

ANTIVIRAL COMPOUNDS WITH A HETEROTRICYCLE MOIETY

FIELD OF THE INVENTION

The present invention relates to antiviral compounds, their tautomeric forms, their stereoisomers, and their pharmaceutically acceptable salts, pharmaceutical compositions comprising one or more such compounds, and methods of treating viral infection.

CROSS-REFERENCE TO A RELATED APPLICATION

The present application claims the benefit of Indian Provisional Patent Application Nos. 0147/KOL/2012 filed 10th February 2012, and 1017/KOL/2012 filed 4th September 2012, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Persistent hepatitis C virus (HCV) infection is a major health problem globally affecting ~3% of the world population and is an important contributor to chronic liver disease culminating with liver cirrhosis, hepatocellular carcinoma and liver failure [Szabo E, Lotz G, et al., *Pathol. Oncol. Res.*, 2003, 9, 215-221; Hoofnagle JH., *Hepatology*, 1997, 26 15S-20]. An estimated 170 million chronic carriers worldwide are at risk of developing liver disease. In the United States alone ~3 million are chronically infected with HCV and the number of HCV related deaths is increasing significantly over the years [Barnes E., WHO factsheet 2010. Available at: http://www.who.int/vaccine_research/diseases/viral_cancers/en/index2.html]. Clinically, chronic infection is often asymptomatic with latent periods lasting for decades before manifestation by which time extensive liver damage has occurred. HCV is spread primarily by unscreened blood transfusions and use of contaminated needles and syringes; the highest risk groups are intravenous

drug users and people who received blood transfusions (mainly haemophiliacs) before 1990 when screening for HCV was introduced. Factors that have been reported to influence the rate of HCV disease progression include age (increasing age is associated with more rapid progression), gender (males have
5 more rapid disease progression than females), alcohol consumption (associated with an increased rate of disease progression), HIV co-infection (associated with a markedly increased rate of disease progression), and fatty liver.

The standard therapy for HCV was a combination of pegylated interferon (PEG-IFN) α and weight based ribavirin (RBV), which was inadequate for majority of
10 the patients and therapy associated side effects such as pancytopenia, flu-like symptoms or depression were commonly observed leading to early treatment discontinuation [Fried MW, *et al.*, *N. Engl. J. Med.*, 2002, 347, 975-982]. The approval of two direct acting agents (DAA), i.e., 1st generation protease inhibitors, Incivek and Victrelis in May 2011 ushered in the era of specifically
15 targeted HCV therapy [Jesudian AB, Gambarin-Gelwan M and Jacobson IM., *Gastroenterology Hepatol.* 2012, 8, 91-101].

The combination of above mentioned DAAs, PEG-IFN and RBV (triple therapy) substantially increased the rate of sustained virologic response in the treatment naïve and experienced patients. However, a number of issues restrict the usage
20 of these drugs – i) complex treatment algorithms issued by the regulatory bodies; ii) they are restricted to genotype 1; iii) low barrier to resistance mutations and/or iv) increased cost of therapy leading to only limited access to care. Hence, there exists a need for alternative therapeutic strategies that provide a broader genotype coverage, better efficacy, better tolerance and/or
25 limited selection of resistant HCV variants.

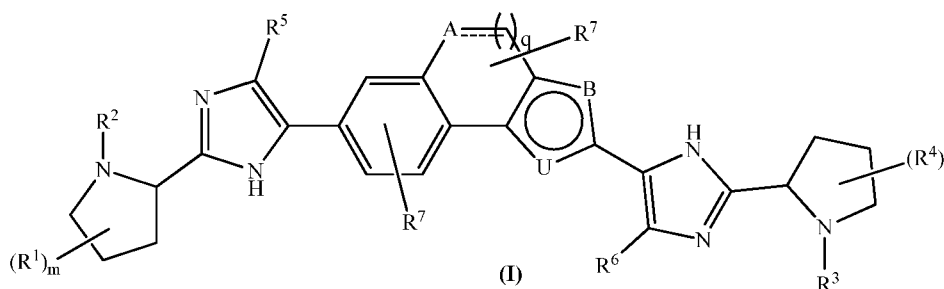
The sequence diversity of HCV is complex with the virus organized into 6 distinct genotypes and over 100 subtypes. Additionally, HCV exists as many closely related viral sequences, termed as quasi-species, in the infected individual, making specific pharmaceutical targeting of HCV proteins
30 challenging due to the rapid evolution of escape mutants. It is increasingly evident that a broad collection of specific, pan genotypic anti-viral drugs

targeting multiple essential viral functions, in addition to the current viral therapies, will be required for effective global control of HCV.

Disclosures describing HCV inhibitors include US 2009/0202478, US 2009/0202483, WO 2009/020828, WO 2009/020825, WO 2009/102318, WO 2009/102325, WO 2009/102694, WO 2008/144380, WO 2008/021927, WO 2008/021928, WO 2008/021936, WO 2006/133326, WO 2004/014852, WO 2008/070447, WO 2009/034390, WO 2006/079833, WO 2007/031791, WO 2007/070556, WO 2007/070600, WO 2008/064218, WO 2008/154601, WO 2007/082554, WO 2008/048589, EP 2121697, US 8008264, US 8008263, US 2011/0217265, US 2011/0217261, US 8012982, US 8012942, US 8012941, US 2011/0223134, WO 2011/106992, WO 2011/106929, US 2011/0237636, US 2011/0237579, US 2011/0236348, US 2011/0250176, US 2011/0250172, US 2011/269956, US 2011/274648, EP 2385048, US 2011/0281910, US 2011/0286961, US 2011/0294819, US 2011/0293563, US 2011/300104, WO 2011/156543, WO 2011/153396, WO 2011/151652, WO 2011/151651, US 2012/004196, US 8093243, US 8101643, US 2012/0028978, WO 2012/018534, WO 2012/018325, WO 2012/021704, WO 2012/021591, US 2012/0040977, US 2012/0040962, WO 2012/024363, EP 2086995, EP 2049116, US 8133884, US 2012/0076755, EP 2250163, US 8143414, US 8143301, US 8143288, US 2012/0083483, US 8147818, WO 2012/039717, WO 2012/041227, WO 2012/041014, EP 2146984, US 8188132, and US 8198449, the disclosures of which are incorporated by reference.

BRIEF SUMMARY OF THE INVENTION

The present invention provides antiviral compounds of the general formula (I):



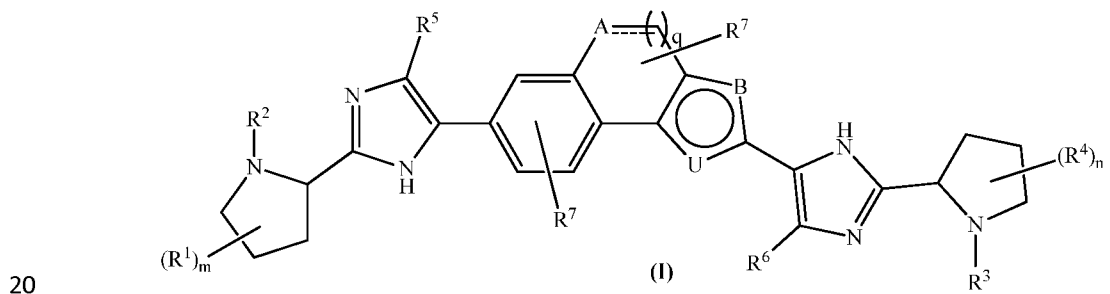
their tautomeric forms, their isomers, their pharmaceutically acceptable salts, pharmaceutical composition containing them, methods of making the above compounds, and their use as antiviral compounds; wherein A, B, U, and R¹-R⁷, m, n, and q are described in detail below.

- 5 According to one aspect of the present invention there is provided compounds represented by the general formula I, its tautomeric forms, its stereoisomers, its pharmaceutically acceptable salts, their combinations with suitable medicament and pharmaceutical compositions containing them having a broader spectrum of activity as they show inhibitory actions against multiple genotypes of HCV
10 with high potency.

The present invention also provide compounds represented by the general formula I, its tautomeric forms, its stereoisomers, its pharmaceutically acceptable salts, their combinations with suitable medicament and pharmaceutical compositions containing them having good stability in human
15 liver microsomes and promising oral bioavailability with enhanced liver concentrations and high liver to plasma ratio.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides compounds of the general formula (I):



their tautomeric forms, their isomers, their pharmaceutically acceptable salts, pharmaceutical composition containing them, methods of making of the above compounds, and their use as antiviral compounds;

wherein,

A is selected from $-\text{CR}^7=$, $-\text{C}(\text{H})(\text{R}^7)-$ and $-\text{O}-$;

B is selected from $-\text{C}(\text{R}^7)=$ and $-\text{S}-$;

U is selected from $-\text{N}=$ and $-\text{S}-$;

with a proviso that B and U both cannot be S at the time;

5 “-----” represents a single or double bond;

R^1 and R^4 are divalent groups, each of which along with the respective carbon atoms to which they are attached form a 3 to 7 membered carbocyclic ring or a 5 to 7 membered heterocyclic ring containing nitrogen, and optionally oxygen;

10 R^2 and R^3 are each independently selected from hydrogen, substituted- or unsubstituted- alkyl, substituted- or unsubstituted- cycloalkyl, substituted- or unsubstituted- aryl, substituted- or unsubstituted- heteroaryl, substituted- or unsubstituted- heterocyclyl, $\text{R}^{8a}\text{C}(=\text{O})-$, $\text{R}^{8a}\text{S}(=\text{O})_2-$, $\text{R}^{8a}\text{OC}(=\text{O})-$, $(\text{R}^9)\text{R}^8\text{NC}(=\text{O})-$, $\text{R}^{8a}\text{OC}(=\text{O})\text{N}(\text{R}^9)\text{CR}^b(\text{R}^a)\text{C}(=\text{O})-$, $\text{R}^{8a}\text{OC}(=\text{O})\text{N}(\text{R}^9)\text{CR}^b(\text{R}^a)\text{C}(\text{R}^d)(\text{R}^c)\text{C}(=\text{O})-$, $\text{R}^{8a}\text{C}(=\text{O})\text{N}(\text{R}^9)\text{C}(\text{R}^b)(\text{R}^a)\text{C}(=\text{O})-$, $\text{R}^{8a}\text{C}(=\text{O})\text{N}(\text{R}^9)\text{CR}^b(\text{R}^a)\text{C}(\text{R}^d)(\text{R}^c)\text{C}(=\text{O})-$,
 15 $(\text{R}^9)\text{R}^8\text{NC}(=\text{O})\text{N}(\text{R}^{10})\text{C}(\text{R}^b)(\text{R}^a)\text{C}(=\text{O})-$, and $\text{R}^9(\text{R}^8)\text{NC}(=\text{O})\text{N}(\text{R}^{10})\text{CR}^b(\text{R}^a)\text{C}(\text{R}^d)(\text{R}^c)\text{C}(=\text{O})-$;
 ;

R^5 and R^6 are each independently selected from hydrogen, halogen, substituted- or unsubstituted- alkyl, and substituted- or unsubstituted- cycloalkyl;

20 R^7 is selected from hydrogen, halogen, and substituted- or unsubstituted C_{1-3} alkyl;

R^8 is selected from hydrogen, substituted- or unsubstituted- alkyl, substituted- or unsubstituted- cycloalkyl, substituted- or unsubstituted- aryl, substituted- or unsubstituted- heteroaryl, and substituted- or unsubstituted- heterocyclyl;

25 R^9 and R^{10} are each independently selected from hydrogen, substituted- or unsubstituted- alkyl;

R^{8a} is independently selected from the group consisting of substituted- or unsubstituted- alkyl, substituted- or unsubstituted- cycloalkyl, substituted- or

unsubstituted- aryl, substituted- or unsubstituted- heteroaryl, and substituted- or unsubstituted- heterocyclyl;

R^a, R^b, R^c and R^d, are independently selected from hydrogen, substituted- or unsubstituted- C₁₋₆ alkyl, substituted- or unsubstituted- aryl, substituted- or unsubstituted- heteroaryl, substituted- or unsubstituted- cycloalkyl, and substituted- or unsubstituted- heterocyclyl, or R^a, R^b, R^c and R^d together with the carbon atom(s) to which they are attached forming substituted- or unsubstituted- carbocycle, or substituted- or unsubstituted- heterocycle;

m and n are integers independently selected from 0 and 1;

10 q is an integer selected from 1, 2, and 3;

when the alkyl group is a substituted alkyl group, the alkyl group is substituted with 1 to 4 substituents selected independently from oxo, halogen, cyano, perhaloalkyl, cycloalkyl, aryl, heteroaryl, heterocyclyl, R^{11a}O-, (alkyl)S(=O)₂-, (alkyl)C(=O)-, (alkyl)OC(=O)-, (alkyl)C(=O)O-, R¹¹N(H)C(=O)-, R¹¹(alkyl)NC(=O)-, (alkyl)C(=O)N(H)-, R¹¹N(H)-, R¹¹(alkyl)N-, R¹¹(H)NC(=O)N(H)-, and R¹¹(alkyl)NC(=O)N(H)-;

when the 'cycloalkyl' and the carbocyclic groups are substituted, each of them is substituted with 1 to 3 substituents selected independently from oxo, halogen, cyano, C₁₋₆ alkyl, perhaloalkyl, R^{11a}O-, (alkyl)S(=O)₂-, (alkyl)C(=O)-, (alkyl)OC(=O)-, (alkyl)C(=O)O-, R¹¹(H)NC(=O)-, R¹¹(alkyl)NC(=O)-, (alkyl)C(=O)N(H)-, R¹¹(H)N-, R¹¹(alkyl)N-, R¹¹(H)NC(=O)N(H)-, and R¹¹(alkyl)NC(=O)N(H)-;

when the aryl group is substituted, it is substituted with 1 to 3 substituents selected independently from halogen, cyano, hydroxy, C₁₋₆ alkyl, perhaloalkyl, alkyl-O-, perhaloalkyl-O-, alkyl(alkyl)N-, alkyl(H)N-, H₂N-, alkyl-S(=O)₂-, alkyl-C(=O)(alkyl)N-, alkyl-C(=O)N(H)-, alkyl(alkyl)NC(=O)-, alkyl(H)NC(=O)-, H₂NC(=O)-, alkyl(alkyl)NS(=O)₂-, alkyl(H)NS(=O)₂-, and H₂NS(=O)₂-;

when the heteroaryl group is substituted, it is substituted with 1 to 3 substituents selected independently from halogen, cyano, hydroxy, C₁₋₆ alkyl, perhaloalkyl, alkyl-O-, perhaloalkyl-O-, alkyl(alkyl)N-, alkyl(H)N-, H₂N-, alkyl-

$S(=O)_2-$, alkyl-C(=O)(alkyl)N-, alkyl-C(=O)N(H)-, alkyl(alkyl)NC(=O)-, alkyl(H)NC(=O)-, $H_2NC(=O)-$, alkyl(alkyl)NS(=O) $_2-$, alkyl(H)NS(=O) $_2-$, and $H_2NS(=O)_2-$;

- when the heterocyclic group is substituted, it can be substituted either on a ring carbon atom or on a ring hetero atom, when it substituted on a ring carbon atom, it is substituted with 1-3 substituents selected independently from halogen, cyano, oxo, C_{1-6} alkyl, perhaloalkyl, $R^{11a}O-$, (alkyl)OC(=O)-, (alkyl)C(=O)O-, $R^{11}(H)NC(=O)-$, $R^{11}(alkyl)NC(=O)-$, (alkyl)C(=O)N(H)-, $R^{11}(H)N-$, $R^{11}(alkyl)N-$, $R^{11}(H)NC(=O)N(H)-$, and $R^{11}(alkyl)NC(=O)N(H)-$; and
- 10 when the 'heterocyclic' group is substituted on a ring nitrogen, it is substituted with a substituent selected from C_{1-6} alkyl, (alkyl)SO $_2-$, (alkyl)C(=O)-, (alkyl)OC(=O)-, $R^{11}(H)NC(=O)-$, and $R^{11}(alkyl)NC(=O)-$;

R^{11} is selected from hydrogen, alkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl;

- 15 R^{11a} is selected from hydrogen, alkyl, perhaloalkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl.

R^1 and R^4 can be any suitable divalent groups, for example, C_{1-4} alkylenyl groups, particularly, $-CH_2-$ or $-CH_2CH_2-$.

- R^2 and R^3 are each independently selected from $R^{8a}C(=O)-$, $R^{8a}S(=O)_2-$, $R^{8a}OC(=O)-$, $(R^9)R^8NC(=O)-$, $R^{8a}OC(=O)N(R^9)CR^b(R^a)C(=O)-$, $R^{8a}OC(=O)N(R^9)CR^b(R^a)C(R^d)(R^c)C(=O)-$, $R^{8a}C(=O)N(R^9)C(R^b)(R^a)C(=O)-$, $R^{8a}C(=O)N(R^9)CR^b(R^a)C(R^d)(R^c)C(=O)-$, $(R^9)R^8NC(=O)N(R^{10})C(R^b)(R^a)C(=O)-$, and $R^9(R^8)NC(=O)N(R^{10})CR^b(R^a)C(R^d)(R^c)C(=O)-$.
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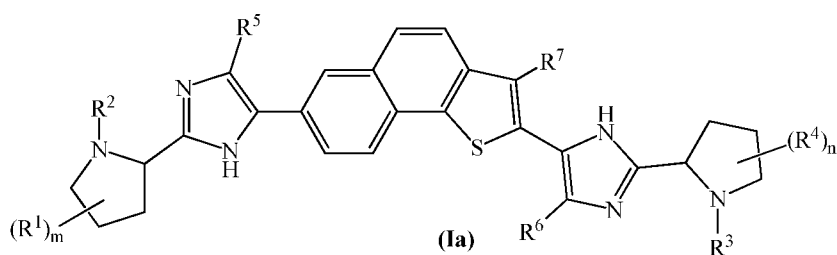
- R^2 and R^3 are each independently selected from $R^{8a}OC(=O)N(R^9)CR^b(R^a)C(=O)-$, $R^{8a}OC(=O)N(R^9)CR^b(R^a)C(R^d)(R^c)C(=O)-$, $R^{8a}C(=O)N(R^9)C(R^b)(R^a)C(=O)-$, $R^{8a}C(=O)N(R^9)CR^b(R^a)C(R^d)(R^c)C(=O)-$, $(R^9)R^8NC(=O)N(R^{10})C(R^b)(R^a)C(=O)-$, and $R^9(R^8)NC(=O)N(R^{10})CR^b(R^a)C(R^d)(R^c)C(=O)-$.
- 25

R^2 and R^3 both are particularly selected as $R^{8a}OC(=O)N(R^9)CR^b(R^a)C(=O)-$.

R^5 and R^6 are each particularly selected from hydrogen and halogen;

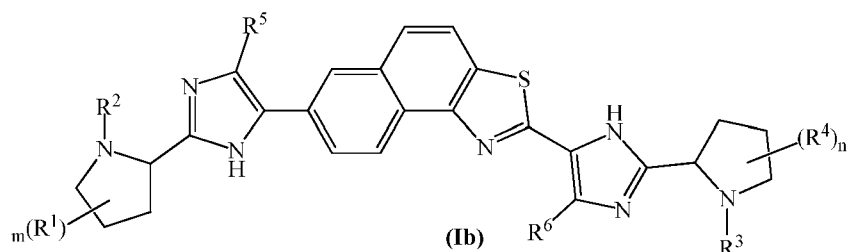
Whenever a range of the number of atoms in a structure is indicated (e.g., a C₁₋₁₂, C₁₋₈, C₁₋₆, or C₁₋₄ alkyl, alkylamino, etc.), it is specifically contemplated that any sub-range or individual number of carbon atoms falling within the indicated range also can be used. Thus, for instance, the recitation of a range of 1-8 carbon atoms (e.g., C₁₋₈), 1-6 carbon atoms (e.g., C₁₋₆), 1-4 carbon atoms (e.g., C₁₋₄), 1-3 carbon atoms (e.g., C₁₋₃), or 2-8 carbon atoms (e.g., C₂₋₈) as used with respect to any chemical group (e.g., alkyl, alkylamino, etc.) referenced herein encompasses and specifically describes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and/or 12 carbon atoms, as appropriate, as well as any sub-range thereof (e.g., 1-2 carbon atoms, 1-3 carbon atoms, 1-4 carbon atoms, 1-5 carbon atoms, 1-6 carbon atoms, 1-7 carbon atoms, 1-8 carbon atoms, 1-9 carbon atoms, 1-10 carbon atoms, 1-11 carbon atoms, 1-12 carbon atoms, 2-3 carbon atoms, 2-4 carbon atoms, 2-5 carbon atoms, 2-6 carbon atoms, 2-7 carbon atoms, 2-8 carbon atoms, 2-9 carbon atoms, 2-10 carbon atoms, 2-11 carbon atoms, 2-12 carbon atoms, 3-4 carbon atoms, 3-5 carbon atoms, 3-6 carbon atoms, 3-7 carbon atoms, 3-8 carbon atoms, 3-9 carbon atoms, 3-10 carbon atoms, 3-11 carbon atoms, 3-12 carbon atoms, 4-5 carbon atoms, 4-6 carbon atoms, 4-7 carbon atoms, 4-8 carbon atoms, 4-9 carbon atoms, 4-10 carbon atoms, 4-11 carbon atoms, and/or 4-12 carbon atoms, etc., as appropriate).

One of the embodiments of the present invention is a compound of formula (Ia):

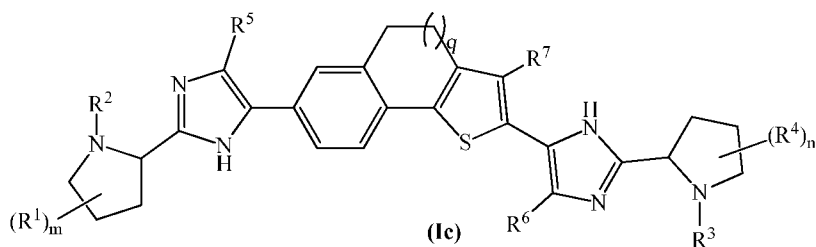


Another embodiment of the present invention is a compound of formula (Ib):

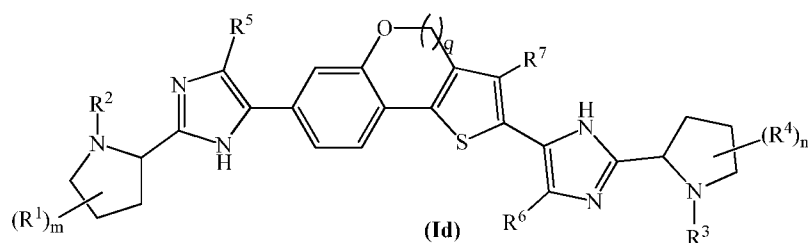
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A further embodiment of the present invention is a compound of formula (Ic):



Yet another embodiment of the present invention is compound of formula (Id):



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In any of the embodiments described above, R² and R³ both are particularly selected as R^{8a}OC(=O)R⁹N(R^b)R^aCC(=O)-.

In any of the embodiments described above, R⁵ and R⁶ are particularly selected independently from hydrogen and halogen.

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General terms used in the description of the formula above can be defined as follows; however, the meaning stated should not be interpreted as limiting the scope of the term *per se*.

The term “**alkyl**”, as used herein, means a straight or branched hydrocarbyl chain containing from 1 to 20 carbon atoms. Preferably, the alkyl group

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contains 1 to 10 carbon atoms. More preferably, alkyl group contains up to 6 carbon atoms. Examples of alkyl groups include, but are not limited to, methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, iso-butyl, tert-butyl, n-pentyl, isopentyl, neopentyl, and n-hexyl.

- 5 In a substituted alkyl group, the alkyl group is substituted with 1 to 4 substituents selected independently from oxo, halogen, cyano, perhaloalkyl, cycloalkyl, aryl, heteroaryl, heterocyclyl, $R^{11a}O-$, $(alkyl)S(=O)_2-$, $(alkyl)C(=O)-$, $(alkyl)OC(=O)-$, $(alkyl)C(=O)O-$, $R^{11}N(H)C(=O)-$, $R^{11}(alkyl)NC(=O)-$, $(alkyl)C(=O)N(H)-$, $R^{11}N(H)-$, $R^{11}(alkyl)N-$, $R^{11}(H)NC(=O)N(H)-$, and
- 10 $R^{11}(alkyl)NC(=O)N(H)-$; wherein, R^{11} is selected from hydrogen, alkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl; and R^{11a} is selected from hydrogen, alkyl, perhaloalkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl.

- The term "**cycloalkyl**" as used herein, means a monocyclic, bicyclic, or tricyclic non-aromatic ring system containing from 3 to 14 carbon atoms, preferably
- 15 monocyclic cycloalkyl ring containing 3 to 6 carbon atoms. Examples of monocyclic ring systems include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, and cyclooctyl. Bicyclic ring systems include monocyclic ring system fused across a bond with another cyclic system which may be an alicyclic ring or an aromatic ring Bicyclic rings also include spirocyclic systems
- 20 wherein the second ring gets annulated on a single carbon atom. Bicyclic ring systems are also exemplified by a bridged monocyclic ring system in which two non-adjacent carbon atoms of the monocyclic ring are linked by an alkylene bridge. Examples of bicyclic ring systems include, but are not limited to, bicyclo[3.1.1]heptane, bicyclo[2.2.1]heptane, bicyclo[2.2.2]octane,
- 25 bicyclo[3.2.2]nonane, bicyclo[3.3.1]nonane, and bicyclo[4.2.1]nonane, bicyclo[3.3.2]decane, bicyclo[3.1.0]hexane, bicyclo[4.1.0]heptane, bicyclo[3.2.0]heptanes, octahydro-1H-indene, spiro[2.5]octane, spiro[4.5]decane, spiro[bicyclo[4.1.0]heptane-2,1'-cyclopentane], hexahydro-2H-spiro[cyclopropane-1,1'-pentalene]. Tricyclic ring systems are the systems
- 30 wherein the bicyclic systems as described about are further annulated with third ring, which may be alicyclic ring or aromatic ring. Tricyclic ring systems are also exemplified by a bicyclic ring system in which two non-adjacent carbon atoms of the bicyclic ring are linked by a bond or an alkylene bridge. Examples

of tricyclic-ring systems include, but are not limited to, tricyclo[3.3.1.0^{3,7}]nonane and tricyclo[3.3.1.1^{3,7}]decane (adamantane).

The term “**carbocycle**” as used herein, means a cyclic system made up of carbon atoms, which includes cycloalkyl, cycloalkenyl and aryl.

When the cycloalkyl or the carbocyclic groups’ are substituted, they are substituted with 1 to 3 substituents selected independently from oxo, halogen, cyano, C₁₋₆ alkyl, perhaloalkyl, R^{11a}O-, (alkyl)S(=O)₂-, (alkyl)C(=O)-, (alkyl)OC(=O)-, (alkyl)C(=O)O-, R¹¹(H)NC(=O)-, R¹¹(alkyl)NC(=O)-, (alkyl)C(=O)N(H)-, R¹¹(H)N-, R¹¹(alkyl)N-, R¹¹(H)NC(=O)N(H)-, and R¹¹(alkyl)NC(=O)N(H)-; wherein, R¹¹ is selected from hydrogen, alkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl; and R^{11a} is selected from hydrogen, alkyl, perhaloalkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl.

The term “**aryl**” refers to a monocyclic, bicyclic or tricyclic aromatic hydrocarbon ring system. Examples of aryl groups include phenyl, naphthyl, anthracenyl, fluorenyl, indenyl, azulenyl, and the like. Aryl group also includes partially saturated bicyclic and tricyclic aromatic hydrocarbons such as tetrahydro-naphthalene.

When the aryl group is substituted, it is substituted with 1 to 3 substituents selected independently from halogen, nitro, cyano, hydroxy, C₁₋₆ alkyl, perhaloalkyl, alkyl-O-, perhaloalkyl-O-, alkyl(alkyl)N-, alkyl(H)N-, H₂N-, alkyl-S(=O)₂-, alkyl-C(=O)(alkyl)N-, alkyl-C(=O)N(H)-, alkyl(alkyl)NC(=O)-, alkyl(H)NC(=O)-, H₂NC(=O)-, alkyl(alkyl)NS(=O)₂-, alkyl(H)NS(=O)₂-, and H₂NS(=O)₂-.

The term “**heteroaryl**” refers to a 5-14 membered monocyclic, bicyclic, or tricyclic ring system having 1-4 ring heteroatoms selected from O, N, or S, and the remainder ring atoms being carbon (with appropriate hydrogen atoms unless otherwise indicated), wherein at least one ring in the ring system is aromatic. Heteroaryl groups may be optionally substituted with one or more substituents. In one embodiment, 0, 1, 2, 3, or 4 atoms of each ring of a heteroaryl group may be substituted by a substituent. Examples of heteroaryl

groups include, but not limited to pyridyl, 1-oxo-pyridyl, furanyl, thienyl, pyrrolyl, oxazolyl, oxadiazolyl, imidazolyl, thiazolyl, isoxazolyl, quinoliny, pyrazolyl, isothiazolyl, pyridazinyl, pyrimidinyl, pyrazinyl, triazinyl, triazolyl, thiadiazolyl, isoquinoliny, benzoxazolyl, benzofuranyl, indoliziny, imidazopyridyl, tetrazolyl, benzimidazolyl, benzothiazolyl, benzothiadiazolyl, benzoxadiazolyl, indolyl, azaindolyl, imidazopyridyl, quinazolinyl, purinyl, pyrrolo[2,3]pyrimidinyl, pyrazolo[3,4]pyrimidinyl, and benzo(b)thienyl, 2,3-thiadiazolyl, 1H-pyrazolo[5,1-c]-1,2,4-triazolyl, pyrrolo[3,4-d]-1,2,3-triazolyl, cyclopentatriazolyl, 3H-pyrrolo[3,4-c] isoxazolyl, 2,3-dihydro-benzo[1,4]dioxin-6-yl, 2,3-dihydro-benzo[1,4]dioxin-5-yl, 2,3-dihydro-benzofuran-5-yl, 2,3-dihydro-benzofuran-4-yl, 2,3-dihydro-benzofuran-6-yl, 2,3-dihydro-benzofuran-6-yl, 2,3-dihydro-1H-indol-5-yl, 2,3-dihydro-1H-indol-4-yl, 2,3-dihydro-1H-indol-6-yl, 2,3-dihydro-1H-indol-7-yl, benzo[1,3]dioxol-4-yl, benzo[1,3]dioxol-5-yl, 1,2,3,4-tetrahydroquinoliny, 1,2,3,4-tetrahydroisoquinoliny, 2,3-dihydrobenzothien-4-yl, 2-oxoindolin-5-yl and the like.

When the heteroaryl group is substituted, it is substituted with 1 to 3 substituents selected independently from halogen, nitro, cyano, hydroxy, C₁₋₆ alkyl, perhaloalkyl, alkyl-O-, perhaloalkyl-O-, alkyl(alkyl)N-, alkyl(H)N-, H₂N-, alkyl-S(=O)₂-, alkyl-C(=O)(alkyl)N-, alkyl-C(=O)N(H)-, alkyl(alkyl)NC(=O)-, alkyl(H)NC(=O)-, H₂NC(=O)-, alkyl(alkyl)NS(=O)₂-, alkyl(H)NS(=O)₂- and H₂NS(=O)₂-.

The term "**heterocycle**" or "heterocyclic" as used herein, means a 'cycloalkyl' group wherein one or more of the carbon atoms replaced by -O-, -S-, -S(O₂)-, -S(O)-, -N(R^m)-, -Si(R^m)Rⁿ-, wherein, R^m and Rⁿ are independently selected from hydrogen, alkyl, aryl, heteroaryl, cycloalkyl, and heterocyclyl. The heterocycle may be connected to the parent molecular moiety through any carbon atom or any nitrogen atom contained within the heterocycle. Examples of monocyclic heterocycle include, but are not limited to, azetidiny, azepanyl, aziridiny, diazepanyl, 1,3-dioxanyl, 1,3-dioxolanyl, 1,3-dithiolanyl, 1,3-dithianyl, imidazolinyl, imidazolidinyl, isothiazolinyl, isothiazolidinyl, isoxazolinyl, isoxazolidinyl, morpholiny, oxadiazolinyl, oxadiazolidinyl, oxazoliny, oxazolidinyl, piperazinyl, piperidiny, pyranyl, pyrazolinyl, pyrazolidinyl, pyrroliny, pyrrolidinyl, tetrahydrofuranyl, tetrahydrothienyl, thiadiazolinyl,

thiadiazolidinyl, thiazolinyl, thiazolidinyl, thiomorpholinyl, 1,1-dioxidothiomorpholinyl (thiomorpholine sulfone), thiopyranyl, and trithianyl. Examples of bicyclic heterocycle include, but are not limited to 1,3-benzodioxolyl, 1,3-benzodithiolyl, 2,3-dihydro-1,4-benzodioxinyl, 2,3-dihydro-1-benzofuranyl, 2,3-dihydro-1-benzothienyl, 2,3-dihydro-1 H-indolyl and 1,2,3,4-tetrahydroquinolinyl. The term heterocycle also include bridged heterocyclic systems such as azabicyclo[3.2.1]octane, azabicyclo[3.3.1]nonane and the like.

The heterocyclic group, when it is substituted, it may be substituted on a ring carbon atom or a ring hetero atom. For example, it is substituted on a ring carbon with 1-3 substituents selected independently from halogen, nitro, cyano, oxo, C₁₋₆ alkyl, perhaloalkyl, R^{11a}O-, (alkyl)OC(=O)-, (alkyl)C(=O)O-, R¹¹(H)NC(=O)-, R¹¹(alkyl)NC(=O)-, (alkyl)C(=O)N(H)-, R¹¹(H)N-, R¹¹(alkyl)N-, R¹¹(H)NC(=O)N(H)-, and R¹¹(alkyl)NC(=O)N(H)-; wherein, R¹¹ is selected from hydrogen, alkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl; and R^{11a} is selected from hydrogen, alkyl, perhaloalkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl.

When the heterocyclic group is substituted on ring nitrogen, it is substituted with a substituent selected from C₁₋₆ alkyl, (alkyl)SO₂-, (alkyl)C(=O)-, (alkyl)OC(=O)-, R¹¹(H)NC(=O)-, and R¹¹(alkyl)NC(=O)-; wherein, R¹¹ is selected from hydrogen, alkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl; and R^{11a} is selected from hydrogen, alkyl, perhaloalkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl.

When a parent group is substituted with an “**oxo**” group, it means a divalent oxygen (=O) becomes attached to a carbon atom of the parent group. For example, when a CH₂ group is substituted with an oxo substituent, the parent CH₂ group becomes a carbonyl (C=O) group; thus, oxo substituted on cyclohexane forms a cyclohexanone, for example.

The term “**annulated**” means the ring system under consideration is either annulated with another ring at a carbon atom of the cyclic system or across a bond of the cyclic system as in the case of spiro or fused ring systems.

The term “**bridged**” means the ring system under consideration contain an alkylene bridge having 1 to 4 methylene units joining two non-adjacent ring atoms.

In a specific embodiment, the invention provides a compound, its stereoisomers, racemates, pharmaceutically acceptable salts thereof as described hereinabove wherein the compound of general formula I is selected from:

1. dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,9*b*-dihydro-3*aH*-thieno[3,2-*c*]chromene-2,7-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 1);
- 10 2. dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 2);
3. dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-diyl))bis(4-chloro-1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-
15 diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 3);
4. dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(naphtho[1,2-*d*]thiazole-2,7-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 4);
5. dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,5-dihydronaphtho[1,2-*b*]thiophene-
20 2,7-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 5);
6. dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(3-chloro-4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl))bis(4-chloro-1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 6);
- 25 7. dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 7);
8. dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl))bis(1*H*-imidazole-5,2-

diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 8);

9. dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl))bis(4-chloro-1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 9);

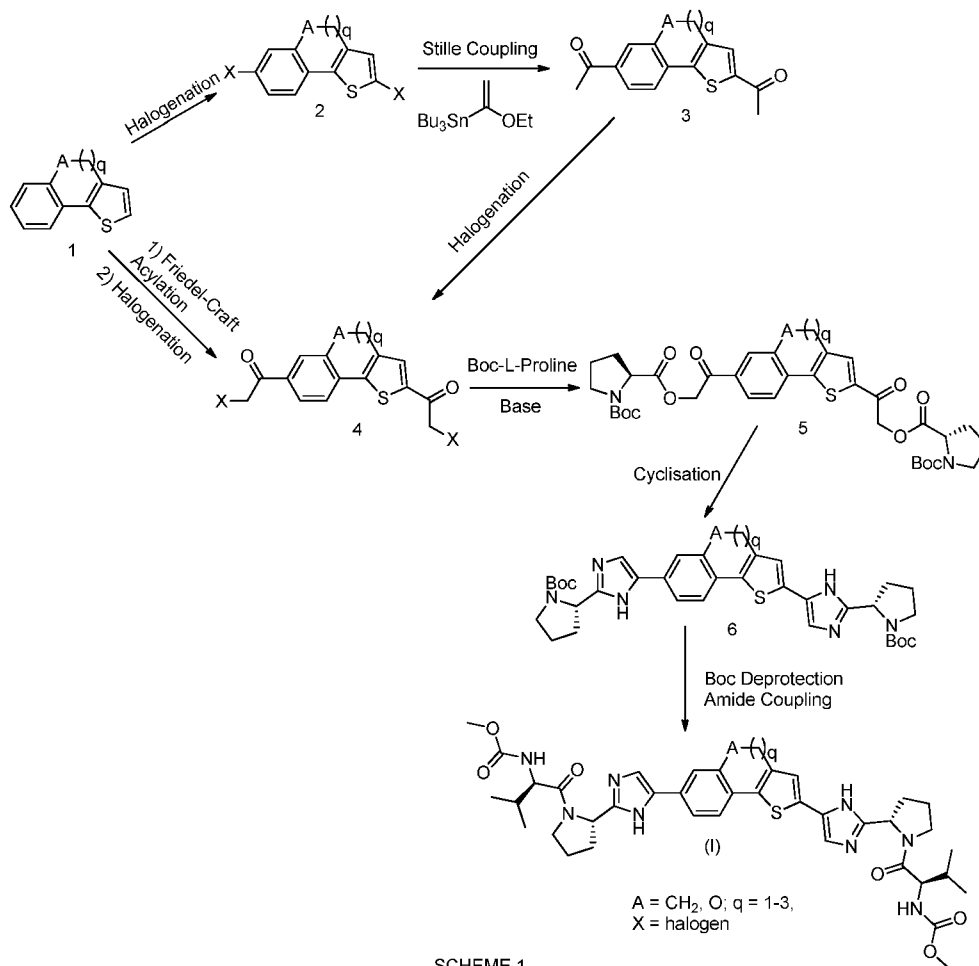
10. dimethyl ((2*S*,2'*S*)-((1*R*,1'*R*,3*S*,3'*S*,4*S*,4'*S*)-3,3'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl))bis(1*H*-imidazole-5,2-diyl))bis(2-azabicyclo[2.2.1]heptane-3,2-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 10); and

11. methyl ((*S*)-1-((*S*)-2-(5-(2-(2-((1*R*,3*S*,4*S*)-2-((*S*)-2-(methoxycarbonyl)amino-3-methylbutanoyl)-2-azabicyclo[2.2.1]heptan-3-yl)-1*H*-imidazol-5-yl)naphtho[1,2-*b*]thiophen-7-yl)-1*H*-imidazol-2-yl)pyrrolidin-1-yl)-3-methyl-1-oxobutan-2-yl)carbamate (Compound 11).

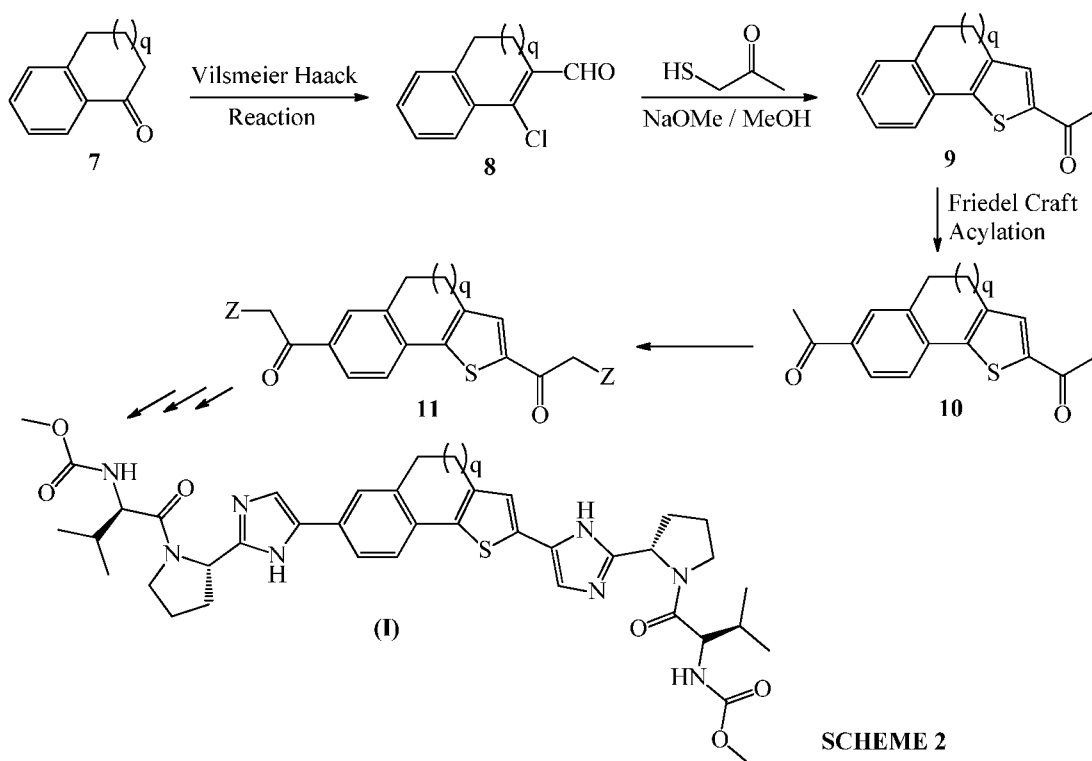
15 According to an embodiment of the present invention, the compounds of general formula (I) where all the symbols are as defined earlier can be prepared by methods illustrated in the schemes below and in the examples. Representative procedures are shown below, however; the disclosure should not be construed to limit the scope of the invention arriving at compound of formula (I) as disclosed hereinabove.

Scheme 1

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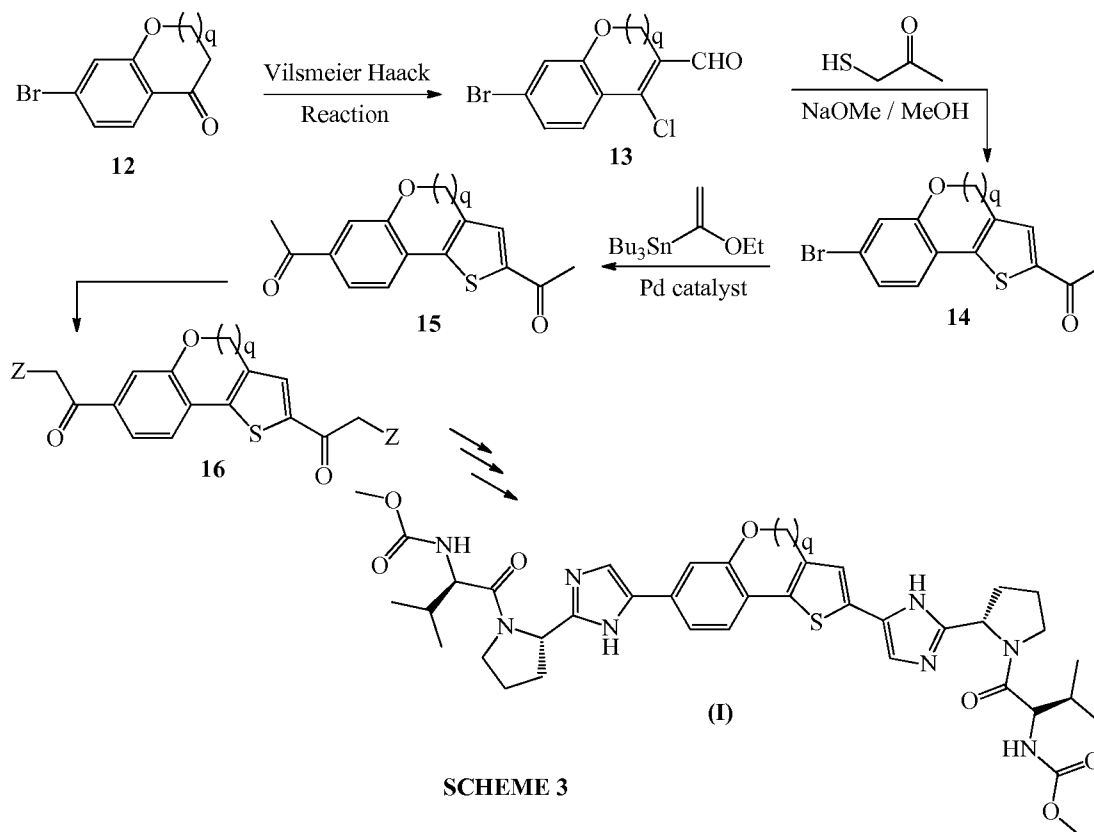
Halogenation of **1** (synthesized according to methods described in EP 1650202) using a halogenating agent such as bromine lead to the formation of **2**, which on Stille coupling gives rise to compound **3**. Alternately, direct Friedel Crafts acylation of **1** leads to the formation **3**. Halogenation of **3** using halogenating agents like NBS, NCS, NIS, bromine and iodine leads to the synthesis of **4** (where X = halogen) which undergoes O-alkylation using Boc-L-proline leading to the formation of **5** as shown in Scheme 1. Cyclization of **5** using a reagent like ammonium acetate in toluene, xylene, or 1,4-dioxane leads to the formation of **6**. The intermediate **6** thus obtained is deprotected under acidic conditions and the amine thus obtained is coupled with acid such as (S)-2-[(methoxycarbonyl)-amino]-3-methylbutanoic acid using methods known in the art to generate the compounds of formula (I).

Scheme 2

An alternative way for the synthesis of compound of general formula **(I)** containing the thiophene tricycle is illustrated in Scheme 2 and is starting from a benzo fused cyclic ketone such as **7** and then converting it to chloro vinyl aldehyde **8** by the Vilsmeier-Haack reaction. Base mediated cyclisation of **8** with mercaptoacetone generates the tricycle such as **9**, which on Friedel Crafts acylation provides the diacetyl tricycle **10**. Alpha halogenation of the acetyl group or hydroxylation followed by protection in one step provides the intermediate **11** (where Z depicts leaving groups such as Br, I, Cl, OTs, OMs), which is further converted to the compound of general formula (I) by a sequence of O-alkylation, cyclisation, aromatisation (in case of aromatic tricycle) and peptide coupling as shown in Scheme 1.

Scheme 3

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For incorporating an oxygen atom in the middle ring of the tricycle, the starting compound is bromobenzo fused pyranone or oxepanone **12**, which is converted to the chloro vinyl aldehyde **13** by the Vilsmeier-Haack reaction. Base mediated cyclisation of **13** with mercaptoacetone provides tricycles such as **14**. A Stille reaction on this intermediate provides the diacetyl tricyclic **15**. Alpha halogenation of the acetyl group or hydroxylation followed by protection in one step provides the intermediate **16** (where Z depicts leaving groups such as Br, I, Cl, OTs, OMs), which is then converted to the compound of general formula (I) by a sequence of O-alkylation, cyclisation, and peptide coupling as shown in Scheme 1.

The intermediates and the compounds of the present invention are obtained, e.g., in pure form, in a manner known *per se*, for example by distilling off the solvent in vacuum and re-crystallizing the residue obtained from a suitable solvent, such as pentane, diethyl ether, isopropyl ether, chloroform,

dichloromethane, ethyl acetate, acetone or their combinations or subjecting it to one of the purification methods, such as column chromatography (e.g., flash chromatography) on a suitable support material such as alumina or silica gel using eluent such as dichloromethane, ethyl acetate, hexane, methanol, acetone
5 and their combinations. Preparative HPLC method is also used for the purification of molecules described herein.

Salts of the compounds of formula (I) are obtained by dissolving the compound in a suitable solvent, for example, a chlorinated hydrocarbon, such as methylene chloride or chloroform or a low molecular weight aliphatic alcohol,
10 for example, ethanol or isopropanol, which is then treated with the desired acid or base, for example, as described in Berge S. M. et al., "Pharmaceutical Salts, a review article," *Journal of Pharmaceutical Sciences*, volume 66, page 1-19 (1977)" and in the Handbook of Pharmaceutical Salts - Properties, Selection, and Use, by P. H. Einrich Stahland Camille G. wermuth, Wiley- VCH (2002). Lists of
15 suitable salts can also be found in *Remington's Pharmaceutical Sciences*, 18th ed., Mack Publishing Company, Easton, PA, 1990, p. 1445, and *Journal of Pharmaceutical Science*, 66, 2-19 (1977). For example, they can be a salt of an alkali metal (e.g., sodium or potassium), alkaline earth metal (e.g., calcium), or ammonium salt.

20 The compound of the invention or a composition thereof can potentially be administered as a pharmaceutically acceptable acid-addition, base neutralized or addition salt, formed by reaction with inorganic acids, such as hydrochloric acid, hydrobromic acid, perchloric acid, nitric acid, thiocyanic acid, sulfuric acid, and phosphoric acid, and organic acids such as formic acid, acetic acid,
25 propionic acid, glycolic acid, lactic acid, pyruvic acid, oxalic acid, malonic acid, succinic acid, maleic acid, and fumaric acid, or by reaction with an inorganic base, such as sodium hydroxide, potassium hydroxide. The conversion to a salt is accomplished by treatment of the base compound with at least a stoichiometric amount of an appropriate acid. Typically, the free base is
30 dissolved in an inert organic solvent such as diethyl ether, ethyl acetate, chloroform, ethanol, methanol, and the like, and the acid is added in a similar solvent. The mixture is maintained at a suitable temperature (e.g., between 0°C

and 50°C). The resulting salt precipitates spontaneously or can be brought out of solution with a less polar solvent.

The stereoisomers of the compounds of formula I of the present invention may be prepared by stereospecific synthesis or resolution of the racemic compound
5 using an optically active amine, acid or complex forming agent, and separating the diastereomeric salt/complex by fractional crystallization or by column chromatography.

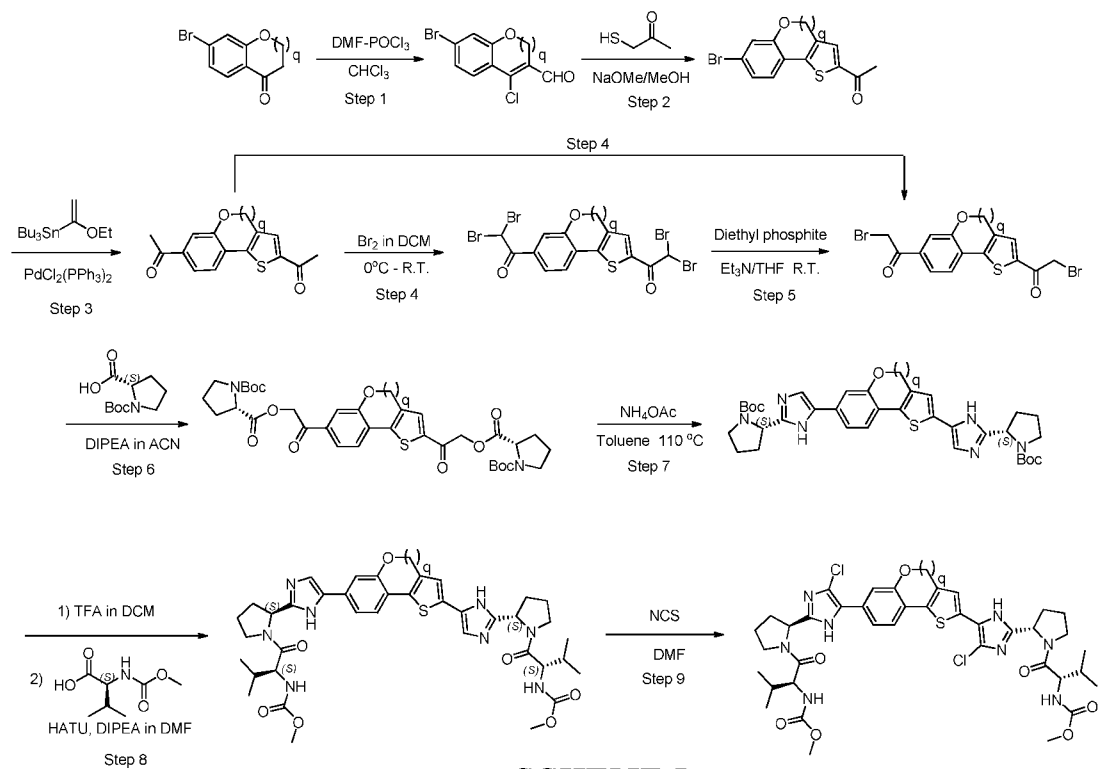
The compounds of the invention, their tautomeric forms, their stereoisomers, their pharmaceutically acceptable salts, their combinations with suitable
10 medicament and pharmaceutical compositions containing them exhibited a broader spectrum of activity as they show inhibitory actions against multiple genotypes of HCV with high potency.

The compounds of the invention, their tautomeric forms, their stereoisomers, their pharmaceutically acceptable salts, their combinations with suitable
15 medicament and pharmaceutical compositions containing them, have demonstrated good stability in human liver microsomes and exhibited promising oral bioavailability in preclinical species with enhanced liver concentrations and high liver to plasma ratio.

20 Compounds of the present invention were prepared using synthetic schemes provided below:

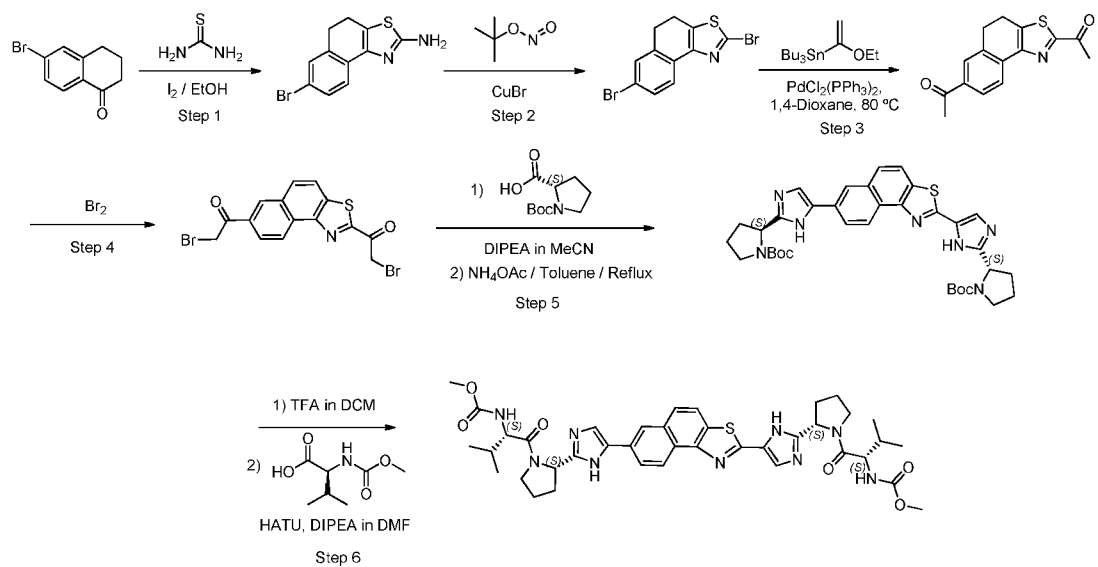
Compounds **1** to **3** were prepared by following the route illustrated in Scheme I:

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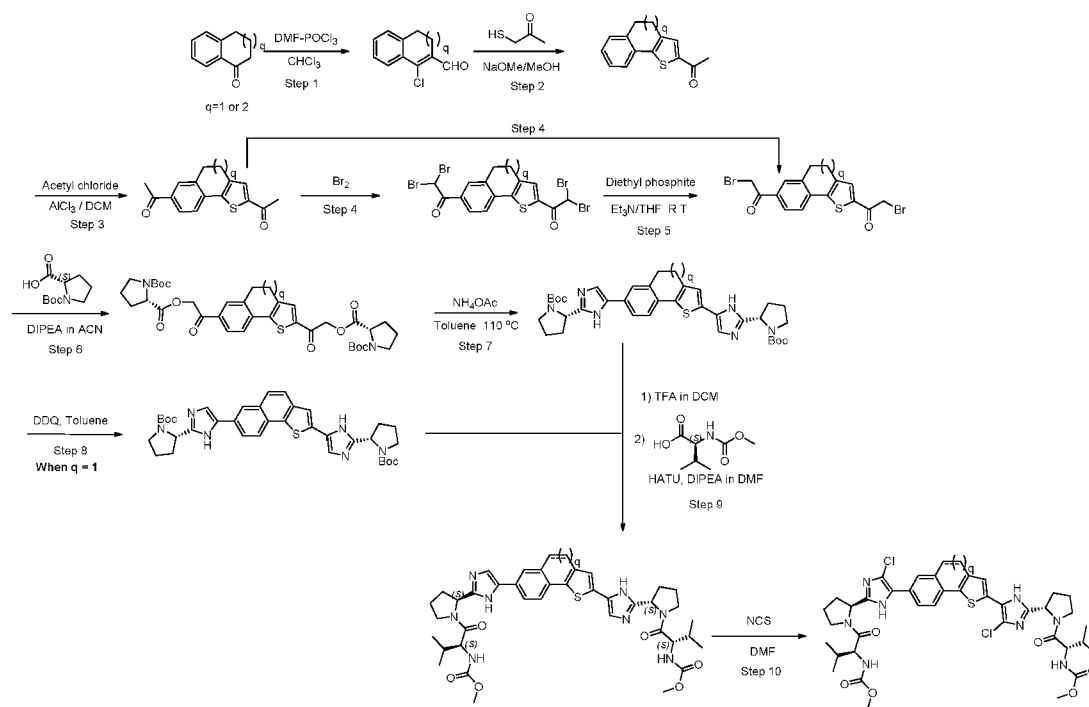
SCHEME I

Compound **4** was prepared by following the route illustrated in Scheme II:



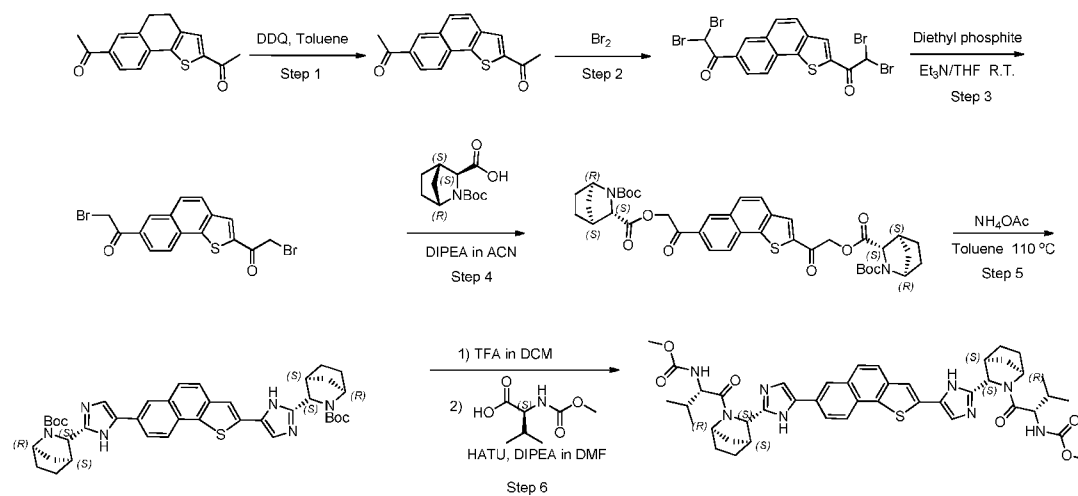
SCHEME II

Compounds **5-9** were prepared by following the route illustrated in Scheme III:



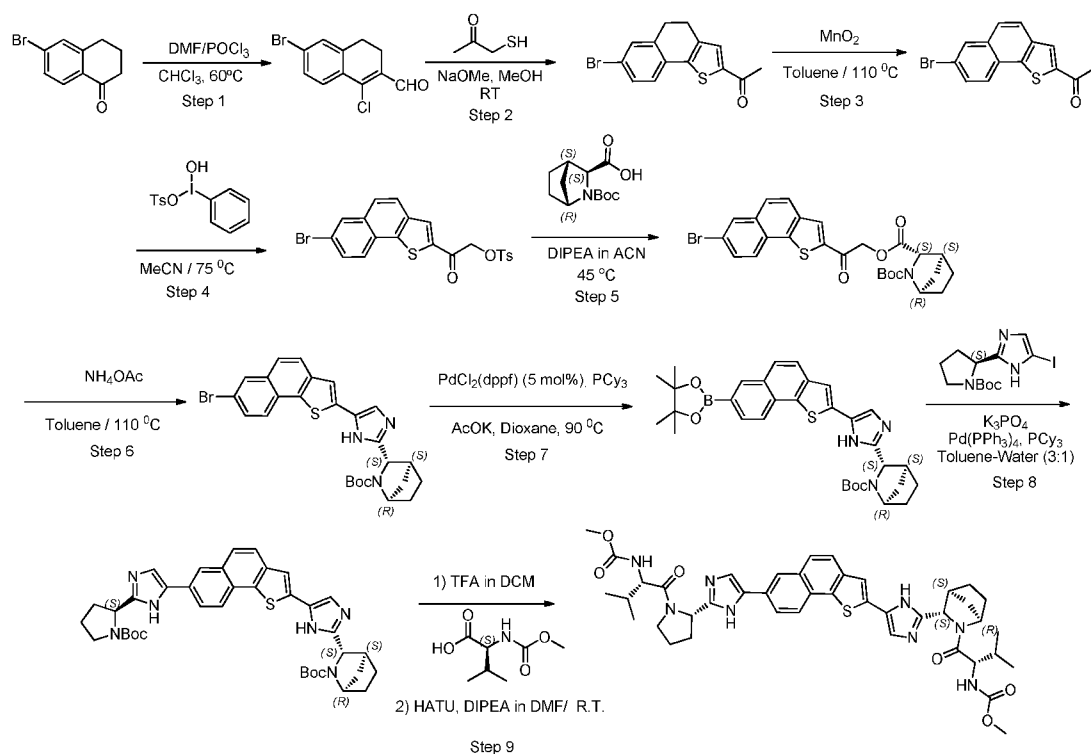
SCHEME III

Compound **10** was prepared by following the route illustrated in Scheme IV:



SCHEME IV

Compound **11** was prepared by following the route illustrated in Scheme V:



SCHEME V

A further embodiment of the present invention includes pharmaceutical compositions comprising any single compound, a tautomer, or isomer thereof, a combination of two or more compounds delineated herein, tautomers, or isomers thereof, or a pharmaceutically acceptable salt or salts thereof, with a pharmaceutically acceptable carrier or excipient.

Yet a further embodiment of the present invention is a pharmaceutical composition comprising any single compound, a tautomer, or isomer thereof, or a combination of two or more compounds delineated herein, tautomers, or isomers thereof, or a pharmaceutically acceptable salt or salts thereof, in combination with one or more agents known in the art, with a pharmaceutically acceptable carrier or excipient.

The pharmaceutically acceptable carrier (or excipient) is preferably one that is chemically inert to the compound of the invention and one that has no

detrimental side effects or toxicity under the conditions of use. Such pharmaceutically acceptable carriers preferably include saline (e.g., 0.9% saline), Cremophor EL (which is a derivative of castor oil and ethylene oxide available from Sigma Chemical Co., St. Louis, MO) (e.g., 5% Cremophor EL/5% ethanol/90% saline, 10% Cremophor EL/90% saline, or 50% Cremophor EL/50% ethanol), propylene glycol (e.g., 40% propylene glycol/10% ethanol/50% water), polyethylene glycol (e.g., 40% PEG 400/60% saline), and alcohol (e.g., 40% ethanol/60% water). A preferred pharmaceutical carrier is polyethylene glycol, such as PEG 400, and particularly a composition comprising 40% PEG 400 and 60% water or saline. The choice of carrier will be determined in part by the particular compound chosen, as well as by the particular method used to administer the composition. Accordingly, there is a wide variety of suitable formulations of the pharmaceutical composition of the present invention.

The formulations for oral, aerosol, parenteral, subcutaneous, intravenous, intra-arterial, intramuscular, inter-peritoneal, rectal, and vaginal administration are merely exemplary and are in no way limiting.

The pharmaceutical compositions can be administered parenterally, e.g., intravenously, intra-arterially, subcutaneously, intra-dermally, intra-theccally, or intramuscularly. Thus, the invention provides compositions for parenteral administration that comprise a solution of the compound of the invention dissolved or suspended in an acceptable carrier suitable for parenteral administration, including aqueous and non-aqueous, isotonic sterile injection solutions.

Overall, the requirements for effective pharmaceutical carriers for parenteral compositions are well known to those of ordinary skill in the art. See *Pharmaceutics and Pharmacy Practice*, J.B. Lippincott Company, Philadelphia, PA, Banker and Chalmers, eds., pages 238-250 (1982), and *ASHP Handbook on Injectable Drugs*, Toissel, 4th ed., pages 622-630 (1986). Such compositions include solutions containing anti-oxidants, buffers, bacteriostats, and solutes that render the formulation isotonic with the blood of the intended recipient, and aqueous and non-aqueous sterile suspensions that can include suspending

agents, solubilizers, thickening agents, stabilizers, and preservatives. The compound can be administered in a physiologically acceptable diluent in a pharmaceutical carrier, such as a sterile liquid or mixture of liquids, including water, saline, aqueous dextrose and related sugar solutions, an alcohol, such as ethanol, isopropanol (for example in topical applications), or hexadecyl alcohol, glycols, such as propylene glycol or polyethylene glycol, dimethylsulfoxide, glycerol ketals, such as 2,2-dimethyl-1,3-dioxolane-4-methanol, ethers, such as poly(ethyleneglycol) 400, an oil, a fatty acid, a fatty acid ester or glyceride, or an acetylated fatty acid glyceride with or without the addition of a pharmaceutically acceptable surfactant, such as a soap or a detergent, suspending agent, such as pectin, carbomers, methylcellulose, hydroxypropylmethylcellulose, or carboxymethylcellulose, or emulsifying agents and other pharmaceutical adjuvants.

Oils useful in parenteral formulations include petroleum, animal, vegetable, and synthetic oils. Specific examples of oils useful in such formulations include peanut, soybean, sesame, cottonseed, corn, olive, petrolatum, and mineral oil. Suitable fatty acids for use in parenteral formulations include oleic acid, stearic acid, and isostearic acid. Ethyl oleate and isopropyl myristate are examples of suitable fatty acid esters.

Suitable soaps for use in parenteral formulations include fatty alkali metal, ammonium, and triethanolamine salts, and suitable detergents include (a) cationic detergents such as, for example, dimethyl dialkyl ammonium halides, and alkyl pyridinium halides, (b) anionic detergents such as, for example, alkyl, aryl, and olefin sulfonates, alkyl, olefin, ether, and monoglyceride sulfates, and sulfosuccinates, (c) nonionic detergents such as, for example, fatty amine oxides, fatty acid alkanolamides, and polyoxyethylene polypropylene copolymers, (d) amphoteric detergents such as, for example, alkyl- β -aminopropionates, and 2-alkyl-imidazoline quaternary ammonium salts, and (e) mixtures thereof.

The parenteral formulations typically will contain from about 0.5% or less to about 25% or more by weight of a compound of the invention, a tautomer, or isomer thereof, or salt thereof in solution. Preservatives and buffers can be

used. In order to minimize or eliminate irritation at the site of injection, such compositions can contain one or more nonionic surfactants having a hydrophile-lipophile balance (HLB) of from about 12 to about 17. The quantity of surfactant in such formulations will typically range from about 5% to about 15% by weight. Suitable surfactants include polyethylene sorbitan fatty acid esters, such as sorbitan monooleate and the high molecular weight adducts of ethylene oxide with a hydrophobic base, formed by the condensation of propylene oxide with propylene glycol. The parenteral formulations can be presented in unit-dose or multi-dose sealed containers, such as ampoules and vials, and can be stored in a freeze-dried (lyophilized) condition requiring only the addition of the sterile liquid excipient, for example, water, for injections, immediately prior to use. Extemporaneous injection solutions and suspensions can be prepared from sterile powders, granules, and tablets.

Formulations suitable for oral administration can consist of (a) liquid solutions, such as an effective amount of a compound of the invention, a tautomer, or isomer thereof, or salt thereof, dissolved in diluents, such as water, saline, or orange juice; (b) capsules, sachets, tablets, lozenges, and troches, each containing a pre-determined amount of the compound of the invention, a tautomer, or isomer thereof, or salt thereof, as solids or granules; (c) powders; (d) suspensions in an appropriate liquid; and (e) suitable emulsions. Liquid formulations can include diluents, such as water and alcohols, for example, ethanol, benzyl alcohol, and the polyethylene alcohols, either with or without the addition of a pharmaceutically acceptable surfactant, suspending agent, or emulsifying agent. Capsule forms can be of the ordinary hard- or soft-shelled gelatine type containing, for example, surfactants, lubricants, and inert fillers, such as lactose, sucrose, calcium phosphate, and cornstarch. Tablet forms can include one or more of lactose, sucrose, mannitol, corn starch, potato starch, alginic acid, microcrystalline cellulose, acacia, gelatine, guar gum, colloidal silicon dioxide, croscarmellose sodium, talc, magnesium stearate, calcium stearate, zinc stearate, stearic acid, and other excipients, colorants, diluents, buffering agents, disintegrating agents, moistening agents, preservatives, flavoring agents, and pharmacologically compatible excipients. Lozenge forms can comprise the compound ingredient in a flavor, usually sucrose and acacia

or tragacanth, as well as pastilles comprising a compound of the invention in an inert base, such as gelatine and glycerine, or sucrose and acacia, emulsions, gels, and the like containing, in addition to the compound of the invention, such excipients as are known in the art.

5 A compound of the present invention, a tautomer, or isomer thereof, or salt thereof, alone or in combination with other suitable components, can be made into aerosol formulations to be administered via inhalation. A compound of the invention, a tautomer, or isomer thereof, or salt thereof, is preferably supplied in finely divided form along with a surfactant and propellant. Typical
10 percentages of the compounds of the invention can be about 0.01% to about 20% by weight, preferably about 1% to about 10% by weight. The surfactant must, of course, be nontoxic, and preferably soluble in the propellant. Representative of such surfactants are the esters or partial esters of fatty acids containing from 6 to 22 carbon atoms, such as caproic, octanoic, lauric,
15 palmitic, stearic, linoleic, linolenic, olesteric and oleic acids with an aliphatic polyhydric alcohol or its cyclic anhydride. Mixed esters, such as mixed or natural glycerides can be employed. The surfactant can constitute from about 0.1% to about 20% by weight of the composition, preferably from about 0.25% to about 5%. The balance of the composition is ordinarily propellant. A carrier
20 can also be included as desired, e.g., lecithin, for intranasal delivery. These aerosol formulations can be placed into acceptable pressurized propellants, such as dichlorodifluoromethane, propane, nitrogen, and the like. They also can be formulated as pharmaceuticals for non-pressured preparations, such as in a nebulizer or an atomizer. Such spray formulations can be used to spray
25 mucosa.

Additionally, the compound of the invention, a tautomer, or isomer thereof, or salt thereof, can be made into suppositories by mixing with a variety of bases, such as emulsifying bases or water-soluble bases. Formulations suitable for vaginal administration can be presented as pessaries, tampons, creams, gels,
30 pastes, foams, or spray formulas containing, in addition to the compound ingredient, such carriers as are known in the art to be appropriate.

The concentration of the compound, a tautomer, or isomer thereof, or salt thereof, in the pharmaceutical formulations can vary, e.g., from less than about 1% to about 10%, to as much as 20% to 50% or more by weight, and can be selected primarily by fluid volumes, and viscosities, in accordance with the particular mode of administration selected.

For example, a typical pharmaceutical composition for intravenous infusion could be made up to contain 250 ml of sterile Ringer's solution, and 100 mg of at least one compound, a tautomer, or isomer thereof, or salt thereof, of the invention. Actual methods for preparing parenterally administrable compounds of the invention will be known or apparent to those skilled in the art and are described in more detail in, for example, *Remington's Pharmaceutical Science* (17th ed., Mack Publishing Company, Easton, PA, 1985).

It will be appreciated by one of ordinary skill in the art that, in addition to the afore-described pharmaceutical compositions, the compound of the invention, a tautomer, or isomer thereof, or salt thereof, can be formulated as inclusion complexes, such as cyclodextrin inclusion complexes, or liposomes. Liposomes can serve to target a compound of the invention to a particular tissue, such as lymphoid tissue or cancerous hepatic cells. Liposomes can also be used to increase the half-life of a compound of the invention. Many methods are available for preparing liposomes, as described in, for example, Szoka et al., *Ann. Rev. Biophys. Bioeng.*, 9, 467 (1980) and U.S. Patents 4235871, 4501728, 4837028, and 5019369.

The compounds of the invention, a tautomer, or isomer thereof, or salt thereof, can be administered in a dose sufficient to treat the disease, condition or disorder. Such doses are known in the art (see, for example, the *Physicians' Desk Reference* (2004)). The compounds can be administered using techniques such as those described in, for example, Wasserman et al., *Cancer*, 36, pp. 1258-1268 (1975) and *Physicians' Desk Reference*, 58th ed., Thomson PDR (2004).

Suitable doses and dosage regimens can be determined by conventional range-finding techniques known to those of ordinary skill in the art. Generally, treatment is initiated with smaller dosages that are less than the optimum dose

of the compound of the present invention. Thereafter, the dosage is increased by small increments until the optimum effect under the circumstances is reached. The present method can involve the administration of about 0.1 µg to about 50 mg of at least one compound of the invention per kg body weight of the individual. For a 70 kg patient, dosages of from about 10 µg to about 200 mg of the compound of the invention would be more commonly used, depending on a patient's physiological response.

By way of example and not intending to limit the invention, the dose of the pharmaceutically active agent(s) described herein for methods of treating or preventing a disease or condition as described above can be about 0.001 to about 1 mg/kg body weight of the subject per day, for example, about 0.001 mg, 0.002 mg, 0.005 mg, 0.010 mg, 0.015 mg, 0.020 mg, 0.025 mg, 0.050 mg, 0.075 mg, 0.1 mg, 0.15 mg, 0.2 mg, 0.25 mg, 0.5 mg, 0.75 mg, or 1 mg/kg body weight per day. The dose of the pharmaceutically active agent(s) described herein for the described methods can be about 1 to about 1000 mg/kg body weight of the subject being treated per day, for example, about 1 mg, 2 mg, 5 mg, 10 mg, 15 mg, 0.020 mg, 25 mg, 50 mg, 75 mg, 100 mg, 150 mg, 200 mg, 250 mg, 500 mg, 750 mg, or 1000 mg/kg body weight per day.

In accordance with embodiments, the present invention provides methods of treating, preventing, ameliorating, and/or inhibiting a hepatitis C virus infection comprising administering a compound of formula (I) or a salt thereof.

The compounds of the present invention are effective against the HCV 1b and 2a genotypes. It should also be understood that the compounds of the present invention can inhibit multiple genotypes of the HCV. Hence, in accordance with an embodiment of the invention, the compounds of the present invention are active against the 1a, 1b, 2a, 2b, 3a, 4a, and 5a genotypes of the HCV.

The terms "treat," "prevent," "ameliorate," and "inhibit," as well as words stemming therefrom, as used herein, do not necessarily imply 100% or complete treatment, prevention, amelioration, or inhibition. Rather, there are varying degrees of treatment, prevention, amelioration, and inhibition of which one of ordinary skill in the art recognizes as having a potential benefit or therapeutic effect. In this respect, the inventive methods can provide any amount of any

level of treatment, prevention, amelioration, or inhibition of the disorder in a mammal. For example, a disorder, including symptoms or conditions thereof, may be reduced by, for example, 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, or 10%. Furthermore, the treatment, prevention, amelioration, or inhibition provided by the inventive method can include treatment, prevention, amelioration, or inhibition of one or more conditions or symptoms of the disorder. Also, for purposes herein, "treatment," "prevention," "amelioration," or "inhibition" can encompass delaying the onset of the disorder, or a symptom or condition thereof.

10 In accordance with the invention, the term subject includes an "animal" which in turn includes a mammal such as, without limitation, the order Rodentia, such as mice, and the order Lagomorpha, such as rabbits. It is preferred that the mammals are from the order Carnivora, including Felines (cats) and Canines (dogs). It is more preferred that the mammals are from the order
15 Artiodactyla, including Bovines (cows) and Swine (pigs) or of the order Perssodactyla, including Equines (horses). It is most preferred that the mammals are of the order Primates, Ceboids, or Simoids (monkeys) or of the order Anthropoids (humans and apes). An especially preferred mammal is the human.

20 The term "viral infection" refers to the introduction of a virus into cells or tissues, e.g., hepatitis C virus (HCV). In general, the introduction of a virus is also associated with replication. Viral infection may be determined by measuring virus antibody titer in samples of a biological fluid, such as blood, using, e.g., enzyme immunoassay. Other suitable diagnostic methods include
25 molecular based techniques, such as RT-PCR, direct hybrid capture assay, nucleic acid sequence based amplification, and the like. A virus may infect an organ, e.g., liver, and cause disease, e.g., hepatitis, cirrhosis, chronic liver disease and hepatocellular carcinoma.

The term "immune modulator" refers to any substance meant to alter the
30 working of the humoral or cellular immune system of a subject. Such immune modulators include inhibitors of mast cell-mediated inflammation, interferons,

interleukins, prostaglandins, steroids, cortico-steroids, colony-stimulating factors, chemotactic factors, etc.

It will be further appreciated that compounds of the present invention can be administered as the sole active pharmaceutical agent, or used in combination
5 with one or more agents to treat or prevent hepatitis C infections or the symptoms associated with HCV infection. Other agents to be administered in combination with a compound or combination of compounds of the present invention include therapies for diseases caused by HCV infection that suppresses HCV viral replication by direct or indirect mechanisms. These
10 agents include, but not limited to, host immune modulators (for example, interferon-alpha, pegylated interferon-alpha, consensus interferon, interferon-beta, interferon-gamma, CpG oligonucleotides and the like); antiviral compounds that inhibit host cellular functions such as inosine monophosphate dehydrogenase (for example, ribavirin and the like); cytokines that modulate
15 immune function (for example, interleukin 2, interleukin 6, and interleukin 12); a compound that enhances the development of type 1 helper T cell response; interfering RNA; anti-sense RNA; vaccines comprising HCV antigens or antigen adjuvant combinations directed against the HCV; agents that interact with host cellular components to block viral protein synthesis by inhibiting the internal
20 ribosome entry site (IRES) initiated translation step of HCV viral replication or to block viral particle maturation and release with agents targeted toward the viroporin family of membrane proteins such as, for example, HCV P7 and the like; and any agent or combination of agents that inhibit the replication of HCV by targeting other proteins of the viral genome involved in the viral replication
25 and/or interfere with the function of other viral targets, such as inhibitors of NS3/NS4A protease, NS3 helicase, NS5B polymerase, NS4A protein and NS5A protein.

According to yet another embodiment, the pharmaceutical compositions of the present invention may further comprise inhibitor(s) of other targets in the HCV
30 life cycle, including, but not limited to, helicase, polymerase, metalloprotease, NS4A protein, NS5A protein, and internal ribosome entry site (IRES).

Accordingly, one embodiment of the present invention is directed to a method for treating or preventing an infection caused by an RNA-containing virus comprising co-administering to a patient in need of such treatment one or more agents selected from the group consisting of a host immune modulator and a
5 second or more antiviral agents, or a combination thereof, with a therapeutically effective amount of a compound or combination of compounds of the present invention, or a pharmaceutically acceptable salt thereof. Examples of the host immune modulator are, but not limited to, interferon-alpha, pegylated-interferon-alpha, interferon-beta, interferon-gamma, a cytokine, a vaccine, and
10 a vaccine comprising an antigen and an adjuvant, and said second antiviral agent inhibits replication of HCV either by inhibiting host cellular functions associated with viral replication or by targeting proteins of the viral genome.

A further embodiment of the present invention is directed to a method of treating or preventing infection caused by an RNA-containing virus comprising
15 co-administering to a patient in need of such treatment an agent or combination of agents that treat or alleviate symptoms of HCV infection including cirrhosis and inflammation of the liver, with a therapeutically effective amount of a compound or combination of compounds of the present invention, or a pharmaceutically acceptable salt thereof. Yet another embodiment of the
20 present invention provides a method of treating or preventing infection caused by an RNA-containing virus comprising co-administering to a patient in need of such treatment one or more agents that treat patients for disease caused by hepatitis B (HBV) infection, with a therapeutically effective amount of a compound or a combination of compounds of the present invention, or a
25 pharmaceutically acceptable salt thereof. An agent that treats patients for disease caused by hepatitis B (HBV) infection may be for example, but not limited thereto, L-deoxythymidine, adefovir, lamivudine or tenofovir, or any combination thereof.

A further embodiment of the present invention provides a method of treating or
30 preventing infection caused by an RNA-containing virus comprising co-administering to a patient in need of such treatment one or more agents that treat patients for disease caused by human immunodeficiency virus (HIV) infection, with a therapeutically effective amount of a compound or a

combination of compounds of the present invention, or a pharmaceutically acceptable salt thereof. The agent that treats patients for disease caused by human immunodeficiency virus (HIV) infection may include, but is not limited thereto, ritonavir, lopinavir, indinavir, nelfinavir, saquinavir, amprenavir, 5 atazanavir, tipranavir, TMC-114, fosamprenavir, zidovudine, lamivudine, didanosine, stavudine, tenofovir, zalcitabine, abacavir, efavirenz, nevirapine, delavirdine, TMC-125, L-870812, S-1360, enfuvirtide (T-20) or T-1249, or any combination thereof.

10 An example of the RNA-containing virus in any of the above embodiments includes, but not limited to, the hepatitis C virus (HCV).

It can occur that a patient may be co-infected with hepatitis C virus and one or more other viruses, including but not limited to human immunodeficiency virus (HIV), hepatitis A virus (HAV) and hepatitis B virus (HBV). Thus also contemplated is a combination therapy to treat such co-infections by co- 15 administering a compound according to the present invention with at least one of an HIV inhibitor, an HAV inhibitor and an HBV inhibitor.

In addition, the present invention provides the use of a compound or a combination of compounds of the invention, or a therapeutically acceptable salt thereof, and one or more agents selected from the group consisting of a host 20 immune modulator and a second or more antiviral agents, or a combination thereof, to prepare a medicament for the treatment of an infection caused by an RNA-containing virus in a patient, particularly hepatitis C virus. Examples of the host immune modulators include, but are not limited to, interferon-alpha, pegylated-interferon-alpha, interferon-beta, interferon-gamma, a cytokine, a 25 vaccine, and a vaccine comprising an antigen and an adjuvant, and said second antiviral agent inhibits replication of HCV either by inhibiting host cellular functions associated with viral replication or by targeting proteins of the viral genome.

30 When used in the above or other treatments, combination of compound or compounds of the present invention, together with one or more agents as defined herein above, can be employed in pure form or, where such forms exist, in pharmaceutically acceptable salt thereof. Alternatively, such combination of

therapeutic agents can be administered as a pharmaceutical composition containing a therapeutically effective amount of the compound or combination of compounds of interest, or their pharmaceutically acceptable salt thereof, in combination with one or more agents as defined hereinabove, and a
5 pharmaceutically acceptable carrier. Such pharmaceutical compositions can be used for inhibiting the replication of an RNA-containing virus, particularly Hepatitis C virus (HCV), by contacting said virus with said pharmaceutical composition. In addition, such compositions are useful for the treatment or prevention of an infection caused by an RNA-containing virus, particularly
10 Hepatitis C virus (HCV).

Hence, a still further embodiment of the invention is directed to a method of treating or preventing infection caused by an RNA-containing virus, particularly a hepatitis C virus (HCV), comprising administering to a patient in need of such treatment a pharmaceutical composition comprising a compound or
15 combination of compounds of the invention or a pharmaceutically acceptable salt thereof, and one or more agents as defined hereinabove, with a pharmaceutically acceptable carrier.

When administered as a combination, the therapeutic agents can be formulated as separate compositions which are given at the same time or within a
20 predetermined period of time, or the therapeutic agents can be given as a single unit dosage form. The therapeutic agents can be administered simultaneously, sequentially, or cyclically.

Antiviral agents contemplated for use in such combination therapy include agents (compounds or biologicals) that are effective to inhibit the formation
25 and/or replication of a virus in a mammal, including but not limited to agents that interfere with either host or viral mechanisms necessary for the formation and/or replication of a virus in a mammal. Such agents can be selected from another anti-HCV agent; an HIV inhibitor; an HAV inhibitor; and an HBV inhibitor.

30 Other agents to be administered in combination with a compound of the present invention include a cytochrome P450 monooxygenase inhibitor, which is expected to inhibit metabolism of the compounds of the invention. Therefore,

the cytochrome P450 monooxygenase inhibitor would be in an amount effective to inhibit metabolism of the compounds of the present invention. Accordingly, the CYP inhibitor is administered in an amount such that the bioavailability of the compounds of the present invention is increased in comparison to the bioavailability in the absence of the CYP inhibitor.

The term "room temperature" used in the specification denotes any temperature ranging between about 20°C to about 40°C, except and otherwise it is specifically mentioned in the specification.

Unless mentioned otherwise, abbreviations used in description herein below have following meaning:

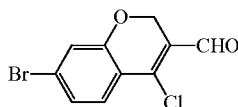
EDCI means 1-ethyl-3-(3-dimethylaminopropyl)-dicarbodiimide; HATU means 2-(7-aza-1*H*-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate; DIPEA means diisopropyl ethylamine; Boc means butoxycarbonyl; DMF means dimethylformamide; DMSO means dimethylsulfoxide; NBS means *N*-bromosuccinimide; NCS means *N*-chlorosuccinimide; NIS means *N*-iodosuccinimide; EtOAc means ethyl acetate; THF means tetrahydrofuran; Tf means triflate; DCM means dichloromethane; Et₃N means triethylamine; MeOH means methanol; ACN means acetonitrile; Ts means tosyl, Ms means mesyl, RT means room temperature; Ac means acetyl; HPLC means high performance liquid chromatography, TLC means thin layer chromatography, PEG means polyethylene glycol; TFA means trifluoroacetic acid; KF means potassium fluoride; and DDQ means 2,3-dichloro-5,6-dicyanobenzoquinone.

The following examples are provided to further illustrate the present invention and therefore should not be construed in any way to limit the scope of the present invention. All ¹HNMR spectra were obtained in the solvents indicated and chemical shifts are reported in δ units downfield from the internal standard tetramethylsilane (TMS) and interproton coupling constants are reported in Hertz (Hz). In the case of mixture of isomers, the peak values given are for the dominant isomer (rotamer/tautomer).

Example 1: Synthesis of dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,9*b*-dihydro-3*aH*-thieno[3,2-*c*]chromene-2,7-diyl)bis(1*H*-imidazole-5,2-

diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 1)

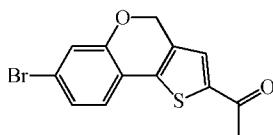
Step 1: 7-bromo-4-chloro-2*H*-chromene-3-carbaldehyde (1a)



- 5 Anhydrous dimethylformamide (8.18 ml, 106 mmol) was taken in a two-necked round bottomed flask fitted with a dropping funnel. POCl₃ (7.23 ml, 78 mmol) was added to it by keeping the flask in an ice bath and after the completion of addition, the ice bath was removed and the mixture was stirred at RT for 1 hr. 7-bromochroman-4-one (16 g, 71 mmol) was dissolved in 200 ml of chloroform and was slowly added to the flask kept on an ice bath, and after completion of the addition, the ice bath was removed and the reaction mixture was stirred overnight at 60°C. The reaction was brought to RT and ice cold water was added to it and the compound was extracted with chloroform. The organic layer was washed with 10% NaHCO₃ solution and dried over Na₂SO₄, filtered and concentrated to obtain the crude title compound (15.1 g, 78 %) which was sufficiently pure enough for the next step. m/z 273.9 (M⁺)

¹H-NMR (400 MHz, CDCl₃): δ 10.16 (s, 1H), 7.55 (d, *J* = 8Hz, 1H), 7.23-7.20 (m, 1H), 7.12-7.11 (m, 1H), 5.03 (s, 2H).

Step 2: 1-(7-bromo-4*H*-thieno[3,2-*c*]chromen-2-yl)ethanone (1b)



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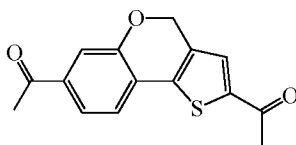
- To a solution of sodium methoxide (5.57 g, 103 mmol) in 250 ml of methanol at 0°C, mercaptoacetone (5.11 g, 57 mmol) was added portion-wise, and after 15 min., 7-bromo-4-chloro-2*H*-chromene-3-carbaldehyde (1a) (14 g, 52 mmol) was added to it portion-wise with stirring. After the addition, the ice bath was removed and the product gradually started precipitating out as a yellow solid. Stirring was continued for another 3 h, after which water was added to quench

25

the reaction and the methanol was removed under vacuum. Addition of more water yielded the title compound as a yellow solid (1b) which was filtered and dried (14.1 g, 78 %). m/z 308.9 (^{79}Br) & 310.9 (^{81}Br).

$^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.41 (s, 1H), 7.25-7.22 (m, 1H), 7.13-7.11 (m, 2H),
5 5.27 (s, 2H), 2.56 (s, 3H).

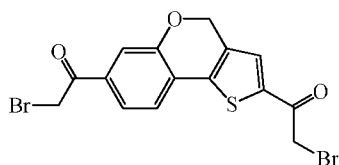
Step 3: 1,1'-(4*H*-thieno[3,2-*c*]chromene-2,7-diyl)diethanone (1c)



A solution of 1-(7-bromo-4*H*-thieno[3,2-*c*]chromen-2-yl)ethanone (1b) (14 g, 45.3 mmol) in 300 ml of anhydrous dioxane was degassed by passing nitrogen gas
10 for 45 min. Tributyl(1-ethoxyvinyl)stannane (16.35 g, 45.3 mmol) was added to it followed by $\text{Pd}(\text{PPh}_3)_4$ (4.19 g, 3.62 mmol) and $\text{PdCl}_2(\text{dppf})\text{-CH}_2\text{Cl}_2$ adduct (2.65 g, 3.62 mmol) and the solution was heated at 90 °C for overnight. After cooling, the volume of dioxane was reduced, and a saturated solution of KF was added to it and stirred for 15 min., after which the mixture was passed through a pad
15 of celite and washed with ethyl acetate. The combined filtrate was stirred with 4N HCl solution for 1 h and the organic layer was dried over Na_2SO_4 , filtered and concentrated. The residue was purified by column chromatography to obtain the diacetyl compound (1c) (11.5 g, 68%). m/z 272.9 ($\text{M}+\text{H}$) $^+$.

$^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.60-7.58 (m, 1H), 7.54-7.53 (m, 1H), 7.47-7.45
20 (m, 2H), 5.33 (s, 2H), 2.60 (s, 3H), 2.58 (s, 3H).

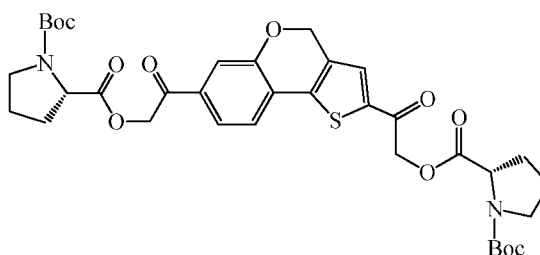
Step 4: Synthesis of 1,1'-(4*H*-thieno[3,2-*c*]chromene-2,7-diyl)bis(2-bromoethanone) (1d)



To a solution of 1,1'-(4*H*-thieno[3,2-*c*]chromene-2,7-diyl)diethanone (1c) (7 g, 25.7 mmol) in 100 ml of DCM at 0°C, bromine (3.97 ml, 77 mmol) was added dropwise and stirred at room temperature for 2 hr. The reaction mixture was then added to ice cold water and the DCM layer was partitioned. The DCM layer was then washed with saturated sodium bicarbonate solution and saturated brine solution, respectively. The organic layer was dried over anhydrous sodium sulphate, filtered and concentrated under reduced pressure to afford 1,1'-(4*H*-thieno[3,2-*c*]chromene-2,7-diyl)bis(2-bromoethanone) (12 g, 79%) as a brown solid (1d).

¹H-NMR (400 MHz, CDCl₃): δ 7.98 (s, 1H), 7.72-7.56 (m, 3H), 5.43-5.40 (m, 2H), 4.97 (s, 2H), 4.82 (s, 2H).

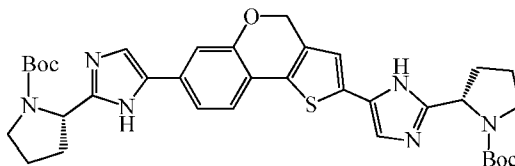
Step 5: (S)-2-(2-(7-(2-(((S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-carbonyl)oxy)acetyl)-4*H*-thieno[3,2-*c*]chromen-2-yl)-2-oxoethyl) 1-*tert*-butyl pyrrolidine-1,2-dicarboxylate (1e)



To a solution of (S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-carboxylic acid (1d) (8.81 g, 40.9 mmol) in 40 ml of acetonitrile at room temperature, Hunig's base (12.96 ml, 74.4 mmol) followed by 1,1'-(4*H*-thieno[3,2-*c*]chromene-2,7-diyl)bis(2-bromoethanone) (8 g, 18.60 mmol) were added and stirred at 50°C for 4 hr. The volume of solvent was reduced and ethyl acetate was added to the remaining organic layer, which was then washed with water and brine solution. The organic layer was dried over anhydrous sodium sulphate and concentrated under reduced pressure to afford the product (7 g, 54%) as sticky oil (1e).

¹H-NMR (400 MHz, CDCl₃): δ 7.53-7.42 (m, 4H), 5.40-5.15 (m, 2H), 4.44-4.15 (m, 4H), 3.72-3.30 (m, 6H), 2.35-2.20 (m, 4H), 2.10-1.85 (m, 4H), 1.45 (s, 9H), 1.35 (s, 9H).

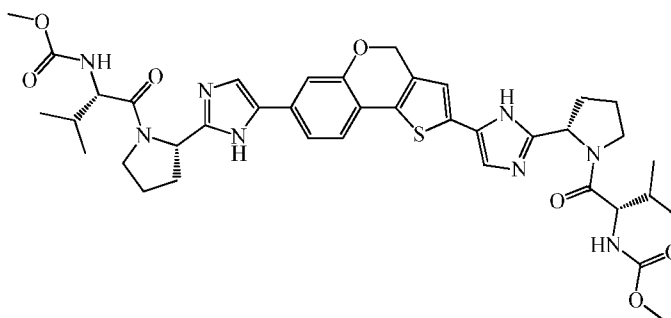
Step 6: (2*S*,2'*S*)-di-*tert*-butyl 2,2'-(5,5'-(4*H*-thieno[3,2-*c*]chromene-2,7-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) (1f)



To a solution of (S)-2-(2-(7-(2-(((S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-carbonyl)oxy)acetyl)-4*H*-thieno[3,2-*c*]chromen-2-yl)-2-oxoethyl) 1-*tert*-butyl pyrrolidine-1,2-dicarboxylate (1e) (10 g, 14.31 mmol) in 500 ml of toluene, ammonium acetate (22.06 g, 286 mmol) was added and the mixture was refluxed overnight. Toluene was removed under vacuum and ethyl acetate was added to dissolve the reaction mixture. The ethyl acetate layer was washed with water and brine, dried over anhydrous sodium sulphate and concentrated under reduced pressure to afford the crude product, which was then purified by column chromatography to afford the pure compound (1f) (6 g, 64%). *m/z* 659.3 (M+H)⁺.

¹H-NMR (400 MHz, CDCl₃): δ 7.23-7.02 (m, 5H), 6.85-6.80 (m, 1H), 5.23 (s, 2H), 5.01-4.97 (m, 2H), 3.52-3.43 (m, 4H), 2.30-1.90 (m, 8H), 1.50 (s, 18H).

Step 7: dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4*H*-thieno[3,2-*c*]chromene-2,7-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 1)



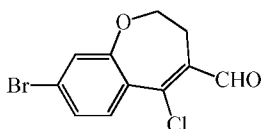
To a solution of (2*S*,2'*S*)-di-*tert*-butyl 2,2'-(5,5'-(4*H*-thieno[3,2-*c*]chromene-2,7-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) (1f) (3 g, 4.55 mmol) in 50 ml of DCM, 10 ml of trifluoroacetic acid was added at room

temperature and the solution was stirred for 4 hr. The volatiles were removed under vacuum and the solid obtained was washed with diethyl ether and filtered to obtain the TFA salt of the deprotected compound. To the TFA salt in 10 ml of anhydrous DMF at 0 °C, DIPEA (3.98 ml, 22.77 mmol) was added and the contents were stirred for 10 min. after which (S)-2-((methoxycarbonyl)amino)-3-methylbutanoic acid (1.84 g, 10.47 mmol) and HATU (4.33 g, 11.38 mmol) were added and the reaction mixture was warmed to room temperature and stirred overnight under nitrogen atmosphere. Crushed ice was added to the reaction mixture and the precipitate formed was filtered, the solid was washed with water, n-pentane and dried and then purified on a Combiflash column with EtOAc-MeOH as eluent to obtain a pale yellow solid (2.28 g, 65%). m/z 773.6 (M+H)⁺.

¹H-NMR (400 MHz, DMSO-d₆): δ 8.13 (s, 1H), 7.95 (s, 1H), 7.58-7.55 (m, 3H), 7.45-7.43 (m, 1H), 7.30-7.28 (d, *J* = 8 Hz, 2H), 5.38 (s, 2H), 5.18-5.11 (m, 2H), 4.13-4.09 (m, 2H), 3.98-3.96 (m, 2H), 3.82-3.65 (m, 2H), 3.53 (s, 6H), 2.37-2.33 (m, 2H), 2.17-1.98 (m, 8H), 0.91-0.82 (m, 6H), 0.77-0.75 (m, 6H).

Example 2: Synthesis of dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 2)

Step 1: 8-bromo-5-chloro-2,3-dihydrobenzo[*b*]oxepine-4-carbaldehyde (2a)

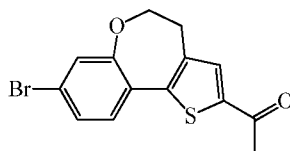


was synthesized from 8-bromo-3,4-dihydrobenzo[*b*]oxepin-5(2*H*)-one by following an analogous procedure described in Step 1, Example 1. m/z 288.2 (M+H)⁺.

¹H-NMR (400 MHz, CDCl₃): δ 10.35 (s, 1H), 7.62 (d, *J* = 8 Hz, 1H), 7.41-7.38 (m, 1H), 7.31 (d, *J* = 2 Hz, 1H), 4.52 (t, *J* = 6 Hz, 2H), 2.62 (t, *J* = 6 Hz, 2H).

Step 2: 1-(8-bromo-4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepin-2-yl)ethanone (2b)

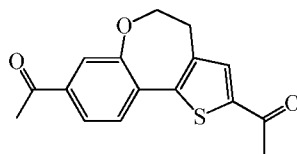
41



was synthesized from 8-bromo-5-chloro-2,3-dihydrobenzo[b]oxepine-4-carbaldehyde (2a) by following an analogous procedure described in Step 2, Example 1. m/z 322.9 (^{79}Br) & 324.9 (^{81}Br).

- 5 $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.62 (d, $J = 8$ Hz, 1H), 7.48 (s, 1H), 7.24-7.23 (m, 1H), 7.21-7.19 (m, 1H), 4.35 (t, $J = 5$ Hz, 2H), 3.24 (t, $J = 5$ Hz, 2H), 2.55 (s, 3H).

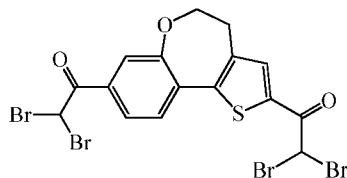
Step 3: 1,1'-(4,5-dihydrobenzo[b]thieno[2,3-d]oxepine-2,8-diyl)diethanone (2c)



- 10 was synthesized from 1-(8-bromo-4,5-dihydrobenzo[b]thieno[2,3-d]oxepin-2-yl)ethanone and Tributyl(1-ethoxyvinyl)stannane (2b) by following an analogous procedure described in Step 3, Example 1. m/z 287.0 ($\text{M}+\text{H}$) $^+$

$^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.85 (d, $J = 8$ Hz, 1H), 7.66-7.62 (m, 2H), 7.52 (s, 1H), 4.38 (t, $J = 5$ Hz, 2H), 3.30 (t, $J = 5$ Hz, 2H), 2.61 (s, 3H), 2.58 (s, 3H).

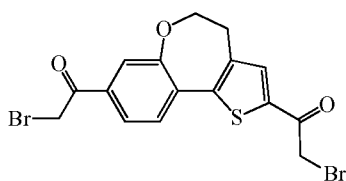
- Step 4:** 1,1'-(4,5-dihydrobenzo[b]thieno[2,3-d]oxepine-2,8-diyl)bis(2,2-dibromoethanone) (2d)
- 15



was synthesized from 1,1'-(4,5-dihydrobenzo[b]thieno[2,3-d]oxepine-2,8-diyl)diethanone (2c) by following an analogous procedure described in Step 4, Example 1.

¹H-NMR (400 MHz, CDCl₃): δ 7.91-7.78 (m, 3H), 7.67-7.65 (m, 1H), 6.64 (s, 1H), 6.43 (s, 1H), 4.45-4.41 (m, 2H), 3.36-3.33 (m, 2H).

Step 5: 1,1'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-diyl)bis(2-bromoethanone) (2e)

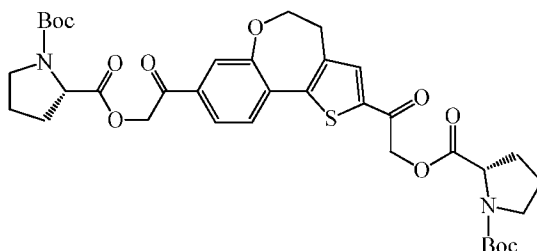


5

To a stirred solution of 1,1'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-diyl)bis(2,2-dibromoethanone) (2d) (0.65 g, 1.08 mmol) in 20 ml THF at 0 °C was added Et₃N (0.45 ml, 3.24 mmol) and diethyl phosphite (0.42 ml, 3.24 mmol). The reaction mixture was gradually warmed to room temperature and the mixture was stirred for 1 hr. The volatiles were removed under reduced pressure and the crude residue was washed with n-pentane to yield an yellow solid (2e) that was used in the next step without purification (0.42 g, 88%).

¹H-NMR (400 MHz, CDCl₃): δ 7.90-7.64 (m, 4H), 4.43 (s, 2H), 4.35 (s, 2H), 4.30-4.10 (m, 2H), 3.36-3.33 (m, 2H).

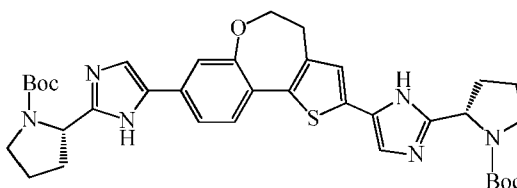
15 **Step 6:** (S)-2-(2-(8-(2-(((S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-carbonyl)oxy)acetyl)-4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepin-2-yl)-2-oxoethyl) 1-*tert*-butyl pyrrolidine-1,2-dicarboxylate (2f)



was synthesized from 1,1'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-
20 diyl)bis(2-bromoethanone) and (S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-
carboxylic acid (2e) by following an analogous procedure described in Step 5,
Example 1.

¹H-NMR (400 MHz, CDCl₃): δ 7.84-7.82 (m, 1H), 7.65-7.50 (m, 3H), 5.39-5.13 (m, 4H), 4.50-4.10 (m, 4H), 3.60-3.25 (m, 6H), 2.40-1.91 (m, 8H), 1.50 (s, 9H), 1.45 (s, 9H).

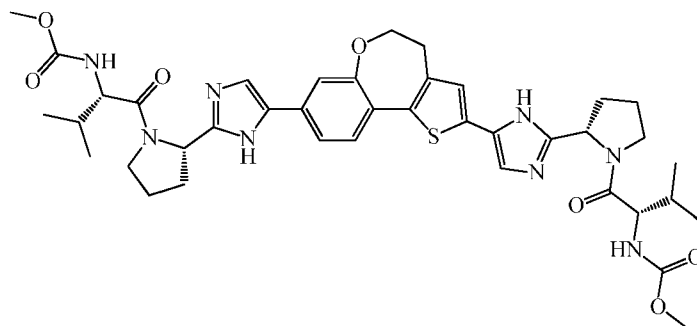
Step 7: (2*S*,2'*S*)-di-*tert*-butyl 2,2'-(5,5'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) (2g)



was synthesized from (S)-2-(2-(8-(2-(((S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-carbonyl)oxy)acetyl)-4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepin-2-yl)-2-oxoethyl) 1-*tert*-butyl pyrrolidine-1,2-dicarboxylate (2f) by following an analogous procedure described in Step 6, Example 1. *m/z* 673.3 (M+H)⁺

¹H-NMR (400 MHz, DMSO-*d*₆): δ 12.00-11.92 (m, 2H), 7.56-7.52 (m, 2H), 7.44-7.28 (m, 3H), 7.08 (s, 1H), 4.81-4.73 (m, 2H), 4.27-4.24 (m, 2H), 3.52-3.50 (m, 2H), 3.40-3.35 (m, 2H), 3.16-3.15 (m, 2H), 2.30-1.65 (m, 8H), 1.33 (s, 9H), 1.17 (s, 9H).

Step 8: dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 2)

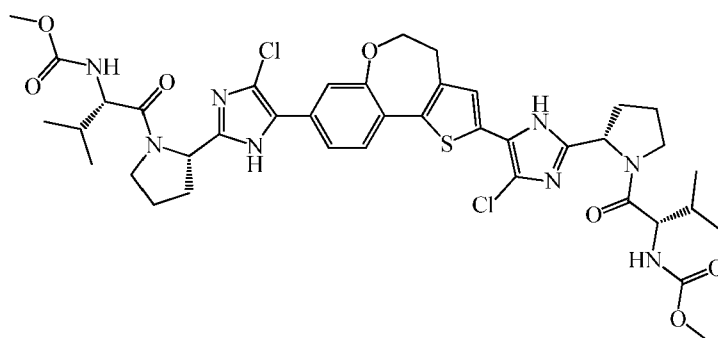


was synthesized from (2*S*,2'*S*)-di-*tert*-butyl 2,2'-(5,5'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) and (S)-2-((methoxycarbonyl)amino)-3-

methylbutanoic acid by following an analogous procedure described in Step 7, Example 1. m/z 394.3 $(M+2H)^{+2}$.

^1H -NMR (400 MHz, DMSO- d_6): δ 12.10-11.84 (m, 2H), 7.52-7.49 (m, 2H), 7.40-7.34 (m, 4H), 7.05 (s, 2H), 5.06-5.01 (m, 2H), 4.30-4.26 (m, 2H), 4.06-4.02 (m, 2H), 3.85-3.79 (m, 4H), 3.55 (s, 6H), 3.15-3.10 (m, 2H), 2.20-1.90 (m, 10H), 0.83-0.81 (m, 12H).

Example 3: Synthesis of dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(4,5-dihydrobenzo[b]thieno[2,3-d]oxepine-2,8-diyl)bis(4-chloro-1H-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 3)



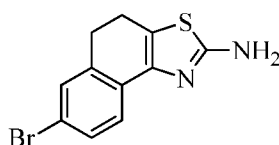
To a stirred solution of dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(4,5-dihydrobenzo[b]thieno[2,3-d]oxepine-2,8-diyl)bis(1H-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 2) (0.17 g, 0.216 mmol) in 10 ml DMF, NCS (0.063 g, 0.475 mmol) was added and the reaction mixture was stirred for 2 h at 40 °C. The progress of the reaction was monitored by TLC. After complete reaction of the starting material, the reaction mixture was poured into water, and the aqueous layer was extracted with ethyl acetate, dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude material was purified by preparative HPLC to obtain the desired product. m/z 855.4 $(M+H)^{+}$.

^1H -NMR (400 MHz, DMSO- d_6): δ 7.71-7.67 (m, 1H), 7.47-7.45 (m, 1H), 7.42-7.40 (m, 1H), 7.33-7.31 (m, 2H), 7.25 (s, 1H), 4.98-4.94 (m, 2H), 4.33-4.31 (m,

2H), 4.06-4.02 (m, 2H), 3.79-3.77 (m, 4H), 3.53 (s, 6H), 3.24-3.21 (m, 2H), 2.15-1.90 (m, 10H), 0.88-0.82 (m, 12H).

Example 4: Synthesis of dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(naphtho[1,2-d]thiazole-2,7-diyl))bis(1H-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 4)

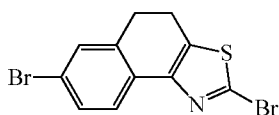
Step 1: 7-bromo-4,5-dihydronaphtho[1,2-d]thiazol-2-amine (4a)



6-bromo-3,4-dihydronaphthalen-1(2H)-one (3.5 g, 15.55 mmol), thiourea (3.55 g, 46.6 mmol) and iodine (4.34 g, 17.10 mmol) were dissolved in 20 ml of ethanol and the solution was heated at 100°C for 4 hr. The volume of ethanol was reduced and the solid amine hydroiodide salt was filtered and washed with ether. The solid obtained was dissolved in water and basified with 10% NaOH solution and extracted with ethyl acetate. The ethyl acetate layer was dried over Na₂SO₄ and concentrated to obtain the desired compound (4a) (4.37 g, 80%).
m/z 280.9 (⁷⁹Br) & 282.9 (⁸¹Br) (M+H)⁺.

¹H-NMR (400 MHz, CDCl₃): δ 7.54 (d, *J* = 8.4 Hz, 1H), 7.37 (dd, *J* = 2 Hz, 8.4 Hz, 1H), 7.32 (d, *J* = 2 Hz, 1H), 5.05 (br s, 2H), 3.03-2.99 (m, 2H), 2.88-2.83 (m, 2H).

Step 2: 2,7-dibromo-4,5-dihydronaphtho[1,2-d]thiazole (4b)

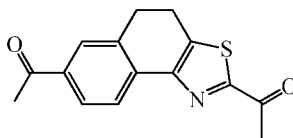


To a solution of 7-bromo-4,5-dihydronaphtho[1,2-d]thiazol-2-amine (4a) (1.4 g, 4.98 mmol) in 25 ml of acetonitrile, tert-butyl nitrite (0.724 ml, 5.48 mmol) and copper(I) bromide (0.786 g, 5.48 mmol) were added and the resulting black solution was stirred at 50°C for 30 min. The volume of acetonitrile was reduced under vacuum and water was added to it. The organic material was extracted

with ethyl acetate and the organic layer was dried and concentrated to obtain a brown solid (4b) (1.7 g, 99%). m/z 345.7 ($M+H$)⁺.

¹H-NMR (400 MHz, CDCl₃): δ 7.74 (d, J = 8.4 Hz, 1H), 7.42 (dd, J = 2 Hz, 8.4 Hz, 1H), 7.36 (d, J = 2 Hz, 1H), 3.06-3.02 (m, 2H), 3.00-2.95 (m, 2H).

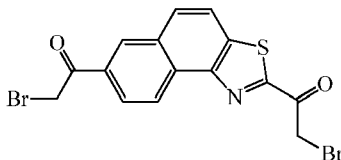
5 **Step 3:** 1,1'-(4,5-dihydronaphtho[1,2-d]thiazole-2,7-diyl)diethanone (4c)



A solution of 2,7-dibromo-4,5-dihydronaphtho[1,2-d]thiazole (4b) (1.7 g, 5.07 mmol) in 30 ml of anhydrous dioxane was degassed by passing nitrogen gas for 15 min. Tributyl(1-ethoxyvinyl)stannane (4.58 g, 12.68 mmol) was added to it
10 followed by PdCl₂(PPh₃)₂ (0.36 g, 0.51 mmol) and the solution was heated at 90 °C overnight. After cooling, the volume of dioxane was reduced and a saturated solution of KF was added to it and stirred for 15 min., after which the mixture was passed through a pad of celite and washed with ethyl acetate. The combined filtrate was stirred with 4 N HCl solution for 1 h and the organic layer
15 was dried and concentrated and the residue was purified by column chromatography to obtain the diacetyl compound (4c) (1.37 g, 73%). m/z 271.0 (M ⁺).

¹H-NMR (400 MHz, CDCl₃), δ 8.09 (d, J = 8 Hz, 1H), 7.94 (dd, J = 1.6 Hz, 8 Hz, 1H), 7.87 (d, J = 1.6 Hz, 1H), 3.20-3.15 (m, 4H), 2.78 (s, 3H), 2.65 (s, 3H).

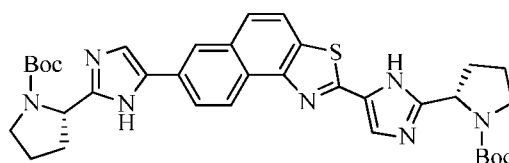
20 **Step 4:** 1,1'-(naphtho[1,2-d]thiazole-2,7-diyl)bis(2-bromoethanone) (4d)



was synthesized from 1,1'-(4,5-dihydronaphtho[1,2-d]thiazole-2,7-diyl)diethanone (4c) by following an analogous procedure described in Step 4, Example 1.

¹H-NMR (400 MHz, DMSO-d₆): δ 8.85-8.82 (m, 1H), 8.40-8.26 (m, 3H), 7.95 (s, 1H), 5.21 (s, 2H), 5.11 (s, 2H).

Step 5: (2S,2'S)-di-tert-butyl 2,2'-(5,5'-(naphtho[1,2-d]thiazole-2,7-diyl))bis(1H-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) (4e)



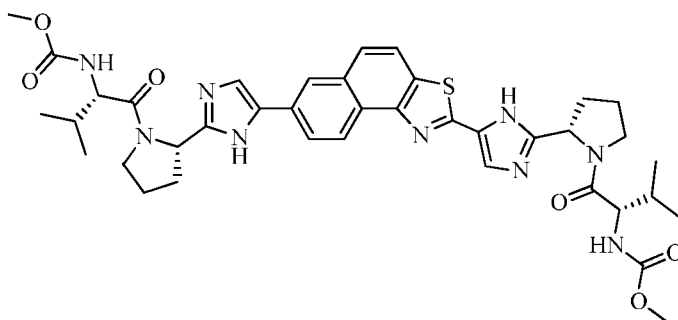
5

was synthesized from 1,1'-(naphtho[1,2-d]thiazole-2,7-diyl)bis(2-bromoethanone) (4d) and (S)-1-(tert-butoxycarbonyl)pyrrolidine-2-carboxylic acid by following an analogous procedure described in Step 5 of Example 1 followed by Step 6, Example 1. m/z 656.1 (M+H)⁺.

10 ¹H-NMR (400 MHz, CDCl₃): δ 8.75-8.72 (m, 1H), 8.47 (s, 1H), 8.22-8.19 (m, 1H), 8.01-7.86 (m, 3H), 7.43 (s, 1H), 5.18-5.16 (m, 2H), 4.38-4.35 (m, 2H), 3.69-3.50 (m, 2H), 3.40-3.37 (m, 2H), 2.27-2.19 (m, 2H), 2.06-1.90 (m, 4H), 1.54 (s, 9H), 1.51 (s, 9H).

Step 6: dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(naphtho[1,2-d]thiazole-2,7-diyl))bis(1H-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 4)

15



was synthesized from (2S,2'S)-di-tert-butyl 2,2'-(5,5'-(naphtho[1,2-d]thiazole-2,7-diyl))bis(1H-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) (4e) by following an analogous procedure described in Step 7, Example 1. m/z 770.2 (M+H)⁺.

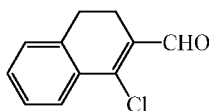
20

¹H-NMR (400 MHz, CD₃OD): δ 8.72 (d, *J* = 8.8 Hz, 1H), 8.34-8.26 (m, 1H), 7.98-7.96 (m, 2H), 7.86-7.80 (m, 2H), 7.47 (s, 1H), 5.22-5.20 (m, 2H), 4.27-4.25 (m, 2H), 4.05-3.99 (m, 2H), 3.94-3.92 (m, 2H), 3.67 (s, 6H), 3.48-3.45 (m, 2H), 2.40-2.22 (m, 4H), 2.16-2.01 (m, 4H), 1.03-0.91 (m, 12H).

5 Example 5: Synthesis of dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl)bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 5)

Step 1: 1-chloro-3,4-dihydronaphthalene-2-carbaldehyde (5a)

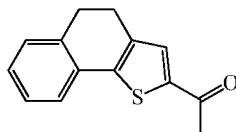
10



was synthesized from α-tetralone by following an analogous procedure described in Step 1, Example 1. *m/z* 193.0 (M+H)⁺.

¹H-NMR (400 MHz, CDCl₃): δ 10.41 (s, 1H), 7.89-7.87 (m, 1H), 7.41-7.33 (m, 2H), 7.24-7.22 (m, 1H), 2.90-2.84 (m, 2H), 2.67-2.63 (m, 2H).

15 Step 2: 1-(4,5-dihydronaphtho[1,2-*b*]thiophen-2-yl)ethanone (5b)

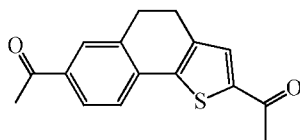


was synthesized from 1-chloro-3,4-dihydronaphthalene-2-carbaldehyde (5a) by following an analogous procedure described in Step 2, Example 1. *m/z* 227.9 (M⁺).

¹H-NMR (400 MHz, CDCl₃): δ 7.52 (s, 1H), 7.49-7.46 (m, 1H), 7.29-7.24 (m, 3H), 3.10-2.97 (m, 2H), 2.88-2.84 (m, 2H), 2.57 (s, 3H).

Step 3: 1,1'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)diethanone (5c)

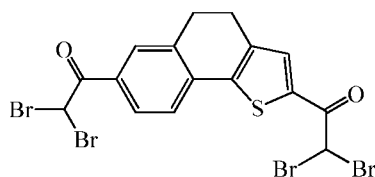
49



To a solution of 1-(4,5-dihydronaphtho[1,2-*b*]thiophen-2-yl)ethanone (5b) (30 g, 131 mmol) in 500 mL of DCM at 0°C, AlCl₃ (52.6 g, 394 mmol) was added portion wise and after 15 min, acetyl chloride (18.69 ml, 263 mmol) was added dropwise at the same temperature over 30 min and the mixture was stirred at room temperature for 48 hr. The reaction mass was slowly added to ice water and acidified with 2 N HCl solution and extracted with DCM, and the organic layer was dried over anhydrous sodium sulphate and concentrated under reduced pressure to afford the title compound as an yellow solid (5c) (28.3 g, 80%). m/z 270.0 (M⁺).

¹H-NMR (400 MHz, CDCl₃): δ 7.86-7.83 (m, 2H), 7.54-7.52 (m, 2H), 3.07-3.04 (m, 2H), 2.93-2.89 (m, 2H), 2.62 (s, 3H), 2.58 (s, 3H).

Step 4: 1,1'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(2,2-dibromoethanone) (5d)



15

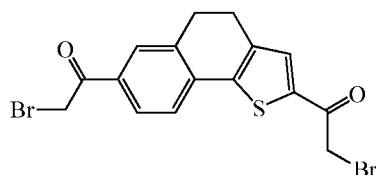
was synthesized from 1,1'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)diethanone (5c) by following an analogous procedure described in Step 4, Example 1.

¹H-NMR (400 MHz, DMSO-*d*₆): δ 8.15-7.97 (m, 2H), 7.90-7.87 (m, 2H), 7.68-7.62 (m, 2H), 3.06-3.02 (m, 2H), 2.90-2.88 (m, 2H).

20

Step 5: 1,1'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(2-bromoethanone) (5e)

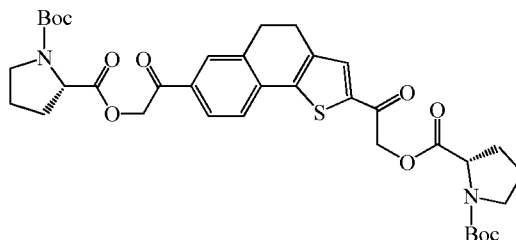
50



was synthesized from 1,1'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(2,2-dibromoethanone) (5d) by following an analogous procedure described in Step 5, Example 2.

- 5 $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.89-7.87 (m, 2H), 7.58-7.53 (m, 2H), 4.45 (s, 2H), 4.36 (m, 2H), 3.87-3.78 (m, 2H), 3.75-3.70 (m, 2H).

Step 6: (S)-2-(2-(7-(2-(((S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-carbonyl)oxy)acetyl)-4,5-dihydronaphtho[1,2-*b*]thiophen-2-yl)-2-oxoethyl) 1-*tert*-butyl pyrrolidine-1,2-dicarboxylate (5f)

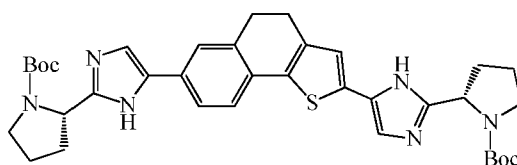


10

was synthesized from 1,1'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(2-bromoethanone) and (S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-carboxylic (5e) acid by following an analogous procedure described in Step 5, Example 1.

- 15 $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ 7.79-7.77 (m, 2H), 7.59-7.52 (m, 2H), 5.39-5.25 (m, 4H), 4.41-4.20 (m, 4H), 3.60-3.30 (m, 4H), 3.10-2.90 (m, 2H), 2.40-2.20 (m, 4H), 2.10-1.85 (m, 4H), 1.47-1.40 (m, 18H).

Step 7: (2*S*,2'*S*)-di-*tert*-butyl 2,2'-(5,5'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) (5g)

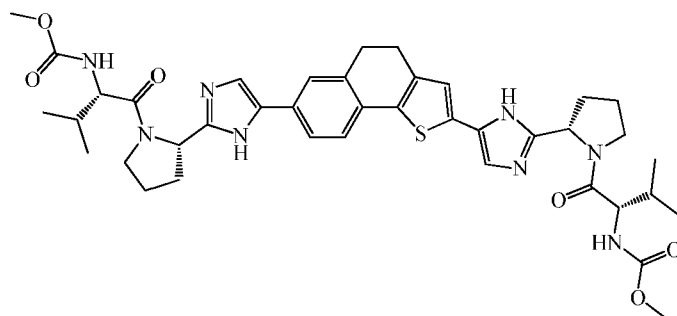


was synthesized from (S)-2-(2-(7-(2-(((S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-carbonyl)oxy)acetyl)-4,5-dihydronaphtho[1,2-*b*]thiophen-2-yl)-2-oxoethyl) 1-*tert*-butyl pyrrolidine-1,2-dicarboxylate (5f) by following an analogous procedure described in Step 6, Example 1. m/z 657.4 (M+H)⁺

- 5 ¹H-NMR (400 MHz, CDCl₃): δ 7.61-7.50 (m, 2H), 7.32-7.30 (m, 1H), 7.21-7.13 (m, 2H), 7.10-7.01 (m, 1H), 4.98-4.95 (m, 2H), 3.56-3.33 (m, 4H), 2.98-2.80 (m, 4H), 2.26-1.92 (m, 8H), 1.51 (s, 18H).

Step 8: dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate dihydrochloride salt (dihydrochloride salt of Compound 5)

10



was synthesized from ((2*S*,2'*S*)-di-*tert*-butyl 2,2'-(5,5'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) (5g) and (S)-2-((methoxycarbonyl)amino)-3-methylbutanoic acid by following an analogous procedure described in Step 7, Example 1. The free base was dissolved in MeOH and a 3 N HCl solution in MeOH was added to it and the resulting solution was stirred for 30 min., after which the volume of MeOH was reduced and acetone was added to precipitate out a pale yellow solid, which was washed with diethyl ether and dried to obtain the dihydrochloride salt of the title compound. m/z 771.4 (M+H)⁺.

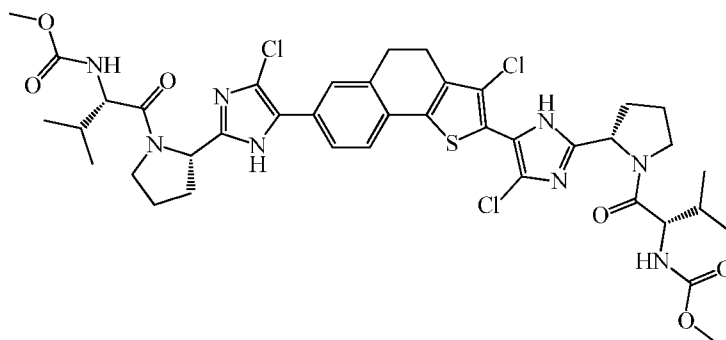
15

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¹H-NMR (400 MHz, DMSO-*d*₆): δ 8.14-8.10 (m, 1H), 7.95-7.91 (m, 1H), 7.80-7.73 (m, 2H), 7.65-7.52 (m, 1H), 7.46-7.44 (d, *J* = 8 Hz, 1H), 7.36-7.34 (d, *J* = 8 Hz, 2H), 5.15-5.10 (m, 2H), 4.11-4.10 (m, 2H), 3.91-3.85 (m, 4H), 3.54 (s, 6H), 3.00-2.89 (m, 2H), 2.87-2.85 (m, 2H), 2.39-2.01 (m, 8H), 0.90-0.76 (m, 12H).

25

Example 6: Synthesis of dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(3-chloro-4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(4-chloro-1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 6)



5

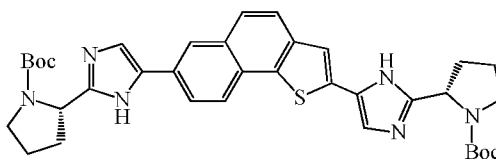
was synthesized from dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate, (Compound 5) by following an analogous procedure described in Example 3.

10 m/z 875.2 ($M+H$)⁺.

¹H-NMR (400 MHz, DMSO-*d*₆): δ 12.60-12.50 (m, 2H), 7.68-7.60 (m, 2H), 7.50-7.48 (m, 1H), 7.40-7.30 (m, 2H), 5.05-4.95 (m, 2H), 4.11-4.00 (m, 2H), 3.85-3.70 (m, 4H), 3.54 (s, 6H), 3.10-3.00 (m, 2H), 2.90-2.80 (m, 2H), 2.20-1.85 (m, 10H), 0.90-0.76 (m, 12H).

15 **Example 7: Synthesis of dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 7)**

Step 1: ((2S,2'S)-di-*tert*-butyl 2,2'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) (7a)

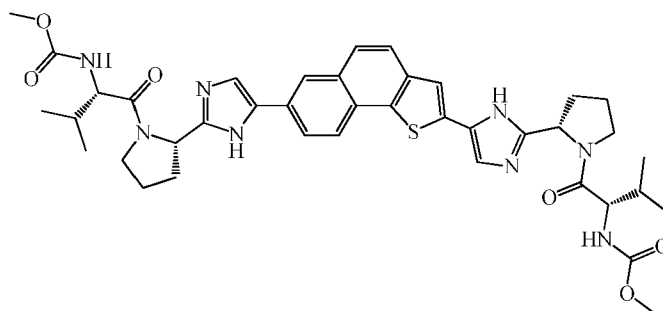


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To a stirred solution of ((2*S*,2'*S*)-di-*tert*-butyl 2,2'-(5,5'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate), (5g) (0.5 g, 0.76 mmol) in 20 ml of toluene, DDQ (0.346 g, 1.52 mmol) was added and the mixture was stirred at 90 °C for 16 hr. The reaction mixture was then concentrated under reduced pressure, and 100 ml of saturated sodium bicarbonate solution was added and the organic material was extracted with ethyl acetate. The ethyl acetate layer was dried over anhydrous sodium sulphate and concentrated under reduced pressure to obtain the crude compound which was purified by column chromatography to obtain the aromatised compound as an yellow solid (7a) (0.25 g, 51%). m/z 655.5 (M+H)⁺

¹H-NMR (400 MHz, CDCl₃): δ 12.11-12.03 (m, 1H), 11.97-11.90 (m, 1H), 8.32 (s, 1H), 8.00 (s, 2H), 7.77 (s, 2H), 7.63-7.55 (m, 3H), 4.87-4.80 (m, 2H), 3.56-3.50 (m, 2H), 3.40-3.35 (m, 3H), 2.27-2.20 (m, 3H), 2.02-1.87 (m, 4H), 1.41 (s, 9H), 1.18 (s, 9H).

Step 2: dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 7 and its dihydrochloride salt)



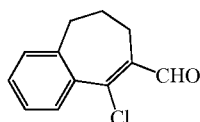
was synthesized from ((2*S*,2'*S*)-di-*tert*-butyl 2,2'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) (7a) by following an analogous procedure described in Step 7, Example 1. The free base was dissolved in MeOH and a 3 N HCl solution in MeOH was added to it and the resulting solution was stirred for 30 min., after which the volume of MeOH was reduced and acetone was added to precipitate out a pale yellow solid, which was washed with diethyl ether and dried to obtain the dihydrochloride salt of the title compound. m/z 769.2 (M+H)⁺.

¹H-NMR (400 MHz, DMSO-d₆): δ 15.33 (br s, 1H), 14.77 (br s, 1H), 8.62 (s, 1H), 8.25-8.18 (m, 2H), 8.13-8.01 (m, 4H), 7.89-7.87 (m, 1H), 7.34-7.32 (m, 2H), 5.21-5.15 (m, 2H), 4.16-4.10 (m, 2H), 3.98-3.85 (m, 4H), 3.54 (s, 6H), 2.50-2.38 (m, 2H), 2.20-2.19 (m, 4H), 2.10-2.01 (m, 4H), 0.92-0.77 (m, 12H).

- 5 **Example 8: Synthesis of dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 8)**

Step 1: 9-chloro-6,7-dihydro-5*H*-benzo[7]annulene-8-carbaldehyde (8a)

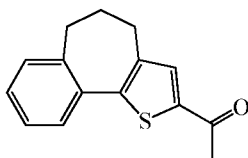
10



was synthesized from 6,7,8,9-tetrahydro-5*H*-benzo[7]annulene-5-one by following an analogous procedure described in Step 1, Example 1. *m/z* 205.9 (*M*⁺).

¹H-NMR (400 MHz, CDCl₃): δ 10.10 (s, 1H), 7.70-7.66 (m, 1H), 7.41-7.36 (m, 2H), 7.29-7.28 (m, 1H), 2.63 (t, *J* = 7 Hz, 2H), 2.26-2.06 (m, 4H).

- 15 **Step 2:** 1-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophen-2-yl)ethanone (8b)

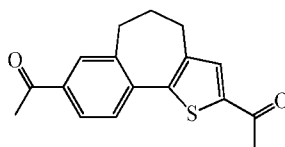


- was synthesized from 9-chloro-6,7-dihydro-5*H*-benzo[7]annulene-8-carbaldehyde (8a) by following an analogous procedure described in Step 2, Example 1. *m/z* 242.1 (*M*⁺).
- 20

¹H-NMR (400 MHz, CDCl₃): δ 7.56 (s, 1H), 7.52-7.47 (m, 1H), 7.36-7.25 (m, 3H), 2.71-2.63 (m, 4H), 2.58 (s, 3H), 2.30-2.19 (m, 2H).

Step 3: 1,1'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl)diethanone (8c)

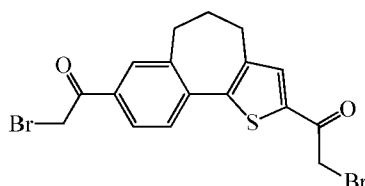
55



was synthesized from 1-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophen-2-yl)ethanone (8b) by following an analogous procedure described in Step 3, Example 5. *m/z* 283.9 (*M*⁺).

- 5 ¹H-NMR (400 MHz, CDCl₃): δ 8.05-8.02 (m, 1H), 7.90-7.86 (m, 1H), 7.57-7.55 (m, 1H), 7.40-7.38 (m, 1H), 2.75-2.68 (m, 4H), 2.64 (s, 3H), 2.58 (s, 3H), 2.29-2.26 (m, 2H).

Step 4: 1,1'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl)bis(2-bromoethanone) (8d)



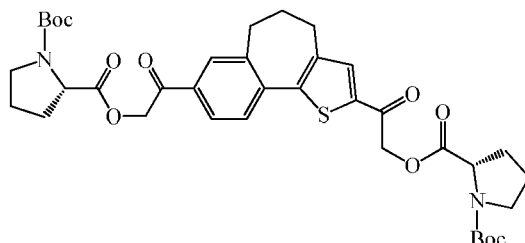
10

was synthesized from 1,1'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl)diethanone (8c) by following an analogous procedure described in Step 4, Example 1.

- 15 ¹H-NMR (400 MHz, CDCl₃): δ 8.09-8.05 (m, 1H), 7.96-7.90 (m, 1H), 7.68-7.59 (m, 1H), 7.57-7.54 (m, 1H), 4.48 (s, 2H), 4.37 (s, 2H), 2.78-2.65 (m, 4H), 2.34-2.28 (m, 2H).

Step 5: (S)-2-(2-(8-(2-(((S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-carbonyl)oxy)acetyl)-5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophen-2-yl)-2-oxoethyl) 1-*tert*-butyl pyrrolidine-1,2-dicarboxylate (8e)

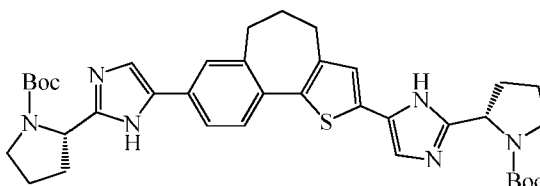
56



was synthesized from 1,1'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-
b]thiophene-2,8-diyl)bis(2-bromoethanone) and (S)-1-(*tert*-
 butoxycarbonyl)pyrrolidine-2-carboxylic acid (8d) by following an analogous
 5 procedure described in Step 5, Example 1.

¹H-NMR (400 MHz, CDCl₃): δ 8.06-7.43 (m, 4H), 4.48-4.14 (m, 4H), 3.74-3.70
 (m, 2H), 3.45-3.33 (m, 2H), 3.16-3.12 (m, 2H), 2.71-2.68 (m, 4H), 2.34-2.29 (m,
 4H), 2.06-1.90 (m, 6H), 1.48-1.34 (m, 18H).

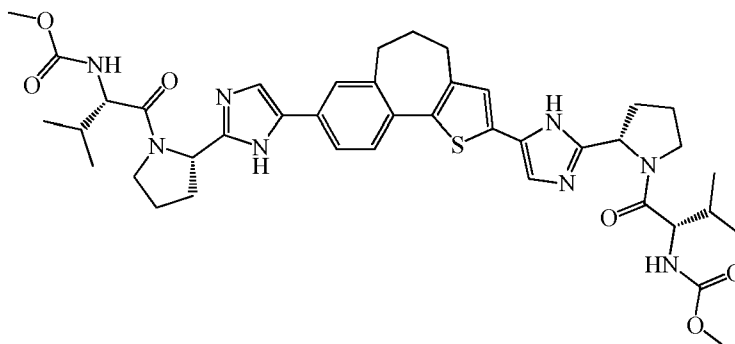
Step 6: (2*S*,2'*S*)-di-*tert*-butyl 2,2'-(5,5'-(5,6-dihydro-4*H*-
 10 benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl)bis(1*H*-imidazole-5,2-
 diyl))bis(pyrrolidine-1-carboxylate) (8f)



was synthesized from (S)-2-(2-(8-(2-(((S)-1-(*tert*-butoxycarbonyl)pyrrolidine-2-
 carbonyl)oxy)acetyl)-5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophen-2-yl)-
 15 2-oxoethyl) 1-*tert*-butyl pyrrolidine-1,2-dicarboxylate (8e) by following an
 analogous procedure described in Step 6, Example 1. *m/z* 671.4 (M+H)⁺.

¹H-NMR (400 MHz, CDCl₃): δ 7.70-7.10 (m, 6H), 5.01-4.98 (m, 2H), 3.57-3.36
 (m, 4H), 2.90-2.56 (m, 4H), 2.35-1.91 (m, 8H), 1.51-1.40 (m, 18H).

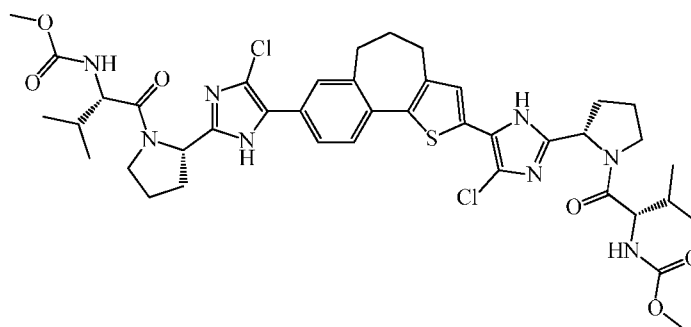
Step 7: dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(5,6-dihydro-4*H*-
 20 benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl)bis(1*H*-imidazole-5,2-
 diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate
 (Compound 8)



was synthesized from (2*S*,2'*S*)-di-*tert*-butyl 2,2'-(5,5'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-1-carboxylate) (8f) by following an analogous procedure described in Step 7, Example 1. m/z 782.5 ($M+H$)⁺.

¹H-NMR (400 MHz, CD₃OD): δ 7.78-7.73 (m, 1H), 7.56-7.42 (m, 2H), 7.31-7.25 (m, 2H), 7.20-7.16 (m, 1H), 7.10-7.09 (m, 1H), 5.15-5.10 (m, 2H), 4.24-4.22 (m, 2H), 4.05-3.87 (m, 4H), 3.66 (s, 6H), 2.75-2.69 (m, 4H), 2.35-2.21 (m, 8H), 2.07-2.02 (m, 4H), 1.00-0.90 (m, 12H).

Example 9: Synthesis of dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl))bis(4-chloro-1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 9)



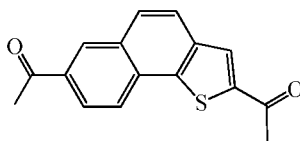
was synthesized from dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate

(Compound 8) by following an analogous procedure described in Example 3. m/z 853.3 (M+H)⁺.

¹H-NMR (400 MHz, CD₃OD): δ 7.78-7.75 (m, 1H), 7.67-7.55 (m, 2H), 7.35-7.33 (m, 1H), 7.09-7.06 (m, 2H), 5.07-5.06 (m, 2H), 4.22-4.20 (m, 2H), 4.05-3.87 (m, 4H), 3.65 (s, 6H), 2.75-2.69 (m, 4H), 2.35-2.21 (m, 8H), 2.07-2.02 (m, 4H), 1.00-0.92 (m, 12H).

Example 10: Synthesis of dimethyl ((2S,2'S)-((1R,1'R,3S,3'S,4S,4'S)-3,3'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(2-azabicyclo[2.2.1]heptane-3,2-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 10)

Step 1: 1,1'-(naphtho[1,2-*b*]thiophene-2,7-diyl)diethanone (10a)

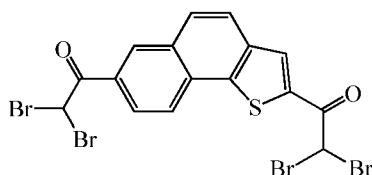


To a stirred solution of 1,1'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)diethanone (5c) (1 g, 3.7 mmol) in 30 ml of toluene, DDQ (0.84 g, 3.7 mmol) was added and the mixture was stirred at 110 °C for 60 hr. The reaction mixture was concentrated under reduced pressure, 100 ml water was added and the organics were extracted with ethyl acetate. The organic layer was dried over anhydrous sodium sulphate and concentrated under reduced pressure to obtain the crude compound which was purified by column chromatography to obtain 1,1'-(naphtho[1,2-*b*]thiophene-2,7-diyl)diethanone as a brown solid (10a) (0.45 g, 55%).

¹H-NMR (400 MHz, CDCl₃): δ 8.55 (s, 1H), 8.24 (d, J = 8 Hz, 1H), 8.17 (dd, J = 8 Hz, 1 Hz, 1H), 8.01 (s, 1H), 7.92-7.86 (m, 2H), 2.77 (s, 3H), 2.73 (s, 3H).

Step 2: 1,1'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(2,2-dibromoethanone) (10b)

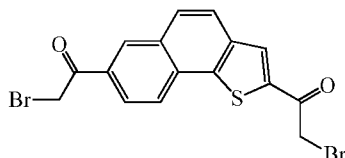
59



To a solution of 1,1'-(naphtho[1,2-*b*]thiophene-2,7-diyl)diethanone (10a) (100 g, 373 mmol) in 300 ml of DCM, bromine (48 ml, 932 mmol) was added drop wise at room temperature. After the addition, the solution was stirred at room temperature for 3 hr. The reaction mixture was concentrated under reduced pressure at 35 °C to obtain a semi-solid material, which was washed with a minimum amount of DCM and filtered to obtain a brown solid. The brown solid was washed with diethyl ether to yield the title compound (10b) (189 g, 88%).

¹H-NMR (400 MHz, CDCl₃): δ 8.74 (s, 1H), 8.42 (s, 1H), 8.28 (s, 2H), 8.00-7.80 (m, 2H), 6.83 (s, 1H), 6.61 (s, 1H).

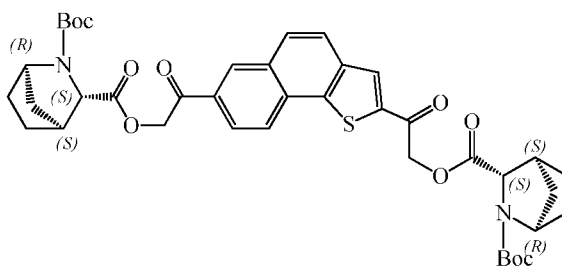
Step 3: 1,1'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(2-bromoethanone) (10c)



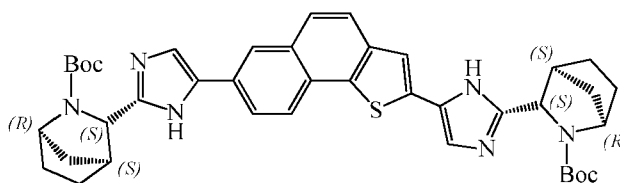
1,1'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(2,2-dibromoethanone) (10b) (180 g, 310 mmol) obtained as above was dissolved in 500 ml of THF and the solution was cooled to 0 °C. A mixture of diethyl phosphite (80 ml, 620 mmol) and triethylamine (86 ml, 210 mmol) in 50 ml THF was added dropwise to the solution which was kept on an ice bath. After the addition, the ice bath was removed and the reaction mixture was stirred at room temperature for 2 hr. The volume of THF was reduced by rotary evaporation to obtain a solid residue which was washed with pentane to afford 1,1'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(2-bromoethanone) as a brown solid (10c) (110 g, 84%).

¹H-NMR (400 MHz, DMSO-*d*₆): δ 8.88-8.84 (m, 1H), 8.66 (s, 1H), 8.44-8.38 (m, 1H), 8.19-8.09 (m, 3H), 5.11 (s, 2H), 5.03 (s, 2H).

Step 4: (1*R*,3*S*,4*S*)-3-(2-(2-(2-(((1*R*,3*S*,4*S*)-2-(*tert*-butoxycarbonyl)-2-azabicyclo[2.2.1]heptane-3-carbonyl)oxy)acetyl)naphtho[1,2-*b*]thiophen-7-yl)-2-oxoethyl) 2-*tert*-butyl 2-azabicyclo[2.2.1]heptane-2,3-dicarboxylate (10d)

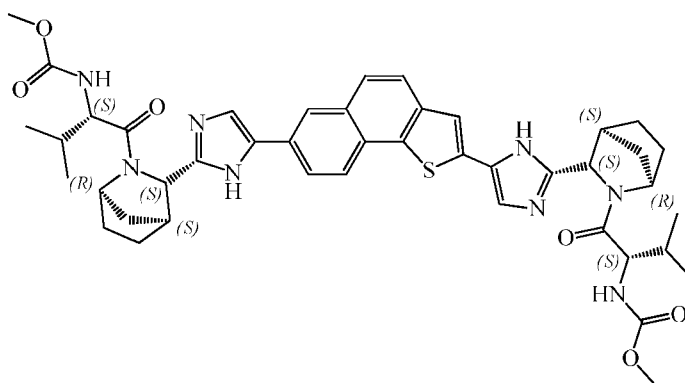


- 5 was synthesized from 1,1'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(2-bromoethanone) (10c) and (1*R*,3*S*,4*S*)-2-(*tert*-butoxycarbonyl)-2-azabicyclo[2.2.1]heptane-3-carboxylic acid (see, e.g., WO 2012/041227) by following an analogous procedure described in Step 5, Example 1. *m/z* 746.3 (*M*+*H*)⁺.
- 10 ¹H-NMR (400 MHz, CDCl₃): δ 8.52-8.50 (m, 1H), 8.27-8.25 (m, 1H), 8.15-8.10 (m, 2H), 7.95-7.87 (m, 2H), 5.57-5.31 (m, 4H), 4.41-4.40 (m, 1H), 4.29-4.27 (m, 1H), 4.05-4.04 (m, 2H), 3.99-3.97 (m, 2H), 3.07-2.88 (m, 2H), 1.80-1.75 (m, 4H), 1.74-1.65 (m, 4H), 1.62-1.57 (m, 2H), 1.51-1.44 (m, 18H).
- Step 5:** (1*R*,1'*R*,3*S*,3'*S*,4*S*,4'*S*)-di-*tert*-butyl 3,3'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(2-azabicyclo[2.2.1]heptane-2-carboxylate) (10e)



- was synthesized from (1*R*,3*S*,4*S*)-3-(2-(2-(2-(((1*R*,3*S*,4*S*)-2-(*tert*-butoxycarbonyl)-2-azabicyclo[2.2.1]heptane-3-carbonyl)oxy)acetyl)naphtho[1,2-*b*]thiophen-7-yl)-2-oxoethyl) 2-*tert*-butyl 2-azabicyclo[2.2.1]heptane-2,3-dicarboxylate (10d) and ammonium acetate by following an analogous procedure described in Step 6, Example 1. *m/z* 706.1 (*M*+*H*)⁺.
- 20

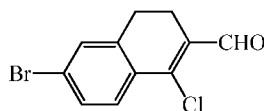
Step 6: dimethyl ((2*S*,2'*S*)-((1*R*,1'*R*,3*S*,3'*S*,4*S*,4'*S*)-3,3'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(2-azabicyclo[2.2.1]heptane-3,2-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate (Compound 10)



- 5 was synthesized from (1*R*,1'*R*,3*S*,3'*S*,4*S*,4'*S*)-di-*tert*-butyl 3,3'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(2-azabicyclo[2.2.1]heptane-2-carboxylate) and (S)-2-((methoxycarbonyl)-amino)-3-methylbutanoic acid (10e) by following an analogous procedure described in Step 7, Example 1. *m/z* 820.4 (M+H)⁺.
- 10 ¹H-NMR (400 MHz, CDCl₃): δ 8.28 (br s, 1H), 7.98-7.97 (m, 2H), 7.77-7.54 (m, 5H), 7.21-7.19 (d, *J* = 8 Hz, 2H), 4.54-4.52 (m, 4H), 4.16-4.12 (m, 2H), 3.54 (s, 6H), 2.60-2.55 (m, 2H), 2.01-1.99 (m, 2H), 1.86-1.75 (m, 6H), 1.56-1.44 (m, 4H), 1.23-1.12 (m, 2H), 1.01-0.94 (m, 6H), 0.90-0.89 (m, 6H).

Example 11: Synthesis of methyl ((S)-1-((S)-2-(5-(2-(2-((1*R*,3*S*,4*S*)-2-((S)-2-(methoxycarbonyl)amino-3-methylbutanoyl)-2-azabicyclo[2.2.1]heptan-3-yl)-1*H*-imidazol-5-yl)naphtho[1,2-*b*]thiophen-7-yl)-1*H*-imidazol-2-yl)pyrrolidin-1-yl)-3-methyl-1-oxobutan-2-yl)carbamate (Compound 11)

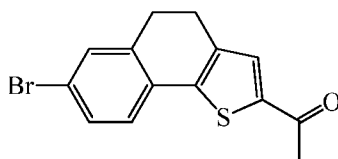
Step 1: 6-bromo-1-chloro-3,4-dihydronaphthalene-2-carbaldehyde (11a)



- 20 was synthesized from 6-bromo-3,4-dihydronaphthalen-1(2H)-one by following an analogous procedure described in Step 1, Example 1.

¹H-NMR (400 MHz, CDCl₃): δ 7.72 (d, *J* = 8 Hz, 1H), 7.48 (dd, *J* = 8 Hz, 2 Hz, 1H), 7.39 (s, 1H), 2.84 (t, *J* = 6 Hz, 2H), 2.64 (t, *J* = 6 Hz, 2H).

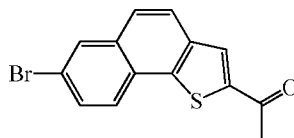
Step 2: 1-(7-bromo-4,5-dihydronaphtho[1,2-*b*]thiophen-2-yl)ethanone (11b)



5 was synthesized from 6-bromo-1-chloro-3,4-dihydronaphthalene-2-carbaldehyde (11a) by following an analogous procedure described in Step 2, Example 1. *m/z* 305.9, 307.9.

¹H-NMR (400 MHz, CDCl₃): δ 7.50 (s, 1H), 7.40 (s, 1H), 7.37 (d, *J* = 2 Hz, 1H), 7.32 (d, *J* = 8 Hz, 1H), 2.97 (t, *J* = 6 Hz, 2H), 2.85 (t, *J* = 6 Hz, 2H), 2.56 (s, 3H).

10 **Step 3:** 1-(7-bromonaphtho[1,2-*b*]thiophen-2-yl)ethanone (11c)

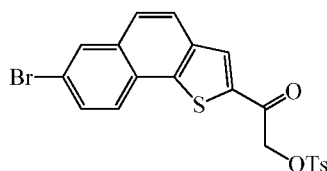


1-(7-bromo-4,5-dihydronaphtho[1,2-*b*]thiophen-2-yl)ethanone (11b) (600 mg, 1.95 mmol) was dissolved in 20 ml toluene and manganese dioxide (943 mg, 9.77 mmol) was added and the mixture was heated at 100°C for 26 hr. Aliquots
15 were taken in between to check the progress of the reaction by HPLC. Once the reaction was complete, the mixture was filtered over a pad of celite, and the celite pad was washed with ethyl acetate. The ethyl acetate layer was concentrated to obtain the desired compound (11c) (0.51 g, 85%). *m/z* 304, 306 (M+H)⁺.

20 ¹H-NMR (400 MHz, CDCl₃): δ 8.09 (d, *J* = 2 Hz, 1H), 8.04 (d, *J* = 8 Hz, 2H), 7.83 (d, *J* = 8 Hz, 1H), 7.69 (dd, *J* = 8 Hz, 2 Hz, 1H), 7.66 (d, *J* = 8 Hz, 1H), 2.71 (s, 3H).

Step 4: 2-(7-bromonaphtho[1,2-*b*]thiophen-2-yl)-2-oxoethyl 4-methylbenzenesulfonate (11d)

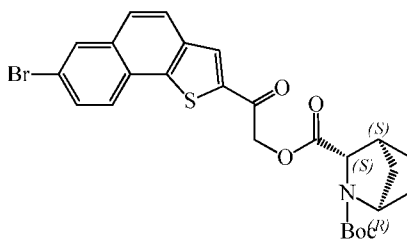
63



To a solution of 1-(7-bromonaphtho[1,2-*b*]thiophen-2-yl)ethanone (11c) (1.26 g, 4.13 mmol) in 15 ml of acetonitrile at 75°C, hydroxytosyloxyiodobenzene (2.59 g, 6.61 mmol) was added and the mixture was refluxed for 8 hr. The volume of acetonitrile was reduced under vacuum and ethanol was added to it. The orange solid obtained was filtered and washed with ether to obtain the desired compound (11d) (1.6 g, 82%).

¹H-NMR (400 MHz, DMSO-*d*₆): δ 8.53 (s, 1H), 8.39 (d, *J* = 8 Hz, 1H), 8.21 (d, *J* = 8 Hz, 1H), 8.02 (d, *J* = 8 Hz, 1H), 7.93 (s, 1H), 7.89 (d, *J* = 8 Hz, 2H), 7.82 (dd, *J* = 8 Hz & 2 Hz, 1H), 7.50 (d, *J* = 8 Hz, 2H), 5.65 (s, 2H), 2.43 (s, 3H).

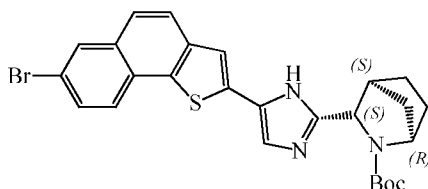
Step 5: Synthesis of (1*R*,3*S*,4*S*)-3-(2-(7-bromonaphtho[1,2-*b*]thiophen-2-yl)-2-oxoethyl) 2-*tert*-butyl 2-azabicyclo[2.2.1]heptane-2,3-dicarboxylate (11e)



The above compound was synthesized from 2-(7-bromonaphtho[1,2-*b*]thiophen-2-yl)-2-oxoethyl 4-methylbenzenesulfonate (11d) and (1*R*,3*S*,4*S*)-2-(*tert*-butoxycarbonyl)-2-azabicyclo[2.2.1]heptane-3-carboxylic acid by following an analogous procedure described in Step 5, Example 1. *m/z* 543.9, 545.9 (*M*+*H*)⁺.

¹H-NMR (400 MHz, CDCl₃): δ 8.11-8.09 (m, 2H), 8.04-8.01 (m, 1H), 7.85 (d, *J* = 8.8 Hz, 1H), 7.72-7.64 (m, 2H), 5.60-5.25 (m, 2H), 4.40-4.27 (m, 1H), 4.04-3.96 (m, 1H), 3.02-3.00 (m, 1H), 2.11-2.06 (m, 2H), 1.83-1.58 (m, 4H), 1.48-1.46 (m, 9H).

Step 6: (1*R*,3*S*,4*S*)-*tert*-butyl 3-(5-(7-bromonaphtho[1,2-*b*]thiophen-2-yl)-1*H*-imidazol-2-yl)-2-azabicyclo[2.2.1]heptane-2-carboxylate (11f)

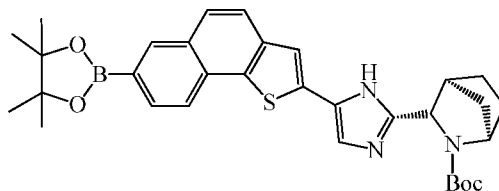


was synthesized from (1*R*,3*S*,4*S*)-3-(2-(7-bromonaphtho[1,2-*b*]thiophen-2-yl)-2-oxoethyl) 2-*tert*-butyl 2-azabicyclo[2.2.1]heptane-2,3-dicarboxylate (11e) and ammonium acetate by following an analogous procedure described in Step 6,

5 Example 1. *m/z* 524.4, 526.4 (*M*+*H*)⁺.

¹H-NMR (400 MHz, CDCl₃): δ 8.04 (m, 1H), 7.94 (d, *J* = 8.8 Hz, 1H), 7.75 (d, *J* = 8.8 Hz, 1H), 7.59 (d, *J* = 8.8 Hz, 2H), 7.30 (s, 1H), 4.46 (s, 1H), 4.18 (s, 1H), 3.47 (s, 1H), 2.06-1.62 (m, 6H), 1.55-1.52 (m, 9H).

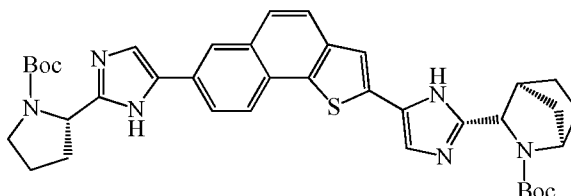
Step 7: (1*R*,3*S*,4*S*)-*tert*-butyl 3-(5-(7-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)naphtho[1,2-*b*]thiophen-2-yl)-1*H*-imidazol-2-yl)-2-azabicyclo[2.2.1]heptane-2-carboxylate (11g)



Dioxane (10 ml) was degassed by passing nitrogen for 15 min. and a mixture of bis-pinacolatodiboron (261 mg, 1.03 mmol), potassium acetate (152 mg, 1.55 mmol), tricyclohexylphosphine (11.55 mg, 0.04 mmol), PdCl₂(dppf)-CH₂Cl₂-adduct (33.6 mg, 0.04 mmol) and (1*R*,3*S*,4*S*)-*tert*-butyl 3-(5-(7-bromonaphtho[1,2-*b*]thiophen-2-yl)-1*H*-imidazol-2-yl)-2-azabicyclo[2.2.1]heptane-2-carboxylate (11f) (270 mg, 0.52 mmol) was added in a microwave vial and the cap was sealed. The mixture was heated at 95 °C for 8 hr. The reaction mixture was diluted with ethyl acetate and the ethyl acetate layer was washed with water, dried and concentrated to obtain the crude compound which was purified on a Combiflash column to obtain the title compound (11g) (0.27 g, 92%). *m/z* 571.8 (*M*+*H*)⁺.

¹H-NMR (400 MHz, CDCl₃): δ 8.42 (s, 1H), 8.06 (d, *J* = 8 Hz, 1H), 7.93 (d, *J* = 8 Hz, 1H), 7.75 (s, 2H), 7.64 (s, 1H), 7.31 (s, 1H), 4.46 (s, 1H), 4.18 (s, 1H), 3.54 (s, 1H), 2.06-1.61 (m, 6H), 1.42 (s, 12H), 1.27-1.24 (m, 9H).

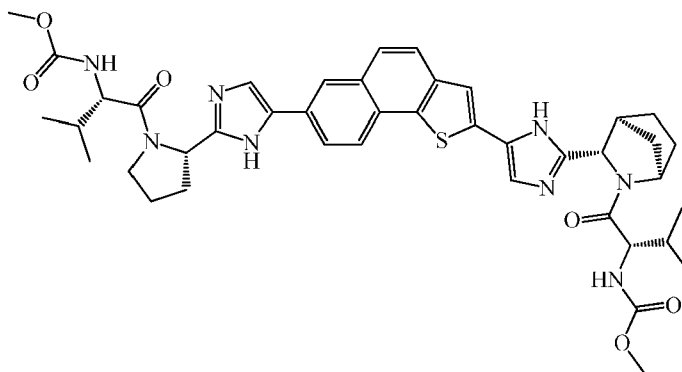
Step 8: (1*R*,3*S*,4*S*)-*tert*-butyl 3-(5-(7-(2-((*S*)-1-(*tert*-butoxycarbonyl)pyrrolidin-2-yl)-1*H*-imidazol-5-yl)naphtho[1,2-*b*]thiophen-2-yl)-1*H*-imidazol-2-yl)-2-azabicyclo[2.2.1]heptane-2-carboxylate (11h)



A mixture of 6 ml of toluene and 2 ml of water was purged with nitrogen and (1*R*,3*S*,4*S*)-*tert*-butyl 3-(5-(7-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)naphtho[1,2-*b*]thiophen-2-yl)-1*H*-imidazol-2-yl)-2-azabicyclo[2.2.1]heptane-2-carboxylate (11h) (300 mg, 0.53 mmol), (*S*)-*tert*-butyl 2-(5-iodo-1*H*-imidazol-2-yl)pyrrolidine-1-carboxylate (286 mg, 0.79 mmol), (see, e.g., WO 2010/096302), K₃PO₄ (334 mg, 1.58 mmol), Pd(PPh₃)₄ (61 mg, 0.05 mmol) and tricyclohexylphosphine (15 mg, 0.05 mmol) were added in a reaction vessel and sealed. The reaction vessel was heated in an oil bath at 100°C for 24 hr. After completion of the reaction, the compound formed was extracted into ethyl acetate, and the ethyl acetate layer was washed with water, dried over Na₂SO₄ and concentrated. The crude material was purified on a Combiflash column to obtain the title compound (11h) (0.16 g, 45%). *m/z* 681.2 (*M*+*H*)⁺.

¹H-NMR (400 MHz, CDCl₃): δ 7.81 (s, 1H), 7.70-7.66 (m, 2H), 7.61-7.54 (m, 2H), 7.51-7.46 (m, 2H), 7.07 (s, 1H), 5.13 (br s, 2H), 4.50 (m, 2H), 3.51 (m, 3H), 2.22-1.75 (m, 6H), 1.55-1.49 (m, 18H), 1.34-1.30 (m, 3H).

Step 9: Synthesis of methyl ((*S*)-1-((*S*)-2-(5-(2-(2-((1*R*,3*S*,4*S*)-2-((*S*)-2-(methoxycarbonyl)amino-3-methylbutanoyl)-2-azabicyclo[2.2.1]heptan-3-yl)-1*H*-imidazol-5-yl)naphtho[1,2-*b*]thiophen-7-yl)-1*H*-imidazol-2-yl)pyrrolidin-1-yl)-3-methyl-1-oxobutan-2-yl)carbamate dihydrochloride salt (Compound 11)



The above compound was synthesized from (1*R*,3*S*,4*S*)-*tert*-butyl 3-(5-(7-(2-((*S*)-1-(*tert*-butoxycarbonyl)pyrrolidin-2-yl)-1*H*-imidazol-5-yl)naphtho[1,2-*b*]thiophen-2-yl)-1*H*-imidazol-2-yl)-2-azabicyclo[2.2.1]heptane-2-carboxylate (11h) and (*S*)-2-((methoxycarbonyl)-amino)-3-methylbutanoic acid by following an analogous procedure described in Step 7, Example 1. *m/z* 795.2 (*M*+*H*)⁺.

¹H-NMR (400 MHz, DMSO-*d*₆): δ 15.26 (br s, 1H), 14.74 (br s, 1H), 8.58 (s, 1H), 8.22-8.19 (m, 2H), 8.09 (d, *J* = 8 Hz, 1H), 8.01 (d, *J* = 8 Hz, 1H), 7.86 (d, *J* = 8 Hz, 1H), 7.35-7.33 (m, 2H), 5.20-5.18 (m, 2H), 4.72-4.48 (m, 2H), 4.22-4.11 (m, 2H), 3.96-3.86 (m, 2H), 3.56 (s, 3H), 3.54 (s, 3H), 2.72-2.70 (m, 2H), 2.19-2.05 (m, 4H), 1.85-1.71 (m, 4H), 1.52-1.49 (m, 2H), 0.96-0.76 (m, 12H).

Example 12: Biological Activity

Anti-viral activity of the compounds of the invention was monitored using an HCV replicon assay. The Huh7.5/ Con1/SG-Neo(I)hRluc2aUb cell line persistently expressing a bicistronic genotype 1b replicon in Huh 7.5 cells and the Huh7.5/ J6/JFH1/EMCVIRES/hRlucNeo cell line expressing a bicistronic genotype 2a replicon in Huh 7.5 cells were obtained from Apath LLC. These cell lines were used to test inhibition of replicon levels by test compound using *Renilla* luciferase enzyme activity readout as a measure of viral replication efficiency.

Briefly, 7000-7500 cells were seeded in 96 well black clear bottom plates and allowed to adhere overnight. The next day each compound was added in triplicate to the cells at the desired concentration with a final DMSO concentration of 0.5%. Cells in media alone and cells incubated without drug

with 0.5% DMSO served as controls. The plates were incubated for 72h at 37°C prior to running the luciferase assay. Enzyme activity was measured using *Renilla-Glo* Luciferase Assay kit from Promega as per the manufacturer's instructions. The following equation was used to generate the percent inhibition value for each test concentration.

$$\% \text{ Inhibition} = \frac{\text{Average Control (cells alone +0.5\% DMSO)} - \text{Average compound value (cells + drug)}}{\text{Average Control (cells alone +0.5\% DMSO)}} \times 100$$

The IC₅₀ value was determined using GraphPad Prism and the following equation:

$$Y = \text{Bottom} + (\text{Top} - \text{Bottom}) / (1 + 10^{((\text{LogIC}_{50} - X) * \text{Hill slope})})$$

10 IC₅₀ values/% inhibitions of compounds were determined 2-3 times in the replicon assays.

Table 1 sets forth the IC₅₀ values, for inhibition of genotype 1b and 2a replicons, of the compounds in accordance with an embodiment of the invention. Group A compounds exhibited IC₅₀ value between 1 pM to 999 pM, Group B exhibited
15 IC₅₀ value between 1nM to 100 nM, and Group C exhibited IC₅₀ value of more than 100 nM.

Table 1:

Compound No	Gt1b IC ₅₀	Gt2a IC ₅₀
1	A	A
2	A	B
3	A	B
4	A	C
5	A	A
6	A	A
7	A	A
8	A	A
9	A	A
10	A	A
11	A	A

All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

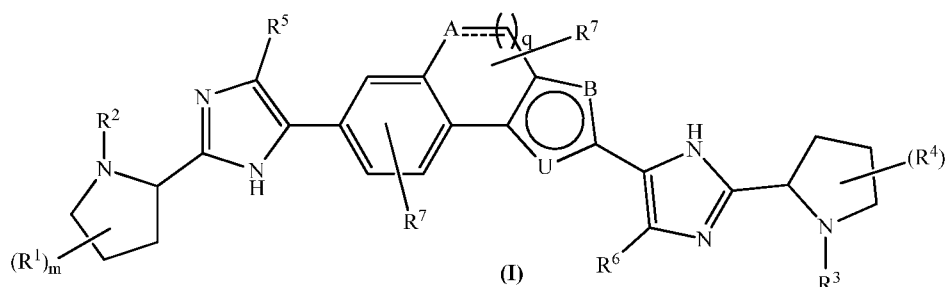
The use of the terms “a” and “an” and “the” and “at least one” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The use of the term “at least one” followed by a list of one or more items (for example, “at least one of A and B”) is to be construed to mean one item selected from the listed items (A or B) or any combination of two or more of the listed items (A and B), unless otherwise indicated herein or clearly contradicted by

context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each
5 separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary
10 language (e.g., “such as”) provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

15 Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for
20 the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated
25 herein or otherwise clearly contradicted by context.

CLAIMS

1. A compound of formula (I), its tautomeric form, its isomer, or its pharmaceutically acceptable salt,



5 wherein,

A is selected from $-\text{CR}^7=$, $-\text{C}(\text{H})(\text{R}^7)-$ and $-\text{O}-$;

B is selected from $-\text{C}(\text{R}^7)=$ and $-\text{S}-$;

U is selected from $-\text{N}=$ and $-\text{S}-$;

with a proviso that B and U both cannot be S at the time;

10 "=====" represents a single or double bond;

R^1 and R^4 are divalent groups, each of which along with the respective carbon atoms to which they are attached form a 3 to 7 membered carbocyclic ring or a 5 to 7 membered heterocyclic ring containing nitrogen, and optionally oxygen;

15 R^2 and R^3 are each independently selected from hydrogen, substituted- or unsubstituted- alkyl, substituted- or unsubstituted- cycloalkyl, substituted- or unsubstituted- aryl, substituted- or unsubstituted- heteroaryl, substituted- or unsubstituted- heterocyclyl, $\text{R}^{8a}\text{C}(=\text{O})-$, $\text{R}^{8a}\text{S}(=\text{O})_2-$, $\text{R}^{8a}\text{OC}(=\text{O})-$, $(\text{R}^9)\text{R}^8\text{NC}(=\text{O})-$, $\text{R}^{8a}\text{OC}(=\text{O})\text{N}(\text{R}^9)\text{CR}^b(\text{R}^a)\text{C}(=\text{O})-$,
 20 $\text{R}^{8a}\text{OC}(=\text{O})\text{N}(\text{R}^9)\text{CR}^b(\text{R}^a)\text{C}(\text{R}^d)(\text{R}^c)\text{C}(=\text{O})-$, $\text{R}^{8a}\text{C}(=\text{O})\text{N}(\text{R}^9)\text{C}(\text{R}^b)(\text{R}^a)\text{C}(=\text{O})-$, $\text{R}^{8a}\text{C}(=\text{O})\text{N}(\text{R}^9)\text{CR}^b(\text{R}^a)\text{C}(\text{R}^d)(\text{R}^c)\text{C}(=\text{O})-$, $(\text{R}^9)\text{R}^8\text{NC}(=\text{O})\text{N}(\text{R}^{10})\text{C}(\text{R}^b)(\text{R}^a)\text{C}(=\text{O})-$, and $\text{R}^9(\text{R}^8)\text{NC}(=\text{O})\text{N}(\text{R}^{10})\text{CR}^b(\text{R}^a)\text{C}(\text{R}^d)(\text{R}^c)\text{C}(=\text{O})-$;

R⁵ and R⁶ are each independently selected from hydrogen, halogen, substituted- or unsubstituted- alkyl, and substituted- or unsubstituted- cycloalkyl;

5 R⁷ is selected from hydrogen, halogen, and substituted- or unsubstituted C₁₋₃ alkyl;

R⁸ is selected from hydrogen, substituted- or unsubstituted- alkyl, substituted- or unsubstituted- cycloalkyl, substituted- or unsubstituted- aryl, substituted- or unsubstituted- heteroaryl, and substituted- or unsubstituted- heterocyclyl;

10 R⁹ and R¹⁰ are each independently selected from hydrogen, substituted- or unsubstituted- alkyl;

15 R^{8a} is independently selected from the group consisting of substituted- or unsubstituted- alkyl, substituted- or unsubstituted- cycloalkyl, substituted- or unsubstituted- aryl, substituted- or unsubstituted- heteroaryl, and substituted- or unsubstituted- heterocyclyl;

20 R^a, R^b, R^c and R^d, are independently selected from hydrogen, substituted- or unsubstituted- C₁₋₆ alkyl, substituted- or unsubstituted- aryl, substituted- or unsubstituted- heteroaryl, substituted- or unsubstituted- cycloalkyl, and substituted- or unsubstituted- heterocyclyl, or R^a, R^b, R^c and R^d together with the carbon atom(s) to which they are attached forming substituted- or unsubstituted- carbocycle, or substituted- or unsubstituted- heterocycle;

m and n are integers independently selected from 0 and 1;

q is an integer selected from 1, 2, and 3;

25 when the alkyl group is a substituted alkyl group, the alkyl group is substituted with 1 to 4 substituents selected independently from oxo, halogen, cyano, perhaloalkyl, cycloalkyl, aryl, heteroaryl, heterocyclyl, R^{11a}O-, (alkyl)S(=O)₂-, (alkyl)C(=O)-, (alkyl)OC(=O)-, (alkyl)C(=O)O-, R¹¹N(H)C(=O)-, R¹¹(alkyl)NC(=O)-, (alkyl)C(=O)N(H)-, R¹¹N(H)-, R¹¹(alkyl)N-, 30 R¹¹(H)NC(=O)N(H)-, and R¹¹(alkyl)NC(=O)N(H)-;

when the 'cycloalkyl' and the carbocyclic groups are substituted, each of them is substituted with 1 to 3 substituents selected independently from oxo, halogen, cyano, C₁₋₆ alkyl, perhaloalkyl, R^{11a}O-, (alkyl)S(=O)₂-, (alkyl)C(=O)-, (alkyl)OC(=O)-, (alkyl)C(=O)O-, R¹¹(H)NC(=O)-, R¹¹(alkyl)NC(=O)-, (alkyl)C(=O)N(H)-, R¹¹(H)N-, R¹¹(alkyl)N-, R¹¹(H)NC(=O)N(H)-, and R¹¹(alkyl)NC(=O)N(H)-;

when the aryl group is substituted, it is substituted with 1 to 3 substituents selected independently from halogen, cyano, hydroxy, C₁₋₆ alkyl, perhaloalkyl, alkyl-O-, perhaloalkyl-O-, alkyl(alkyl)N-, alkyl(H)N-, H₂N-, alkyl-S(=O)₂-, alkyl-C(=O)(alkyl)N-, alkyl-C(=O)N(H)-, alkyl(alkyl)NC(=O)-, alkyl(H)NC(=O)-, H₂NC(=O)-, alkyl(alkyl)NS(=O)₂-, alkyl(H)NS(=O)₂-, and H₂NS(=O)₂-;

when the heteroaryl group is substituted, it is substituted with 1 to 3 substituents selected independently from halogen, cyano, hydroxy, C₁₋₆ alkyl, perhaloalkyl, alkyl-O-, perhaloalkyl-O-, alkyl(alkyl)N-, alkyl(H)N-, H₂N-, alkyl-S(=O)₂-, alkyl-C(=O)(alkyl)N-, alkyl-C(=O)N(H)-, alkyl(alkyl)NC(=O)-, alkyl(H)NC(=O)-, H₂NC(=O)-, alkyl(alkyl)NS(=O)₂-, alkyl(H)NS(=O)₂-, and H₂NS(=O)₂-;

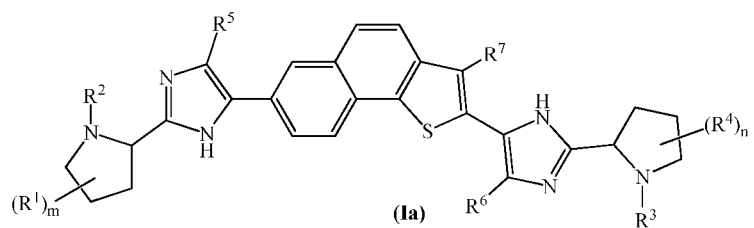
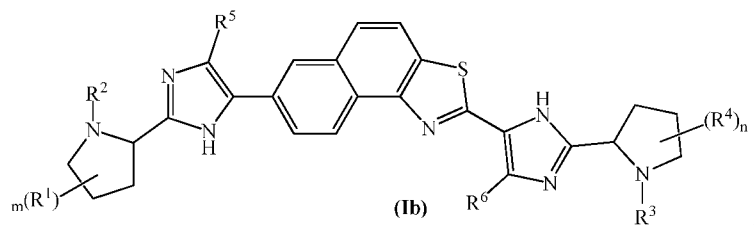
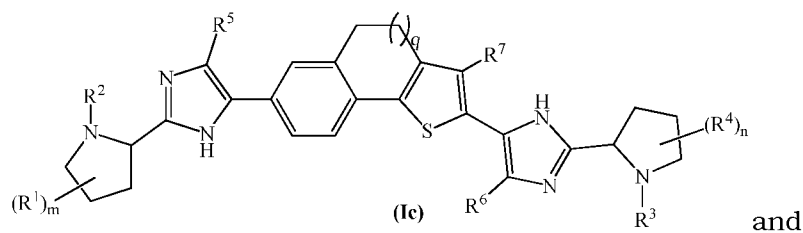
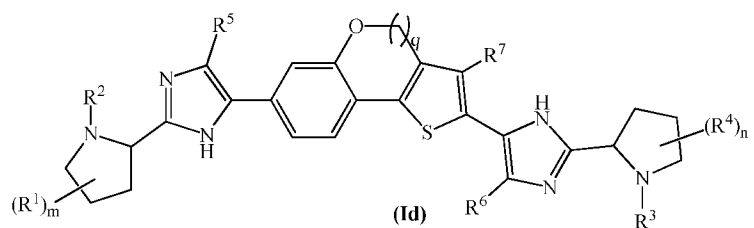
when the heterocyclic group is substituted, it can be substituted either on a ring carbon atom or on a ring hetero atom, when it substituted on a ring carbon atom, it is substituted with 1-3 substituents selected independently from halogen, cyano, oxo, C₁₋₆ alkyl, perhaloalkyl, R^{11a}O-, (alkyl)OC(=O)-, (alkyl)C(=O)O-, R¹¹(H)NC(=O)-, R¹¹(alkyl)NC(=O)-, (alkyl)C(=O)N(H)-, R¹¹(H)N-, R¹¹(alkyl)N-, R¹¹(H)NC(=O)N(H)-, and R¹¹(alkyl)NC(=O)N(H)-; and

when the 'heterocyclic' group is substituted on a ring nitrogen, it is substituted with a substituent selected from C₁₋₆ alkyl, (alkyl)SO₂-, (alkyl)C(=O)-, (alkyl)OC(=O)-, R¹¹(H)NC(=O)-, and R¹¹(alkyl)NC(=O)-;

R¹¹ is selected from hydrogen, alkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl;

R^{11a} is selected from hydrogen, alkyl, perhaloalkyl, cycloalkyl, aryl, heteroaryl, and heterocyclyl.

2. The compound of formula (I), its tautomeric form, its isomer, or its pharmaceutically acceptable salt, as claimed in claim 1, wherein the compound of formula I is selected from



3. The compound of formula (I), its tautomeric form, its isomer, or its pharmaceutically acceptable salt, as claimed in claim 1 or 2, wherein R¹ and R⁴ is C₁₋₄ alkylenyl.

4. The compound of formula (I), its tautomeric form, its isomer, or its pharmaceutically acceptable salt, as claimed in any one of claims 1 to 3, wherein R² and R³ are each independently selected from R^{8a}C(=O)-, R^{8a}S(=O)₂-, R^{8a}OC(=O)-, (R⁹)R⁸NC(=O)-, R^{8a}OC(=O)N(R⁹)CR^b(R^a)C(=O)-, R^{8a}OC(=O)N(R⁹)CR^b(R^a)C(R^d)(R^c)C(=O)-, R^{8a}C(=O)N(R⁹)C(R^b)(R^a)C(=O)-,

$R^{8a}C(=O)N(R^9)CR^b(R^a)C(R^d)(R^c)C(=O)-$, $(R^9)R^8NC(=O)N(R^{10})C(R^b)(R^a)C(=O)-$,
and $R^9(R^8)NC(=O)N(R^{10})CR^b(R^a)C(R^d)(R^c)C(=O)-$.

- 5 **5.** The compound of formula (I), its tautomeric form, its isomer, or its pharmaceutically acceptable salt, as claimed in any one of claims 1 to 4, wherein R^2 and R^3 are each independently selected from $R^{8a}OC(=O)N(R^9)CR^b(R^a)C(=O)-$, $R^{8a}OC(=O)N(R^9)CR^b(R^a)C(R^d)(R^c)C(=O)-$, $R^{8a}C(=O)N(R^9)C(R^b)(R^a)C(=O)-$, $R^{8a}C(=O)N(R^9)CR^b(R^a)C(R^d)(R^c)C(=O)-$, $(R^9)R^8NC(=O)N(R^{10})C(R^b)(R^a)C(=O)-$, and $R^9(R^8)NC(=O)N(R^{10})CR^b(R^a)C(R^d)(R^c)C(=O)-$.
- 10 **6.** The compound of formula (I), its tautomeric form, its isomer, or its pharmaceutically acceptable salt, as claimed in any one of claims 1 to 5, wherein R^2 and R^3 both are selected as $R^{8a}OC(=O)N(R^9)CR^b(R^a)C(=O)-$.
- 7.** The compound of formula (I), its tautomeric form, its isomer, or its pharmaceutically acceptable salt, as claimed in any one of claims 1 to 6, wherein R^5 and R^6 are selected independently from hydrogen and halogen.
- 15 **8.** The compound of formula (I), its tautomeric form, its isomer, or its pharmaceutically acceptable salt, as claimed in any one of claims 1-7, wherein the compound is selected from

20 dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,9*b*-dihydro-3*aH*-thieno[3,2-*c*]chromene-2,7-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate;

dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate;

25 dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(4,5-dihydrobenzo[*b*]thieno[2,3-*d*]oxepine-2,8-diyl))bis(4-chloro-1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate;

30 dimethyl ((2*S*,2'*S*)-((2*S*,2'*S*)-2,2'-(5,5'-(naphtho[1,2-*d*]thiazole-2,7-diyl))bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate;

dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate;

5 dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(3-chloro-4,5-dihydronaphtho[1,2-*b*]thiophene-2,7-diyl)bis(4-chloro-1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate;

dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate;

10 dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl)bis(1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate;

15 dimethyl ((2S,2'S)-((2S,2'S)-2,2'-(5,5'-(5,6-dihydro-4*H*-benzo[6,7]cyclohepta[1,2-*b*]thiophene-2,8-diyl)bis(4-chloro-1*H*-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate;

20 dimethyl ((2S,2'S)-((1*R*,1'*R*,3*S*,3'*S*,4*S*,4'*S*)-3,3'-(5,5'-(naphtho[1,2-*b*]thiophene-2,7-diyl)bis(1*H*-imidazole-5,2-diyl))bis(2-azabicyclo[2.2.1]heptane-3,2-diyl))bis(3-methyl-1-oxobutane-2,1-diyl))dicarbamate; and

25 methyl ((*S*)-1-((*S*)-2-(5-(2-(2-((1*R*,3*S*,4*S*)-2-((*S*)-2-(methoxycarbonyl)amino-3-methylbutanoyl)-2-azabicyclo[2.2.1]heptan-3-yl)-1*H*-imidazol-5-yl)naphtho[1,2-*b*]thiophen-7-yl)-1*H*-imidazol-2-yl)pyrrolidin-1-yl)-3-methyl-1-oxobutan-2-yl)carbamate.

9. A pharmaceutical composition comprising a compound or a combination of compounds according to any one of claims 1-8 or a pharmaceutically acceptable salt thereof, in combination with a pharmaceutically acceptable carrier or excipient.

- 10.** A method of inhibiting the replication of an RNA-containing virus comprising contacting said virus with a therapeutically effective amount of a compound or combination of compounds according to any one of claims 1-8, or a pharmaceutically acceptable salt thereof.
- 5 **11.** A method of treating or preventing infection caused by an RNA-containing virus comprising administering to a patient in need of such treatment or prevention a therapeutically effective amount of a compound or combination of compounds according to any one of claims 1-8, or a pharmaceutically acceptable salt thereof.
- 10 **12.** The method of claim 11, wherein the RNA-containing virus is hepatitis C virus.
- 13.** The method of claim 11, further comprising the step of co-administering one or more agents selected from a host immune modulator and an antiviral agent, or a combination thereof.
- 15 **14.** The method of claim 13, wherein the host immune modulator is selected from interferon-alpha, pegylated-interferon-alpha, interferon-beta, interferon-gamma, consensus interferon, a cytokine, and a vaccine.
- 15.** The method of claim 13, wherein the antiviral agent inhibits replication of HCV by inhibiting a host cellular function associated with viral replication.
- 20 **16.** The method of claim 13, wherein the antiviral agent inhibits the replication of HCV by targeting a protein of the viral genome.
- 17.** The method of claim 13, wherein said antiviral agent is an inhibitor of a HCV viral protein, a replication process, or a combination thereof, wherein said targeting protein or replication process is selected from helicase, protease, polymerase, metalloprotease, NS4A, NS4B, NS5A, assembly, 25 entry, and IRES.
- 18.** The method of claim 13, further comprising the step of co-administering an agent or combination of agents that treat or alleviate symptoms of HCV infection selected from cirrhosis and inflammation of the liver.

- 19.** The method of claim 13, further comprising the step of co-administering one or more agents that treat patients for disease caused by hepatitis B (HBV) infection.
- 20.** The method of claim 13, further comprising the step of co-administering one or more agents that treat patients for disease caused by human immunodeficiency virus (HIV) infection.
- 21.** The pharmaceutical composition of claim 9, further comprising an agent selected from interferon, pegylated interferon, ribavirin, amantadine, an HCV protease inhibitor, an HCV polymerase inhibitor, an HCV helicase inhibitor, or an internal ribosome entry site inhibitor.
- 22.** The composition of claim 9, further comprising a cytochrome P450 monooxygenase inhibitor or a pharmaceutically acceptable salt thereof.
- 23.** A method of treating hepatitis C infection in a subject in need thereof comprising co-administering to said subject a cytochrome P450 monooxygenase inhibitor or a pharmaceutically acceptable salt thereof, and a compound of any one of claims 1-8 or a pharmaceutically acceptable salt thereof.
- 24.** The compound according to any one of claims 1-8, or a pharmaceutically acceptable salt thereof, for use in treating or preventing an infection in a patient caused by an RNA-containing virus.