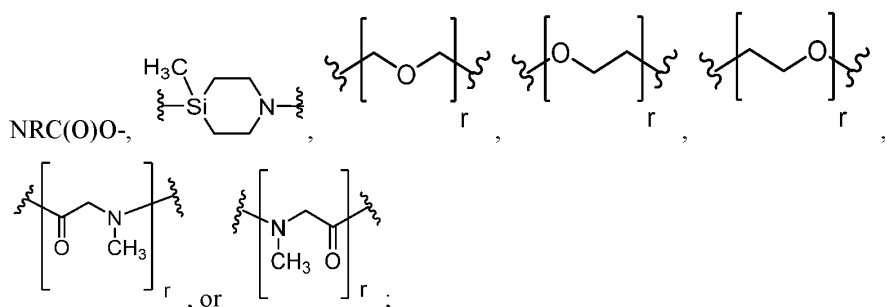
Ring A, Ring B, and Ring E, independently, are selected from phenyl, naphthyl, a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or a 5-10 membered monocyclic or bicyclic heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur;

Ring C is a 4-6 membered saturated or partially unsaturated carbocyclic or heterocyclic ring having 1-2 heteroatoms selected from nitrogen, oxygen, and sulfur;

Ring D is a 4-6 membered saturated or partially unsaturated heterocyclic ring having, in addition to the nitrogen present, 0-2 heteroatoms selected from nitrogen, oxygen, and sulfur;

L is a covalent bond or a bivalent, saturated or unsaturated, straight or branched C_{1-10} hydrocarbon chain, wherein 0-6 methylene units of L are independently replaced by $-\text{CDH}-$, $-\text{CD}_2-$, $-\text{CRF}-$, $-\text{CF}_2-$, $-\text{Cy}-$, $-\text{O}-$, $-\text{NR}-$, $-\text{SiR}_2-$, $-\text{Si}(\text{OH})\text{R}-$, $-\text{Si}(\text{OH})_2-$, $-\text{P}(\text{O})\text{OR}-$, $-\text{P}(\text{O})\text{R}-$, $-\text{P}(\text{O})\text{NR}_2-$, $-\text{S}-$, $-\text{OC}(\text{O})-$, $-\text{C}(\text{O})-$, $-\text{C}(\text{S})-$, $-\text{C}(\text{O})\text{NR}_2-$, $-\text{C}(\text{S})\text{NR}_2-$, $-\text{C}(\text{O})\text{NROR}-$, $-\text{OC}(\text{O})\text{R}-$, $-\text{OC}(\text{O})\text{NR}_2-$, $-\text{NRC}(\text{O})\text{OR}-$, $-\text{NRC}(\text{O})\text{R}-$, $-\text{NRC}(\text{O})\text{NR}_2-$, $-\text{NRSO}_2\text{R}-$, $-\text{N}^+(\text{O}^-)\text{R}_2-$, $-\text{OP}(\text{O})\text{R}_2-$, $-\text{OP}(\text{O})(\text{OR})_2-$, $-\text{OP}(\text{O})(\text{OR})\text{NR}_2-$, $-\text{OP}(\text{O})(\text{NR}_2)_2-$, $-\text{P}(\text{O})\text{R}_2-$, $-\text{SiR}_3-$, $-\text{Si}(\text{OR})\text{R}_2-$, or

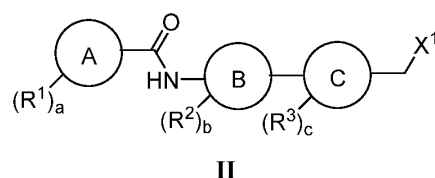
C(O)O-, -C(O)-, -S(O)-, -SO₂-, -NRSO₂-, -SO₂NR-, -NRC(O)-, -C(O)NR-, -OC(O)NR-, -



each -Cy-, independently, is an optionally substituted bivalent ring selected from phenylenyl, an 8-10 membered bicyclic arylene, a 4-7 membered saturated or partially unsaturated carbocyclylenyl, a 4-12 membered saturated or partially unsaturated spiro carbocyclylenyl, an 8-10 membered bicyclic saturated or partially unsaturated carbocyclylenyl, a 4-7 membered saturated or partially unsaturated heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, a 4-12 membered saturated or partially unsaturated spiro heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, an 8-10 membered bicyclic saturated or partially unsaturated heterocyclylenyl having 1-2 heteroatoms independently selected from nitrogen, oxygen, and sulfur, a 5-6 membered heteroarylenyl having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or an 8-10 membered bicyclic heteroarylenyl having 1-5 heteroatoms independently selected from nitrogen, oxygen, or sulfur; and

r is 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10,

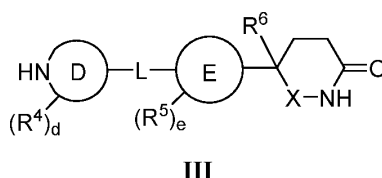
comprising treating a compound of formula II:



or pharmaceutically acceptable salt thereof, wherein:

X¹ is a suitable leaving group,

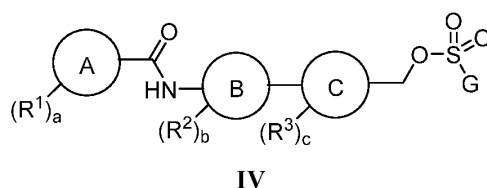
with a compound of formula III:



under suitable conditions to form the compound of formula **I** or a pharmaceutically acceptable salt thereof.

28. The process of claim 27, wherein X^1 is a halogen.

29. A process for preparing a compound of formula **II** as defined in claim 28, the process comprising halogenating a compound of formula **IV**:

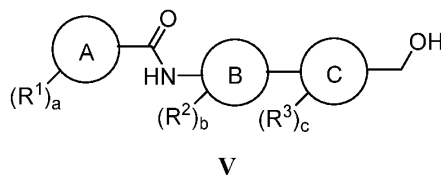


or a pharmaceutically acceptable salt thereof, wherein:

G is an optionally substituted group selected from a C_{1-6} aliphatic, phenyl, naphthyl, a 4-11 membered saturated or partially unsaturated monocyclic, bicyclic, bridged bicyclic, or spirocyclic carbocyclic or heterocyclic ring having 1-3 heteroatoms independently selected from nitrogen, oxygen, and sulfur, or a 5-10 membered monocyclic or bicyclic heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur;

under suitable conditions to form the compound of formula **II** or a pharmaceutically acceptable salt thereof.

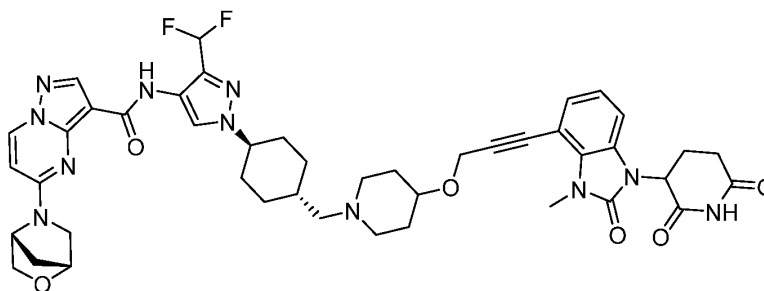
30. A process for preparing a compound of formula **IV** as defined in claim 29, the process comprising sulfonating a compound of formula **V**:



or a pharmaceutically acceptable salt thereof, under suitable conditions to form the compound of formula **IV** or a pharmaceutically acceptable salt thereof.

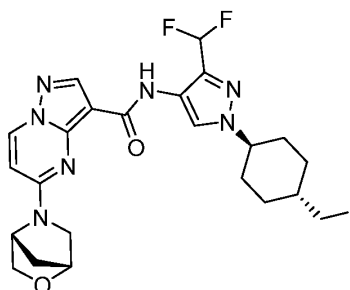
31. The process of any one of claims 27-30, wherein Ring A is phenyl or a 5-10 membered monocyclic or bicyclic heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.

32. The process of any one of claims 27-31, wherein Ring B is phenyl or a 5-6 membered heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.
33. The process of any one of claims 27-32, wherein Ring C is a 6-membered saturated or partially unsaturated carbocyclic or heterocyclic ring having 1-2 heteroatoms selected from nitrogen, oxygen, and sulfur.
34. The process of any one of claims 27-33, wherein Ring D is a 6-membered saturated or partially unsaturated carbocyclic or heterocyclic ring having 1-2 heteroatoms selected from nitrogen, oxygen, and sulfur.
35. The process of any one of claims 27-34, wherein Ring E is a 5-10 membered monocyclic or bicyclic heteroaryl ring having 1-4 heteroatoms independently selected from nitrogen, oxygen, and sulfur.
36. The process of any one of claims 27-35, wherein R¹ is halogen, -CN, -NO₂, -OR, -SR, -NR₂, -SO₂R, -SO₂NR₂, -S(O)R, -CFR₂, -CF₂R, -CF₃, -CR₂OR, -CR₂(NR₂), -C(O)R, -C(O)OR, -C(O)NR₂, -C(S)NR₂, -C(O)NROR, -OC(O)R, -OC(O)NR₂, -NRC(O)OR, -NRC(O)R, -NRC(O)NR₂, or -NRSO₂R.
37. The process of any one of claims 27-36, wherein R² is halogen, -CN, -NO₂, -OR, -SR, -NR₂, -SO₂R, -SO₂NR₂, -S(O)R, -CFR₂, -CF₂R, -CF₃, -CR₂OR, -CR₂(NR₂), -C(O)R, -C(O)OR, -C(O)NR₂, -C(S)NR₂, -C(O)NROR, -OC(O)R, -OC(O)NR₂, -NRC(O)OR, -NRC(O)R, -NRC(O)NR₂, or -NRSO₂R.
38. The process of any one of claims 27-37, wherein c, d, and e are 0.
39. The process of any one of claims 27-38, wherein R⁶ is hydrogen.
40. The process of any one of claims 27-39, wherein the compound of formula I is:

**I-1**

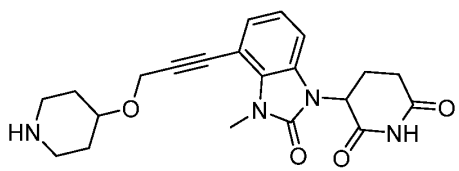
or a pharmaceutically acceptable salt thereof.

41. The process of any one of claims 27-40, wherein the compound of formula **II** is:

**I-3**

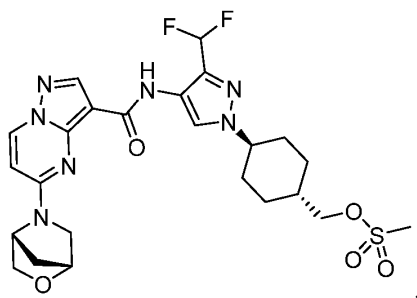
or a pharmaceutically acceptable salt thereof.

42. The process of any one of claims 27-41, wherein the compound of formula **III** is:

**I-4**

or a pharmaceutically acceptable salt thereof.

43. The process of any one of claims 29-42, wherein the compound of formula **IV** is:



I-5

or a pharmaceutically acceptable salt thereof.