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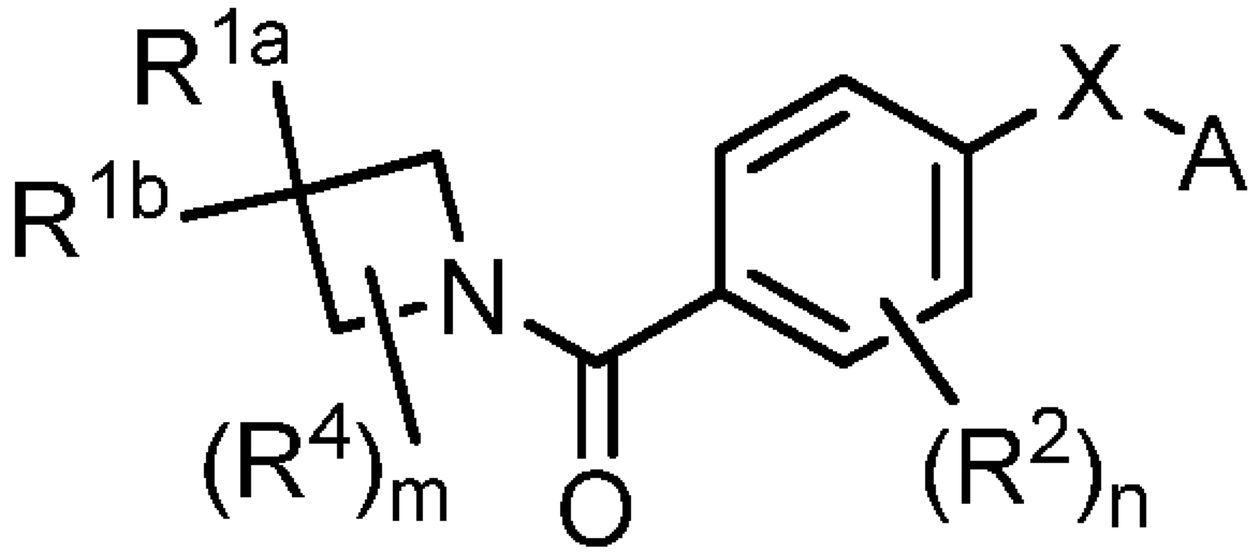
(71) Demandeurs/Applicants:
YAN, SHUNQI, US;
AGIOS PHARMACEUTICALS, INC., US

(72) Inventeurs/Inventors:
YAN, SHUNQI, US;
SALITURO, FRANCESCO G., US;
SAUNDERS, JEFFREY O., US

(74) Agent: GOWLING LAFLEUR HENDERSON LLP

(54) Titre : NOUVEAUX DERIVES DE N-(4-(AZETIDINE- 1 - CARBONYL) PHENYL)-(HETERO-) ARYLSULFONAMIDE EN TANT QUE MODULATEURS DE LA PYRUVATE KINASE M2 (PMK2)

(54) Title: NOVEL N-(4-(AZETIDINE - 1 - CARBONYL)PHENYL)-(HETERO-) ARYLSULFONAMIDE DERIVATIVES AS PYRUVATE KINASE M2 (PMK2) MODULATORS



(I)

(57) Abrégé/Abstract:
Compounds of general Formula (I), and compositions comprising compounds of general formula I that modulate pyruvate kinase M2 (PKM2) are described herein. Also described herein are methods of using the compounds that modulate PKM2 in the treatment of cancer.

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(71) **Applicant** *(for all designated States except US)*: **AGIOS PHARMACEUTICALS, INC.** [US/US]; 38 Sidney Street, Cambridge, Massachusetts 02139 (US).

(72) **Inventor; and**
(71) **Applicant** : **YAN, Shunqi** [US/US]; 55 Stepping Stone, Irvine, California 92603 (US).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **SALITURO, Francesco G.** [US/US]; 28 Baker Drive, Marlborough, Massachusetts 01752 (US). **SAUNDERS, Jeffrey O.** [US/US]; 188 Tower Road, Lincoln, Massachusetts 01773 (US).

(74) **Agents**: **McCarty, Catherine M.** et al.; Lando & Anastasi, LLP, One Main Street, Cambridge, Massachusetts 02142 (US).

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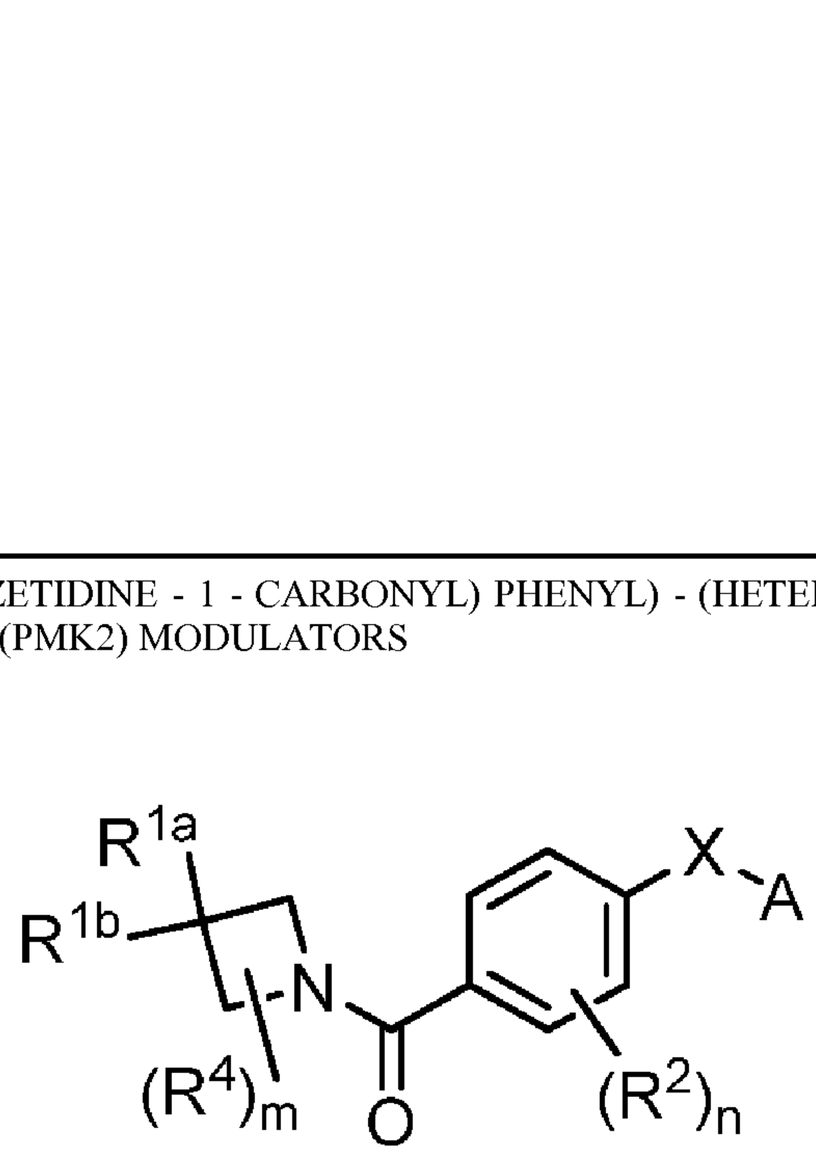

(I)

(57) Abstract: Compounds of general Formula (I), and compositions comprising compounds of general formula I that modulate pyruvate kinase M2 (PKM2) are described herein. Also described herein are methods of using the compounds that modulate PKM2 in the treatment of cancer.

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NOVEL N- (4- (AZETIDINE - 1 - CARBONYL) PHENYL) - (HETERO -) ARYLSULFONAMIDE DERIVATIVES AS PYRUVATE KINASE M2 (PMK2) MODULATORS

CLAIM OF PRIORITY

This application claims priority from U.S.S.N. 61/424,395, filed from December 17, 2010 which is incorporated herein by reference in its entirety.

BACKGROUND OF INVENTION

Cancer cells rely primarily on glycolysis to generate cellular energy and biochemical intermediates for biosynthesis of lipids and nucleotides, while the majority of "normal" cells in adult tissues utilize aerobic respiration. This fundamental difference in cellular metabolism between cancer cells and normal cells, termed the Warburg Effect, has been exploited for diagnostic purposes, but has not yet been exploited for therapeutic benefit.

Pyruvate kinase (PK) is a metabolic enzyme that converts phosphoenolpyruvate to pyruvate during glycolysis. Four PK isoforms exist in mammals: the L and R isoforms are expressed in liver and red blood cells, the M1 isoform is expressed in most adult tissues, and the M2 isoform is a splice variant of M1 expressed during embryonic development. All tumor cells exclusively express the embryonic M2 isoform. A well-known difference between the M1 and M2 isoforms of PK is that M2 is a low-activity enzyme that relies on allosteric activation by the upstream glycolytic intermediate, fructose-1,6-bisphosphate (FBP), whereas M1 is a constitutively active enzyme.

All tumor cells exclusively express the embryonic M2 isoform of pyruvate kinase, suggesting PKM2 as a potential target for cancer therapy. PKM2 is also expressed in adipose tissue and activated T-cells. Phosphotyrosine peptide binding to PKM2 leads to a dissociation of FBP from PKM2 and conformational changes of PKM2 from an active, tetrameric form to an inactive form. Compounds that bind to PKM2 and lock the enzyme in the active confirmation will lead to the loss of allosteric control of PKM2 needed for shunting biochemical intermediates from glycolysis into biosynthesis of nucleotides and lipids. Thus, the activation of PKM2 can inhibit the growth and proliferation of cancer cells, activated immune cells, and

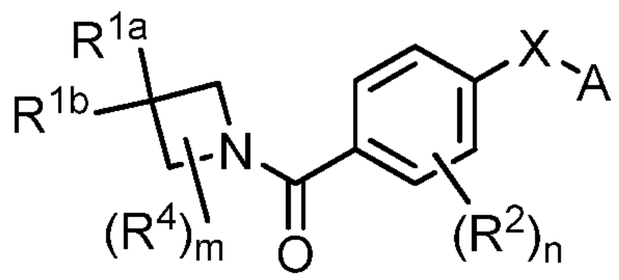
fat cells. Activation of PKM2 may therefore be effective in the treatment of cancer, obesity, diabetes, autoimmune conditions, and proliferation-dependent diseases, e.g., benign prostatic hyperplasia (BPH).

There is a continuing need for novel treatments of diseases such as cancer, diabetes, obesity, autoimmune conditions, proliferation-dependent diseases (e.g., BPH), and other diseases related to the function of pyruvate kinase (e.g., PKM2).

SUMMARY OF INVENTION

Described herein are compounds that activate pyruvate kinase M2 (PKM2) and pharmaceutically acceptable salts, solvates, and hydrates thereof, for example, compounds that activate PKM2. Also provided are pharmaceutical compositions comprising a compound provided herewith and the use of such compositions in methods of treating diseases and conditions that are related to pyruvate kinase function (e.g., PKM2 function), including, e.g., cancer, diabetes, obesity, autoimmune disorders, and benign prostatic hyperplasia (BPH).

In one embodiment, provided is a compound of formula (I):



(I), or a pharmaceutically acceptable salt thereof, wherein:

A is aryl or heteroaryl, wherein the aryl or heteroaryl is optionally substituted, and the aryl or heteroaryl is optionally fused to an optionally substituted carbocyclyl or an optionally substituted heterocyclyl;

X is selected from -NH-$S(O)_2$-, -N(alkyl)-$S(O)_2$-, -$S(O)_2$-N(H)-, and -$S(O)_2$-N(alkyl)-;

R^{1a} is selected from hydrogen, alkyl, aryl, and arylalkyl; and R^{1b} is selected from OR^3, N(alkyl)R^3 and NHR^3; or

R^{1a} is alken-1-yl and R^{1b} is absent;

each R^2 is independently selected from halo, haloalkyl, alkyl, alkoxy and hydroxyl;

R^3 is selected from hydrogen, alkyl, optionally substituted aryl, optionally substituted heteroaryl, arylalkyl, $C(O)R^a$, and $C(O)N(H)R^a$, wherein R^a is selected from alkyl, alkenyl, aryl, heteroaryl, arylalkyl and heteroarylalkyl; and wherein any aryl or heteroaryl portion of R^a is optionally substituted;

each R^4 is independently selected from haloalkyl, alkyl, alkoxy and hydroxyl

n is 0, 1, or 2;

m is 0, 1, or 2.

In another embodiment, provided is a method for treating or preventing (e.g., treating) a disease, condition or disorder as described herein comprising administering a compound provided herein, a pharmaceutically acceptable salt thereof, or pharmaceutical composition thereof.

In another embodiments, provided is a method of increasing the level of PKM2 activity and/or glycolysis in a patient in need thereof. The method comprises the step of administering an effective amount of a compound described herein to the patient in need thereof, thereby increasing the level of PKM2 activity and/or glycolysis in the patient. In some embodiments, a compound or a composition described herein is used to maintain PKM2 in its active conformation or activate pyruvate kinase activity in proliferating cells as a means to divert glucose metabolites into catabolic rather than anabolic processes in the patient.

In another embodiment, provided is a method of inhibiting cell proliferation in a patient in need thereof. The method comprises the step of administering an effective amount of a compound described herein to the patient in need thereof, thereby inhibiting cell proliferation in the patient. In one aspect this method can inhibit growth of a transformed cell, more specifically a cancer cell. In another aspect the method generally inhibits growth of a PKM2-dependent cell that undergoes aerobic glycolysis.

In another embodiment, provided is a method of treating a patient suffering from or susceptible to a disease or disorder associated with reduced PKM2 activity or reduced glycolysis in a patient in need thereof. The method comprises the step of

administering an effective amount of a compound described herein to the patient in need thereof, thereby treating, preventing or ameliorating the disease or disorder in the patient. In certain embodiment the compound described herein is provided in a pharmaceutical composition. In certain embodiments, the method includes the step of identifying or selecting a patient who would benefit from activation of PKM2 prior to treatment. Identifying or selecting such a patient can be on the basis of the level of PKM2 activity in a cell of the patient. In one aspect, the selected patient is suffering from or susceptible to unwanted cell growth or proliferation, e.g., cancer, obesity, diabetes, atherosclerosis, restenosis, and autoimmune diseases. In another aspect, the selected patient is suffering from a cancer associated with PKM2 function.

In another embodiment, the compound described herein is administered at a dosage and frequency sufficient to increase lactate production or oxidative phosphorylation.

DETAILED DESCRIPTION

The details of construction and the arrangement of components set forth in the following description or illustrated in the drawings are not meant to be limiting. Embodiments can be practiced or carried out in various ways. Also, the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having," "containing", "involving", and variations thereof herein, is meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

Definitions

The term "halo" or "halogen" refers to any radical of fluorine, chlorine, bromine or iodine.

The term "alkyl" refers to a monovalent hydrocarbon chain that may be a straight chain or branched chain, containing the indicated number of carbon atoms. For example, C_1-C_{12} alkyl indicates that the group may have from 1 to 12 (inclusive) carbon atoms in it. In certain aspects, the term "alkyl" refers to a monovalent hydrocarbon chain that may be a straight chain or branched chain, containing 1 to 6

carbon atoms. In other aspects, the term "alkyl" refers to a monovalent hydrocarbon chain that may be a straight chain or branched chain, containing 1 to 4 carbon atoms.

The term "haloalkyl" refers to an alkyl in which one or more hydrogen atoms are replaced by halo, and includes alkyl moieties in which all hydrogens have been replaced by halo (e.g., perfluoroalkyl).

The term "alkenyl" refers to a monovalent straight or branched hydrocarbon chain containing 2-12 carbon atoms and having one or more double bonds. Examples of alkenyl groups include, but are not limited to, allyl, propenyl, 2-butenyl, 3-hexenyl and 3-octenyl groups. One of the double bond carbons may optionally be the point of attachment of the alkenyl substituent. In certain aspects, the term "alkenyl" refers to a monovalent straight or branched hydrocarbon chain containing 2-6 carbon atoms and having one or more double bonds. In other aspects, the term "alkenyl" refers to a monovalent straight or branched hydrocarbon chain containing 2-4 carbon atoms and having one or more double bonds.

The term "alkynyl" refers to a monovalent straight or branched hydrocarbon chain containing 2-12 carbon atoms and characterized in having one or more triple bonds. Examples of alkynyl groups include, but are not limited to, ethynyl, propargyl, and 3-hexynyl. One of the triple bond carbons may optionally be the point of attachment of the alkynyl substituent.

The terms "alkylamino" and "dialkylamino" refer to -NH(alkyl) and -NH(alkyl)$_2$ radicals respectively.

The term "aralkylamino" refers to a -NH(aralkyl) radical.

The term "alkylaminoalkyl" refers to a (alkyl)NH-alkyl- radical.

The term "dialkylaminoalkyl" refers to a (alkyl)$_2$N-alkyl- radical.

The term "mercapto" refers to an -SH radical.

The term "thioalkoxy" refers to an -S-alkyl radical.

The term "thioaryloxy" refers to an -S-aryl radical.

The term "alkoxy" refers to an -O-alkyl radical.

The term "aryl" refers to a monocyclic, bicyclic, or tricyclic aromatic hydrocarbon ring system. Examples of aryl moieties include, but are not limited to, phenyl, naphthyl, and anthracenyl.

The terms "arylalkyl" or "aralkyl" refer to an alkyl moiety in which an alkyl hydrogen atom is replaced by an aryl group. Aralkyl includes groups in which more than one hydrogen atom has been replaced by an aryl group. Examples of "arylalkyl" or "aralkyl" include benzyl, 2-phenylethyl, 3-phenylpropyl, 9-fluorenyl, benzhydryl, and trityl groups.

The term "carbocyclyl" refers to a non-aromatic, monocyclic, bicyclic, or tricyclic hydrocarbon ring system. Carbocyclyl groups include fully saturated ring systems (e.g., cycloalkyls), and partially saturated ring systems.

The term "cycloalkyl" as employed herein includes saturated cyclic, bicyclic, tricyclic, or polycyclic hydrocarbon groups having 3 to 12 carbons. Any ring atom can be substituted (e.g., by one or more substituents). Examples of cycloalkyl moieties include, but are not limited to, cyclopropyl, cyclohexyl, methylcyclohexyl, adamantyl, and norbornyl.

The term "heteroaryl" refers to a fully aromatic 5-8 membered monocyclic, 8-12 membered bicyclic, or 11-14 membered tricyclic ring system having 1-3 heteroatoms if monocyclic, 1-6 heteroatoms if bicyclic, or 1-9 heteroatoms if tricyclic, said heteroatoms selected from O, N, or S (e.g., carbon atoms and 1-3, 1-6, or 1-9 heteroatoms selected independently from N, O, or S if monocyclic, bicyclic, or tricyclic, respectively).

The term "heterocyclyl" refers to a nonaromatic, 3-10 membered monocyclic, 8-12 membered bicyclic, or 11-14 membered tricyclic ring system having 1-3 heteroatoms if monocyclic, 1-6 heteroatoms if bicyclic, or 1-9 heteroatoms if tricyclic, said heteroatoms selected from O, N, or S (e.g., carbon atoms and 1-3, 1-6, or 1-9 heteroatoms of N, O, or S if monocyclic, bicyclic, or tricyclic, respectively). The heteroatom may optionally be the point of attachment of the heterocyclyl substituent. Examples of heterocyclyl include, but are not limited to, tetrahydrofuranyl, tetrahydropyranyl, piperidinyl, morpholino, pyrrolinyl, pyrimidinyl, and pyrrolidinyl.

Bicyclic and tricyclic ring systems containing one or more heteroatoms and both aromatic and non-aromatic rings are considered to be heterocyclyl groups according to the present definition. Such bicyclic or tricyclic ring systems may be alternately characterized as being an aryl or a heteroaryl fused to a carbocyclyl or

heterocyclyl, particularly in those instances where the ring bound to the rest of the molecule is required to be aromatic.

The terms "heteroarylalkyl" and "heteroaralkyl", as used herein, refers to an alkyl group substituted with a heteroaryl group.

The term "heterocyclylalkyl", as used herein, refers to an alkyl group substituted with a heterocyclyl group.

The term "acyl" refers to an alkylcarbonyl, cycloalkylcarbonyl, arylcarbonyl, heterocyclylcarbonyl, or heteroarylcarbonyl substituent, any of which may be further substituted (e.g., by one or more substituents).

All ring systems (i.e, aryl, heteroaryl, carbocyclyl, cycloalkyl, heterocyclyl, etc.) or ring system portions of groups (e.g., the aryl portion of an aralkyl group) are optionally substituted at one or more substitutable carbon atoms with substituents independently selected from: halo, -C≡N, C_1-C_4 alkyl, =O, C_3-C_7 cycloalkyl, C_1-C_4 alkyl, -OH, -O-(C_1-C_4 alkyl)-, -SH, -S-(C_1-C_4 alkyl), -(C_1-C_4 alkyl)-N(R^b)(R^b), -N(R^b)(R^b), -O-(C_1-C_4 alkyl)-N(R^b)(R^b), -(C_1-C_4 alkyl)-O-(C_1-C_4 alkyl)-N(R^b)(R^b), -C(O)-N(R^b)(R^b), -(C_1-C_4 alkyl)-C(O)-N(R^b)(R^b), -O-(heteroaryl), -O-(heterocycle), -O-phenyl, -heteroaryl, -heterocycle, and -phenyl, wherein:

each R^b is independently selected from hydrogen, and -C_1-C_4 alkyl; or

two R^b are taken together with the nitrogen atom to which they are bound to form a 4- to 8-membered saturated heterocycle optionally comprising one additional heteroatom selected from N, S, S(=O), S(=O)$_2$, and O,

any alkyl substituent is optionally further substituted with one or more of -OH, -O-(C_1-C_4 alkyl), halo, -NH_2, -NH(C_1-C_4 alkyl), or -N(C_1-C_4 alkyl)$_2$; and

any carbon atom on a phenyl, cycloalkyl, heteroaryl or heterocycle substituent is optionally further substituted with one or more of -(C_1-C_4 alkyl), -(C_1-C_4 fluoroalkyl), -OH, -O-(C_1-C_4 alkyl), -O-(C_1-C_4 fluoroalkyl), halo, -NH_2, -NH(C_1-C_4 alkyl), or -N(C_1-C_4 alkyl)$_2$;

All heterocyclyl ring systems (and any heterocyclyl substituents on any ring system) is optionally substituted on one or more any substitutable nitrogen atom with -C_1-C_4 alkyl, or fluoro-substituted C_1-C_4 alkyl.

The term "substituted" refers to the replacement of a hydrogen atom by another group.

The term "oxo" refers to an oxygen atom, which forms a carbonyl when attached to carbon, an N-oxide when attached to nitrogen, and a sulfoxide or sulfone when attached to sulfur.

The term "selective" is meant at least 2-fold, 3-fold, 4-fold, 5-fold, 6-fold, or 10-fold greater activation of PKM2 than PKM1.

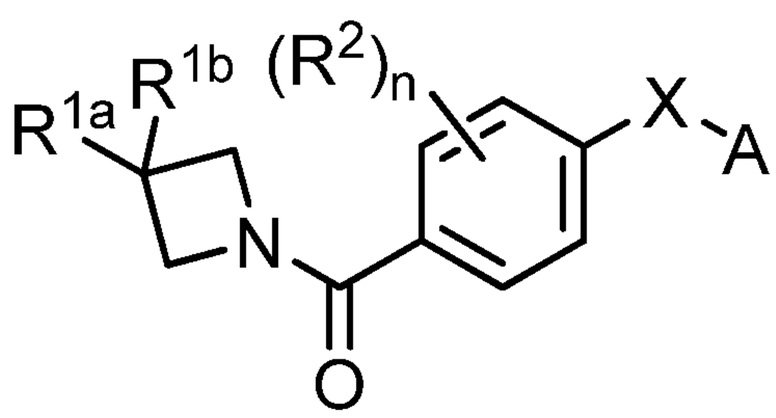
The term "activator" as used herein means an agent that (measurably) increases the activity of PKM2 or causes PKM2 activity to increase to a level that is greater than PKM2's basal levels of activity. For example, the activator may mimic the effect caused by a natural ligand (e.g., FBP). The activator effect caused by a compound provided herein may be to the same, or to a greater, or to a lesser extent than the activating effect caused by a natural ligand, but the same type of effect is caused. A compound provided herein can be evaluated to determine if it is an activator by measuring either directly or indirectly the activity of the pyruvate kinase when subjected to said compound. The activity of PKM2 can be measured, for example, by monitoring the concentration of a substrate such as ATP or NADH.

The abbreviations Me, Et, Ph, Tf, Nf, Ts, Ms represent methyl, ethyl, phenyl, trifluoromethanesulfonyl, nonafluorobutanesulfonyl, *p*-toluenesulfonyl and methanesulfonyl, respectively. A more comprehensive list of the abbreviations utilized by organic chemists of ordinary skill in the art appears in the first issue of each volume of the *Journal of Organic Chemistry*; this list is typically presented in a table entitled Standard List of Abbreviations. The abbreviations contained in said list, and all abbreviations utilized by organic chemists of ordinary skill in the art are hereby incorporated by reference.

Compounds

Provided herein is a compound of Formula (I) or a pharmaceutically acceptable salt thereof as described above in the Summary of the Invention.

In one embodiment, provided is a compound of Formula I, wherein m is 0 (i.e., there are no R^4 substituents on the azetindinyl ring), the compound having Formula (Ia):



(Ia), or a pharmaceutically acceptable salt thereof, wherein:

A is aryl or heteroaryl, wherein the aryl or heteroaryl is optionally substituted; and the aryl or heteroaryl is optionally fused to an optionally substituted carbocyclyl or an optionally substituted heterocyclyl;

X is selected from -N(H)-$S(O)_2$-, -N(alkyl)-$S(O)_2$-, -$S(O)_2$-N(alkyl)- and -$S(O)_2$-N(H)-;

R^{1a} is selected from hydrogen, alkyl, aryl, and arylalkyl; and R^{1b} is selected from OR^3, N(alkyl)R^3 and NHR^3; or

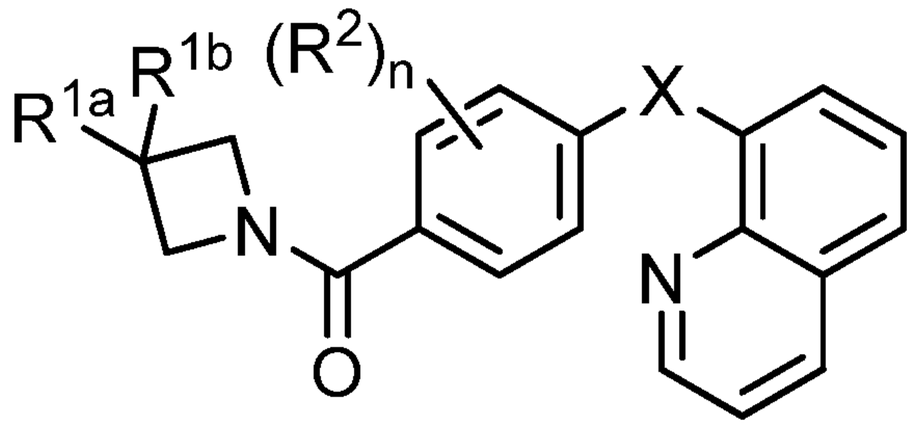
R^{1a} is alken-1-yl and R^{1b} is absent;

each R^2 is independently selected from halo, haloalkyl, alkyl, alkoxy and hydroxyl;

R^3 is selected from hydrogen, alkyl, optionally substituted aryl, optionally substituted heteroaryl, arylalkyl, C(O)R^a, and C(O)N(H)R^a, wherein R^a is selected from alkyl, alkenyl, aryl, heteroaryl, arylalkyl and heteroarylalkyl; and wherein any aryl or heteroaryl portion of R^a is optionally substituted; and

n is 0, 1, or 2.

In certain aspects of the above embodiment, A is an optionally substituted bicyclic heteroaryl. In a more specific aspect, A is quinolin-8-yl and the compound has the structure set forth in formula (II), or a pharmaceutically acceptable salt thereof:



(II)

wherein:

R^{1a}, R^{1b}, R^2, R^3, X, and n are as defined for Formula Ia.

In certain embodiments of Formula I, Ia or II, R^{1a} is hydrogen.

In certain embodiments of Formula I, Ia or II, R^{1a} is optionally substituted phenyl.

In some embodiments of Formula I, Ia or II, R^{1a} is alkyl. In one aspect of these embodiments, R^{1a} is methyl.

In certain embodiments of Formula I, Ia or II, R^{1a} is arylalkyl, wherein the aryl portion is optionally substituted. In one aspect of these embodiments, R^{1a} is optionally substituted benzyl.

In some embodiments of Formula I, Ia or II, R^{1b} is $-OR^3$. In one aspect of these embodiments, R^{1b} is hydroxyl. In an alternate aspect R^{1b} is -O-alkyl. In a more specific aspect, R^{1b} is methoxy. In still another aspect R^{1b} is optionally substituted phenoxy. In another aspect R^{1b} is optionally substituted benzoxy. In another aspect R^{1b} is optionally substituted -OC(O)-benzyl. In still another aspect, R^{1b} is optionally substituted -OC(O)-pyridinyl. In another aspect, R^{1b} is -OC(O)NH(alkyl). In a more specific aspect, R^{1b} is $-OC(O)NH(CH(CH_3)_2)$. In another aspect, R^{1b} is optionally substituted -OC(O)NH(heteroaryl). In a more specific aspect, R^{1b} is optionally substituted -OC(O)NH(pyridinyl).

In some embodiments of Formula I, Ia or II, R^{1b} is NHR^3 or $N(alkyl)R^3$. In one aspect of these embodiments, R^{1b} is NHR^3. In an alternate aspect R^{1b} is $N(CH_3)R^3$. In another aspect of these embodiments R^3 is optionally substituted aryl. In a more specific aspect, R^3 is optionally substituted phenyl. In another aspect of these embodiments R^3 is optionally substituted aralkyl. In a more specific aspect, R^3 is optionally substituted benzyl. In another aspect of these embodiments R^3 is

optionally substituted heteroaryl. In a more specific aspect, R^3 is optionally substituted pyridinyl. In another aspect of these embodiments R^3 is optionally substituted -C(O)-heteroaryl. In a more specific aspect, R^3 is optionally substituted -C(O)-pyridinyl. In another aspect of these embodiments R^3 is optionally substituted -C(O)-NH-heteroaryl. In a more specific aspect, R^3 is optionally substituted -C(O)-NH-pyridinyl. In still another aspect of these embodiments R^3 is -C(O)-NH-alkyl or -C(O)-NH-alkenyl. In a more specific aspect, R^3 is $-C(O)-NH-CH(CH_3)_2$. In another more specific aspect, R^3 is $-C(O)-NH-CH_2-CH=CH_2$.

In certain embodiments of Formula I, Ia or II, n is 0 or 1. In one aspect of an embodiment where n is 1, R^2 is selected from fluoro, methyl, and methoxy.

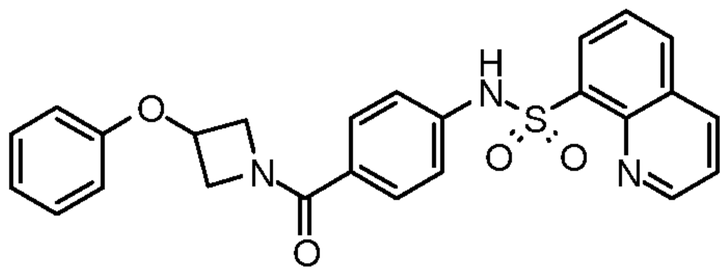
In certain embodiments of Formula I, Ia or II, X is $-NH-S(O)_2$ or $-S(O)_2-NH$.

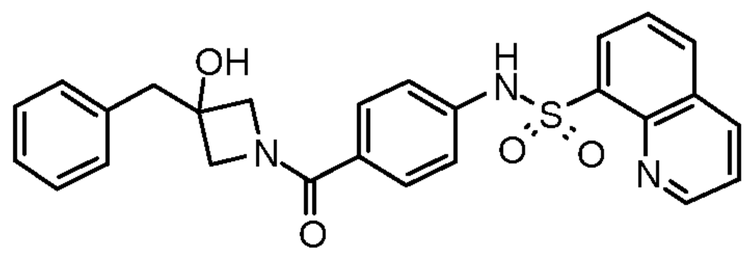
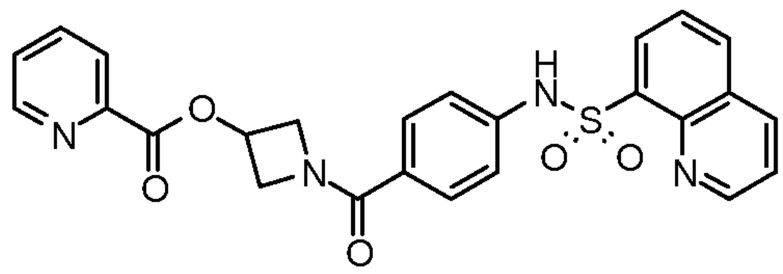
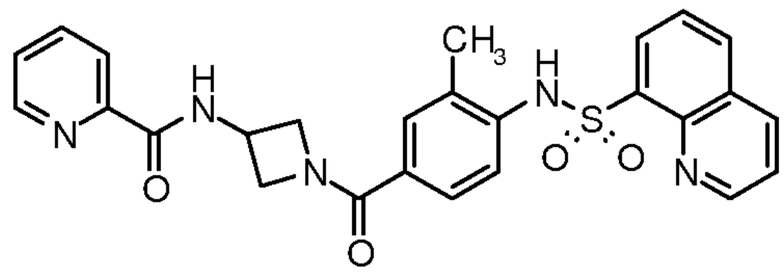
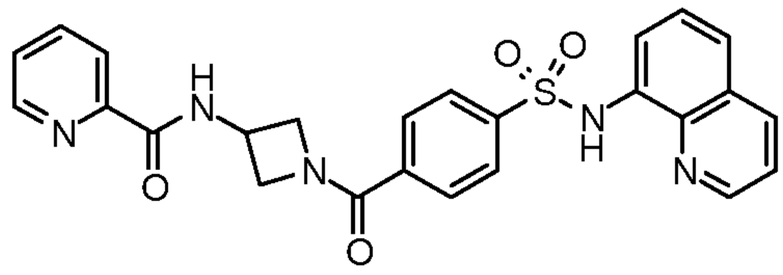
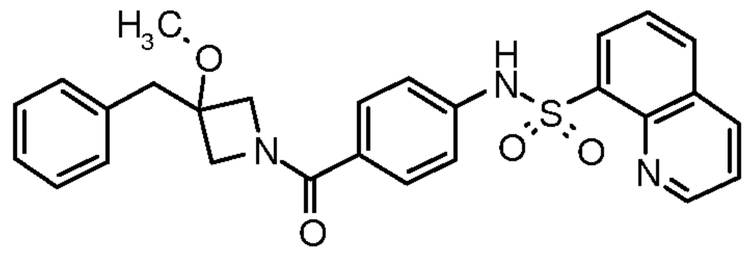
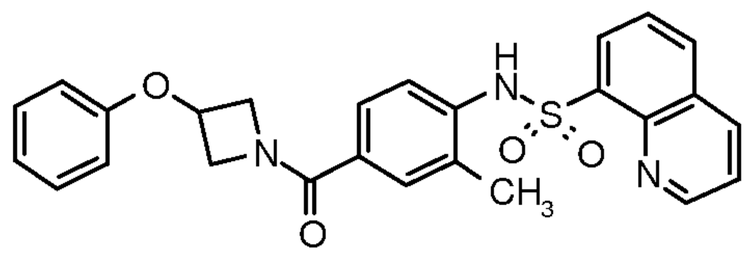
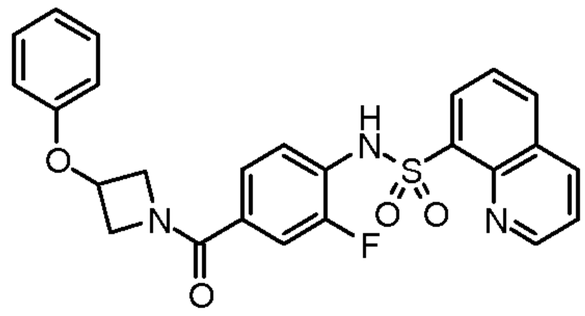
In certain embodiments of Formula II, R^{1a} is phenyl or benzyl, wherein the ring portion of R^{1a} is optionally substituted; and is R^{1b} is hydroxyl. In certain aspects of this embodiment n is 0 or 1; and R^2, when present, is selected from methyl, and methoxy. In other aspects of this embodiment, X is $-NH-S(O)_2$.

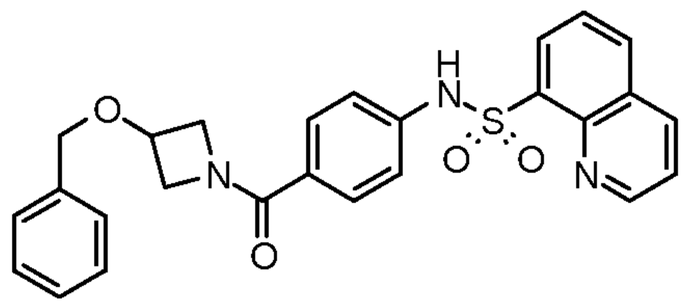
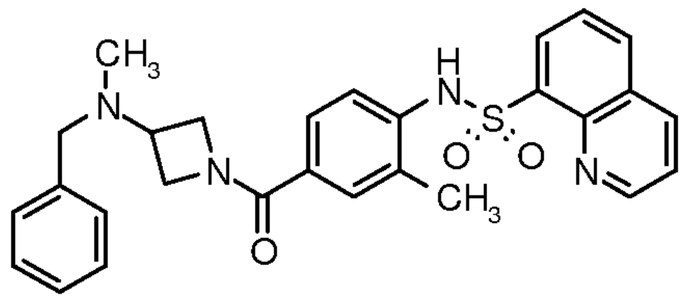
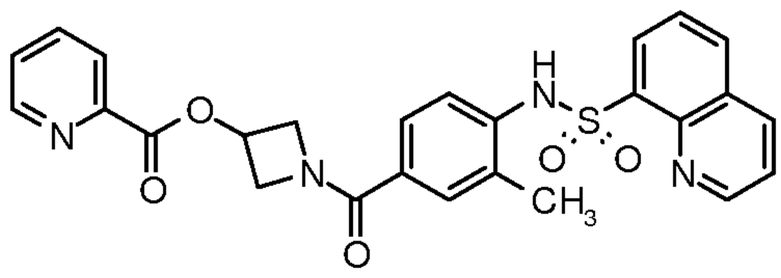
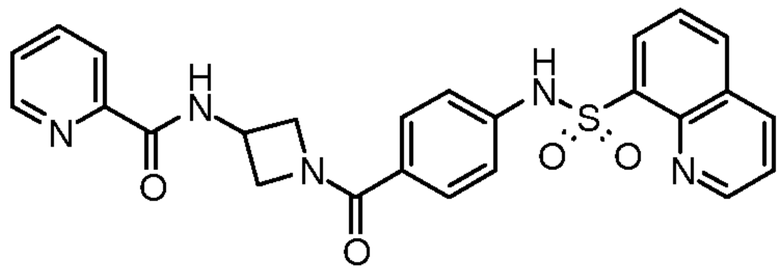
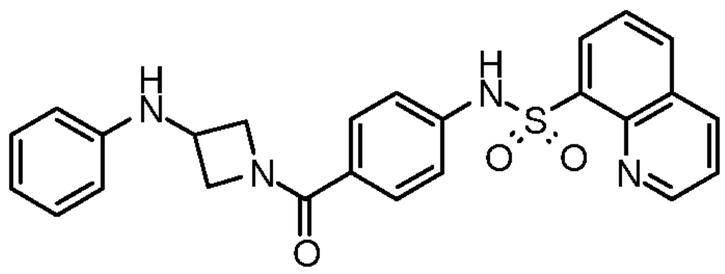
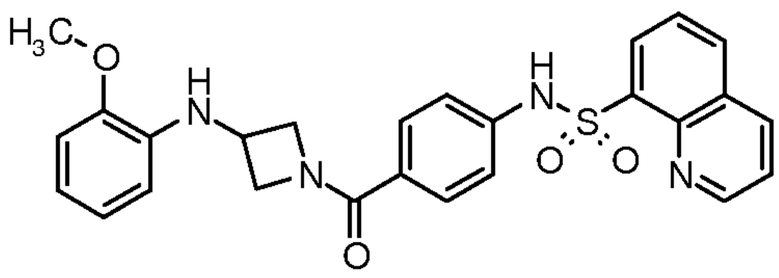
In some embodiments of Formula II, R^{1a} is hydrogen, and R^{1b} is selected from -NH-phenyl, phenoxy, -NH-pyridin-2-yl, $-N(CH_3)$-phenyl, wherein the phenyl or pyridinyl portion of R^{1b} is optionally substituted. In certain aspects of this embodiment n is 0 or 1; and R^2, when present, is selected from methyl, and methoxy. In other aspects of this embodiment, the phenyl or pyridinyl portion of R^{1b} is optionally substituted with methoxy.

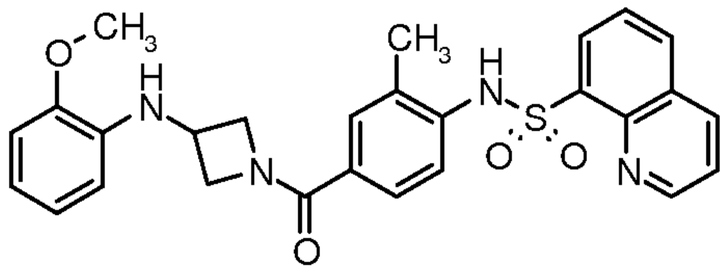
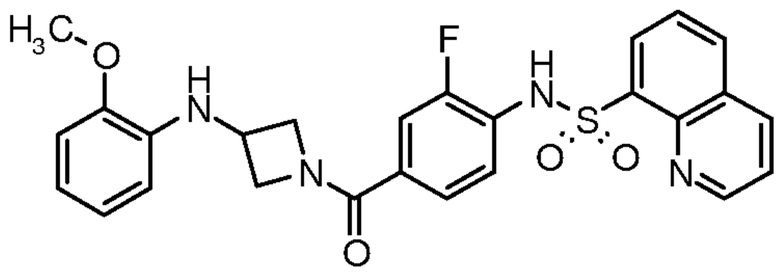
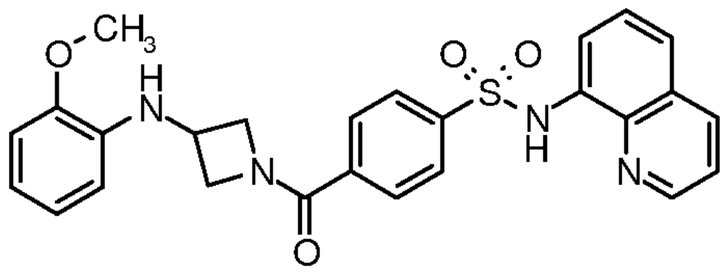
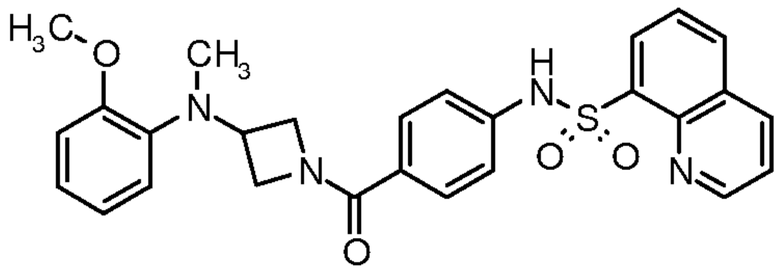
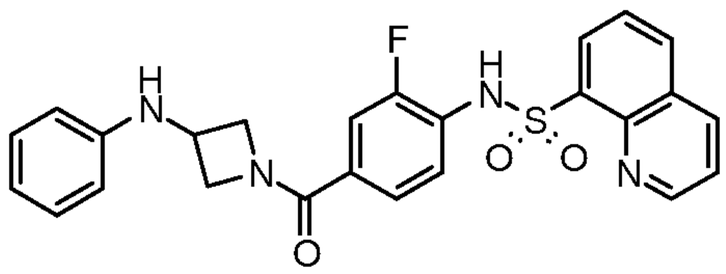
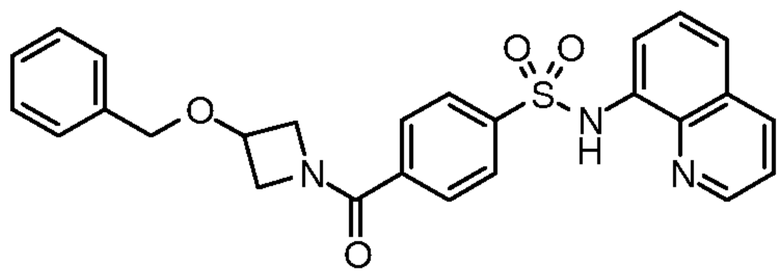
In yet another embodiment, the compound is selected from any one of the compounds set forth in Table 1, below:

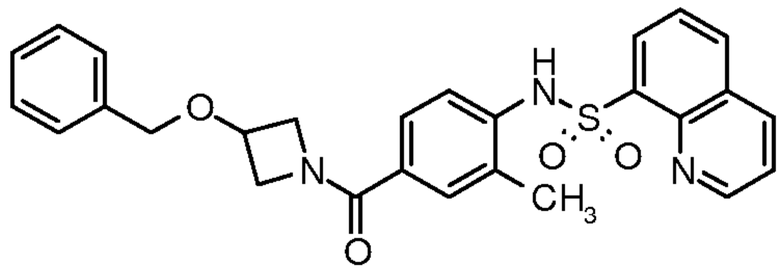
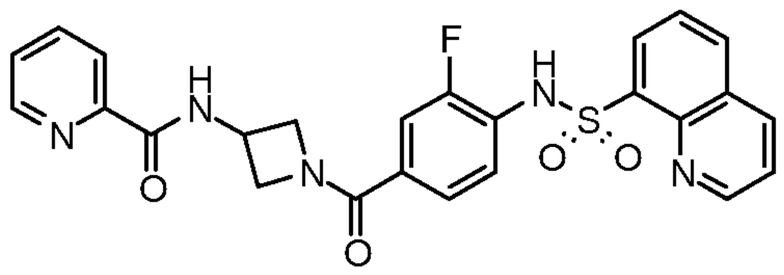
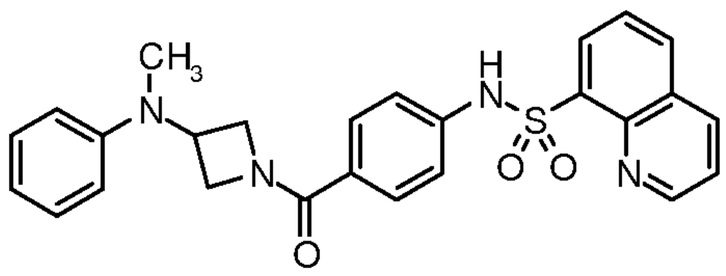
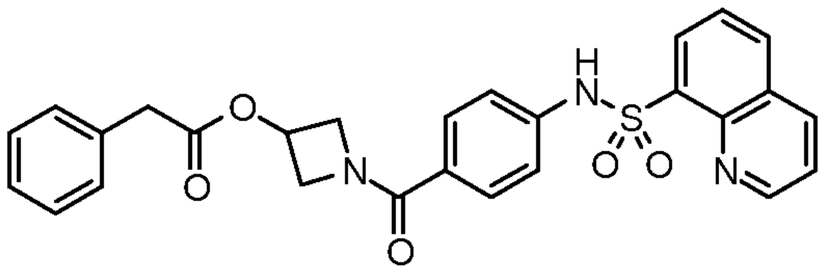
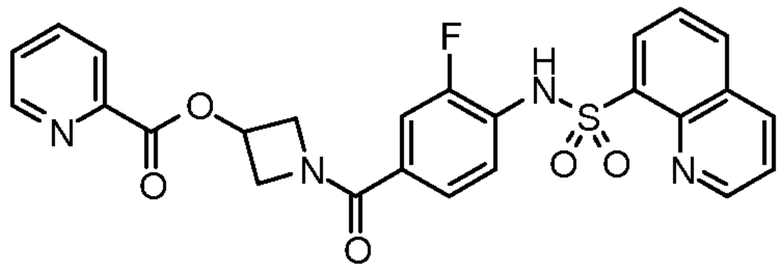
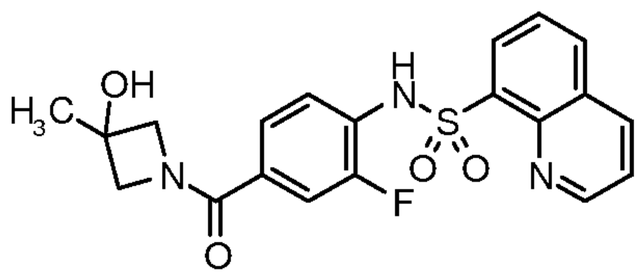
Table 1. Exemplary Compounds of Formula I:

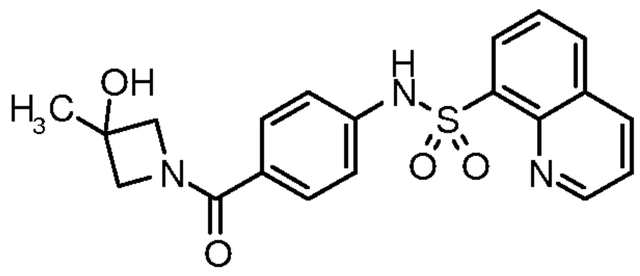
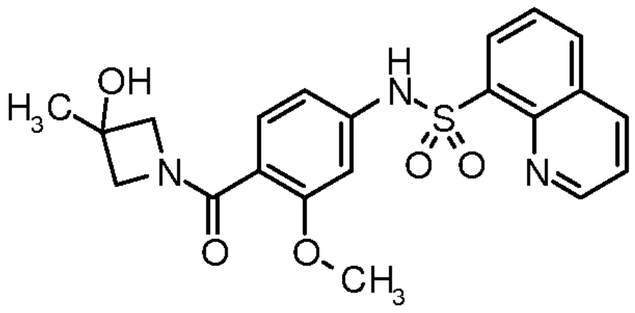
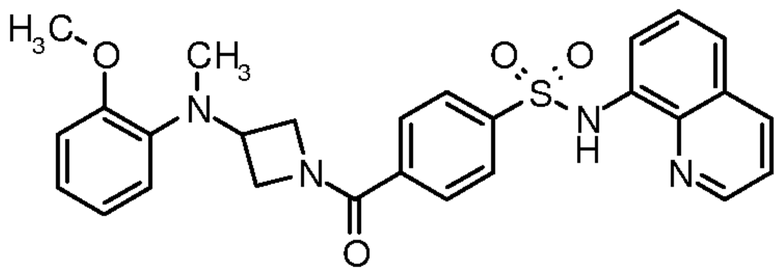
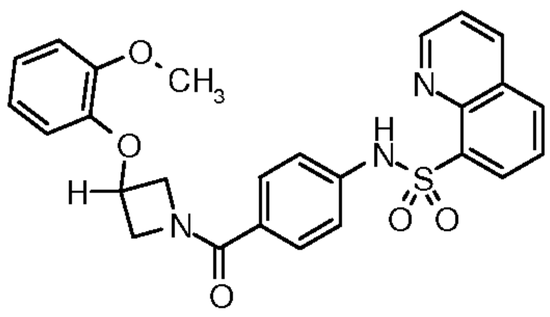
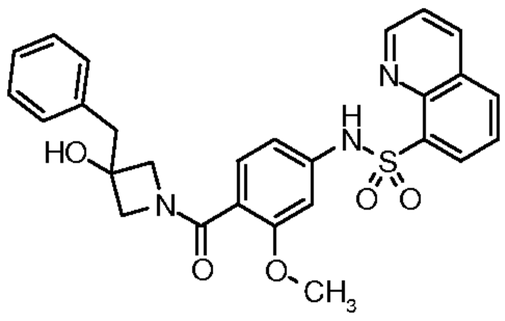
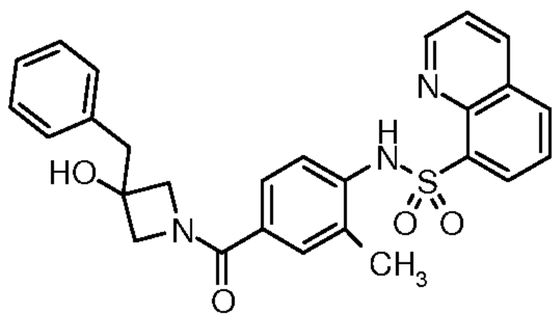
Compound	**Structure**
100	

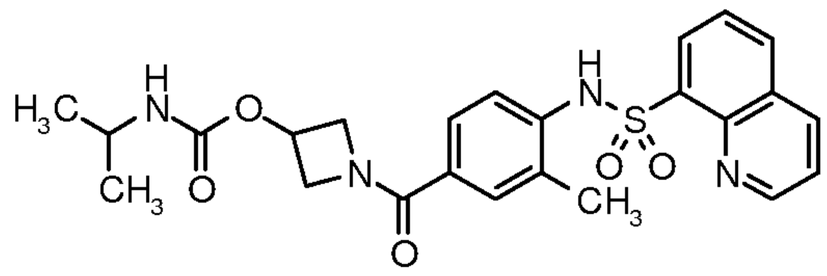
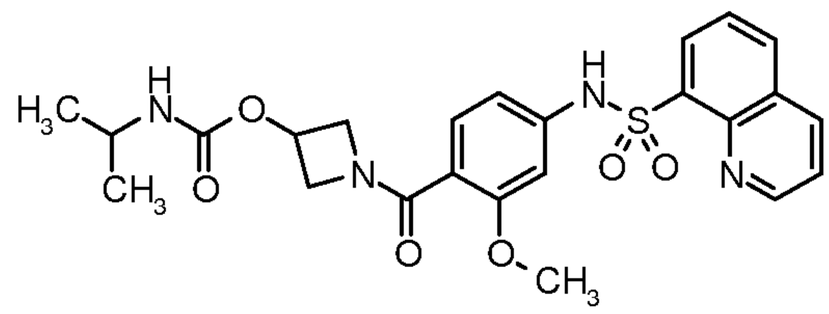
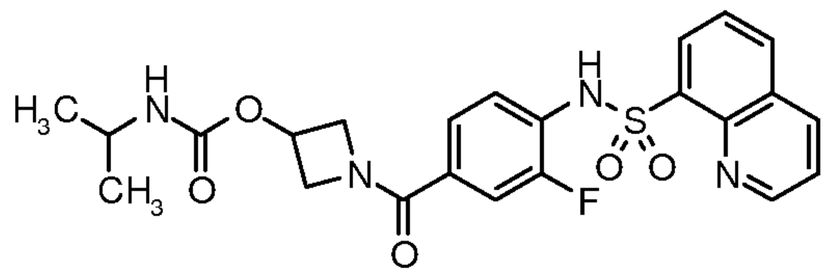
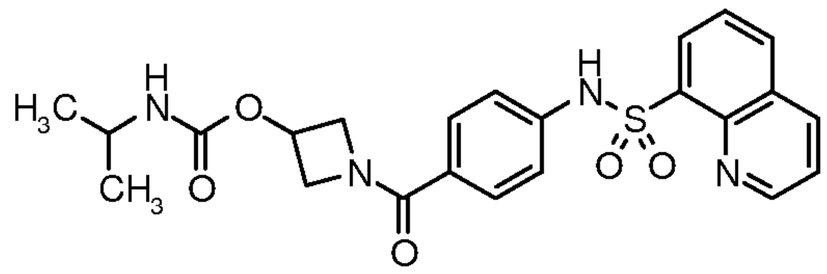
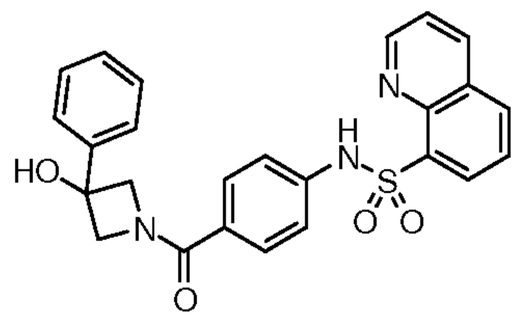
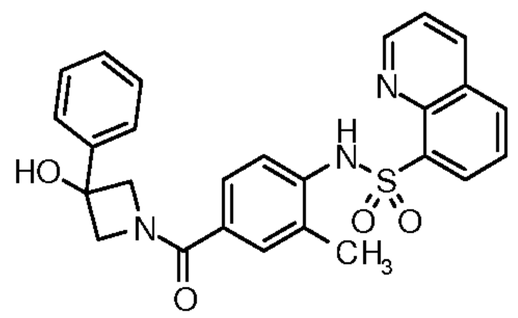
101	
102	
103	
104	
105	
106	
107	

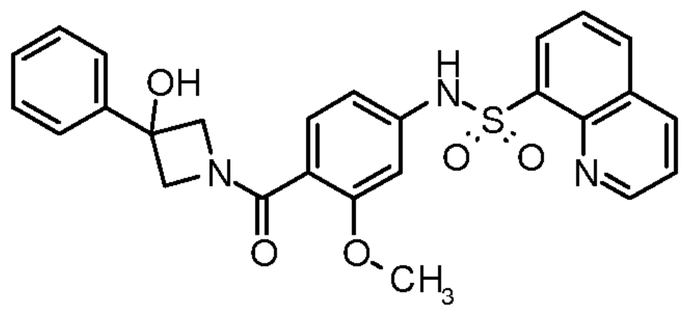
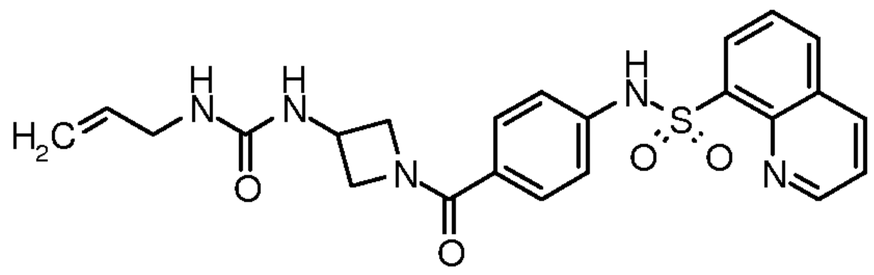
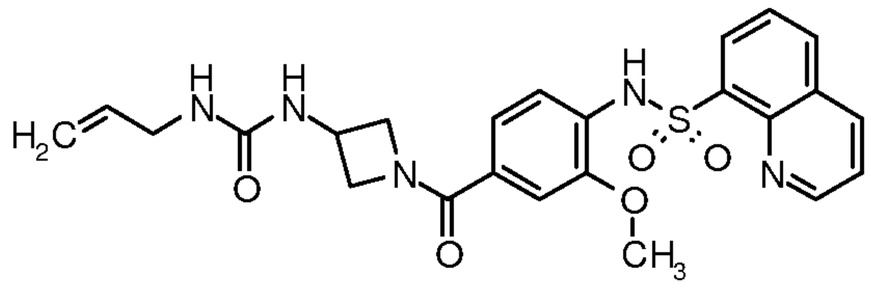
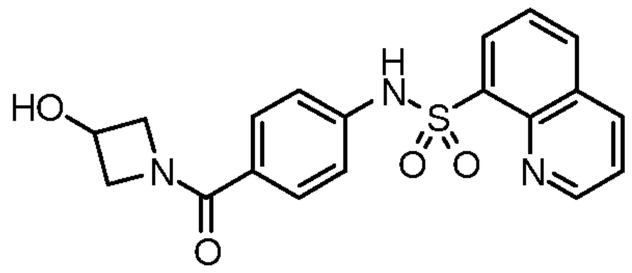
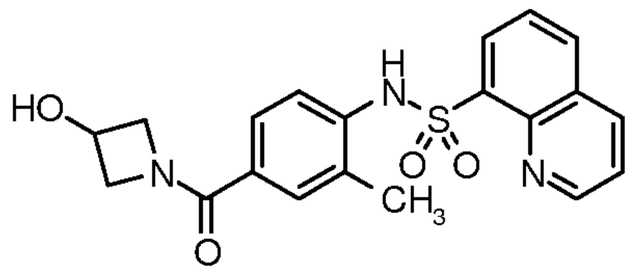
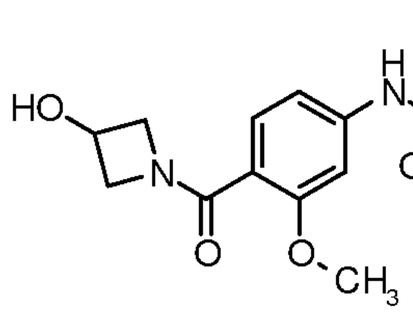
108	
109	
110	
111	
112	
113	

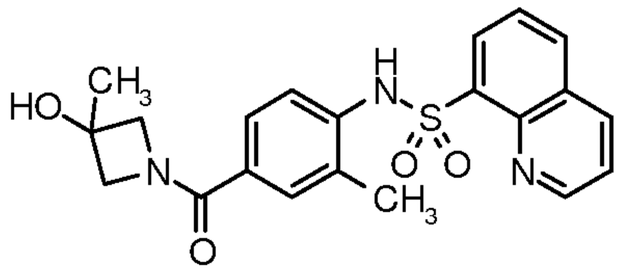
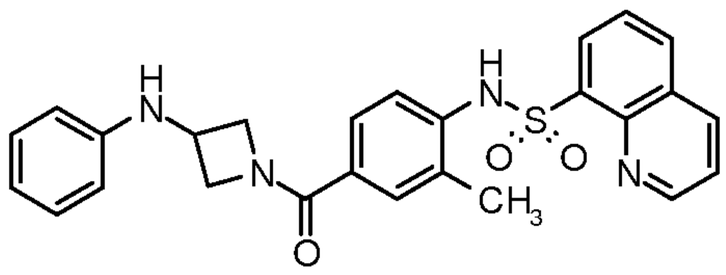
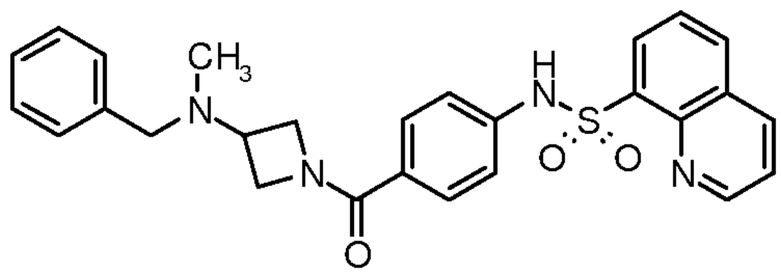
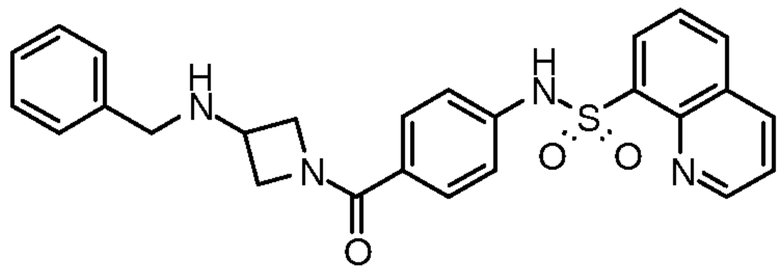
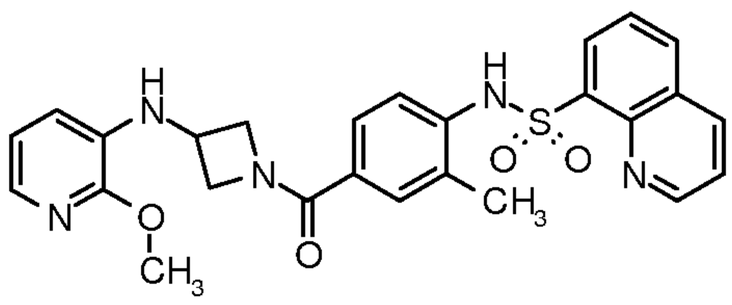
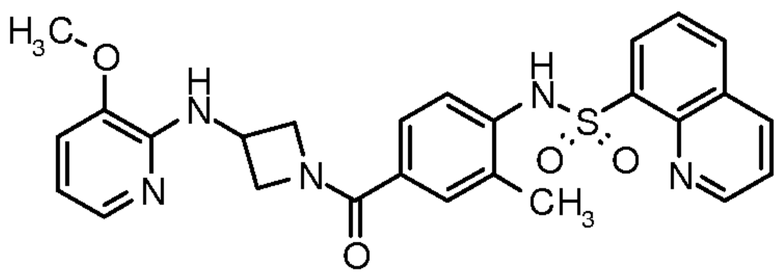
114	
115	
116	
117	
118	
119	

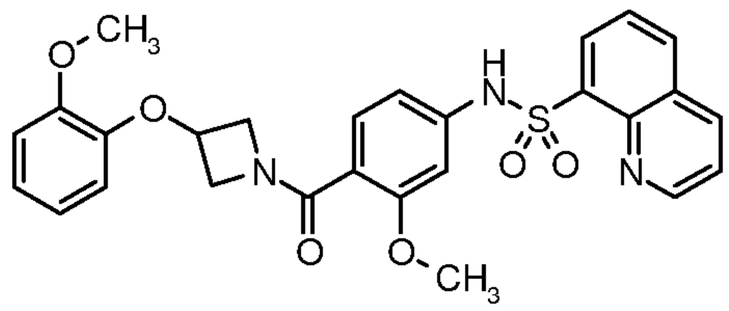
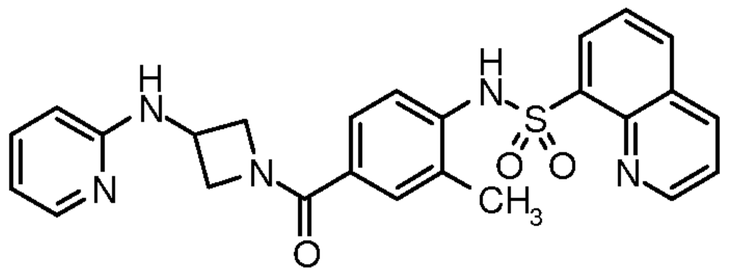
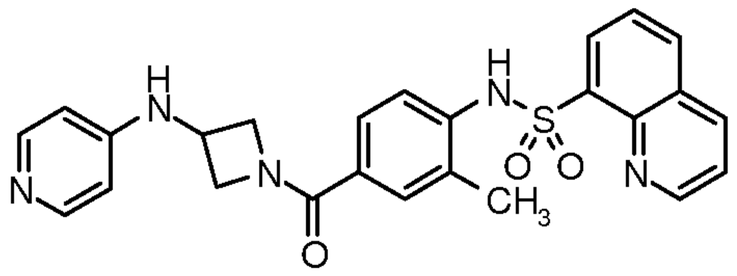
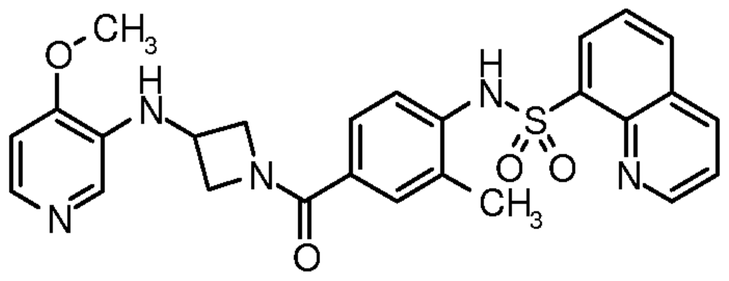
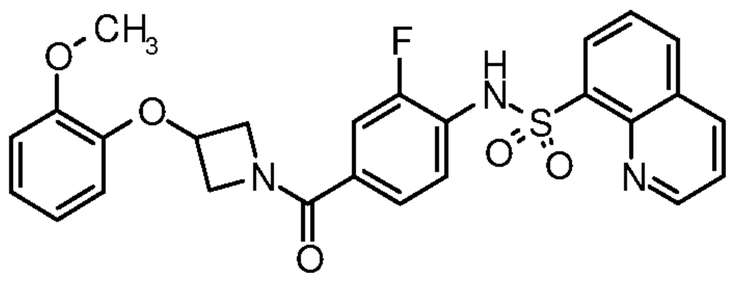
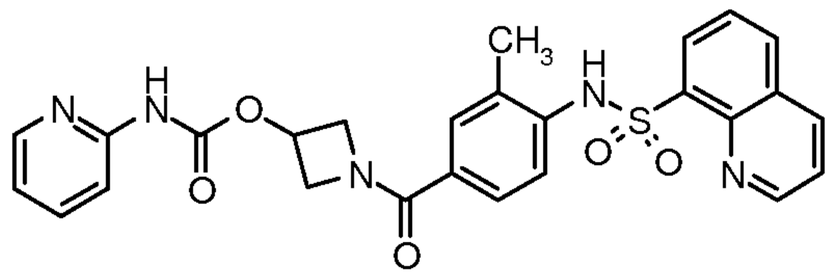
120	
121	
122	
123	
124	
125	

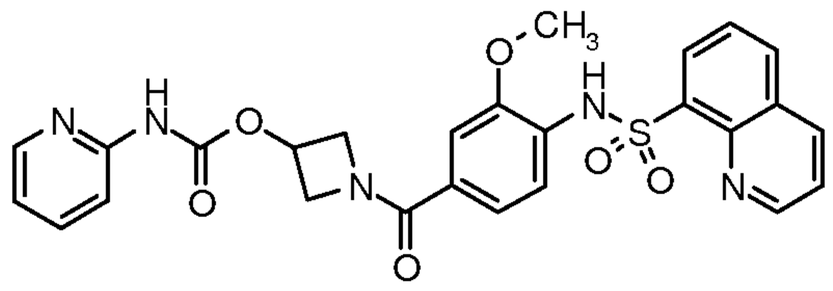
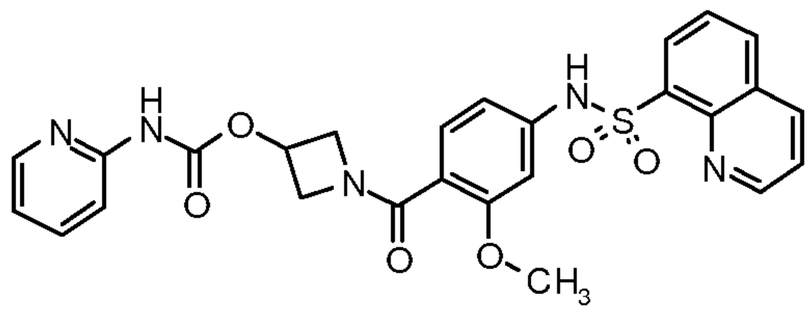
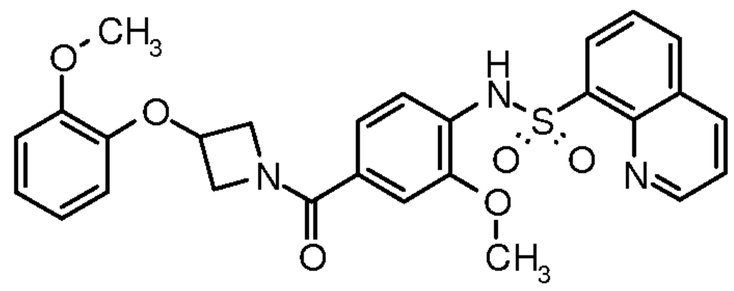
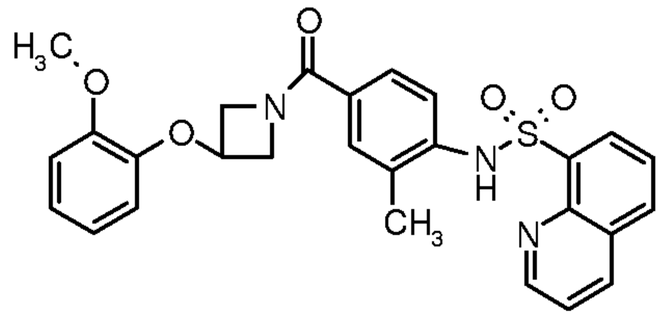
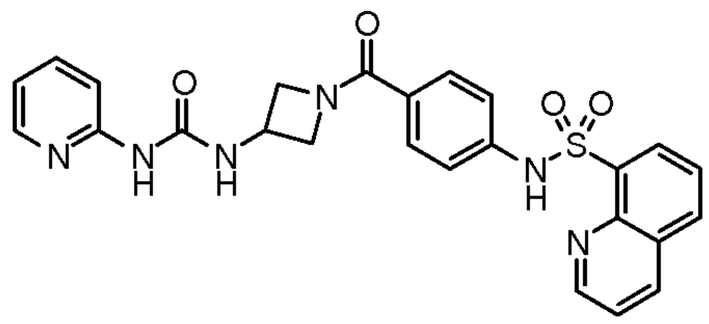
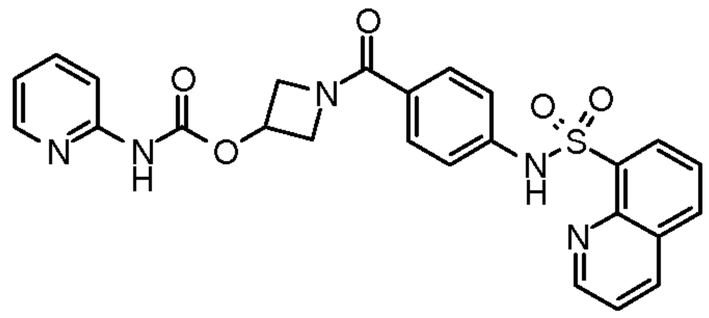
126	
127	
128	
129	
130	
131	

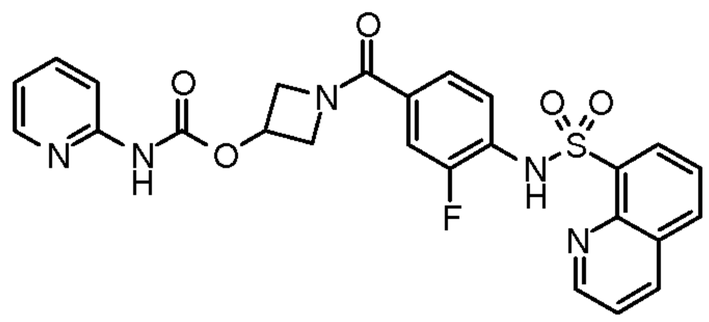
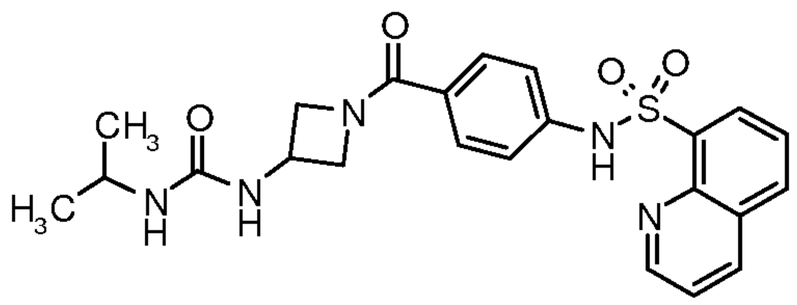
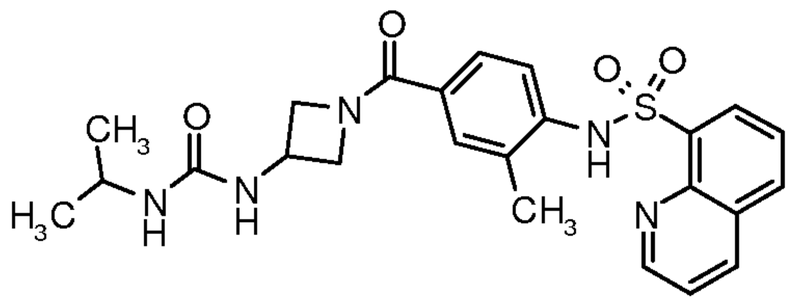
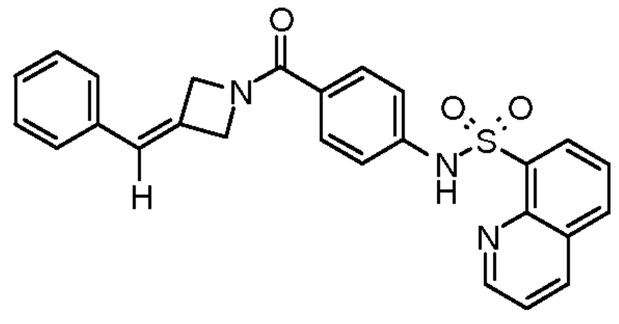
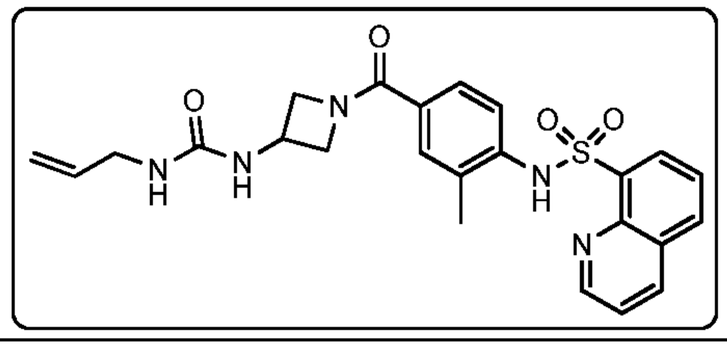
132	
133	
134	
135	
136	
137	

138	
139	
140	
141	
142	
143	

144	
145	
146	
147	
148	
149	

150	
151	
152	
153	
154	
155	

156	
157	
158	
159	
160	
161	

162	
163	
164	
165	
166	

The compounds described herein can be made using a variety of synthetic techniques, general and specific examples of which are set forth in Example section.

As can be appreciated by the skilled artisan, methods of synthesizing the compounds of the formulae herein will be evident to those of ordinary skill in the art. Additionally, the various synthetic steps may be performed in an alternate sequence or order to give the desired compounds. Synthetic chemistry transformations and protecting group methodologies (protection and deprotection) useful in synthesizing

the compounds described herein are known in the art and include, for example, those such as described in R. Larock, *Comprehensive Organic Transformations*, VCH Publishers (1989); T.W. Greene and P.G.M. Wuts, *Protective Groups in Organic Synthesis*, 2d. Ed., John Wiley and Sons (1991); L. Fieser and M. Fieser, *Fieser and Fieser's Reagents for Organic Synthesis*, John Wiley and Sons (1994); and L. Paquette, ed., *Encyclopedia of Reagents for Organic Synthesis*, John Wiley and Sons (1995), and subsequent editions thereof.

The compounds provided herein may contain one or more asymmetric centers and thus occur as racemates and racemic mixtures, single enantiomers, individual diastereomers and diastereomeric mixtures. All such isomeric forms of these compounds are expressly included within the scope. Unless otherwise indicated when a compound is named or depicted by a structure without specifying the stereochemistry and has one or more chiral centers, it is understood to represent all possible stereoisomers of the compound. The compounds provided herewith may also contain linkages (e.g., carbon-carbon bonds) or substituents that can restrict bond rotation, e.g., restriction resulting from the presence of a ring or double bond. Accordingly, all *cis/trans* and *E/Z* isomers are expressly included.

The compounds provided herein (e.g., of Formula I) may also comprise one or more isotopic substitutions. For example, H may be in any isotopic form, including ^{1}H, ^{2}H (D or deuterium), and ^{3}H (T or tritium); C may be in any isotopic form, including ^{12}C, ^{13}C, and ^{14}C; O may be in any isotopic form, including ^{16}O and ^{18}O; and the like. The compounds provided herein may also be represented in multiple tautomeric forms, in such instances, expressly includes all tautomeric forms of the compounds described herein, even though only a single tautomeric form may be represented (e.g., alkylation of a ring system may result in alkylation at multiple sites; all such reaction products are expressly included). All such isomeric forms of such compounds are expressly included. All crystal forms of the compounds described herein are expressly included.

The compounds provided herein include the compounds themselves, as well as their salts and their prodrugs, if applicable. A salt, for example, can be formed between an anion and a positively charged substituent (e.g., amino) on a compound

described herein. Suitable anions include chloride, bromide, iodide, sulfate, nitrate, phosphate, citrate, methanesulfonate, trifluoroacetate, and acetate. Likewise, a salt can also be formed between a cation and a negatively charged substituent (e.g., carboxylate) on a compound described herein. Suitable cations include sodium ion, potassium ion, magnesium ion, calcium ion, and an ammonium cation such as tetramethylammonium ion. Examples of prodrugs include esters and other pharmaceutically acceptable derivatives, which, upon administration to a subject, are capable of providing active compounds.

The compounds provided herein may be modified by appending appropriate functionalities to enhance selected biological properties, e.g., targeting to a particular tissue. Such modifications are known in the art and include those which increase biological penetration into a given biological compartment (e.g., blood, lymphatic system, central nervous system), increase oral availability, increase solubility to allow administration by injection, alter metabolism and alter rate of excretion.

In an alternate embodiment, the compounds described herein may be used as platforms or scaffolds that may be utilized in combinatorial chemistry techniques for preparation of derivatives and/or chemical libraries of compounds. Such derivatives and libraries of compounds have biological activity and are useful for identifying and designing compounds possessing a particular activity. Combinatorial techniques suitable for utilizing the compounds described herein are known in the art as exemplified by Obrecht, D. and Villalgrodo, J.M., *Solid-Supported Combinatorial and Parallel Synthesis of Small-Molecular-Weight Compound Libraries*, Pergamon-Elsevier Science Limited (1998), and include those such as the "split and pool" or "parallel" synthesis techniques, solid-phase and solution-phase techniques, and encoding techniques (see, for example, Czarnik, A.W., *Curr. Opin. Chem. Bio.*, (1997) 1, 60. Thus, one embodiment relates to a method of using the compounds described herein for generating derivatives or chemical libraries comprising: 1) providing a body comprising a plurality of wells; 2) providing one or more compounds identified by methods described herein in each well; 3) providing an additional one or more chemicals in each well; 4) isolating the resulting one or more products from each well. An alternate embodiment relates to a method of using the

compounds described herein for generating derivatives or chemical libraries comprising: 1) providing one or more compounds described herein attached to a solid support; 2) treating the one or more compounds identified by methods described herein attached to a solid support with one or more additional chemicals; 3) isolating the resulting one or more products from the solid support. In the methods described above, "tags" or identifier or labeling moieties may be attached to and/or detached from the compounds described herein or their derivatives, to facilitate tracking, identification or isolation of the desired products or their intermediates. Such moieties are known in the art. The chemicals used in the aforementioned methods may include, for example, solvents, reagents, catalysts, protecting group and deprotecting group reagents and the like. Examples of such chemicals are those that appear in the various synthetic and protecting group chemistry texts and treatises referenced herein.

Methods of evaluating compounds

The compounds described herein can be evaluated for ability to modulate PKM2 (e.g., activate PKM2) by methods known in the art. In some embodiments, compounds described herein are evaluated for ability to modulate PKM2 (e.g., activate PKM2) in serine deficient conditions. In some embodiments, exemplary methods include contacting the compound with a cell-based assay which allows assessment of the ability to modulate (e.g., activate) PKM2. E.g., the candidate compound can be contacted with a cell and measuring the consumption of oxygen or production of lactate. A change in cellular phosphoenolpyruvate, a change in glycerol-phosphate, a change in ribose or deoxyribose, a change in lipid synthesis, or a change in glucose conversion to lipid or nucleic acids or amino acids or protein can also be used to evaluate a compound for its ability to modulate PKM2 (e.g., activate PKM2). The evaluation could also include measuring a change in pyruvate or a determination of an alteration in mitochondrial membrane potential, e.g., as measured by fluorescent potentiometric dyes.

PKM1 and PKM2 for use in the screening/testing method may be produced by any method known in the art for expression of recombinant proteins. For example,

nucleic acids that encode the desired polypeptide may be introduced into various cell types or cell-free systems for expression. Eukaryotic (e.g., COS, HEK293T, CHO, and NIH cell lines) and prokaryotic (e.g., E. coli) expression systems may be generated in which a PKM sequence is introduced into a plasmid or other vector, which is then used to transform living cells. Constructs in which the PKM cDNA contains the entire open reading frame, or biologically active fragment thereof, are inserted in the correct orientation into an expression plasmid and may be used for protein expression. Prokaryotic and eukaryotic expression systems allow for the expression and recovery of fusion proteins in which the PKM protein is covalently linked to a tag molecule on either the amino terminal or carboxy terminal side, which facilitates identification and/or purification. Examples of tags that can be used include hexahistidine, HA, FLAG, and c-myc epitope tags. An enzymatic or chemical cleavage site can be engineered between the PKM protein and the tag molecule so that the tag can be removed following purification.

The activity of the PKM enzyme measured in the screening/testing assay may be measured by, e.g., monitoring the concentration of a substrate (e.g., ATP or NADH) present in the reaction mixture. Pyruvate, produced by the enzymatic activity of pyruvate kinase, is converted into lactate by lactate dehydrogenase, which requires the consumption of NADH (NADH → NAD+). Thus, the activity of PKM2 can be indirectly measured by monitoring the consumption of NADH through, e.g., fluorescence assays. Additionally, the activity of the PKM2 enzyme can be directly monitored by measuring the production of ATP, as ATP is produced when phosphoenolpyruvate is converted to pyruvate. Methods for monitoring the amount of substrate in a reaction mixture include, e.g., absorbance, fluorescence, Raman scattering, phosphorescence, luminescence, luciferase assays, and radioactivity.

The screening procedure requires the presence of specific components in the reaction mixture. Components utilized in the assay include, e.g., a nucleoside diphosphate (e.g., ADP), phosphoenolpyruvate, NADH, lactate dehydrogenase, FBP, a reducing agent (e.g., dithiothreitol), a detergent (e.g., Brij 35), glycerol, and a solvent (e.g., DMSO). Exemplary reaction conditions are found in Table 1.

Table 1

Component of Reaction Condition	Amount in Activation Assay
ADP	0.1-5.0 mM
Phosphoenolpyruvate	0.1-5.0 mM
NADH	10-1000 μM
Lactate dehydrogenase	0.1-10 units
Fructose-1,6-bisphosphate	0
DTT	0.1-50 mM
Brij 35	0.01-1%
Glycerol	0.1-10%
Pyruvate Kinase M2 (used for screen)	1-100 pg
DMSO	1-10%

Compounds useful as PKM2 activators are those that demonstrate specificity and activation of PKM2 enzyme in the absence of FBP to a level greater than that of 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 99, or 100% in the presence of FBP. Furthermore, compounds can be evaluated in the presence or absence of a phosphotyrosine peptide. Phosphotyrosine peptide binding to PKM2 leads to a dissociation of FBP from PKM2 and conformational changes of PKM2 from an active, tetrameric form to an inactive form. Compounds that bind to PKM2 and lock the enzyme in the active confirmation even in the presence of a phosphotyrosine peptide will lead to the loss of allosteric control of PKM2 needed for shunting the biochemical intermediates from glycolysis into biosynthesis of other intermediates. This, in turn, will lead to inhibition of growth of cancer cells, activated immune cells and fat cells.

Methods of Treatment

In one embodiment, provided is a method for treating or preventing a disease, condition or disorder as described herein (e.g., treating) comprising administering a compound, a pharmaceutically acceptable salt of a compound or pharmaceutical composition comprising a compound described herein (e.g., a compound of formula (I), (II), or in Figure 1).

The compounds and compositions described herein can be administered to cells in culture, e.g., *in vitro* or *ex vivo*, or to a subject, e.g., *in vivo*, to treat, prevent, and/or diagnose a variety of disorders, including those described herein below.

As used herein, the term "treat" or "treatment" is defined as the application or administration of a compound, alone or in combination with, a second therapeutic agent to a subject, e.g., a patient, or application or administration of the compound to an isolated tissue or cell, e.g., cell line, from a subject, e.g., a patient, who has a disorder (e.g., a disorder as described herein), a symptom of a disorder, with the purpose to cure, heal, alleviate, relieve, alter, remedy, ameliorate, improve or affect the disorder, or one or more symptoms of the disorder.

As used herein, an amount of a compound effective to treat a disorder, or a "therapeutically effective amount" refers to an amount of the compound which is effective, upon single or multiple dose administration to a subject, in treating a cell, or in curing, alleviating, relieving or improving a subject with a disorder beyond that expected in the absence of such treatment.

As used herein, the term "prevent" is defined as the application or administration of a compound, alone or in combination with, a second therapeutic agent to a subject, e.g., a patient, or application or administration of the compound to an isolated tissue or cell, e.g., cell line, from a subject, e.g., a patient, who has a predisposition toward a disorder, with the purpose to prevent the occurrence of at least one symptom of the disorder or to delay onset of at least one symptom of the disorder).

As used herein, an amount of a compound effective to prevent a disorder, or a "a prophylactically effective amount" of the compound refers to an amount effective, upon single- or multiple-dose administration to the subject, in preventing or delaying the occurrence of the onset or recurrence of a disorder or a symptom of the disorder.

As used herein, the term "subject" is intended to include human and non-human animals. Exemplary human subjects include a human patient having a disorder, e.g., a disorder described herein or a normal subject. The term "non-human animals" includes all vertebrates, e.g., non-mammals (such as chickens, amphibians,

reptiles) and mammals, such as non-human primates, domesticated and/or agriculturally useful animals, e.g., sheep, dog, cat, cow, pig, etc.

Neoplastic Disorders

A compound or composition described herein can be used to treat a neoplastic disorder. A "neoplastic disorder" is a disease or disorder characterized by cells that have the capacity for autonomous growth or replication, e.g., an abnormal state or condition characterized by proliferative cell growth. Exemplary neoplastic disorders include: carcinoma, sarcoma, metastatic disorders (e.g., tumors arising from prostate, colon, lung, breast and liver origin), hematopoietic neoplastic disorders, e.g., leukemias, metastatic tumors. Prevalent cancers include: breast, prostate, colon, lung, liver, and pancreatic cancers. Treatment with the compound may be in an amount effective to ameliorate at least one symptom of the neoplastic disorder, e.g., reduced cell proliferation, reduced tumor mass, etc.

The disclosed methods are useful in the prevention and treatment of cancer, including for example, solid tumors, soft tissue tumors, and metastases thereof. The disclosed methods are also useful in treating non-solid cancers. Exemplary solid tumors include malignancies (e.g., sarcomas, adenocarcinomas, and carcinomas) of the various organ systems, such as those of lung, breast, lymphoid, gastrointestinal (e.g., colon), and genitourinary (e.g., renal, urothelial, or testicular tumors) tracts, pharynx, prostate, and ovary. Exemplary adenocarcinomas include colorectal cancers, renal-cell carcinoma, liver cancer, non-small cell carcinoma of the lung, and cancer of the small intestine.

Without being bound by theory, applicants believe that altered PKM2 levels characterize a subset of all types of cancers, without regard to their cellular nature or location in the body. Thus, the compounds and methods disclosed herein are useful to treat any type of cancer that is characterized by altered PKM2 levels.

Cancer Combination therapies

In some embodiments, a compound described herein is administered together with one or more additional cancer treatments. Exemplary cancer treatments include,

for example: chemotherapy, targeted therapies such as antibody therapies, immunotherapy, and hormonal therapy. Examples of each of these treatments are provided below.

Chemotherapy

In some embodiments, a compound described herein is administered with one or morechemotherapies. Chemotherapy is the treatment of cancer with drugs that can destroy cancer cells. "Chemotherapy" usually refers to cytotoxic drugs which affect rapidly dividing cells in general, in contrast with targeted therapy. Chemotherapy drugs interfere with cell division in various possible ways, e.g., with the duplication of DNA or the separation of newly formed chromosomes. Most forms of chemotherapy target all rapidly dividing cells and are not specific for cancer cells, although some degree of specificity may come from the inability of many cancer cells to repair DNA damage, while normal cells generally can.

Examples of chemotherapeutic agents used in cancer therapy include, for example, antimetabolites (e.g., folic acid, purine, and pyrimidine derivatives) and alkylating agents (e.g., nitrogen mustards, nitrosoureas, platinum, alkyl sulfonates, hydrazines, triazenes, aziridines, spindle poison, cytotoxic agents, toposimerase inhibitors and others). Exemplary agents include Aclarubicin, Actinomycin, Alitretinon, Altretamine, Aminopterin, Aminolevulinic acid, Amrubicin, Amsacrine, Anagrelide, Arsenic trioxide, Asparaginase, Atrasentan, Belotecan, Bexarotene, endamustine, Bleomycin, Bortezomib, Busulfan, Camptothecin, Capecitabine, Carboplatin, Carboquone, Carmofur, Carmustine, Celecoxib, Chlorambucil, Chlormethine, Cisplatin, Cladribine, Clofarabine, Crisantaspase, Cyclophosphamide, Cytarabine, Dacarbazine, Dactinomycin, Daunorubicin, Decitabine, Demecolcine, Docetaxel, Doxorubicin, Efaproxiral, Elesclomol, Elsamitrucin, Enocitabine, Epirubicin, Estramustine, Etoglucid, Etoposide, Floxuridine, Fludarabine, Fluorouracil (5FU), Fotemustine, Gemcitabine, Gliadel implants, Hydroxycarbamide, Hydroxyurea, Idarubicin, Ifosfamide, Irinotecan, Irofulven, Ixabepilone, Larotaxel, Leucovorin, Liposomal doxorubicin, Liposomal daunorubicin, Lonidamine, Lomustine, Lucanthone, Mannosulfan, Masoprocol, Melphalan, Mercaptopurine, Mesna, Methotrexate, Methyl aminolevulinate, Mitobronitol, Mitoguazone, Mitotane,

Mitomycin, Mitoxantrone, Nedaplatin, Nimustine, Oblimersen, Omacetaxine, Ortataxel, Oxaliplatin, Paclitaxel, Pegaspargase, Pemetrexed, Pentostatin, Pirarubicin, Pixantrone, Plicamycin, Porfimer sodium, Prednimustine, Procarbazine, Raltitrexed, Ranimustine, Rubitecan, Sapacitabine, Semustine, Sitimagene ceradenovec, Satraplatin, Streptozocin, Talaporfin, Tegafur-uracil, Temoporfin, Temozolomide, Teniposide, Tesetaxel, Testolactone, Tetranitrate, Thiotepa, Tiazofurin, Tioguanine, Tipifarnib, Topotecan, Trabectedin, Triaziquone, Triethylenemelamine, Triplatin, Tretinoin, Treosulfan, Trofosfamide, Uramustine, Valrubicin, Verteporfin, Vinblastine, Vincristine, Vindesine, Vinflunine, Vinorelbine, Vorinostat, Zorubicin, and other cytostatic or cytotoxic agents described herein.

Because some drugs work better together than alone, two or more drugs are often given at the same time. Often, two or more chemotherapy agents are used as combination chemotherapy. In some embodiments, the chemotherapy agents (including combination chemotherapy) can be used in combination with a compound described herein.

Targeted therapy

In some embodiments, a compound described herein is administered with one or more targeted therapies. Targeted therapy constitutes the use of agents specific for the deregulated proteins of cancer cells. Small molecule targeted therapy drugs are generally inhibitors of enzymatic domains on mutated, overexpressed, or otherwise critical proteins within the cancer cell. Prominent examples are the tyrosine kinase inhibitors such as Axitinib, Bosutinib, Cediranib, dasatinib, erlotinib, imatinib, gefitinib, lapatinib, Lestaurtinib, Nilotinib, Semaxanib, Sorafenib, Sunitinib, and Vandetanib, and also cyclin-dependent kinase inhibitors such as Alvocidib and Seliciclib. Monoclonal antibody therapy is another strategy in which the therapeutic agent is an antibody which specifically binds to a protein on the surface of the cancer cells. Examples include the anti-HER2/neu antibody trastuzumab (HERCEPTIN®) typically used in breast cancer, and the anti-CD20 antibody rituximab and Tositumomab typically used in a variety of B-cell malignancies. Other exemplary anbibodies include Cetuximab, Panitumumab, Trastuzumab, Alemtuzumab, Bevacizumab, Edrecolomab, and Gemtuzumab. Exemplary fusion proteins include

Aflibercept and Denileukin diftitox. In some embodiments, the targeted therapy can be used in combination with a compound described herein.

Targeted therapy can also involve small peptides as "homing devices" which can bind to cell surface receptors or affected extracellular matrix surrounding the tumor. Radionuclides which are attached to these peptides (e.g., RGDs) eventually kill the cancer cell if the nuclide decays in the vicinity of the cell. An example of such therapy includes BEXXAR®.

Immunotherapy

In some embodiments, a compound described herein is administered with one or more immunotherapies. Cancer immunotherapy refers to a diverse set of therapeutic strategies designed to induce the patient's own immune system to fight the tumor. Contemporary methods for generating an immune response against tumors include intravesicular BCG immunotherapy for superficial bladder cancer, and use of interferons and other cytokines to induce an immune response in renal cell carcinoma and melanoma patients.

Allogeneic hematopoietic stem cell transplantation can be considered a form of immunotherapy, since the donor's immune cells will often attack the tumor in a graft-versus-tumor effect. In some embodiments, the immunotherapy agents can be used in combination with a compound described herein.

Hormonal therapy

In some embodiments, a compound described herein is administered with one or more hormonal therapies. The growth of some cancers can be inhibited by providing or blocking certain hormones. Common examples of hormone-sensitive tumors include certain types of breast and prostate cancers. Removing or blocking estrogen or testosterone is often an important additional treatment. In certain cancers, administration of hormone agonists, such as progestogens may be therapeutically beneficial. In some embodiments, the hormonal therapy agents can be used in combination with a compound described herein.

Obesity and fat disorders

A compound or composition described herein can be used to treat or prevent obesity, e.g., in a human subject, e.g., a child or adult subject. "Obesity" refers to a condition in which a subject has a body mass index of greater than or equal to 30. Many compounds described herein can be used to treat or prevent an over-weight condition. "Over-weight" refers to a condition in which a subject has a body mass index of greater or equal to 25.0. The body mass index (BMI) and other definitions are according to the "NIH Clinical Guidelines on the Identification and Evaluation, and Treatment of Overweight and Obesity in Adults" (1998). Treatment with the compound may be in an amount effective to alter the weight of the subject, e.g., by at least 2, 5, 7, 10, 12, 15, 20, 25, 30, 25, 40, 45, 50, or 55%. Treatment with a compound may be in an amount effective to reduce the body mass index of the subject, e.g., to less than 30, 28, 27, 25, 22, 20, or 18. The compounds can be used to treat or prevent aberrant or inappropriate weight gain, metabolic rate, or fat deposition, e.g., anorexia, bulimia, obesity, diabetes, or hyperlipidemia (e.g., elevated triglycerides and/or elevated cholesterol), as well as disorders of fat or lipid metabolism.

A compound or composition described herein can be administered to treat obesity associated with Prader-Willi Syndrome (PWS). PWS is a genetic disorder associated with obesity (e.g., morbid obesity).

A compound or composition described herein can be used to reduce body fat, prevent increased body fat, reduce cholesterol (e.g., total cholesterol and/or ratios of total cholesterol to HDL cholesterol), and/or reduce appetite in individuals having PWS associated obesity, and/or reduce comorbidities such as diabetes, cardiovascular disease, and stroke.

Compositions and routes of administration

The compositions delineated herein include the compounds delineated herein (e.g., a compound described herein), as well as additional therapeutic agents if present, in amounts effective for achieving a modulation of disease or disease symptoms, including those described herein.

The term "pharmaceutically acceptable carrier or adjuvant" refers to a carrier or adjuvant that may be administered to a patient, together with a compound provided herewith, and which does not destroy the pharmacological activity thereof and is nontoxic when administered in doses sufficient to deliver a therapeutic amount of the compound.

Pharmaceutically acceptable carriers, adjuvants and vehicles that may be used in the pharmaceutical compositions provided herewith include, but are not limited to, ion exchangers, alumina, aluminum stearate, lecithin, self-emulsifying drug delivery systems (SEDDS) such as d-α-tocopherol polyethyleneglycol 1000 succinate, surfactants used in pharmaceutical dosage forms such as Tweens or other similar polymeric delivery matrices, 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. Cyclodextrins such as α-, β-, and γ-cyclodextrin, or chemically modified derivatives such as hydroxyalkylcyclodextrins, including 2- and 3-hydroxypropyl-β-cyclodextrins, or other solubilized derivatives may also be advantageously used to enhance delivery of compounds of the formulae described herein.

The pharmaceutical compositions provided herewith may be administered orally, parenterally, by inhalation spray, topically, rectally, nasally, buccally, vaginally or via an implanted reservoir, preferably by oral administration or administration by injection. The pharmaceutical compositions provided herewith may contain any conventional non-toxic pharmaceutically-acceptable carriers, adjuvants or vehicles. In some cases, the pH of the formulation may be adjusted with pharmaceutically acceptable acids, bases or buffers to enhance the stability of the formulated compound or its delivery form. The term parenteral as used herein includes subcutaneous, intracutaneous, intravenous, intramuscular, intraarticular,

intraarterial, intrasynovial, intrasternal, intrathecal, intralesional and intracranial injection or infusion techniques.

The pharmaceutical compositions may be in the form of a sterile injectable preparation, for example, as a sterile injectable aqueous or oleaginous suspension. This suspension may be formulated according to techniques known in the art using suitable dispersing or wetting agents (such as, for example, Tween 80) 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 mannitol, water, Ringer's solution 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 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, or carboxymethyl cellulose or similar dispersing agents which are commonly used in the formulation of pharmaceutically acceptable dosage forms such as emulsions and or suspensions. Other commonly used surfactants such as Tweens or Spans and/or other similar 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.

The pharmaceutical compositions provided herewith may be orally administered in any orally acceptable dosage form including, but not limited to, capsules, tablets, emulsions and aqueous suspensions, dispersions and solutions. In the case of tablets for oral use, carriers which are 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 corn starch. When aqueous suspensions and/or emulsions are administered orally, the active ingredient may be suspended or dissolved in an oily phase is combined with

emulsifying and/or suspending agents. If desired, certain sweetening and/or flavoring and/or coloring agents may be added.

The pharmaceutical compositions provided herewith may also be administered in the form of suppositories for rectal administration. These compositions can be prepared by mixing a compound provided herewith with a suitable non-irritating excipient which is solid at room temperature but liquid at the rectal temperature and therefore will melt in the rectum to release the active components. Such materials include, but are not limited to, cocoa butter, beeswax and polyethylene glycols.

Topical administration of the pharmaceutical compositions provided herewith is useful when the desired treatment involves areas or organs readily accessible by topical application. For application topically to the skin, the pharmaceutical composition should be formulated with a suitable ointment containing the active components suspended or dissolved in a carrier. Carriers for topical administration of the compounds provided herewith include, but are not limited to, mineral oil, liquid petroleum, white petroleum, propylene glycol, polyoxyethylene polyoxypropylene compound, emulsifying wax and water. Alternatively, the pharmaceutical composition can be formulated with a suitable lotion or cream containing the active compound suspended or dissolved in a carrier with suitable emulsifying agents. 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. The pharmaceutical compositions provided herewith may also be topically applied to the lower intestinal tract by rectal suppository formulation or in a suitable enema formulation. Topically-transdermal patches are also included.

The pharmaceutical compositions provided herewith may 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 solubilizing or dispersing agents known in the art.

When the compositions provided herewith comprise a combination of a compound of the formulae described herein and one or more additional therapeutic or

prophylactic agents, both the compound and the additional agent should be present at dosage levels of between about 1 to 100%, and more preferably between about 5 to 95% of the dosage normally administered in a monotherapy regimen. The additional agents may be administered separately, as part of a multiple dose regimen, from the compounds provided herewith. Alternatively, those agents may be part of a single dosage form, mixed together with the compounds provided herewith in a single composition.

The compounds described herein can, for example, be administered by injection, intravenously, intraarterially, subdermally, intraperitoneally, intramuscularly, or subcutaneously; or orally, buccally, nasally, transmucosally, topically, in an ophthalmic preparation, or by inhalation, with a dosage ranging from about 0.5 to about 100 mg/kg of body weight, alternatively dosages between 1 mg and 1000 mg/dose, every 4 to 120 hours, or according to the requirements of the particular drug. The methods herein contemplate administration of an effective amount of compound or compound composition to achieve the desired or stated effect. Typically, the pharmaceutical compositions provided herewith will be administered from about 1 to about 6 times per day or alternatively, as a continuous infusion. Such administration can be used as a chronic or acute therapy. The amount of active ingredient that may be combined with the carrier materials to produce a single dosage form will vary depending upon the host treated and the particular mode of administration. A typical preparation will contain from about 5% to about 95% active compound (w/w). Alternatively, such preparations contain from about 20% to about 80% active compound.

Lower or higher doses than those recited above may be required. Specific dosage and treatment regimens for any particular patient will depend upon a variety of factors, including the activity of the specific compound employed, the age, body weight, general health status, sex, diet, time of administration, rate of excretion, drug combination, the severity and course of the disease, condition or symptoms, the patient's disposition to the disease, condition or symptoms, and the judgment of the treating physician.

Upon improvement of a patient's condition, a maintenance dose of a compound, composition or combination provided herewith may be administered, if necessary. Subsequently, the dosage or frequency of administration, or both, may be reduced, as a function of the symptoms, to a level at which the improved condition is retained when the symptoms have been alleviated to the desired level. Patients may, however, require intermittent treatment on a long-term basis upon any recurrence of disease symptoms.

Patient selection and monitoring

The compounds described herein can modulate PKM2. Accordingly, a patient and/or subject can be selected for treatment using a compound described herein by first evaluating the patient and/or subject to determine whether the subject is in need of modulation of PKM2, and if the subject is determined to be in need of modulation of PKM2, then administering to the subject a compound described herein.

A subject can be evaluated as being in need of modulation of PKM2 using methods known in the art, e.g., by measuring the presence and/or activity of PKM2 in the patient. In some embodiments, the activity and/or level of PKM2 is evaluated in the cancer.

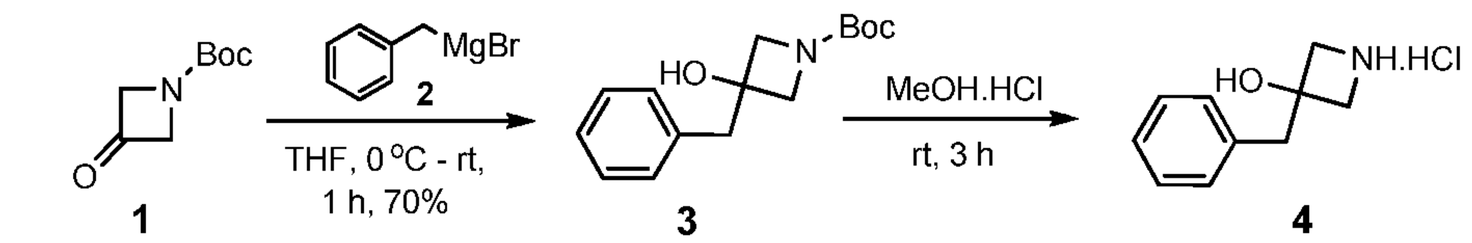
A patient receiving a compound described herein can be monitored, for example, for improvement in the condition and/or adverse effects. Improvement of a patient's condition can be evaluated, for example, by monitoring the growth, absence of growth, or regression of the cancer (e.g., a tumor). In some embodiments, the patient is evaluated using a radiological assay or evaluation of hemolytic parameters.

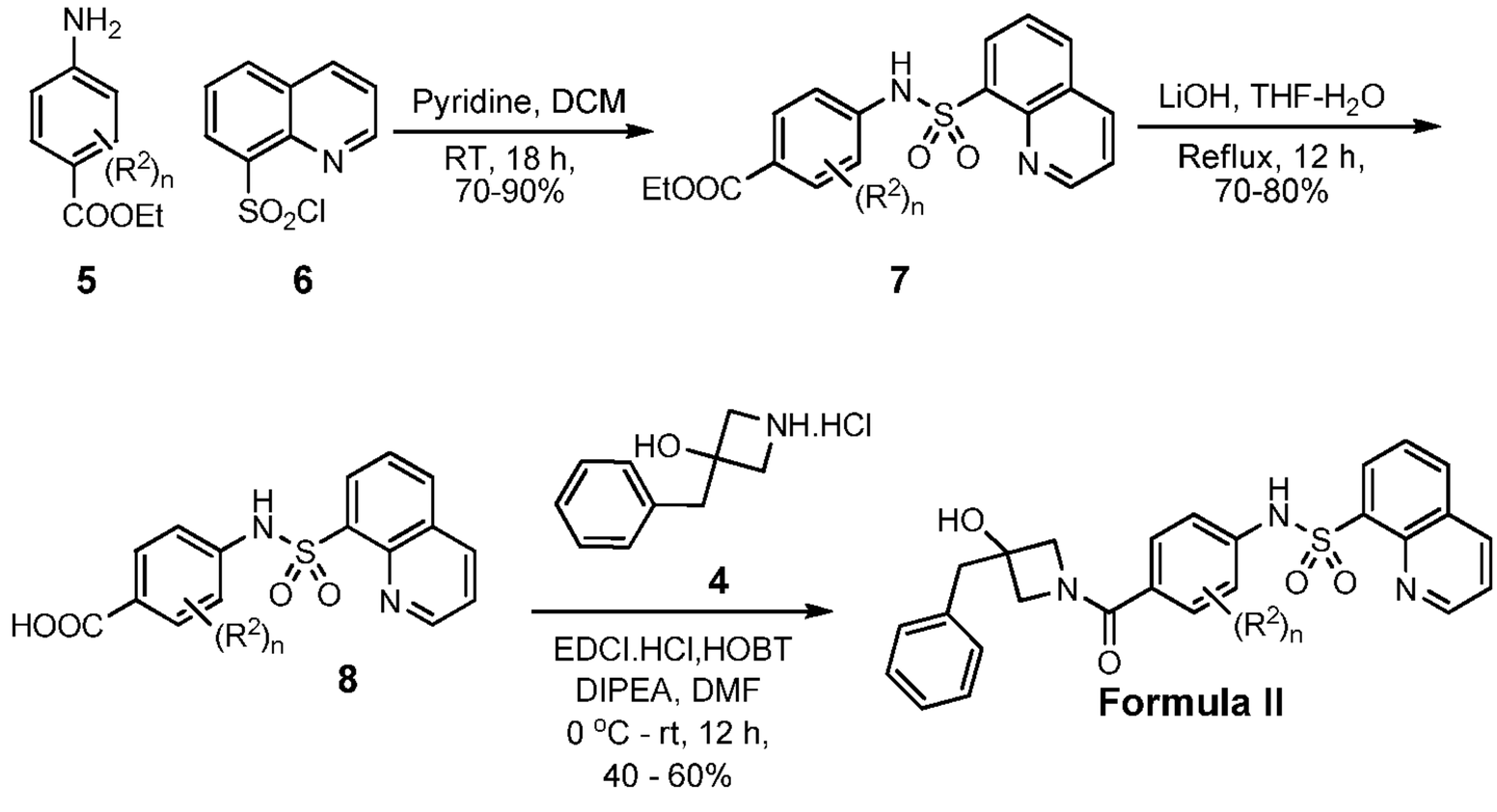
EXAMPLES

Example 1. Synthesis of Compounds of Formula II, wherein R^{1a} is Benzyl R^{1b} and is Hydroxyl or Methoxy.

Compounds of Formula II, wherein R^{1a} is benzyl R^{1b} and is hydroxyl or methoxy are produced by Scheme 1 as follows:

Scheme 1:





Procedure for preparation of tert-butyl 3-benzyl-3-hydroxyazetidine-1-carboxylate (3): 1-Boc-3-azetidinone (**1**) (2.0 gm, 11.68 mmol) was dissolved in dry THF (20 ml) under nitrogen and cooled to 0 °C. Then the solution was added 2.0 M solution of Benzyl magnesium bromide (**2**) in THF (8.76 ml, 17.52 mmol) under nitrogen atmosphere. The reaction mixture was then allowed to warm to room temperature and stirred for 1 h. The reaction completion was monitored by TLC. The reaction was quenched by the addition of saturated ammonium chloride solution and extracted ethyl acetate. The organic layer was dried over anhydrous sodium sulfate, filtered and concentrated under vacuum. Crude product was then purified by column chromatography to give compound **3** (2.15 gm, 70%). ^{1}H NMR (400 MHz, $DMSOd_6$) δ: 1.40 (s, 9H), 2.25 (s, 2H), 4.00 (d, 2H), 4.35 (d, 2H), 6.05 (s, 1H), 7.18 (m, 3H), 7.25 (d, 2H); MS: m/z 263.90 $(M+1)^+$.

Procedure for preparation of 3-benzylazetidin-3-ol hydrochloride (4): tert-butyl 3-benzyl-3-hydroxyazetidine-1-carboxylate **3** (2.0 gm, 7.59 mmol) was taken into a round bottomed flask and was adde d methanolic-HCl (25 mL, 20%) and was stirred for 3 h at room temperature. After completion of the reaction (monitored by TLC), the solvent was removed under vacuum to get a white solid as a crude product.

The crude product was washed with ethyl acetate repeatedly and then dried well to obtain compound **4** as a white solid (1.36 gm, 90%) which was used without further purification.

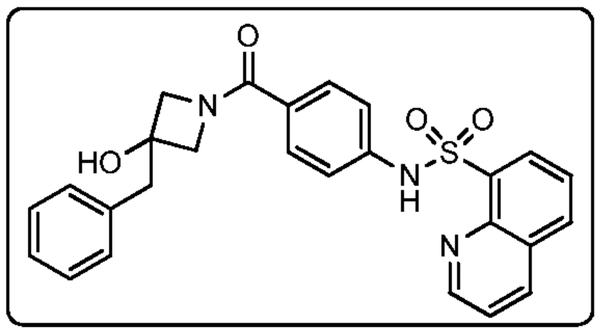
General Procedure for preparation of compound 7: To stirred a solution of amine **5** (30.16 mmol) in a 1:1 mixture of DCM-pyridine (50+50 ml) was added quinoline-8-sulfonyl chloride (**6**) (8.24 g, 36.19 mmol) under nitrogen atmosphere. The resultant solution was stirred overnight at room temperature. On completion of the reaction (monitored by TLC), the reaction mixture was diluted with dichloromethane (150 ml), washed with water (3 x 50 mL), 1N HCl solution (3 x 50 ml) and brine (50 ml). The organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated under vacuum to obtain the crude product. Crude product was co-distilled with toluene to remove the remnants of pyridine and dried to get ester (**7**) (70-90%) as an off-white solid. This product was used as such for the next step without further purification.

General Procedure for preparation of compound 8: A stirred solution of ester **7** (10.05 mmol) in a mixture of THF-water (50 + 50 ml) was added LiOH (2.11 g, 50.25 mmol) and the resultant solution was refluxed overnight. After completion of the reaction (m onitored by TLC), the reaction mixture was extracted with ethyl acetate (3 x 50 ml) and then acidified with dilute HCl. The resultant suspension was filtered and residue was co-distilled with toluene. The product was then dried under vacuum to get carboxylic acid **8** (70-80%) as an off-white solid.

General Procedure for Compounds of Formula II, wherein R^{1a} is benzyl R^{1b} and is hydroxyl or methoxy: To a stirred solution of the carboxylic acid **8** (0.61 mmol) in DMF at 0 °C under nitrogen atmosphere, EDCI (0.129 gm, 0.671 mmol), HOBt (0.91 gm, 0.671 mmol) and DIPEA (0.31 ml, 1.83 mmol) were added and the resultant solution was stirred at room temperature for 30 min. Amine hydrochloride **4** (0.61 mmol) was then added at 0 °C and stirred overnight at room temperature. After completion of the reaction (monitored by TLC), the reaction mixture was poured into 1.0 M HCl and extracted with EtOAc. The organic layer was washed with sat. aq. $NaHCO_3$, dried over $NaSO_4$ and filtered. The solvent was removed by rotary evaporation and the product was isolated by chromatography on silica gel (60-120

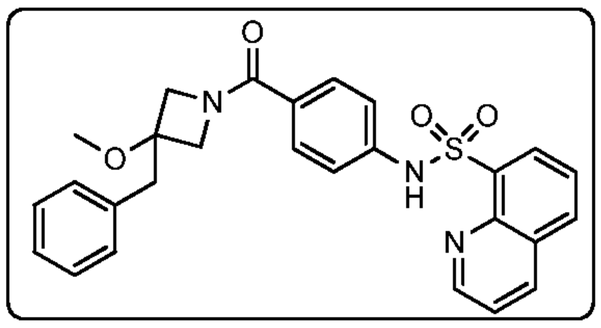
silica gel, 2% MeOH-DCM) or preparative HPLC to yield amide final compound (40-60%) as an off-white solid.

Compound 101: *N*-(4-(3-benzyl-3-hydroxyazetidine-1-carbonyl)phenyl)quinoline-8-sulfonamide:



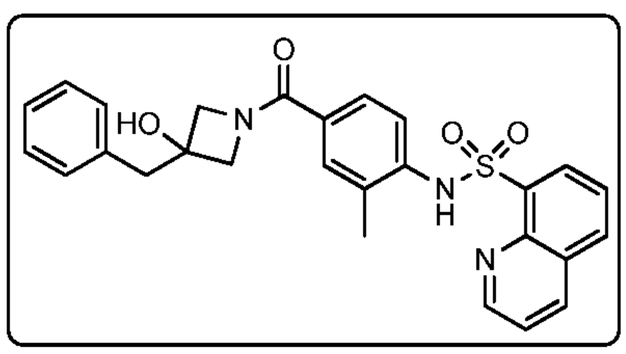
^{1}H NMR (400 MHz, DMSOd_6) δ: 2.2 (dd, 3H), 4.1-4.2 (dd, 2H), 4.5 (d, 1H), 4.8 (d, 1H), 6.1 (s, 1H), 7.16-7.4 (m, 5H), 7.37-7.57 (m, 3H), 7.79-7.84 (m, 2H), 8.2-8.40 (m, 3H), 9.10 (d, 1H), 10.5 (s, 1H); HPLC purity: 96.0%; MS: m/z 474.0 (*M+1*)+.

Compound 105: *N*-(4-(3-benzyl-3-methoxyazetidine-1-carbonyl)phenyl)quinoline-8-sulfonamide:



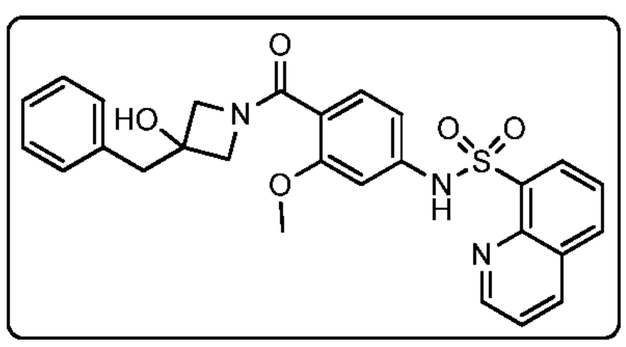
^{1}H NMR (400 MHz, DMSOd_6) δ: 3.8 (s, 3H), 3.9 (s, 2H), 4.1 (s, 2H), 7.16-7.4 (m, 5H), 7.37-7.57 (m, 3H), 7.79-7.84 (m, 2H), 8.2-8.40 (m, 3H), 9.10 (d, 1H), 10.5 (s, 1H); HPLC purity: 97.0%; MS: m/z 488.1 $(M+1)^+$.

Compound 131: *N*-(4-(3-benzyl-3-hydroxyazetidine-1-carbonyl)-2-methylphenyl) quinoline-8-sulfonamide:



^{1}H NMR (400 MHz, DMSOd_6) δ: 2.1 (s, 3H), 2.2 (s, 2H), 2.6 (s, 2H), 2.7 (s, 2H), 7.16-7.4 (m, 5H), 7.37-7.57 (m, 3H), 7.79-7.84 (m, 2H), 8.2-8.40 (m, 3H), 9.10 (d, 1H), 10.5 (s, 1H);; HPLC purity: 96.9%; MS: m/z 488.1 (*M+1*)$^+$.

Compound 130: *N*-(4-(3-benzyl-3-hydroxyazetidine-1-carbonyl)-3-methoxyphenyl)quinoline-8-sulfonamide**:**

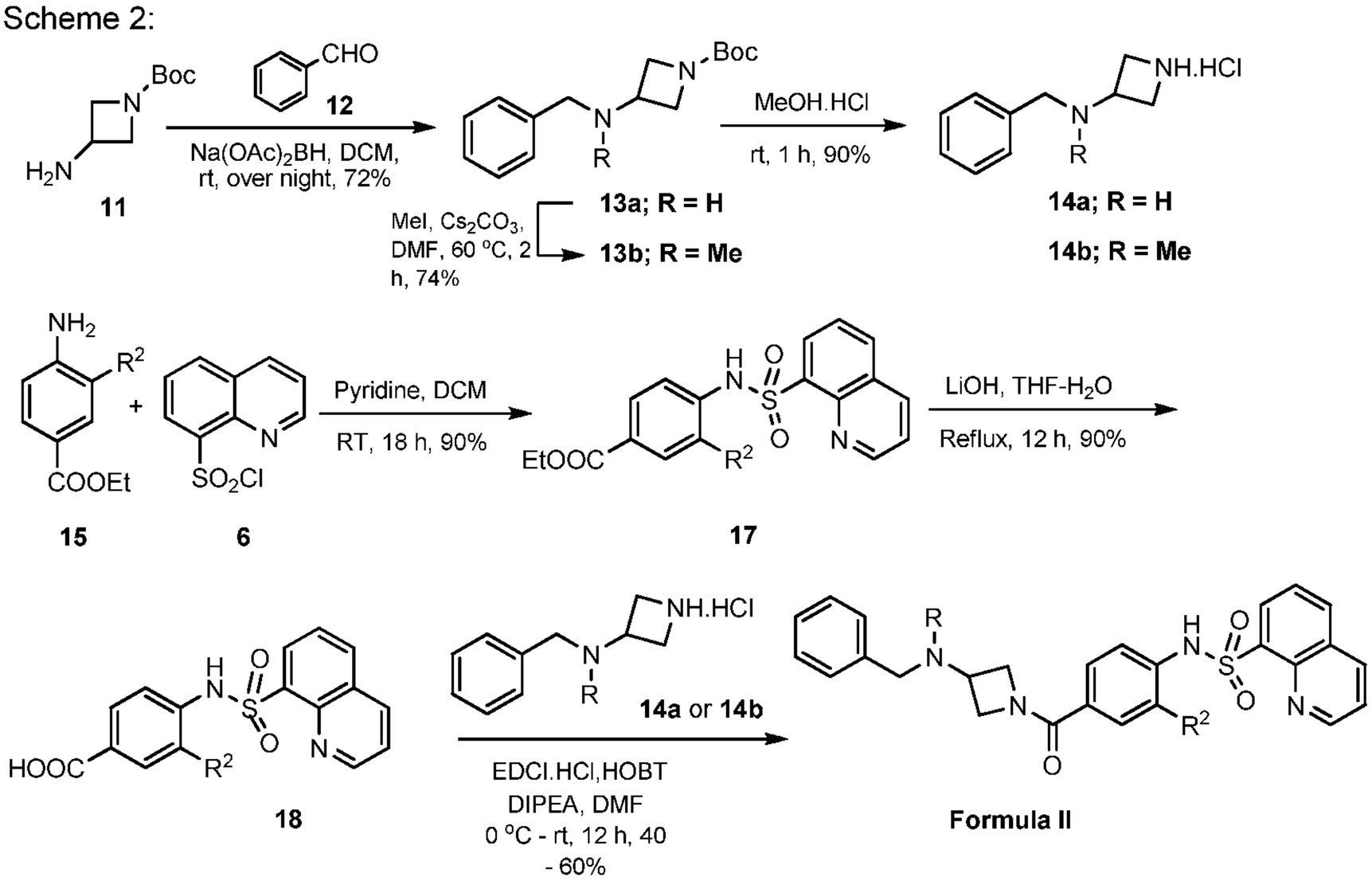


^{1}H NMR (400 MHz, DMSOd_6) δ: 2.2 (s, 2H), 2.6 (s, 2H), 2.7 (s, 2H), 3.9 (s, 3H), 7.16-7.4 (m, 5H), 7.37-7.57 (m, 3H), 7.79-7.84 (m, 2H), 8.2-8.40 (m, 3H), 9.10 (d, 1H), 10.5 (s, 1H); HPLC purity: 96.9%; MS: m/z 504.2 (*M+1*)$^+$.

Example 2. Synthesis of Compounds of Formula II wherein R^{1a} is H and R^{1b} is -N(CH_3)-benzyl or -NH-benzyl.

Compounds of Formula II wherein R^{1a} is H and R^{1b} is -N(CH_3)-benzyl or -NH-benzyl are produced according to Scheme 2:

Scheme 2:



Procedure for preparation of tert-butyl 3-(benzylamino)azetidine-1-carboxylate (13a): 1-Boc-3-aminoazetidine (**11**) (2.2 gm, 12.78 mmol) was dissolved in DCM (20 ml) under nitrogen and cooled to 0 °C. Then the solution was added

benzaldehyde (**12**; 1.35 gm, 12.78 mmol) followed by sodium triacetoxyborohydride (8.13 gm, 38.34 mmol) under nitrogen atmosphere. The reaction mixture was then allowed to warm to room temperature and stirred over night. The reaction's completion was monitored by TLC. After completion of the reaction it was quenched by the addition of water (5 ml) and extracted with DCM. The organic layer was washed with brine (10 ml), dried over anhydrous sodium sulfate, filtered and concentrated under vacuum. Crude product was then purified by column chromatography to give compound (**13a**) (2.46 gm, 72%). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.40 (s, 9H), 3.60 (m, 3H), 3.73 (s, 2H), 4.05 (m, 2H), 7.3 (m, 5H); MS: m/z 263.20 $(M+1)^+$.

Procedure for preparation of tert-butyl 3-(benzyl(methyl)amino)azetidine-1-carboxylate (13b): A solution of tert-butyl 3-(benzylamino)azetidine-1-carboxylate (**13a**) (0.55 gm, 2.09 mmol) in DMF was added methyl iodide (0.26 ml, 4.18 mmol) and cesium carbonate (1.36 gm, 4.18 mmol). The resultant reaction mixture was then warmed to 60 °C and stirred for 2 h. The reaction mixture was then diluted with ethyl acetate (100 ml), washed with water (3 x 25 ml), brine, dried over sodium sulfate and concentrated under vacuum. The crude product was purified by column chromatography to give compound (**13b**) (2.46 gm, 72%). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.40 (s, 9H), 3.40 (m, 5H), 4.00 (m, 2H), 4.20 (m, 2H), 5.2 (m, 1H), 7.50 (m, 3H), 7.70 (d, 2H); MS: m/z 277.10 $(M+1)^+$.

General Procedure for N-Boc deprotection (14a & 14b): Amine (**13a** or **13b**) (2.0 gm) was taken into a round bottomed flask and was added methanolic-HCl (25 mL, 20%) and was stirred for 1h at room temperature. After completion of the reaction (monitored by TLC), the solvent was removed under vacuum to get a white solid as a crude product. The crude product was washed with ethyl acetate repeatedly and then dried well to obtain compound **14a** or **14b**, respectively as a white solid (90%) and was used further without purification.

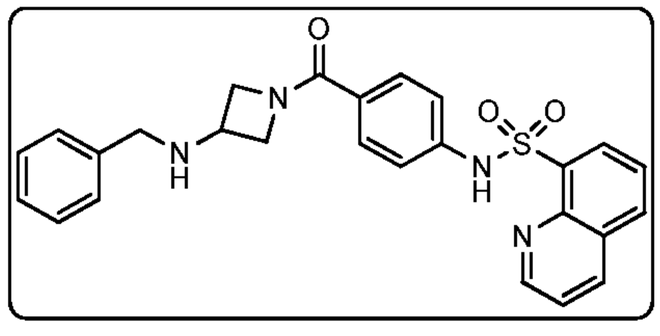
General Procedure for preparation of compound 17: To stirred a solution of amine **15** (30.16 mmol) in a 1:1 mixture of DCM-pyridine (50+50 ml) was added quinoline-8-sulfonyl chloride (**6**) (8.24 g, 36.19 mmol) under nitrogen atmosphere. The resultant solution was stirred overnight at room temperature. On completion of

the reaction (monitored by TLC), the reaction mixture was diluted with dichloromethane (150 ml), washed with water (3 x 50 mL), 1N HCl solution (3 x 50 ml) and brine (50 ml). The organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated under vacuum to obtain the crude product. Crude product was co-distilled with toluene to remove the remnants of pyridine and dried to get ester **17** (70-90%) as an off-white solid. This product was used as such for the next step without further purification.

General Procedure for preparation of compound 18: A stirred solution of ester **17** (10.05 mmol) in a mixture of THF-water (50 + 50 ml) was added LiOH (2.11 g, 50.25 mmol) and the resultant solution was refluxed overnight. After completion of the reaction (m onitored by TLC), the reaction mixture was extracted with ethyl acetate (3 x 50 ml) and then acidified with dilute HCl. The resultant suspension was filtered and residue was co-distilled with toluene. The product was then dried under vacuum to get carboxylic acid **18** (70-80%) as an off-white solid.

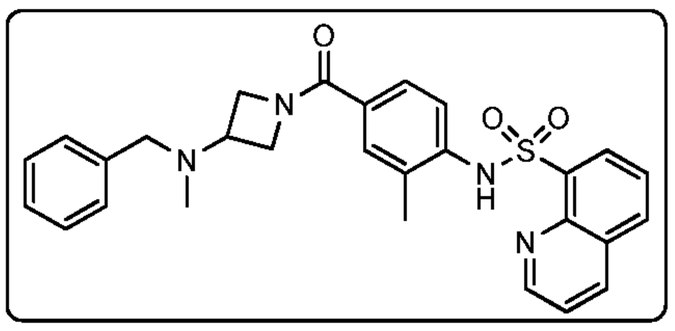
General Procedure for Compounds of Formula II wherein R^{1a} is H and R^{1b} is -N(CH_3)-benzyl or -NH-benzyl: To a stirred solution of the carboxylic acid **18** (0.61 mmol) in DMF at 0 °C under nitrogen atmosphere, EDCI (0.129 gm, 0.671 mmol), HOBt (0.91 gm, 0.671 mmol) and DIPEA (0.31 ml, 1.83 mmol) were added and the resultant solution was stirred at room temperature for 30 min. Amine hydrochloride **14a** or **14b**) (0.61 mmol) was then added at 0 °C and stirred overnight at room temperature. After completion of the reaction (monitored by TLC), the reaction mixture was poured into 1.0 M HCl and extracted with EtOAc. The organic layer was washed with sat. aq. $NaHCO_3$, dried over $NaSO_4$ and filtered. The solvent was removed by rotary evaporation and the product was isolated by chromatography on silica gel (60-120 silica gel, 2% MeOH-DCM) or preparative HPLC to yield final compound (50-60%) as an off-white solid.

Compound 147: *N*-(4-(3-(benzylamino)azetidine-1-carbonyl)phenyl)quinoline-8-sulfonamide:



^{1}H NMR (400 MHz, DMSOd_6) δ: 1.8-1.85 (m, 1H), 2.2 (dd, 2H), 2.6 (dd, 2H), 2.7 (s, 2H), 7.16-7.4 (m, 5H), 7.37-7.57 (m, 4H), 7.79-7.84 (m, 2H), 8.2-8.40 (m, 2H), 9.10 (d, 1H), 10.4 (s, 1H); HPLC purity: 96.9%; MS: m/z 473.1 $(M+1)^+$.

Compound 109: *N*-(4-(3-(benzyl(methyl)amino)azetidine-1-carbonyl)-2-methylphenyl)quinoline-8-sulfonamide:

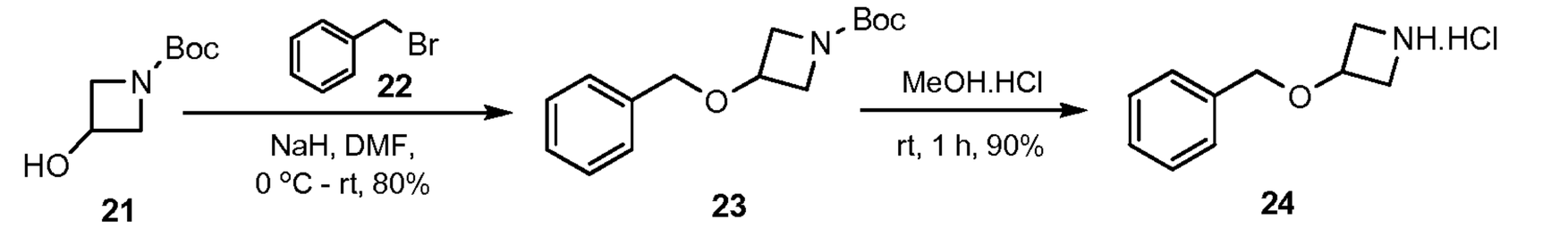


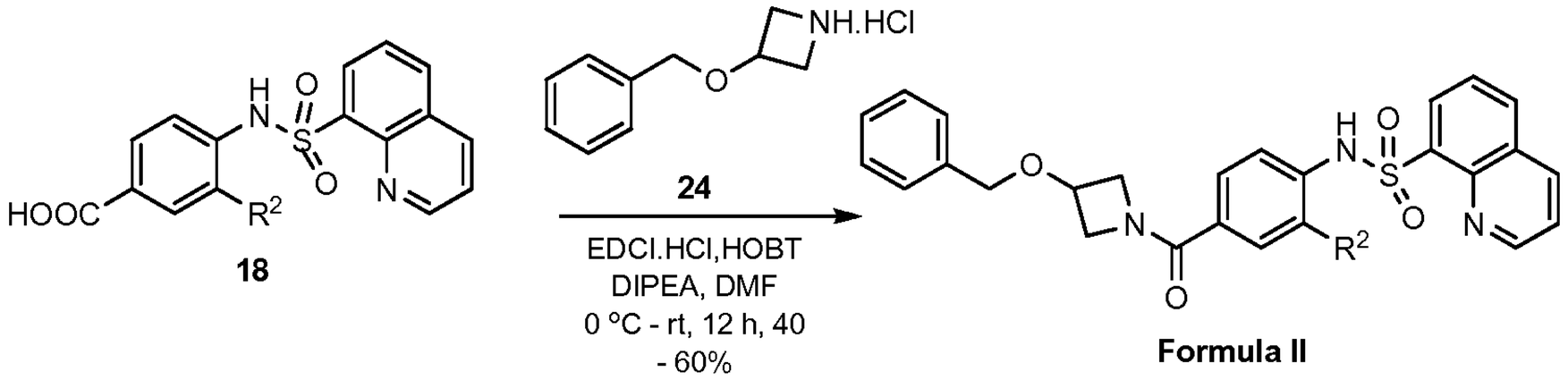
^{1}H NMR (400 MHz, DMSOd_6) δ: 1.8-1.85 (m, 1H), 2.1 (s, 3H), 2.2 (dd, 2H), 2.6 (dd, 2H), 2.7 (s, 2H), 3.1 (s, 3H), 7.16-7.4 (m, 5H), 7.37-7.57 (m, 3H), 7.79-7.84 (m, 2H), 8.2-8.40 (m, 2H), 9.10 (d, 1H), 10.4 (s, 1H); HPLC purity: 96.9%; MS: m/z 488.1 $(M+1)^+$.

Example 3. Synthesis of Compounds of Formula II wherein R^{1a} is Hydrogen and R^{1b} is -O-benzyl:

Compounds of Formula II wherein R^{1a} is hydrogen and R^{1b} is -O-benzyl are prepared according to Scheme 3:

Scheme 3:



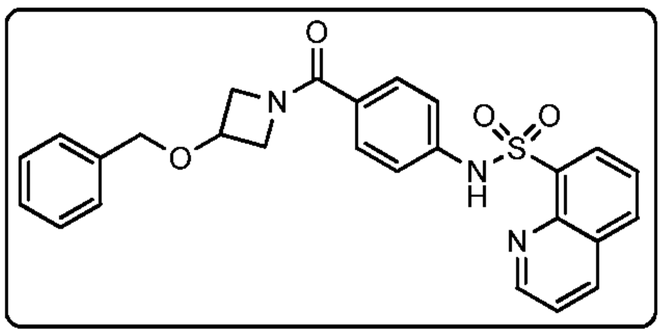


Procedure for preparation of tert-butyl 3-(benzyloxy)azetidine-1-carboxylate (23): tert-butyl 3-hydroxyazetidine-1-carboxylate (**21**) (1 gm, 5.77 mmol) was dissolved in dry DMF (15 ml) and was cooled to 0 °C under nitrogen and was added sodium hydride (0.35 gm, 8.66 mmol). The reaction mixture was allowed to stir at room temperature for 30 min and was added benzylbromide (**22**;1.08 gm, 6.35 mmol) at 0 °C. The reaction mixture was then allowed warm to room temperature and stirred for 2 h. After completion of the reaction it was quenched by the addition of sat. ammonium chloride solution and extracted with ether. The organic layer was then dried over sodium sulfate and concentrated under vacuum. The crude product was purified column chromatography to yield compound **23** (1.21 gm, 80%). ^{1}H NMR ((400 MHz, $DMSOd_6$) δ: 1.4 (s, 9H), 3.65 (m, 2H), 4.00 (t, 2H), 4.30 (m, 1H), 4.40 (s, 2H), 7.35 (m, 5H); MS: m/z 264.20 $(M+1)^+$.

Procedure for preparation of 3-(benzyloxy)azetidine hydrochloride 24: tert-butyl 3-(benzyloxy)azetidine-1-carboxylate **23** (1.0 gm) was taken into a round bottomed flask and was added methanolic-HCl (15 mL, 20%) and was stirred for 1h at room temperature. After completion of the reaction (monitored by TLC), the solvent was removed under vacuum to get a white solid as a crude product. The crude product was washed with ethyl acetate repeatedly and then dried well to obtain compound **24** as a white solid (92%) and was used further without purification.

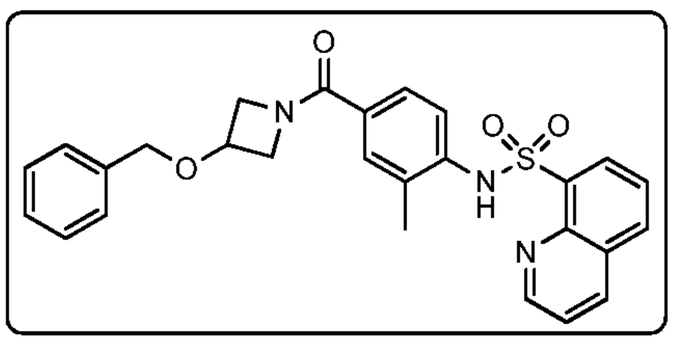
General Procedure for Compound of Formula II wherein R^{1a} is hydrogen and R^{1b} is -O-benzyl: To a stirred solution of the carboxylic acid **18** (0.61 mmol) (prepared as in Example 2) in DMF at 0 °C under nitrogen atmosphere, EDCI (0.129 gm, 0.671 mmol), HOBt (0.91 gm, 0.671 mmol) and DIPEA (0.31 ml, 1.83 mmol) were added and the resultant solution was stirred at room temperature for 30 min. Amine hydrochloride **24** (0.61 mmol) was then added at 0 °C and stirred overnight at room temperature. After completion of the reaction (monitored by TLC), the reaction mixture was poured into 1.0 M HCl and extracted with EtOAc. The organic layer was washed with sat. aq. $NaHCO_3$, dried over $NaSO_4$ and filtered. The solvent was removed by rotary evaporation and the product was isolated by chromatography on silica gel (60-120 silica gel, 2% MeOH-DCM) or preparative HPLC to yield final compound (50-60%) as an off-white solid.

Compound 108: *N*-(4-(3-(benzyloxy)azetidine-1-carbonyl)phenyl)quinoline-8-sulfonamide:



^{1}H NMR (400 MHz, $DMSOd_6$) δ: 2.6 (s, 2H), 2.2 (dd, 2H), 4.1-4.2 (dd, 3H), 7.16-7.4 (m, 5H), 7.37-7.57 (m, 3H), 7.79-7.84 (m, 2H), 8.2-8.40 (m, 3H), 9.10 (d, 1H), 10.5 (s, 1H); HPLC purity: 98.9%; MS: m/z 474.1 $(M+1)^+$.

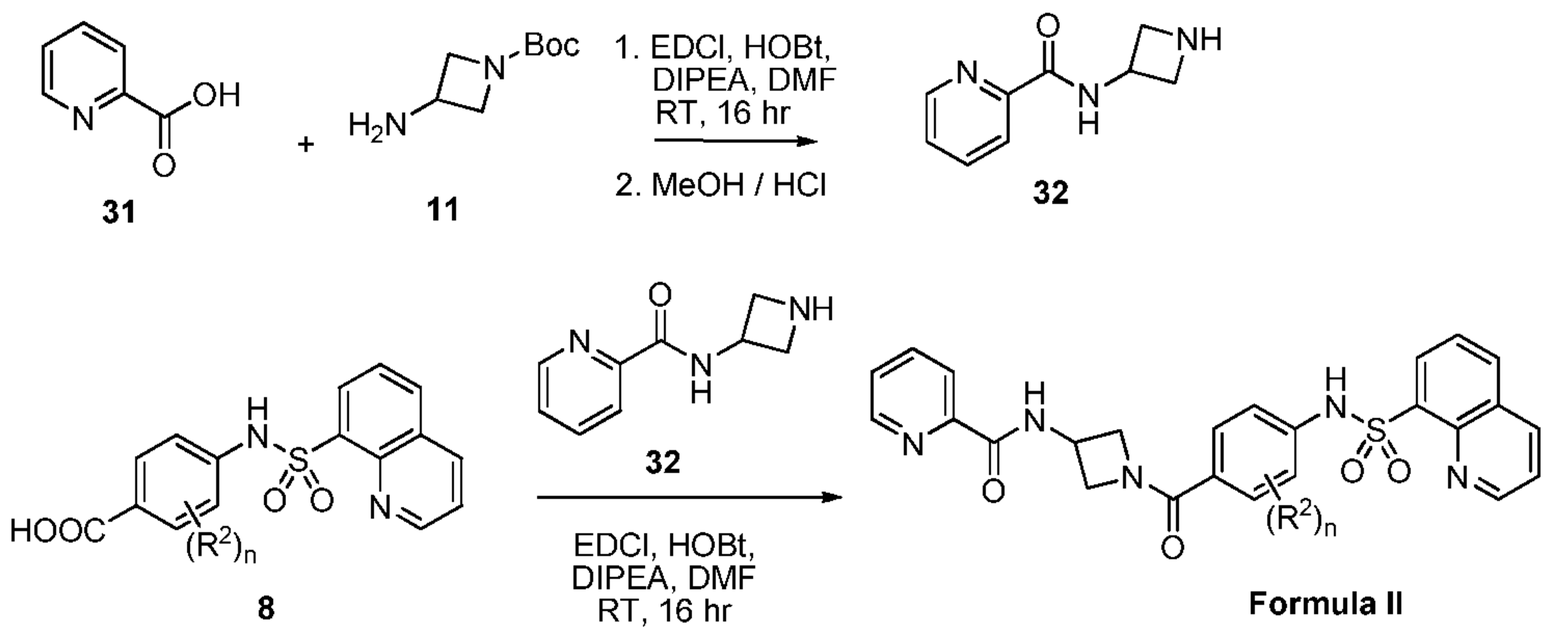
Compound 120: *N*-(4-(3-(benzyloxy)azetidine-1-carbonyl)-2-methylphenyl)quinoline-8-sulfonamide:



^{1}H NMR (400 MHz, $DMSOd_6$) δ: 2.2 (s, 3H), 2.6 (s, 2H), 2.2 (dd, 2H), 4.1-4.2 (dd, 3H), 7.16-7.4 (m, 5H), 7.37-7.57 (m, 3H), 7.79-7.84 (m, 2H), 8.2-8.40 (m, 3H), 9.10 (d, 1H), 10.5 (s, 1H); HPLC purity: 98.5%; MS: m/z 488.3 $(M+1)^+$.

Example 4: Syntheses of Compounds of Formula II wherein R^{1a} is Hydrogen and R^{1b} is -NH-C(O)-R^a:

Compounds of Formula II wherein R^{1a} is Hydrogen and R^{1b} is -NH-C(O)-Ar are prepared as set forth in Scheme 4:

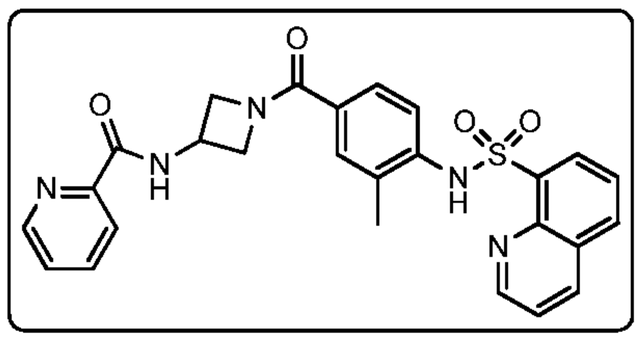


General procedure for the synthesis of urea 32: EDCI (3.8 g, 19.8 mmol) and HOBT (2.67 g, 19.8 mmol) were added to a stirred solution of the acid **31** (19.8 mmol) in anhydrous DMF. The temperature of the mixture was reduced to 0 °C, at which time DIPEA (11 ml, 59.45 mmol) was added under nitrogen atmosphere and the resultant solution (or suspension) was stirred at room temperature for 30 min. 3-amino-1-Boc azetidine (**11**; 19.8 mmol) was then added at 0 °C. The reaction mixture was then brought to room temperature and stirred overnight. After completion of the reaction, the reaction mixture was diluted with water and extracted with ethyl acetate (3 x 70 ml). The organic layer was washed with water (3 x 50 ml), dried over anhydrous sodium sulfate, filtered and concentrated over the rotary evaporator to get the crude product. Crude product was purified by column chromatography (60-120 silica gel, 2% MeOH-DCM) to get pure product, Boc-**32** (81%; not shown) as an off-white solid, which was subjected to the treatment with methanolic HCl (100 ml) for 2 hr at RT. After the complete cleavage of Boc-group, the solvent was removed under low pressure, to give the crude product as an HCl salt. The aqueous solution of the salt was washed with diethylether and basified with $NaHCO_3$ (pH 10). The desired

product was then partitioned into ethyl acetate, dried with anhydrous Na_2SO_4 and the solvent removed under low pressure to get the free amine **32** as off white solid (95 %).

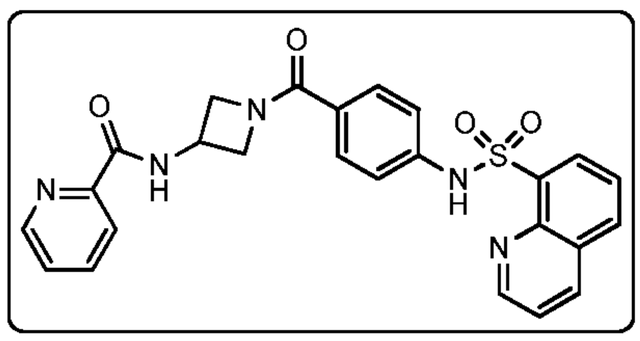
General procedure for the synthesis of amides 22a-c: EDCI (48 mg, 0.2525 mmol) and HOBT (34 mg, 0.2525 mmol) were added to a stirred solution of **8** (0.2525 mmol; prepared as in Example 1) in anhydrous DMF. The temperature of the mixture was reduced to 0 °C, at which time DIPEA (139 µl, 0.7575 mmol) was added under nitrogen atmosphere and the resultant solution (or suspension) was stirred at room temperature for 30 min. Amine **32** (0.2525 mmol) was then added at 0 °C. The reaction mixture was then brought to room temperature and stirred overnight. After completion of the reaction, the reaction mixture was diluted with water and extracted with ethyl acetate (3 x 15 ml). The organic layer was washed with water (3 x 10 ml), dried over anhydrous sodium sulfate, filtered and concentrated over the rotary evaporator to get the crude product. Crude product was purified by either by silica column chromatography or preparative HPLC to obtain the pure products in 45-65% yields.

Compound 103: *N*-(1-(3-Methyl-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl)picolinamide:



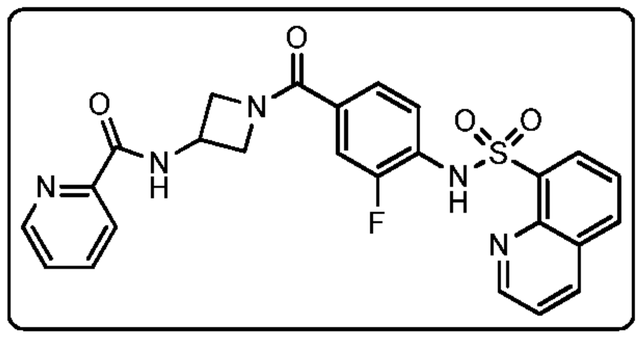
^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.1 (s, 3H), 4.2 (d, 2H), 4.4 (d, 2H), 5.2 (m, 1H), 7.0-8.0 (m, 8H), 8.0-8.4 (m, 4H), 9.1 (m, 1H); HPLC Purity: 97.5%; LCMS, m/z found 502.1 *(M+1)*$^+$.

Compound 111: *N*-(1-(4-(Quinoline-8-sulfonamido)benzoyl)azetidin-3-yl)picolinamide:



^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.2 (d, 2H), 4.4 (d, 2H), 5.2 (m, 1H), 7.0-8.0 (m, 8H), 8.0-8.4 (m, 5H), 9.1 (m, 1H); HPLC Purity: 98.6%; LCMS, m/z found 488.2 *(M+1)*$^+$.

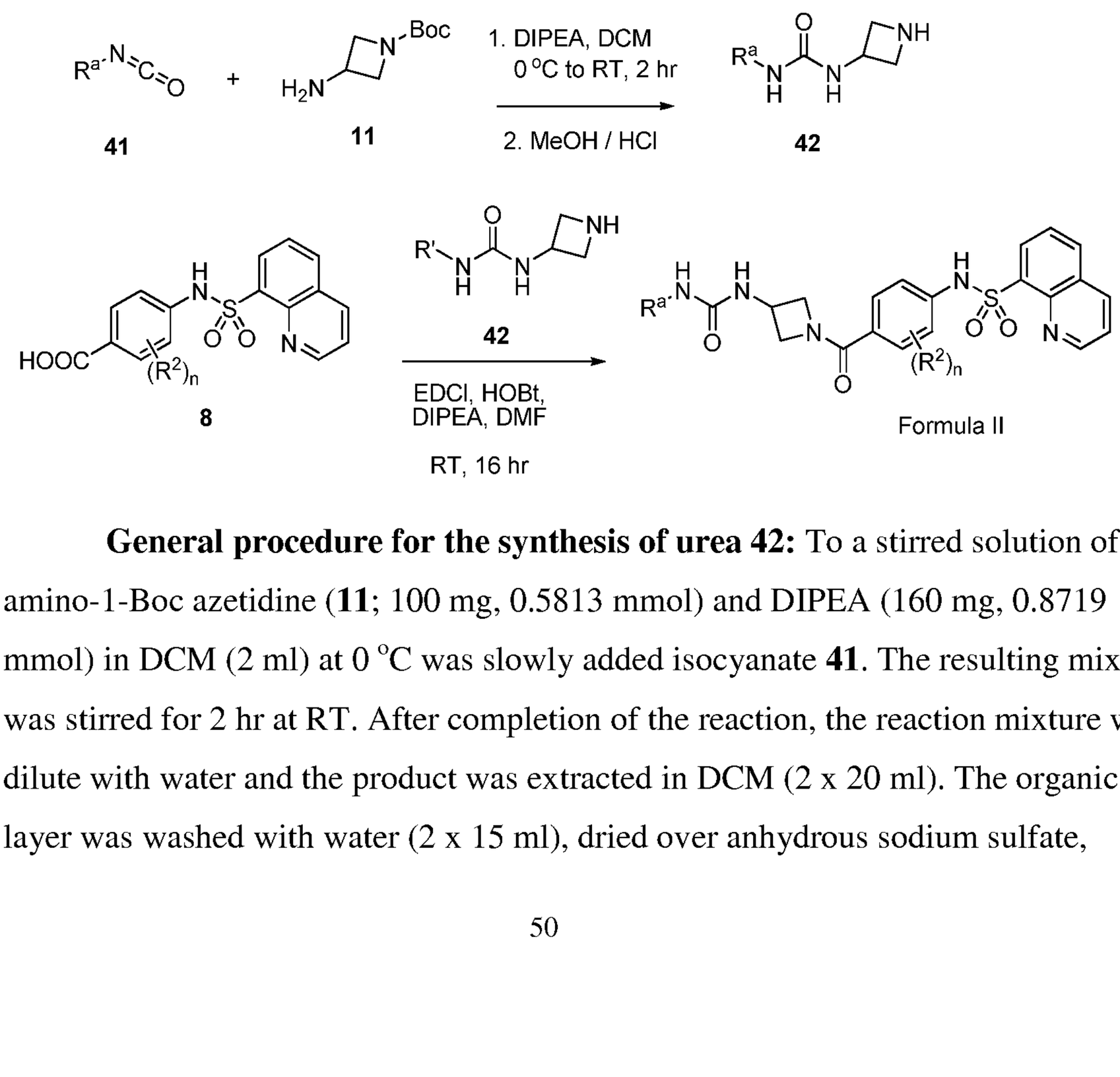
Compound 121: *N*-(1-(3-Fluoro-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl)picolinamide (22c):



^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.2 (d, 2H), 4.4 (d, 2H), 5.2 (m, 1H), 7.0-8.0 (m, 8H), 8.0-8.4 (m, 4H), 9.1 (m, 1H); HPLC Purity: 99.0%; LCMS, m/z found 506.3 *(M+1)*$^+$.

Example 5. Syntheses of Compounds of Formula II, wherein R^{1a} is Hydrogen and R^{1b} is -NH-C(O)-NH-R^a.

Compounds of Formula II, wherein R^{1a} is hydrogen and R^{1b} is -NH-C(O)-NH-R^a are prepared according to Scheme 5:

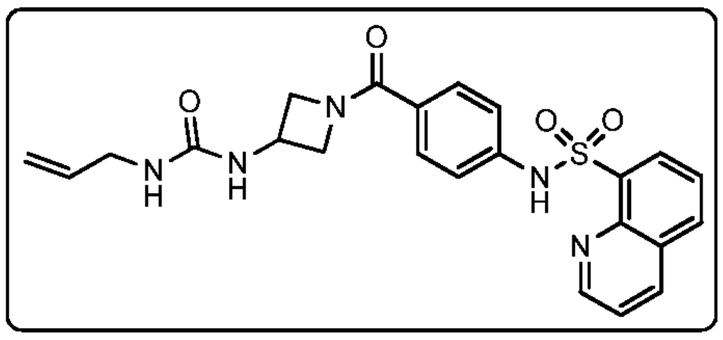


General procedure for the synthesis of urea 42: To a stirred solution of 3-amino-1-Boc azetidine (**11**; 100 mg, 0.5813 mmol) and DIPEA (160 mg, 0.8719 mmol) in DCM (2 ml) at 0 °C was slowly added isocyanate **41**. The resulting mixture was stirred for 2 hr at RT. After completion of the reaction, the reaction mixture was dilute with water and the product was extracted in DCM (2 x 20 ml). The organic layer was washed with water (2 x 15 ml), dried over anhydrous sodium sulfate,

filtered and concentrated over the rotary evaporator to get the crude product. Crude product was purified by column chromatography (60-120 silica gel, 2% MeOH-DCM) to get pure product, Boc-**42** (59%; not shown) as an off-white solid, which was subjected to the treatment with methanolic HCl (10 ml) for 2 hr at RT. After the complete cleavage of Boc-group, the solvent was removed under low pressure, to give the crude product as an HCl salt. The aqueous solution of the salt was washed with diethylether and basified with $NaHCO_3$ (pH 10). The desired product was then partitioned into ethyl acetate, dried over anhydrous Na_2SO_4 and the solvent removed under low pressure to get the free amine **42** as off white solid (87 %).

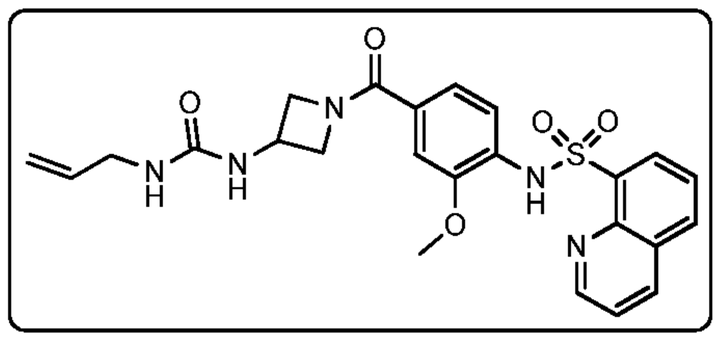
General procedure for the synthesis of compounds of Formula II, wherein R^{1a} is hydrogen and R^{1b} is -NH-C(O)-NH-R^a: EDCI (48 mg, 0.2525 mmol) and HOBT (34 mg, 0.2525 mmol) were added to a stirred solution of **8** (0.2525 mmol; prepared as in Example 1) in anhydrous DMF. The temperature of the mixture was reduced to 0 °C, at which time DIPEA (139 µl, 0.7575 mmol) was added under nitrogen atmosphere and the resultant solution (or suspension) was stirred at room temperature for 30 min. Amine **42** (0.2525 mmol) was then added at 0 °C. The reaction mixture was then brought to room temperature and stirred overnight. After completion of the reaction, the reaction mixture was diluted with water and extracted with ethyl acetate (3 x 15 ml). The organic layer was washed with water (3 x 10 ml), dried over anhydrous sodium sulfate, filtered and concentrated over the rotary evaporator to get the crude product. Crude product was purified by either by silica column chromatography or preparative HPLC to obtain the pure products in 53-63% yields.

Compound 139: *N*-(4-(3-(3-Allylureido)azetidine-1-carbonyl)phenyl)quinoline-8-sulfonamide:



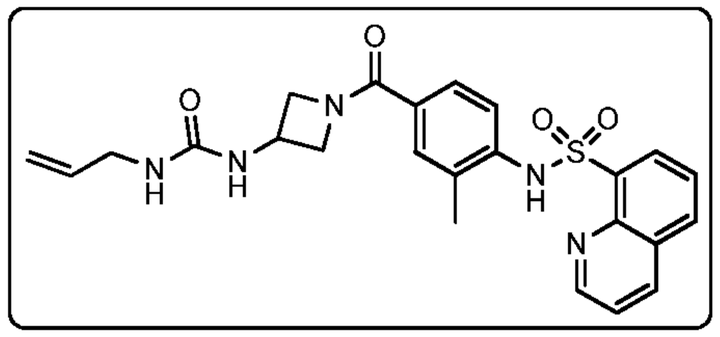
^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.2 (d, 2H), 4.3 (s, 2H), 4.4 (d, 2H), 5.0 (m, 1H), 5.2 (m, 2H), 5.9 (m, 1H), 7.0-8.0 (m, 5H), 8.0-8.4 (m, 4H), 9.1 (m, 1H); HPLC Purity: 97.8%; LCMS, m/z found 484.3 $(M+1)^+$.

Compound 140: *N*-(4-(3-(3-Allylureido)azetidine-1-carbonyl)-2-methoxyphenyl)quinoline-8-sulfonamide :



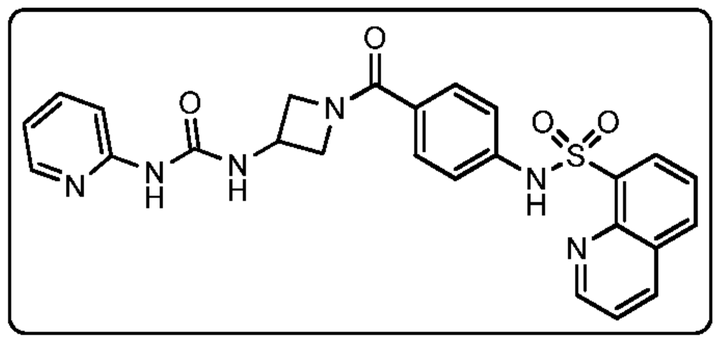
^{1}H NMR (400 MHz, $CDCl_3$) δ: 3.9 (s, 3H), 4.2 (d, 2H), 4.3 (s, 2H), 4.4 (d, 2H), 5.0 (m, 1H), 5.2 (m, 2H), 5.9 (m, 1H), 7.0-8.0 (m, 4H), 8.0-8.4 (m, 4H), 9.1 (m, 1H); HPLC Purity: 99.1%; LCMS, m/z found 496.2 $(M+1)^+$.

Compound 166: *N*-(4-(3-(3-Allylureido)azetidine-1-carbonyl)-2-methylphenyl)quinoline-8-sulfonamide:



^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.1 (s, 3H), 4.2 (d, 2H), 4.3 (s, 2H), 4.4 (d, 2H), 5.0 (m, 1H), 5.2 (m, 2H), 5.9 (m, 1H), 7.0-8.0 (m, 4H), 8.0-8.4 (m, 4H), 9.1 (m, 1H); HPLC Purity: 98.6%; LCMS, m/z found 480.3 $(M+1)^+$.

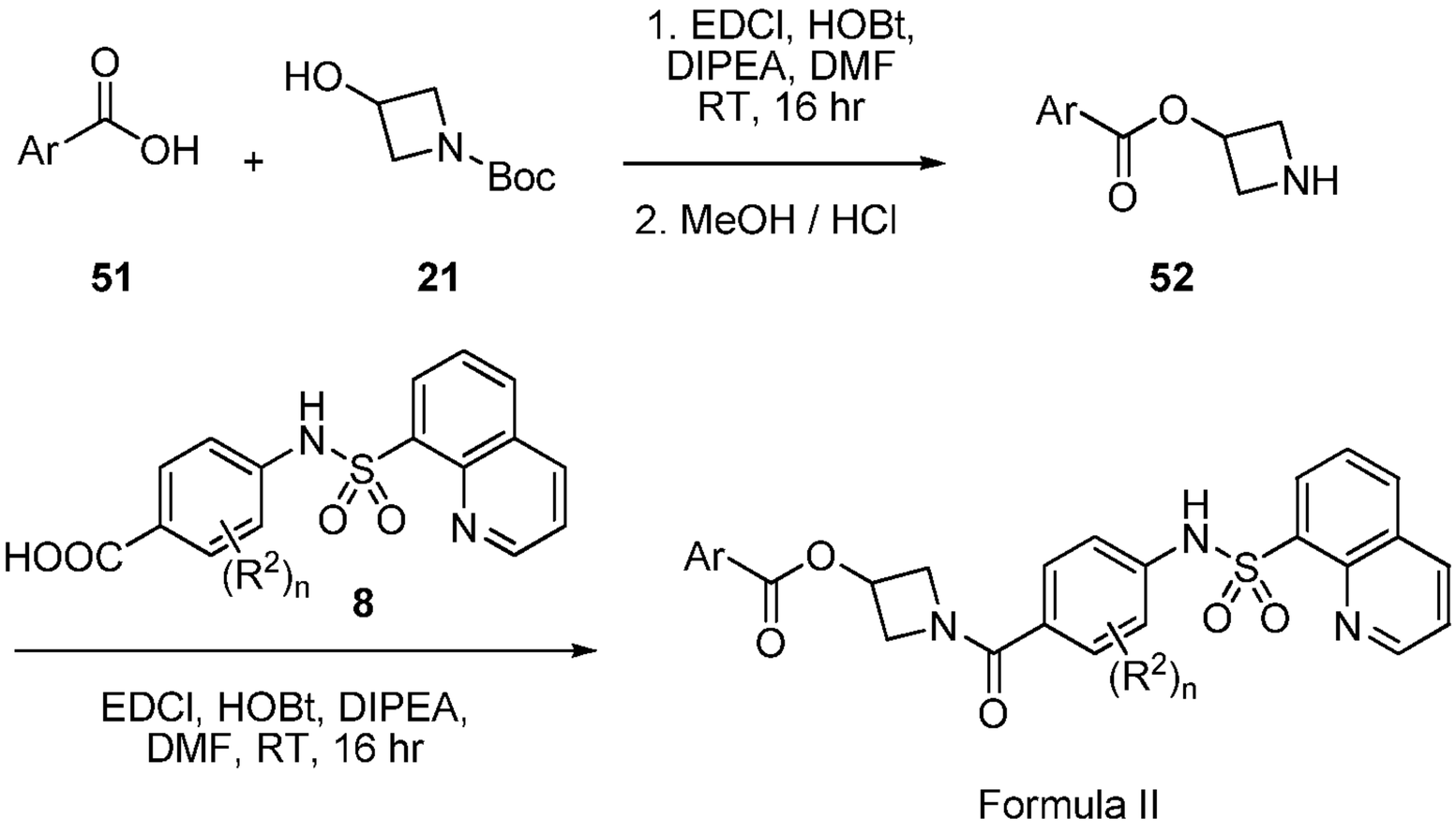
Compound 160: *N*-(4-(3-(3-(Pyridin-2-yl)ureido)azetidine-1-carbonyl)phenyl)quinoline-8-sulfonamide**:**



^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.2 (d, 2H), 4.4 (d, 2H), 5.2 (m, 1H), 7.0-8.0 (m, 8H), 8.0-8.2 (m, 5H), 9.1 (m, 1H); HPLC Purity: 99.2%; LCMS, m/z found 503.1 $(M+1)^+$.

Example 6. Syntheses of Compounds of Formula II wherein R^{1a} is hydrogen and R^{1b} is -O-C(O)-R^a.

Compounds of Formula II wherein R^{1a} is hydrogen and R^{1b} is -O-C(O)-R^a are prepared according to Scheme 6.



51 **21** **52** **8**

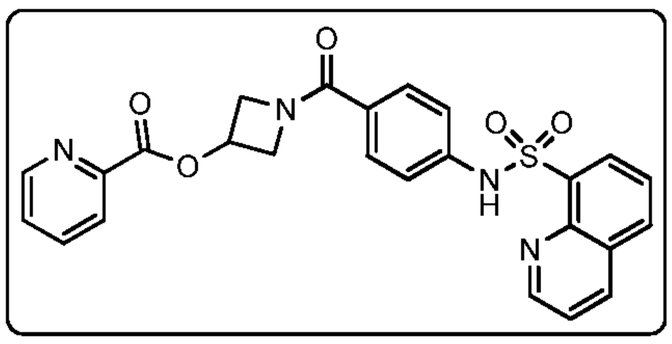
Formula II

General procedure for the synthesis of ester 52: EDCI (48 mg, 0.2525 mmol) and HOBT (34 mg, 0.2525 mmol) were added to a stirred solution of the Ar-COOH (0.2525 mmol) in anhydrous DMF. The temperature of the mixture was reduced to 0 °C, at which time DIPEA (139 µl, 0.7575 mmol) was added under nitrogen atmosphere and the resultant solution (or suspension) was stirred at room temperature for 30 min. 3-Hydroxy-1-Boc azetidine **21** (0.2525 mmol) was then added at 0 °C. The reaction mixture was then brought to room temperature and stirred overnight. After completion of the reaction, the reaction mixture was diluted with water and extracted with ethyl acetate (3 x 15 ml). The organic layer was washed with water (3 x 10 ml), dried over anhydrous sodium sulfate, filtered and concentrated over the rotary evaporator to get crude product. The crude product was purified by column chromatography (60-120 silica gel, 2% MeOH-DCM) to get pure product, Boc-**52** (66%; not shown) as an off-white solid, which was subjected to the treatment with

methanolic HCl (10 ml) for 2 hr at RT. After the complete cleavage of Boc-group, the solvent was removed under low pressure, to give the crude product as an HCl salt. The aqueous solution of the salt was washed with diethylether and basified with $NaHCO_3$ (pH 10). The desired product was then partitioned into ethyl acetate, dried over anhydrous Na_2SO_4 and the solvent removed under low pressure to get the free amine **52** as off white solid (83 %).

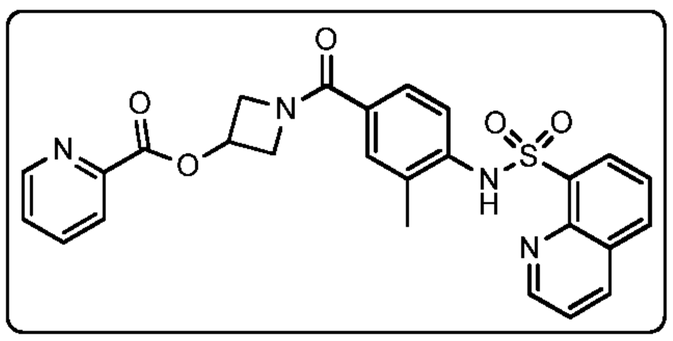
General procedure for the synthesis of compounds of Formula II wherein R^{1a} is hydrogen and R^{1b} is -O-C(O)-R^a: EDCI (48 mg, 0.2525 mmol) and HOBT (34 mg, 0.2525 mmol) were added to a stirred solution of the carboxylic acid **8** (0.2525 mmol; prepared as in Example 1) in anhydrous DMF. The temperature of the mixture was reduced to 0 °C, at which time DIPEA (139 µl, 0.7575 mmol) was added under nitrogen atmosphere and the resultant solution (or suspension) was stirred at room temperature for 30 min. Amine **52** (0.2525 mmol) was then added at 0 °C. The reaction mixture was then brought to room temperature and stirred overnight. After completion of the reaction, the reaction mixture was diluted with water and extracted with ethyl acetate (3 x 15 ml). The organic layer was washed with water (3 x 10 ml), dried over anhydrous sodium sulfate, filtered and concentrated over the rotary evaporator to get crude product. Crude product was purified by either by silica column chromatography or preparative HPLC to obtain the pure products in 47-68% yields.

Compound 102: 1-(4-(Quinoline-8-sulfonamido)benzoyl)azetidin-3-yl picolinate:



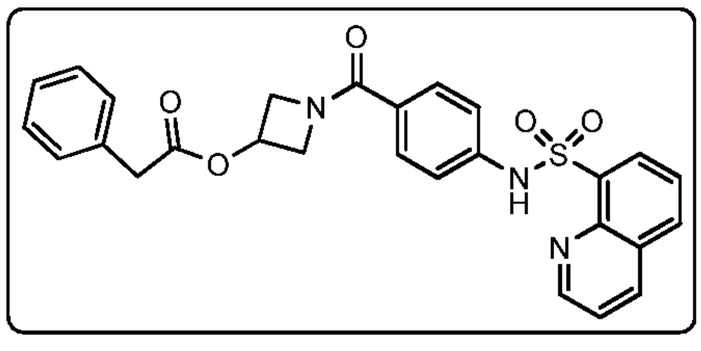
^1H NMR (400 MHz, $CDCl_3$) δ: 4.2-4.8 (m, 4H), 5.5 (m, 1H), 7.2-7.7 (m, 7H), 8.0-8.7 (m, 6H), 9.1 (m, 1H); HPLC Purity: 91.0%; LCMS, m/z found 489.3 $(M+1)^+$.

Compound 110: 1-(3-Methyl-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl picolinate:



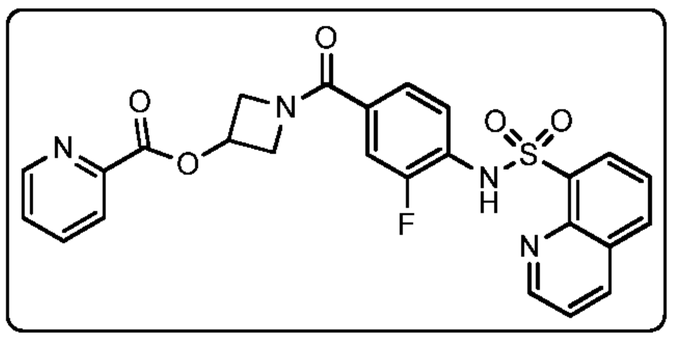
^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.1 (s, 3H), 4.2-4.8 (m, 4H), 5.5 (m, 1H), 7.2-7.7 (m, 6H), 8.0-8.7 (m, 6H), 9.1 (m, 1H); HPLC Purity: 98.4%; LCMS, m/z found 503.1 *(M+1)*$^+$.

Compound 123: 1-(4-(Quinoline-8-sulfonamido)benzoyl)azetidin-3-yl 2-phenylacetate:



^{1}H NMR (400 MHz, $CDCl_3$) δ: 3.6 (m, 1H), 4.2 (d, 2H), 4.4-4.6 (d, 2H), 5.3 (m, 2H), 7.2-7.8 (m, 7H), 8.0-8.7 (m, 7H), 9.1 (m, 1H); HPLC Purity: 97.0%; LCMS, m/z found 502.2 *(M+1)*$^+$.

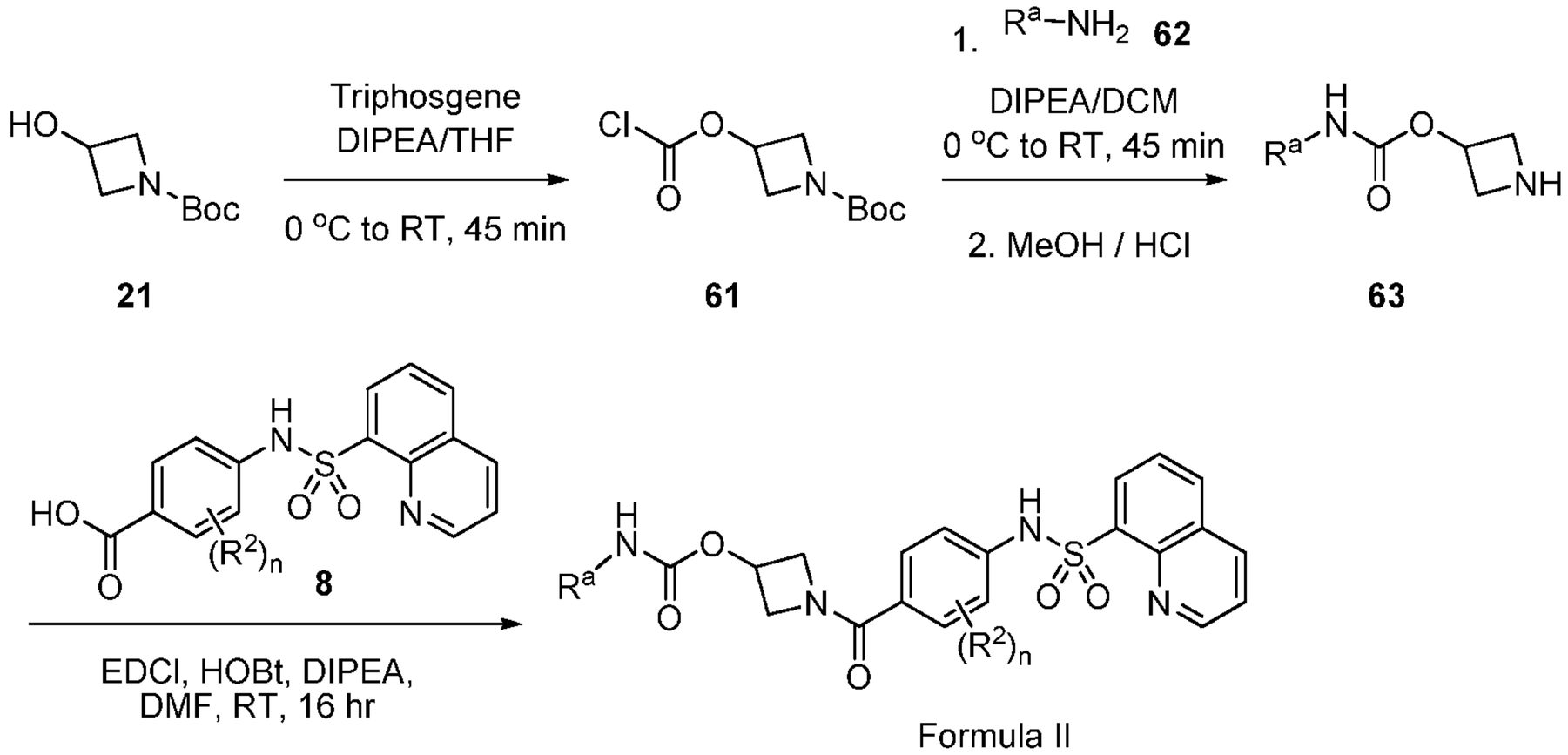
Compound 124: 1-(3-Fluoro-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl picolinate:



^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.2 (d, 2H), 4.6 (d, 2H), 4.7 (m, 1H), 7.2-7.8 (m, 6H), 8.0-8.7 (m, 6H), 9.1 (m, 1H); HPLC Purity: 99.0%; LCMS, m/z found 507.4 *(M+1)*$^+$.

Example 7: Syntheses of Compounds of Formula II wherein R^{1a} is hydrogen and R^{1b} is -O-C(O)-NH-R^a.

Compounds of Formula II wherein R^{1a} is hydrogen and R^{1b} is -O-C(O)-NH-R^a are prepared according to Scheme 7.



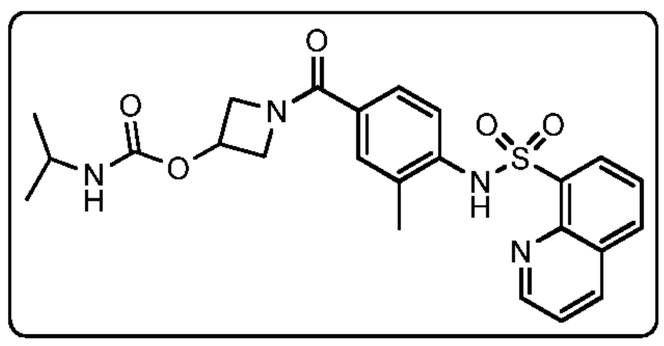
***tert*-Butyl 3-((chlorocarbonyl)oxy)azetidine-1-carboxylate 61:** To a stirred solution of 3-hydroxy-1-Boc azetidine (**21**; 350 mg, 2.023 mmol) and DIPEA (1.3 ml, 7.080 mmol) in THF (5 ml) at 0 °C was slowly added triphosgene (898 mg, 3.034 mmol). The resulting mixture was stirred for 2 hr at RT. After completion of the reaction, the reaction mixture was filtered and washed with fresh THF to get rid of inorganic salts. The filtrate was concentrated under reduced pressure to get crude product **61** in 55% yield. The crude product, thus obtained, was immediately used for the next reaction.

General procedure for the synthesis of carbamate 63: To a stirred solution of amine **62** (100 mg, 1.694 mmol) and DIPEA (0.47 ml, 2.541 mmol) in DCM (2 ml) at 0 °C was slowly added a solution of compound **61** (477 mg, 2.033 mmol) in DCM (1 ml). The resulting mixture was stirred for 2 hr at RT. After completion of the reaction, the reaction mixture was dilute with water and the product was extracted in DCM (2 x 20 ml). The organic layer was washed with water (2 x 15 ml), dried over anhydrous sodium sulfate, filtered and concentrated over the rotary evaporator to get the crude product. Crude product was purified by column chromatography (60-120 silica gel, 2% MeOH-DCM) to get pure product, Boc-**63** (54%; not shown) as an off-white solid, which was subjected to the treatment with methanolic HCl (10 ml) for 2

hr at RT. After the complete cleavage of Boc-group, the solvent was removed under low pressure, to give the crude product as an HCl salt. The aqueous solution of the salt was washed with diethylether and basified with $NaHCO_3$ (pH 10). The desired product was then partitioned into ethyl acetate, dried over anhydrous Na_2SO_4 and the solvent removed under low pressure to get the free amine **63** as off white solid (88 %).

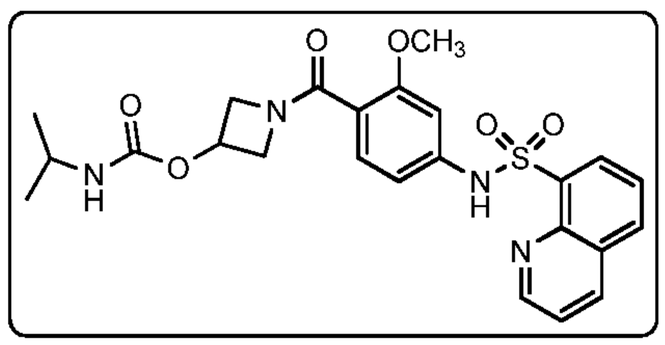
General procedure for the synthesis of compounds of Formula II wherein R^{1a} is hydrogen and R^{1b} is -O-C(O)-NH-R^a: EDCI (58 mg, 0.3048 mmol) and HOBT (41 mg, 0.3048 mmol) were added to a stirred solution of the acid **8** (100 mg, 0.3048 mmol; prepared as in Example 1) in anhydrous DMF. The temperature of the mixture was reduced to 0 °C, at which time DIPEA (196 µl, 1.067 mmol) was added under nitrogen atmosphere and the resultant solution (or suspension) was stirred at room temperature for 30 min. Amine **63** (0.3048 mmol) was then added at 0 °C. The reaction mixture was then brought to room temperature and stirred overnight. After completion of the reaction, the reaction mixture was diluted with water and extracted with ethyl acetate (3 x 15 ml). The organic layer was washed with water (3 x 10 ml), dried over anhydrous sodium sulfate, filtered and concentrated over the rotary evaporator to get the crude product. Crude product was purified by either by silica column chromatography or preparative HPLC to obtain the pure products in 53-78% yields.

Compound 132: 1-(3-Methyl-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl isopropylcarbamate:



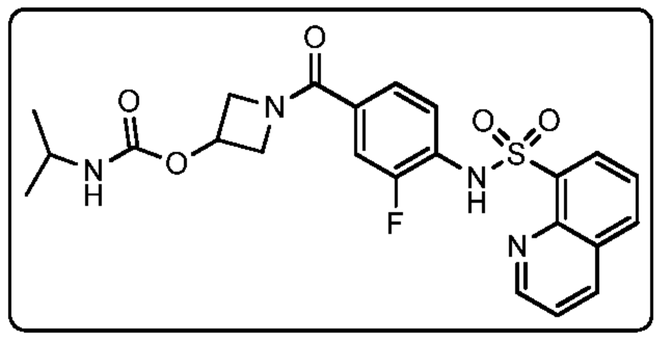
^1H NMR (400 MHz, $CDCl_3$) δ: 1.2 (s, 3H), 2.2 (d, 3H), 2.6 (d, 3H), 3.8 (m, 1H), 4.2 (d, 2H), 4.7 (d, 2H), 5.2 (m, 1H), 7.2-7.8 (m, 5H), 8.0-8.7(m, 3H), 9.1 (m, 1H); HPLC Purity: 99.0%; LCMS, m/z found 483.1 $(M+1)^+$.

Compound 133: 1-(2-Methoxy-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl isopropylcarbamate:



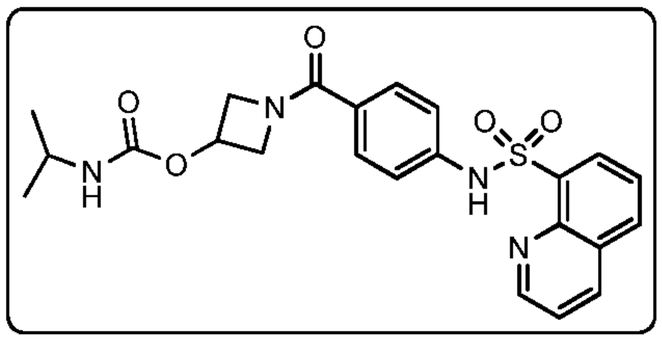
^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.6 (d, 6H), 3.9 (s, 3H), 4.2 (d, 2H), 4.7 (d, 2H), 5.2 (m, 1H), 6.3-7.0 (m, 3H), 7.6-8.4(m, 5H), 9.1 (m, 1H); HPLC Purity: 99.7%; LCMS, m/z found 499.1 $(M+1)^+$.

Compound 134: 1-(3-Fluoro-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl isopropylcarbamate:



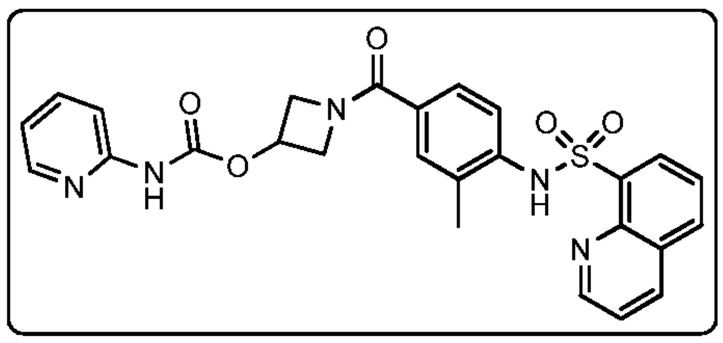
^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.4 (d, 6H), 3.7 (m, 1H), 3.8 (d, 2H), 4.2 (d, 2H), 5.2 (m, 1H), 7.0-7.6 (m, 5H), 8.0-8.4 (m, 3H), 9.1 (m, 1H); HPLC Purity: 98.6%; LCMS, m/z found 509 $(M+Na)^+$.

Compound 135: 1-(4-(Quinoline-8-sulfonamido)benzoyl)azetidin-3-yl isopropylcarbamate:



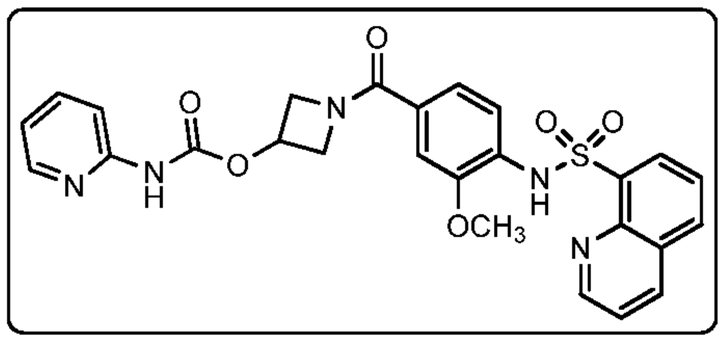
^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.4 (d, 6H), 3.8 (m, 1H), 4.1 (d, 2H), 4.4 (d, 2H), 5.2 (m, 1H), 7.0-7.6 (m, 5H), 8.0-8.4 (m, 4H), 9.1 (m, 1H); HPLC Purity: 98.6%; LCMS, m/z found 469.2 $(M+1)^+$.

Compound 155: 1-(3-Methyl-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl pyridin-2-ylcarbamate:



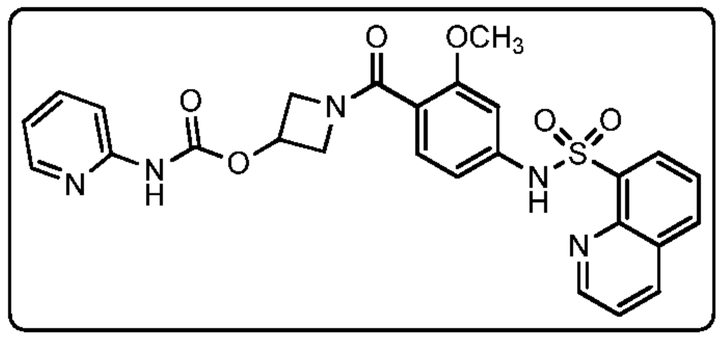
^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.1 (s, 3H), 3.8 (m, 1H), 4.1 (d, 2H), 4.4 (d, 2H), 5.2 (m, 1H), 7.0-7.6 (m, 7H), 8.0-8.4 (m, 5H), 9.1 (m, 1H); HPLC Purity: 96.1%; LCMS, m/z found 518.3 *(M+1)*$^+$.

Compound 156: 1-(3-Methoxy-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl pyridin-2-ylcarbamate (40f):



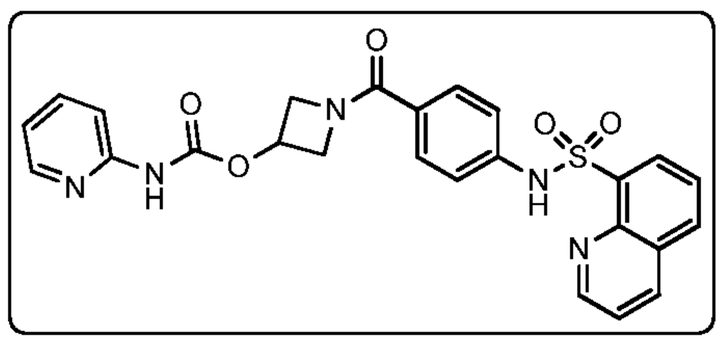
^{1}H NMR (400 MHz, $CDCl_3$) δ: 3.6 (s, 3H), 4.1 (d, 2H), 4.4 (d, 2H), 5.2 (m, 1H), 7.0-7.6 (m, 7H), 8.0-8.4 (m, 5H), 9.1 (m, 1H); HPLC Purity: 99.1%; LCMS, m/z found 534.3 *(M+1)*$^+$.

Compound 157: 1-(2-Methoxy-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl pyridin-2-ylcarbamate:



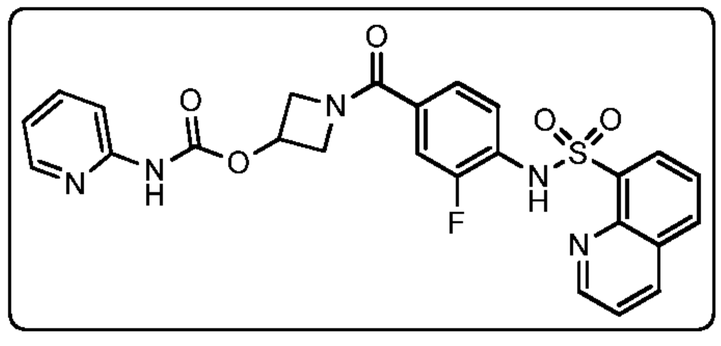
^{1}H NMR (400 MHz, $CDCl_3$) δ: 3.8 (s, 3H), 4.2 (d, 2H), 4.4 (d, 2H), 5.2 (m, 1H), 6.6-7.6 (m, 7H), 8.0-8.4 (m, 5H), 9.1 (m, 1H); HPLC Purity: 96.1%; LCMS, m/z found 534.3 *(M+1)*$^+$.

Compound 161: 1-(4-(Quinoline-8-sulfonamido)benzoyl)azetidin-3-yl pyridin-2-ylcarbamate:



^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.2 (d, 2H), 4.4 (d, 2H), 5.2 (m, 1H), 7.0-8.0 (m, 9H), 8.0-8.4 (m, 4H), 9.1 (m, 1H); HPLC Purity: 98.3%; LCMS, m/z found 504.3 *(M+1)*$^+$.

Compound 162: 1-(3-Fluoro-4-(quinoline-8-sulfonamido)benzoyl)azetidin-3-yl pyridin-2-ylcarbamate:



^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.2 (d, 2H), 4.4 (d, 2H), 5.2 (m, 1H), 7.0-8.0 (m, 8H), 8.0-8.4 (m, 4H), 9.1 (m, 1H); HPLC Purity: 98.8%; LCMS, m/z found 522.3 *(M+1)*$^+$.

Example 8. PKM2 Assay.

Procedure:

- PKM2 stock enzyme solution was diluted in Reaction Buffer
- 2 µL of compound was added into each well first, and then 180 µL of the Reaction Mix was added.
- Reaction mixture with compound (without ADP) were incubated for 30 minutes at 4°C.
- Plates were re-equilibrated to room temperature prior to adding 20 µL ADP to initiate the reaction.
- Reaction progress was measured as changes in absorbance at 340 nm wavelength at room temperature (25°C)

Reaction Mix: PKM2 (50 ng/well), ADP (0.7 mM), PEP (0.15 mM), NADH (180 µM), LDH (2 units) in Reaction Buffer

Reaction Buffer: 100 mM KCl, 50 mM Tris pH 7.5, 5 mM MgCl2, 1 mM DTT, 0.03% BSA.

Certain compounds of Formula I were tested in the above-described assay. The results are showin in Table 2, below. A compound described herein may be tested for its ability to activate PKM2. The activation activity of these compounds is represented as an AC_{50} in Table 2 and throughout the application. As shown in Table 2, "A" refers to an activator of PKM2 with an EC_{50} < 100 nM. "B" refers to an activator of PKM2 with an EC_{50} between 100 nM and 1 μM. "C" refers to an activator of PKM2 with an EC_{50} between 1 μM and 10μM. "D" refers to an activator of PKM2 with an EC_{50} greater than 10 μM. "NA" refers to data that is not available.

Table 2. AC_{50} Values for Exemplary Compounds of Formula I

Compound	AC_{50}
100	B
101	A
102	C
103	B
104	D
105	B
106	A
107	B
108	B
109	B
110	B
111	C
112	A
113	A
114	A
115	B
116	D

Compound	AC_{50}
117	B
118	B
119	C
120	B
121	C
122	A
123	B
124	C
125	D
126	D
127	C
128	D
129	B
130	A
131	A
132	B
133	B

Compound	AC_{50}
134	C
135	C
136	B
137	B
138	A
139	C
140	C
141	D
142	C
143	D
144	C
145	A
146	B
147	B
148	B
149	A
150	A

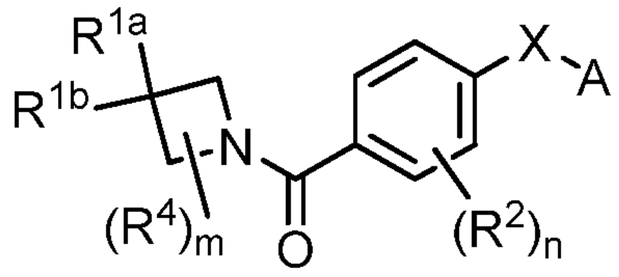
Compound	AC_{50}
151	A
152	NA
153	B
154	B
155	B
156	B
157	B
158	A
159	A
160	B
161	C
162	D
163	C
164	B
165	B
166	NA

Having thus described several aspects of several embodiments, it is to be appreciated various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the spirit and scope of the invention. Accordingly, the foregoing description and drawings are by way of example only.

CLAIMS

What is claimed is:

1. A compound of formula (I):



(I), or a pharmaceutically acceptable salt thereof, wherein:

A is aryl or heteroaryl, wherein the aryl or heteroaryl is optionally substituted, and the aryl or heteroaryl is optionally fused to an optionally substituted carbocyclyl or an optionally substituted heterocyclyl;

X is selected from -NH-$S(O)_2$-, -N(alkyl)-$S(O)_2$-, -$S(O)_2$-N(H)-, and -$S(O)_2$-N(alkyl)-;

R^{1a} is selected from hydrogen, alkyl, and arylalkyl; and R^{1b} is selected from OR^3, N(alkyl)R^3 and NHR^3; or

R^{1a} is alken-1-yl and R^{1b} is absent;

each R^2 is independently selected from halo, haloalkyl, alkyl, alkoxy and hydroxyl;

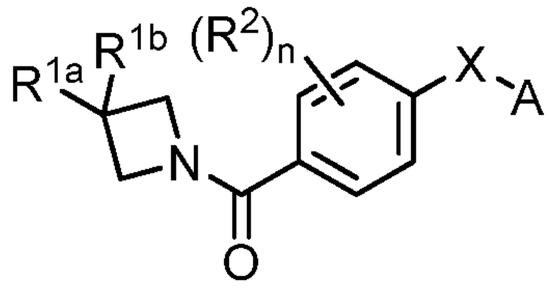
R^3 is selected from hydrogen, alkyl, optionally substituted aryl, optionally substituted heteroaryl, arylalkyl, $C(O)R^a$, and C(O)N(H)R^a, wherein R^a is selected from alkyl, alkenyl, aryl, heteroaryl, arylalkyl and heteroarylalkyl; and wherein any aryl or heteroaryl portion of R^a is optionally substituted;

each R^4 is independently selected from haloalkyl, alkyl, alkoxy and hydroxyl

n is 0, 1, or 2;

m is 0, 1, or 2.

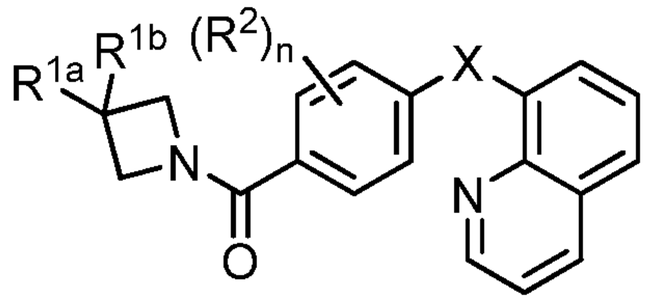
2. The compound of claim 1, wherein m is 0, the compound having Formula (Ia):



(Ia), or a pharmaceutically acceptable salt thereof.

3. The compound of claim 2, wherein A is a bicyclic heterocycle.

4. The compound of claim 3, wherein A is quinolin-8-yl, the compound



having the Formula II: (II).

5. The compound of any one of claims 1-4, wherein R^{1a} is selected from hydrogen, optionally substituted phenyl, methyl and optionally substituted benzyl.

6. The compound of any one of claims 1-5, wherein R^{1b} is selected from hydroxyl, methoxy, optionally substituted benzoxy, optionally substituted -OC(O)-benzyl, optionally substituted -OC(O)-pyridinyl, -OC(O)NH($CH(CH_3)_2$), optionally substituted -OC(O)NH(pyridinyl), -NH(optionally substituted phenyl), -N(CH_3)(optionally substituted phenyl),-NH(optionally substituted benzyl), -NH(optionally substituted pyridinyl), -NH(C(O)-pyridinyl), -NH(C(O)-NH-$CH(CH_3)_2$), and -NH(C(O)-NH-CH_2-$CH=CH_2$).

7. The compound of any one of claims 1-6, wherein n is 0, or where n is 1 and is selected from fluoro, methyl, and methoxy.

8. The compound of claim 4, wherein:

X is -NH-$S(O)_2$-;

R^{1a} is phenyl or benzyl, wherein the ring portion of R^{1a} is optionally substituted;

R^{1b} is hydroxyl; and

n is 0 or 1.

9. The compound of claim 4, wherein:

X is -NH-$S(O)_2$-;

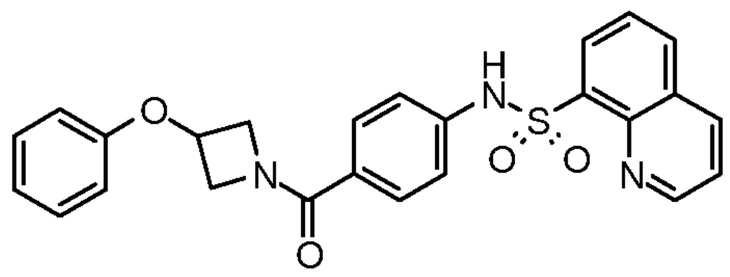
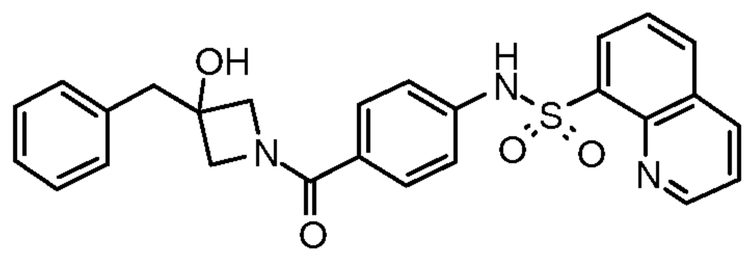
R^{1a} is hydrogen;

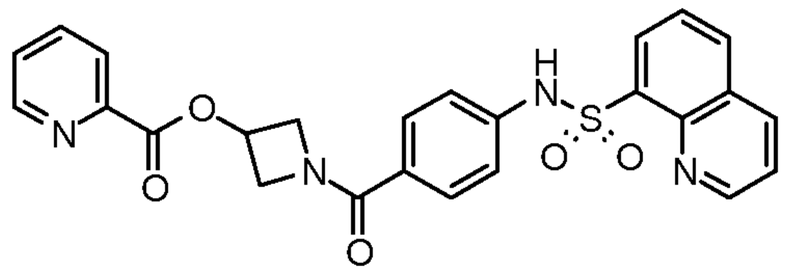
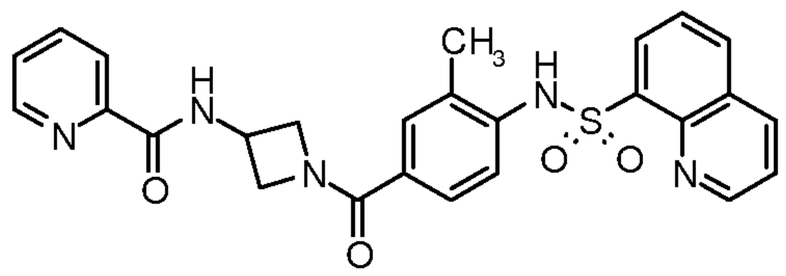
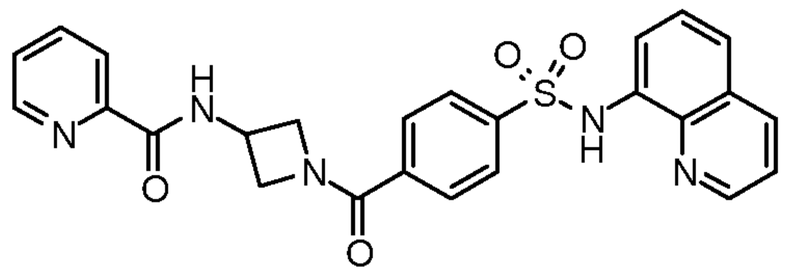
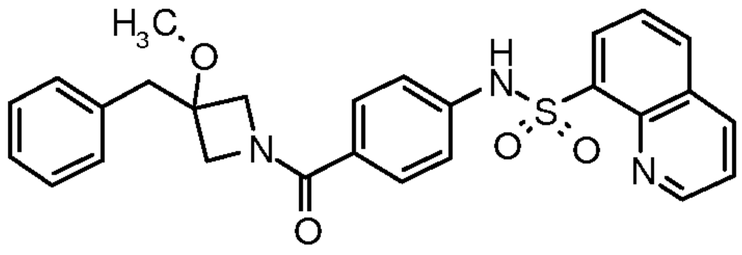
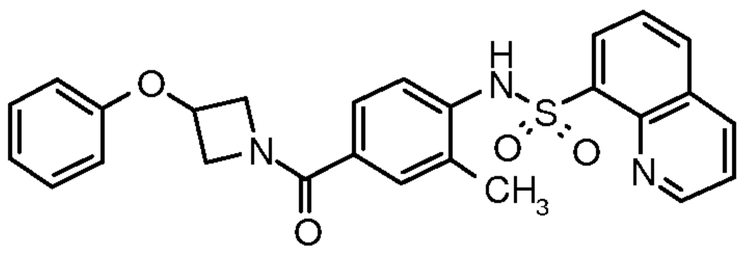
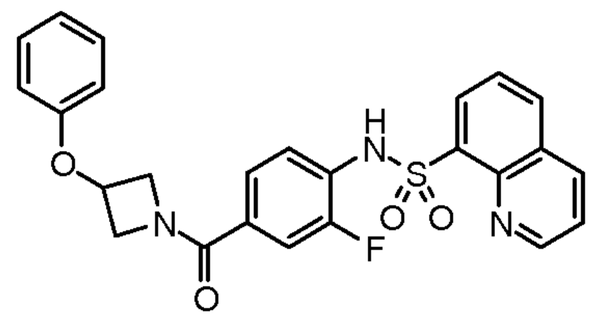
R^{1b} is selected from -NH-phenyl, phenoxy, -NH-pyridin-2-yl, and -$N(CH_3)$-phenyl, wherein the phenyl or pyridinyl portion of R^{1b} is optionally substituted; and

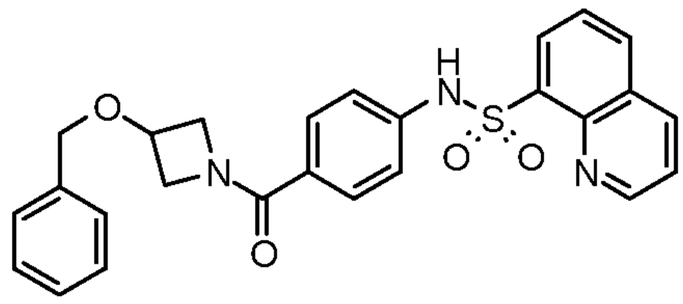
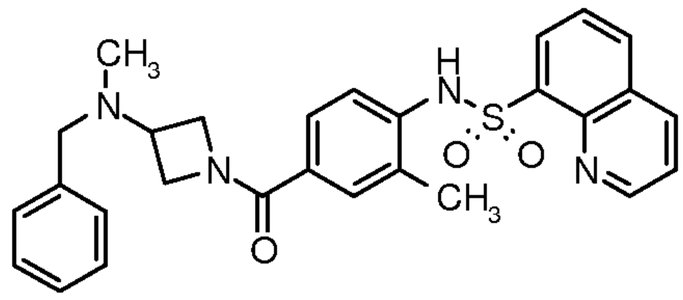
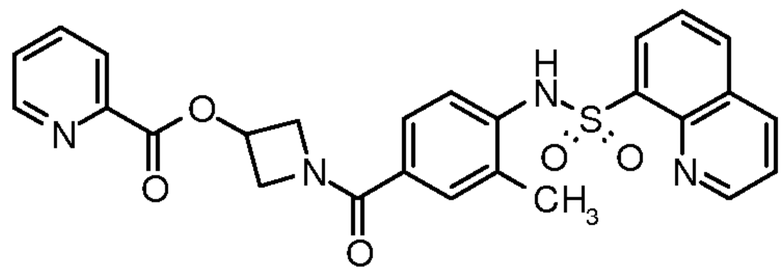
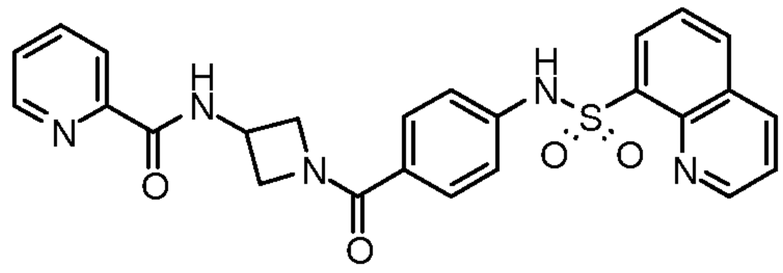
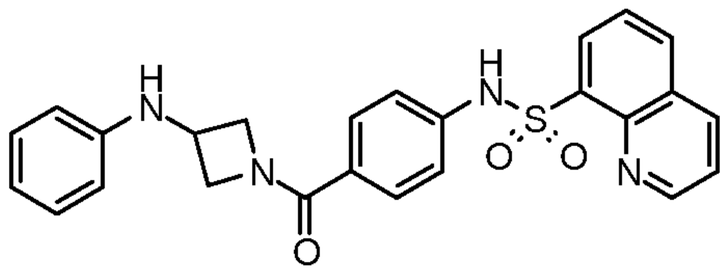
n is 0 or 1.

10. The compound of claim 8 or 9, wherein n is 1 and is selected from methyl, and methoxy.

11. The compound of claim 1, selected from any one of the compounds in the table below:

Compound	**Structure**
100	
101	

102	
103	
104	
105	
106	
107	

108	
109	
110	
111	
112	
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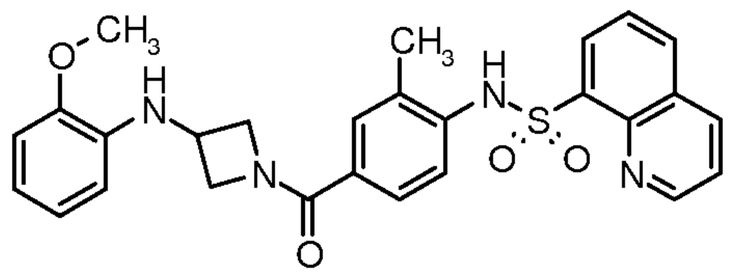
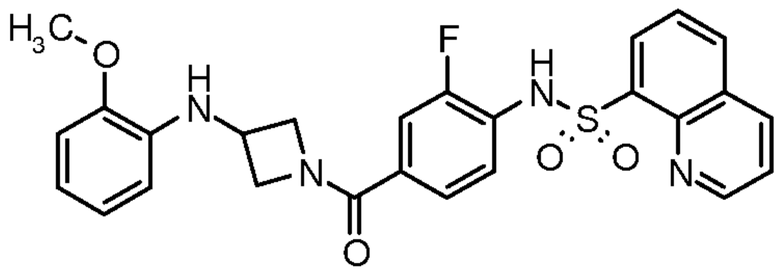
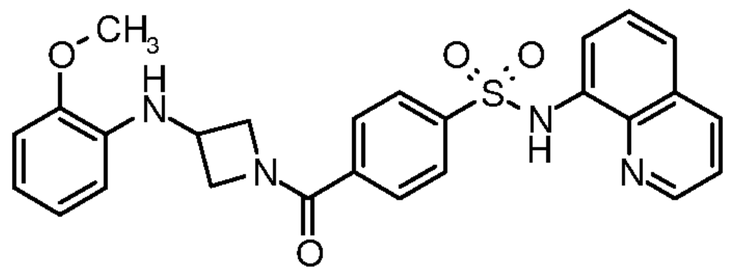
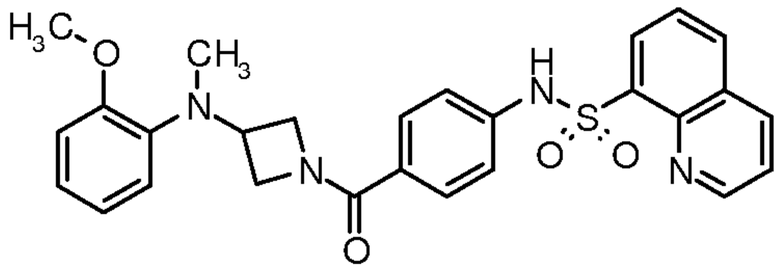
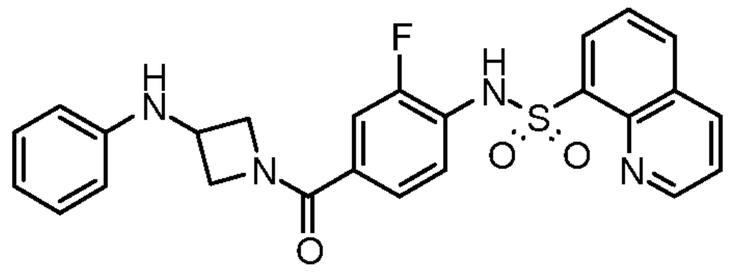
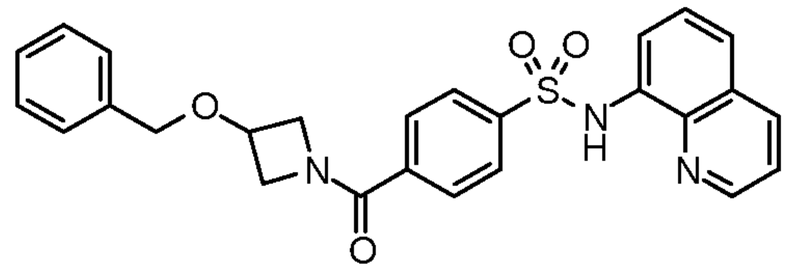
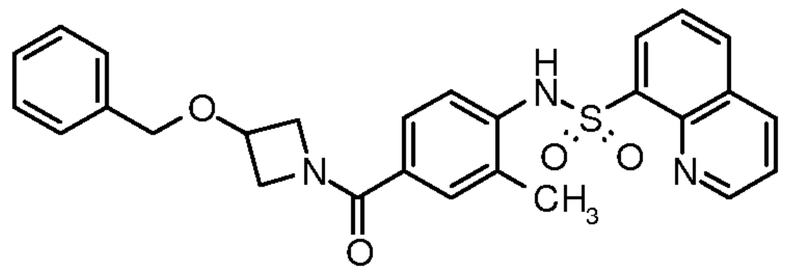
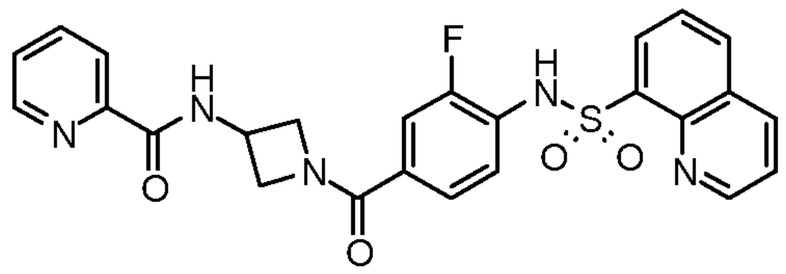
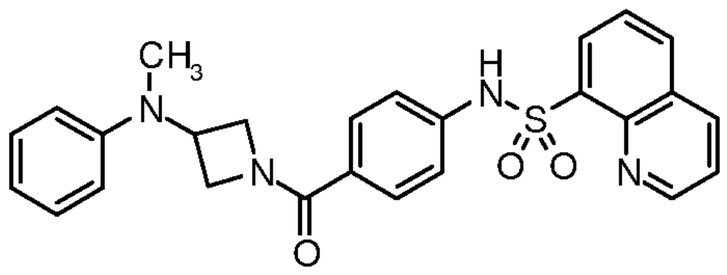
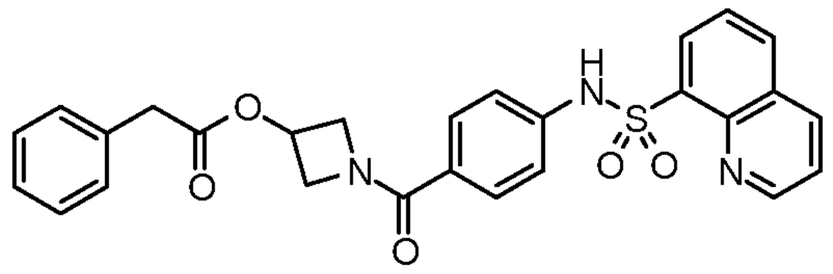
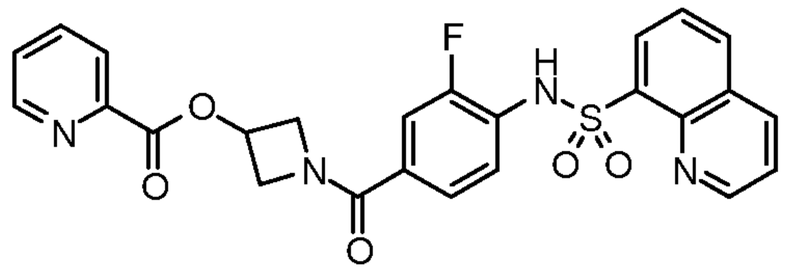
114		
115		
116		
117		
118		
119		

120	
121	
122	
123	
124	
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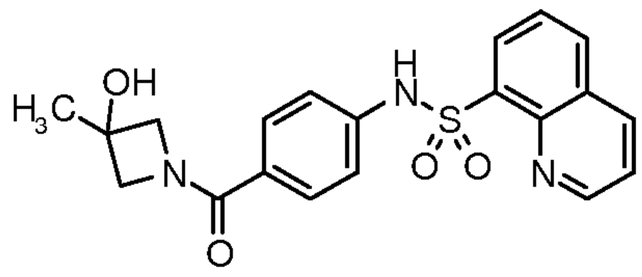
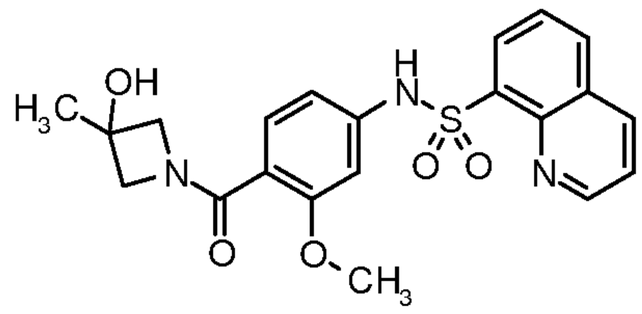
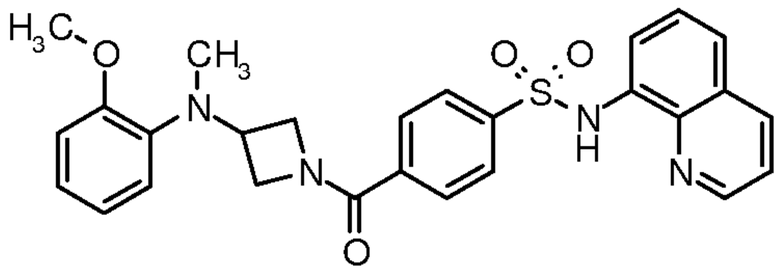
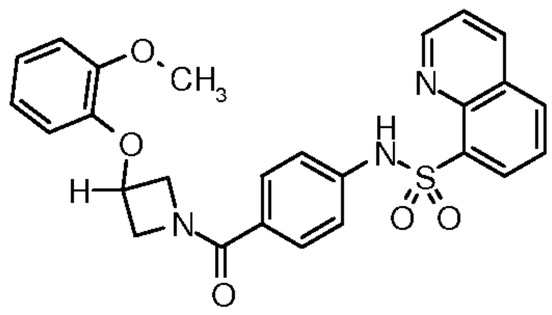
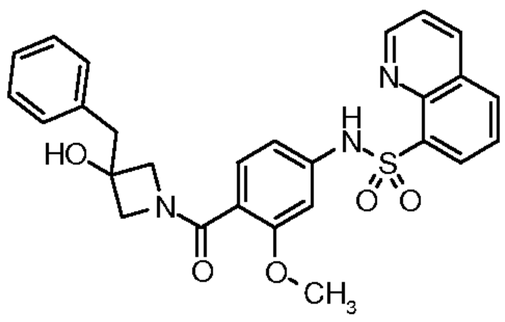
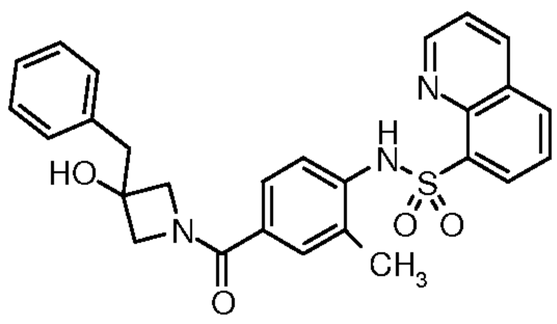
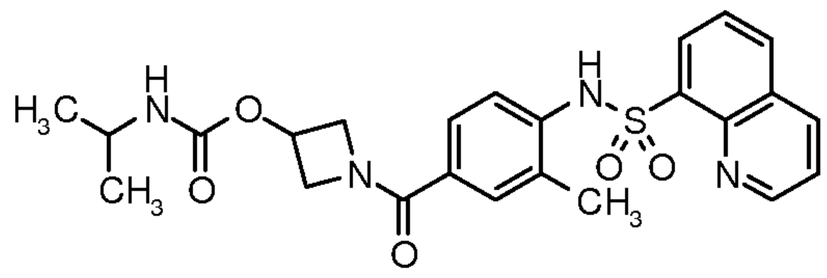
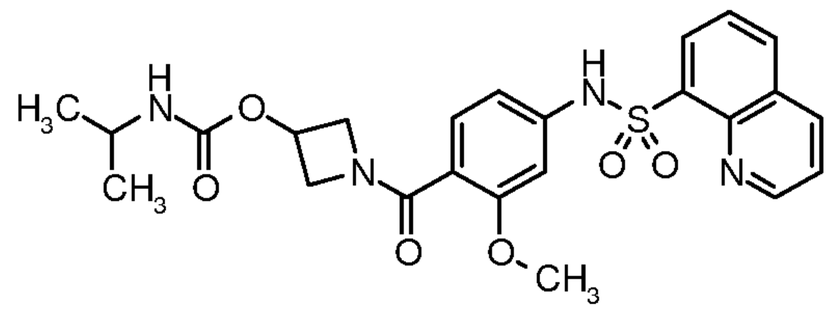
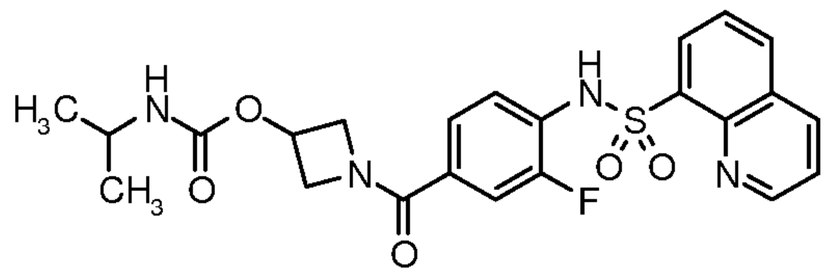
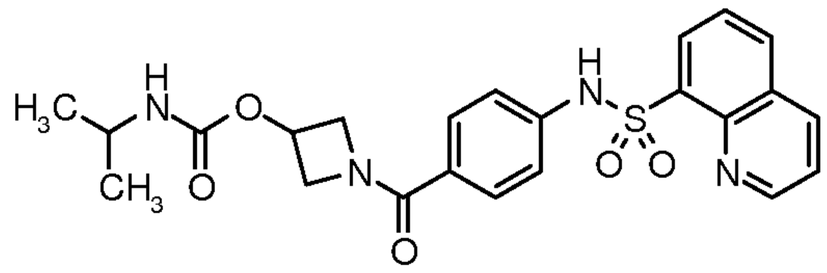
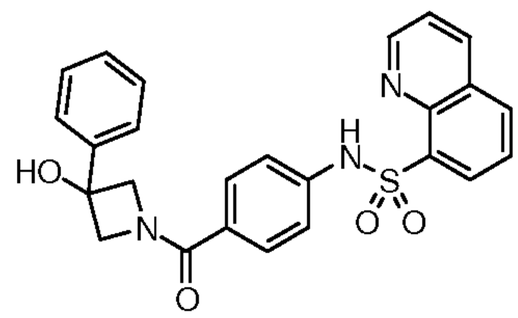
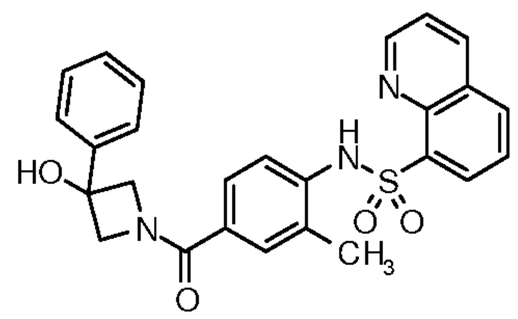
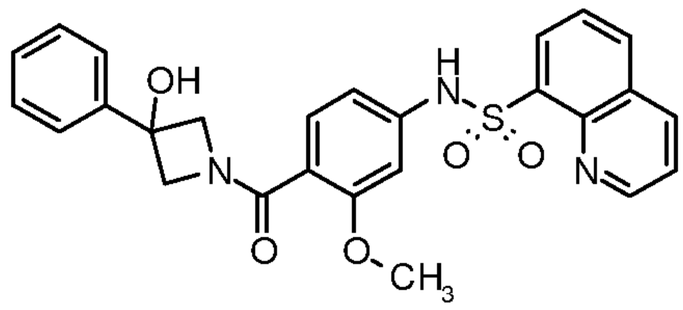
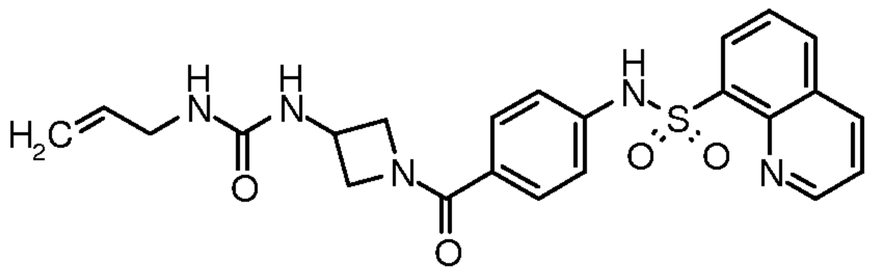
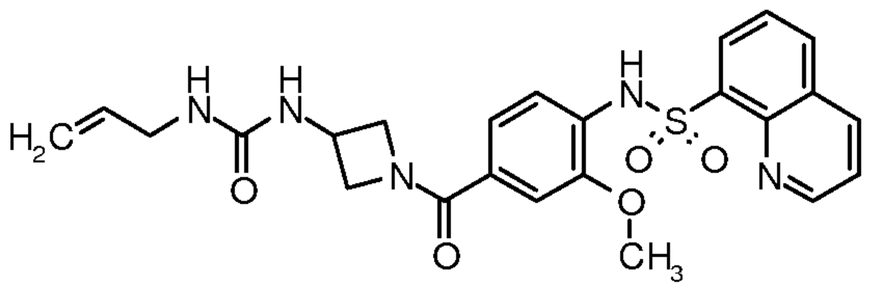
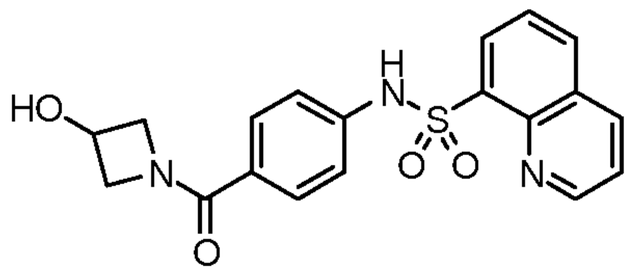
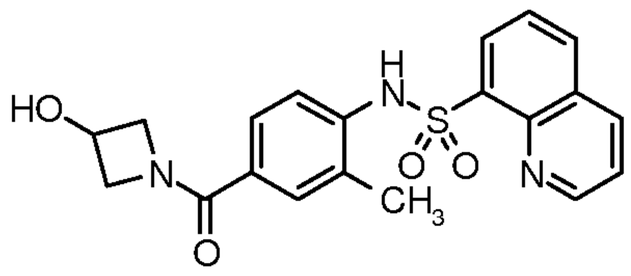
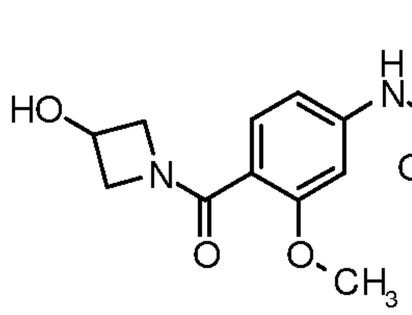
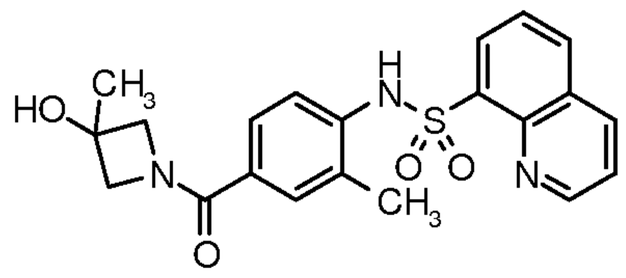
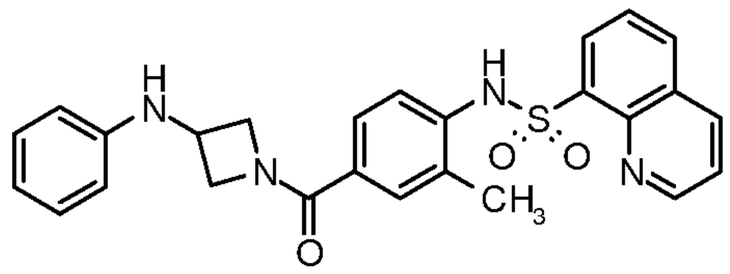
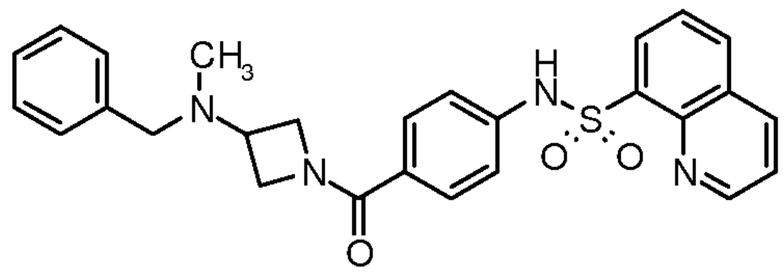
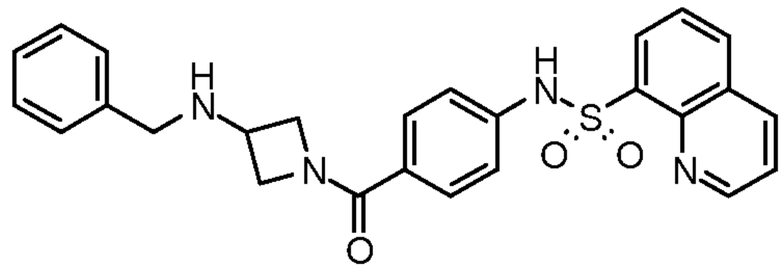
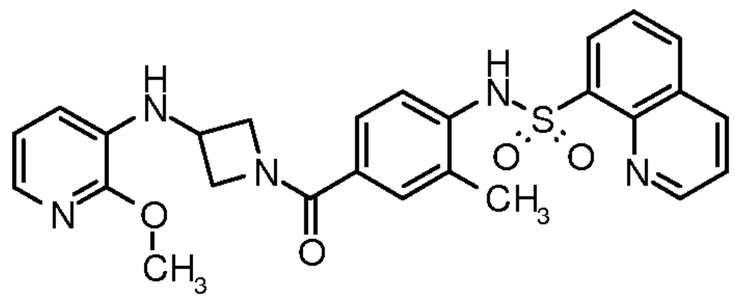
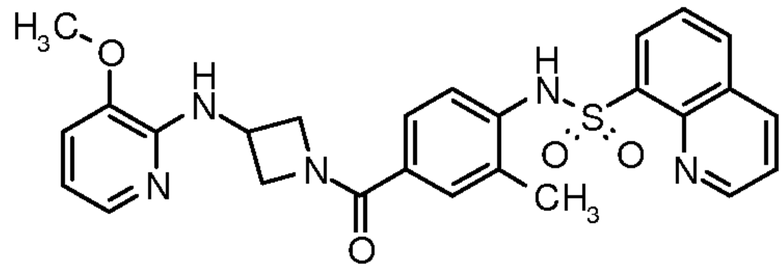
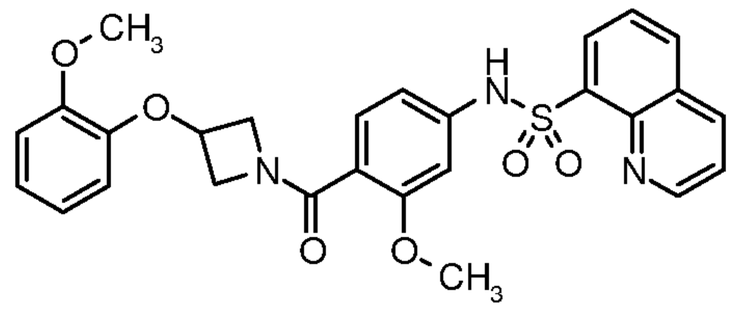
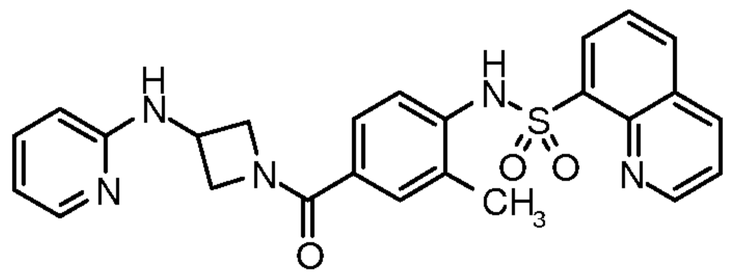
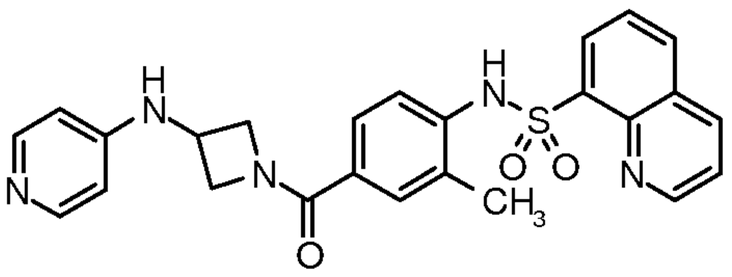
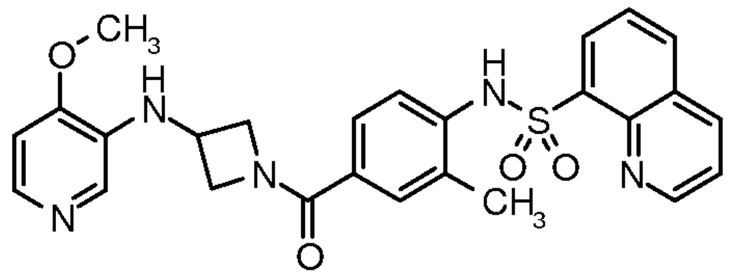
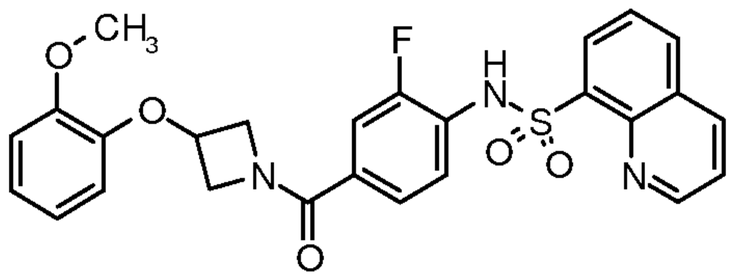
126		
127		
128		
129		
130		
131		

132		
133		
134		
135		
136		
137		

138		
139		
140		
141		
142		
143		

144		
145		
146		
147		
148		
149		

150	
151	
152	
153	
154	
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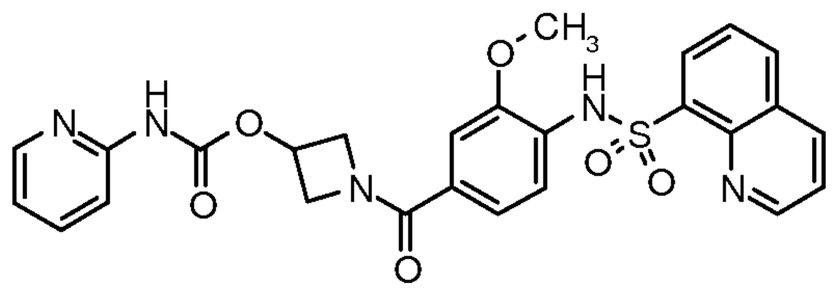
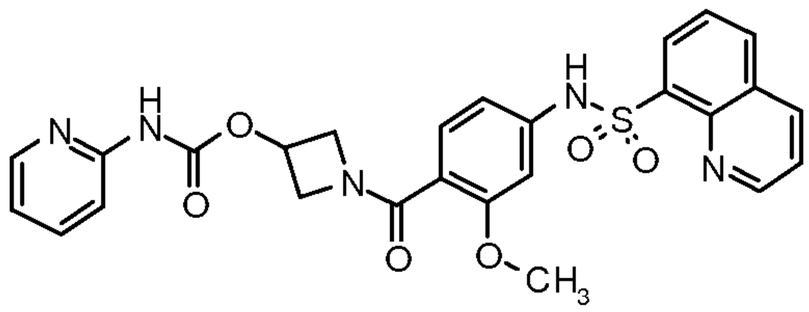
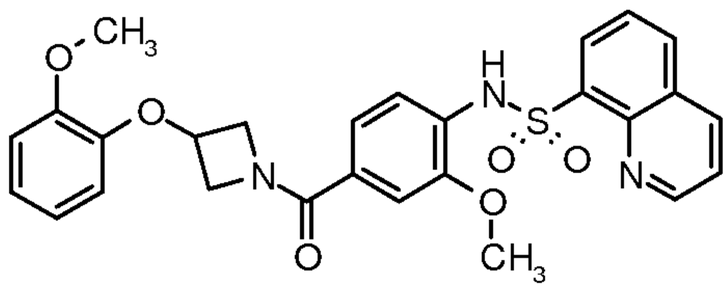
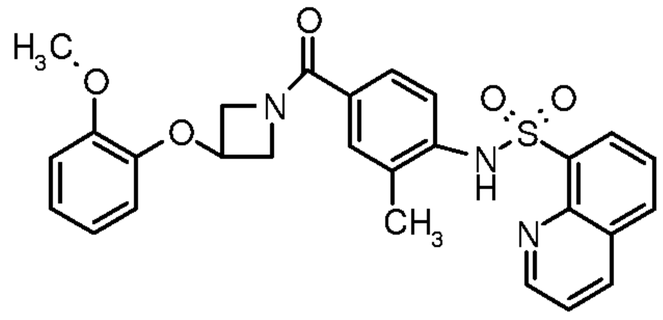
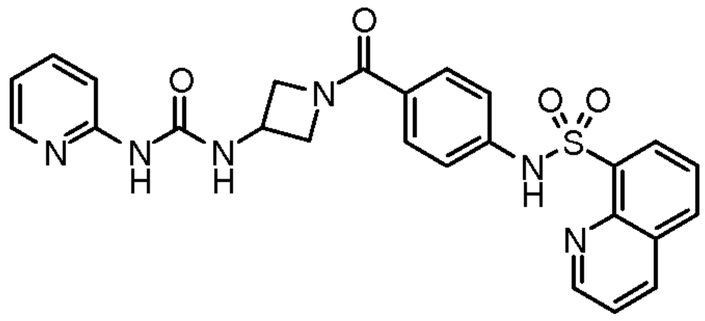
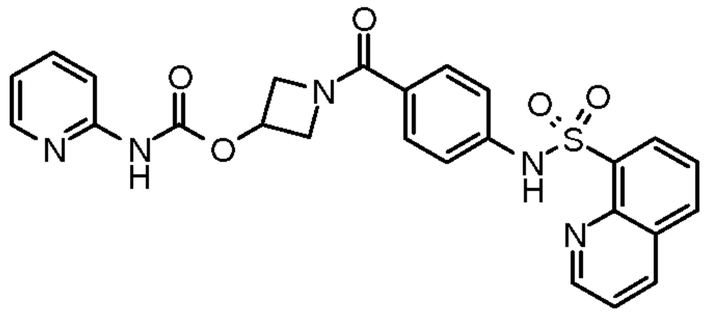
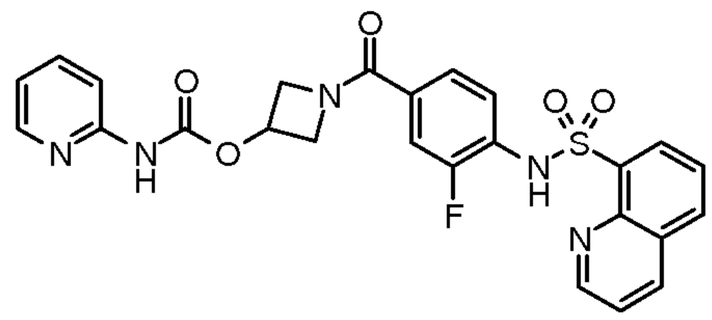
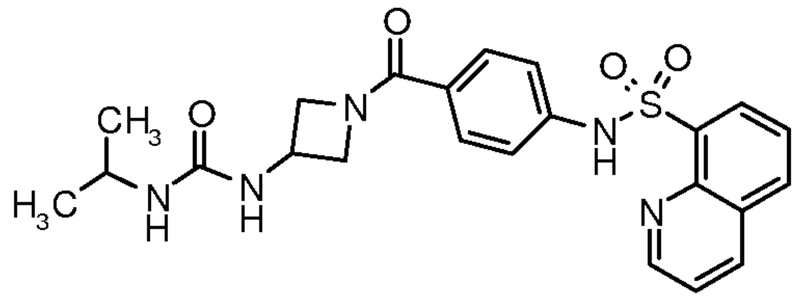
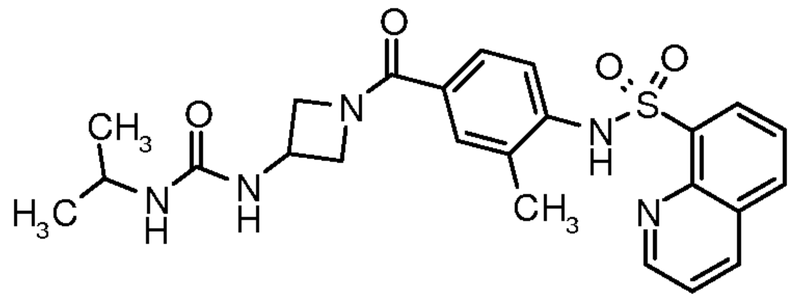
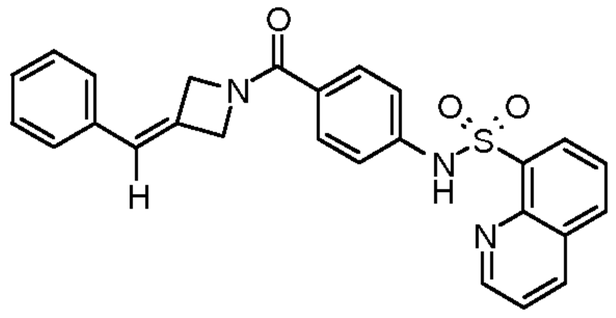
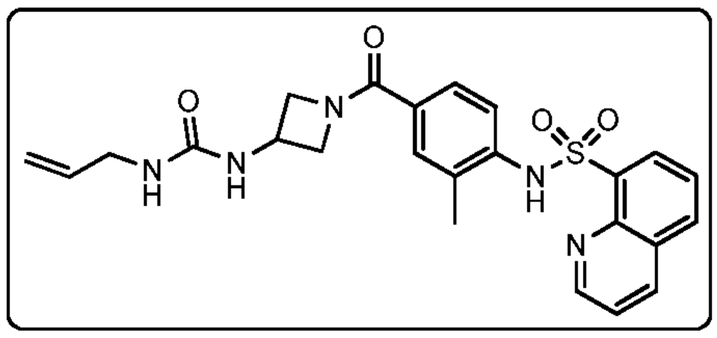
156	
157	
158	
159	
160	
161	

162		
163		
164		
165		
166		

12. The compound of claim 11, selected from any one of Compound 101, 106, 112,113, 114, 122, 130, 131, 138, 145, 149, 150, 151, 158 and 159.

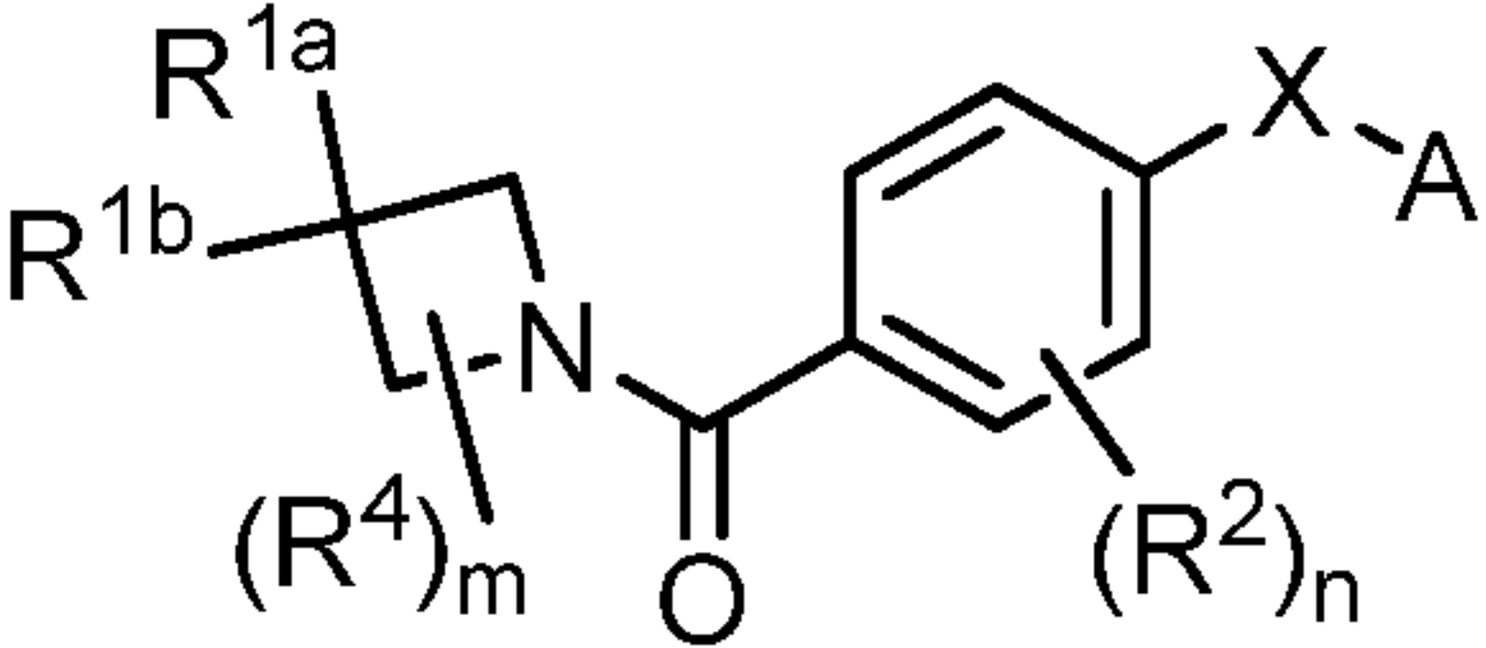
13. A pharmaceutical composition comprising a compound of claim 1 or a pharmaceutical acceptable salt thereof and a pharmaceutically acceptable carrier

14. A method of modulating PKM2 activity in a subject in need thereof, the method comprising administering to said subject a pharmaceutical composition of claim 13.

15. A method of treating a cancer associated with PKM2 activity in a subject in need thereof, the method comprising administering to the subject a pharmaceutical composition of claim 13.

16. Use of a pharmaceutical composition of claim 13 in the manufacture of a medicament for modulating PKM2 activity.

17. Use of a pharmaceutical composition of claim 13 in the manufacture of a medicament for treating a cancer associated with PKM2 activity



(I)