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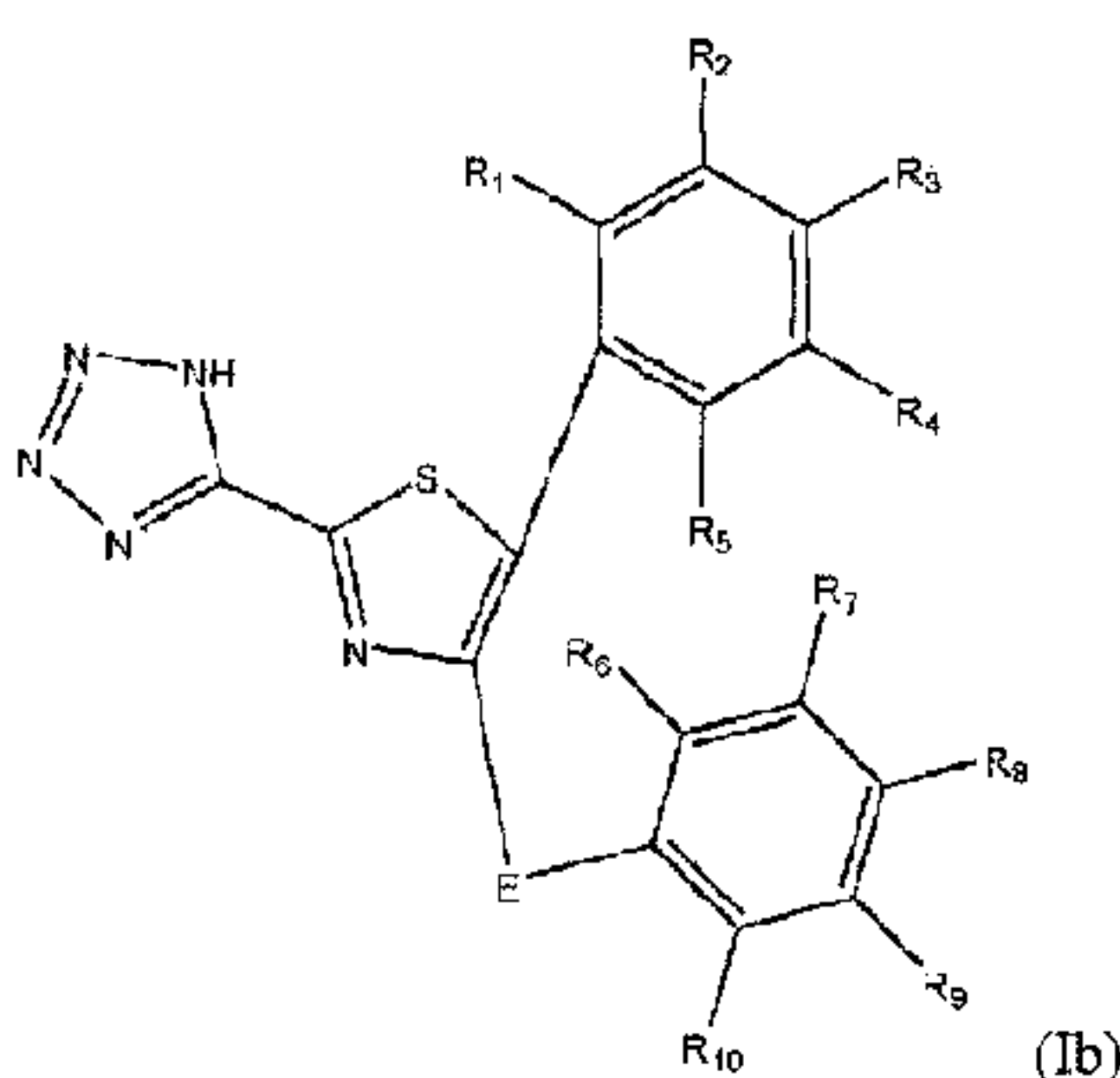
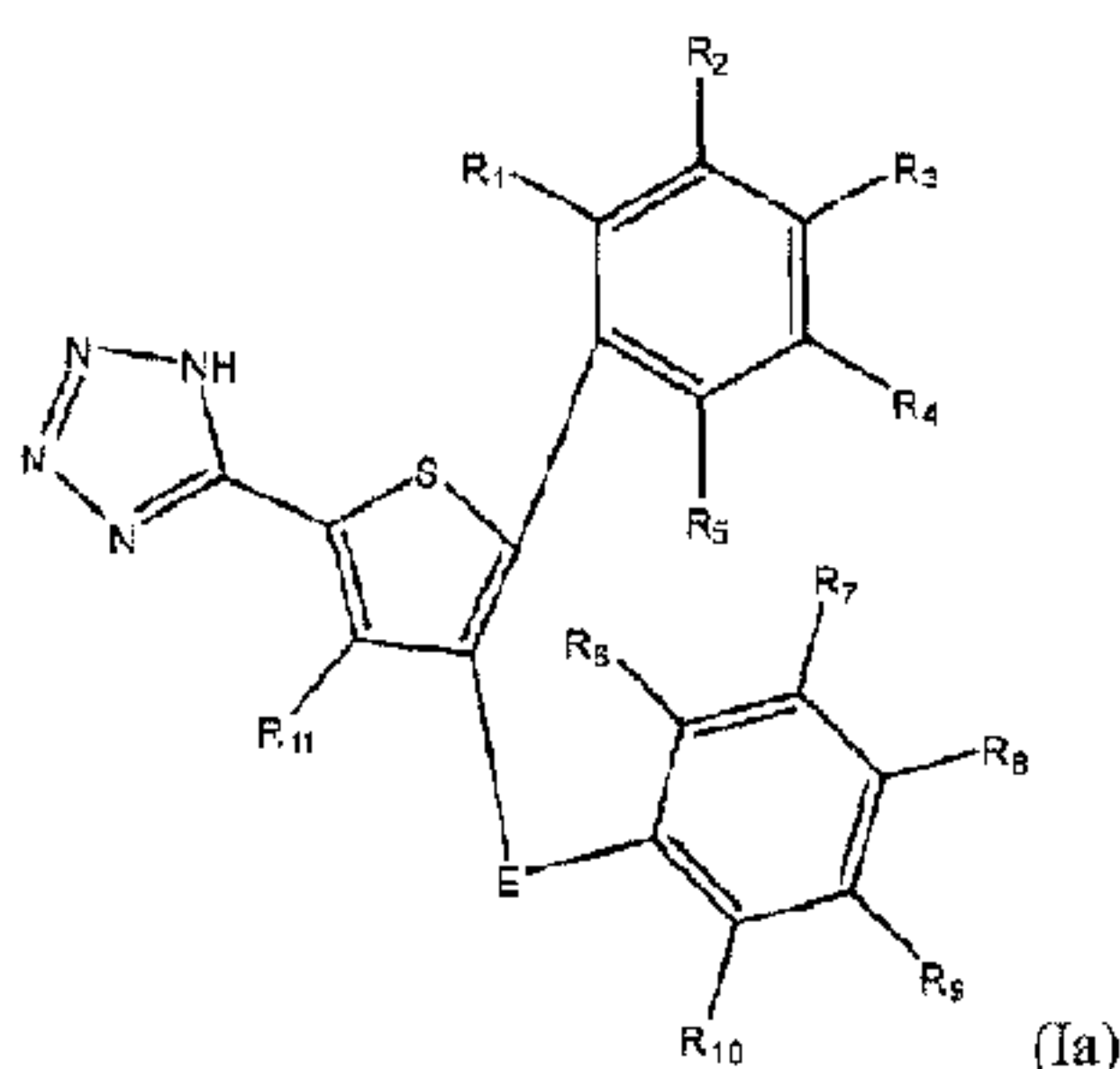
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(54) Title: ANTIMICROBIAL / ADJUVANT COMPOUNDS AND METHODS



(57) Abrégé/Abstract:

Antimicrobial and/or adjuvant compounds are provided according to Formula I.

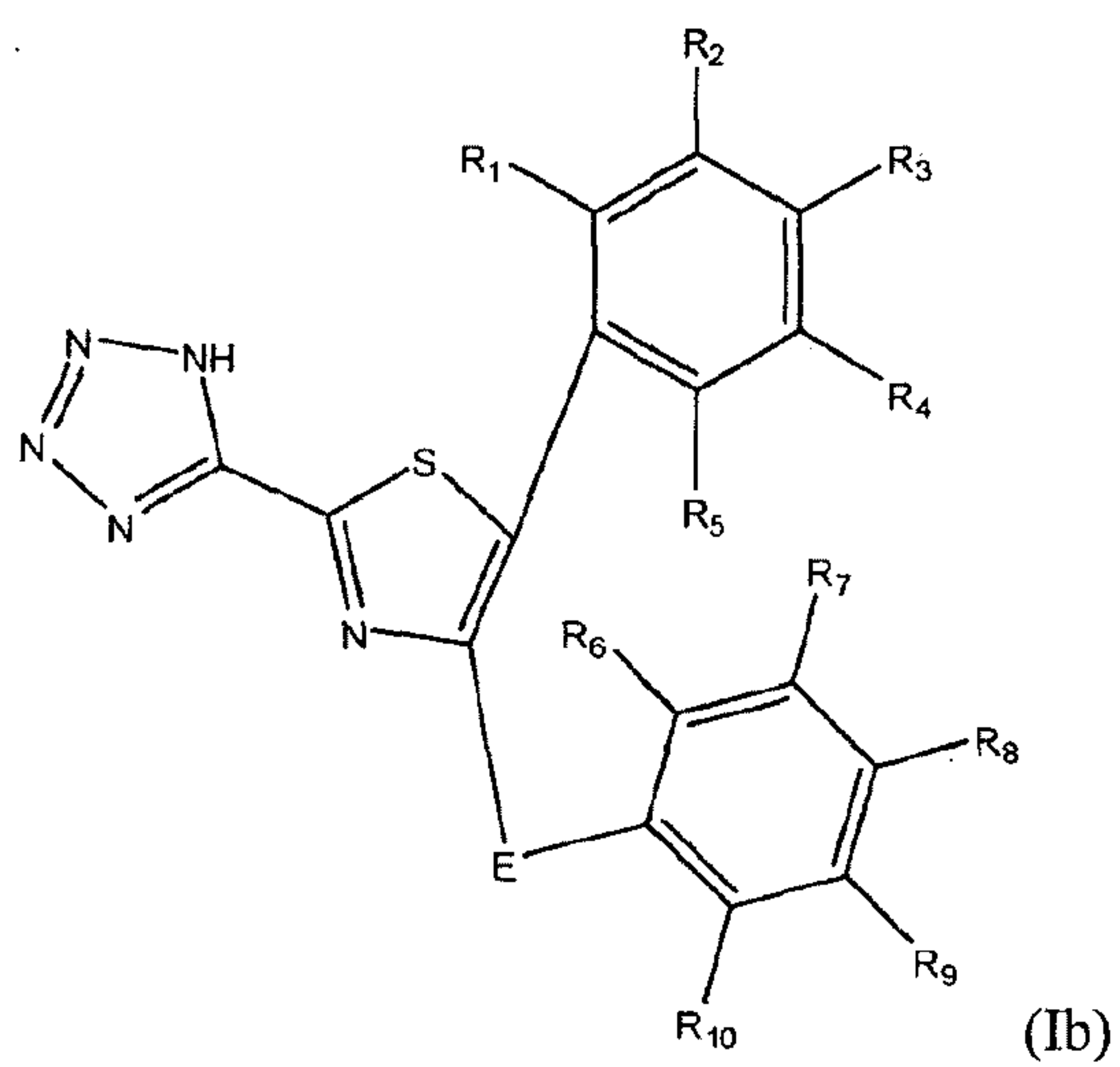
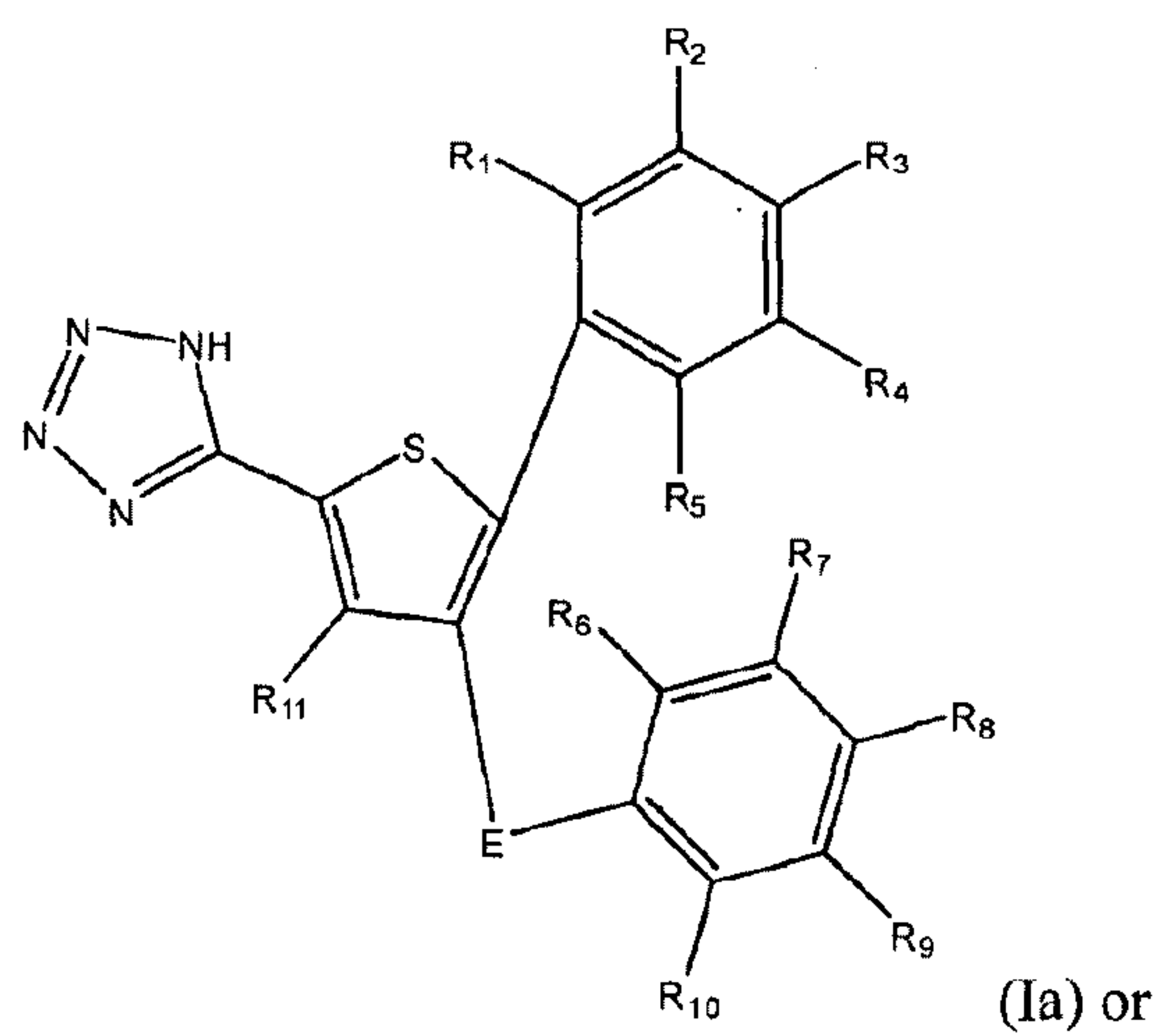
(see formula Ia) or

(see formula Ib)

and prodrugs and pharmaceutically acceptable salts thereof.

ABSTRACT

Antimicrobial and/or adjuvant compounds are provided according to Formula I:



and prodrugs and pharmaceutically acceptable salts thereof.

ANTIMICROBIAL / ADJUVANT COMPOUNDS AND METHODS

BACKGROUND

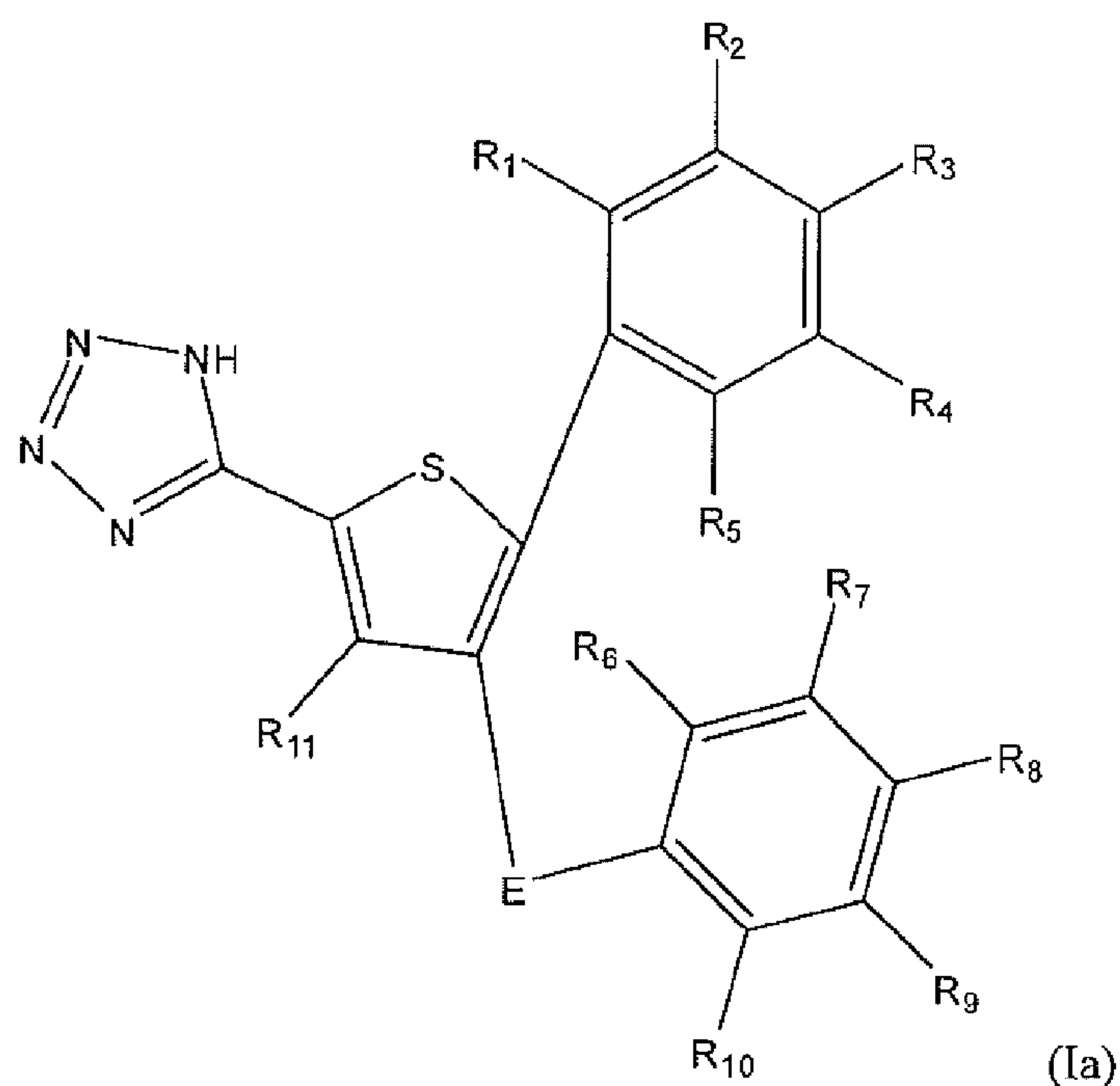
Infection is an invasion of a host organism by a foreign organism, generally to the detriment of normal function in the host. In treating humans and other animals for infection and post-infective inflammatory disease (e.g. septic shock), practitioners usually rely on chemical compounds known to have antibiotic affects, whether antiviral, antibacterial, antifungal, or the like.

Unfortunately, many pathogens have become resistant to current antibiotic treatments. Antibiotic resistance is therefore an increasingly significant clinical issue, calling for novel antibiotics. Especially valuable would be new antimicrobial adjuvant compounds, which, while not necessarily antimicrobial themselves, can increase the potency, efficacy, and/or spectrum of activity of antibiotics when co-administered or given as combination therapy. There is a need for new antimicrobials and new antimicrobial adjuvant compounds.

SUMMARY

The compounds of the present invention are of utility in antimicrobial infections. In some cases, the compounds are themselves antimicrobial. In some cases, the compounds (“antimicrobial adjuvants”) have beneficial effects in conjunction with an antimicrobial, reducing the dose of antibiotic required for antimicrobial activity when administered in combination. In some cases, the compounds are both antimicrobial and antimicrobial adjuvants.

In general, in an aspect, compounds of Formula Ia are provided:



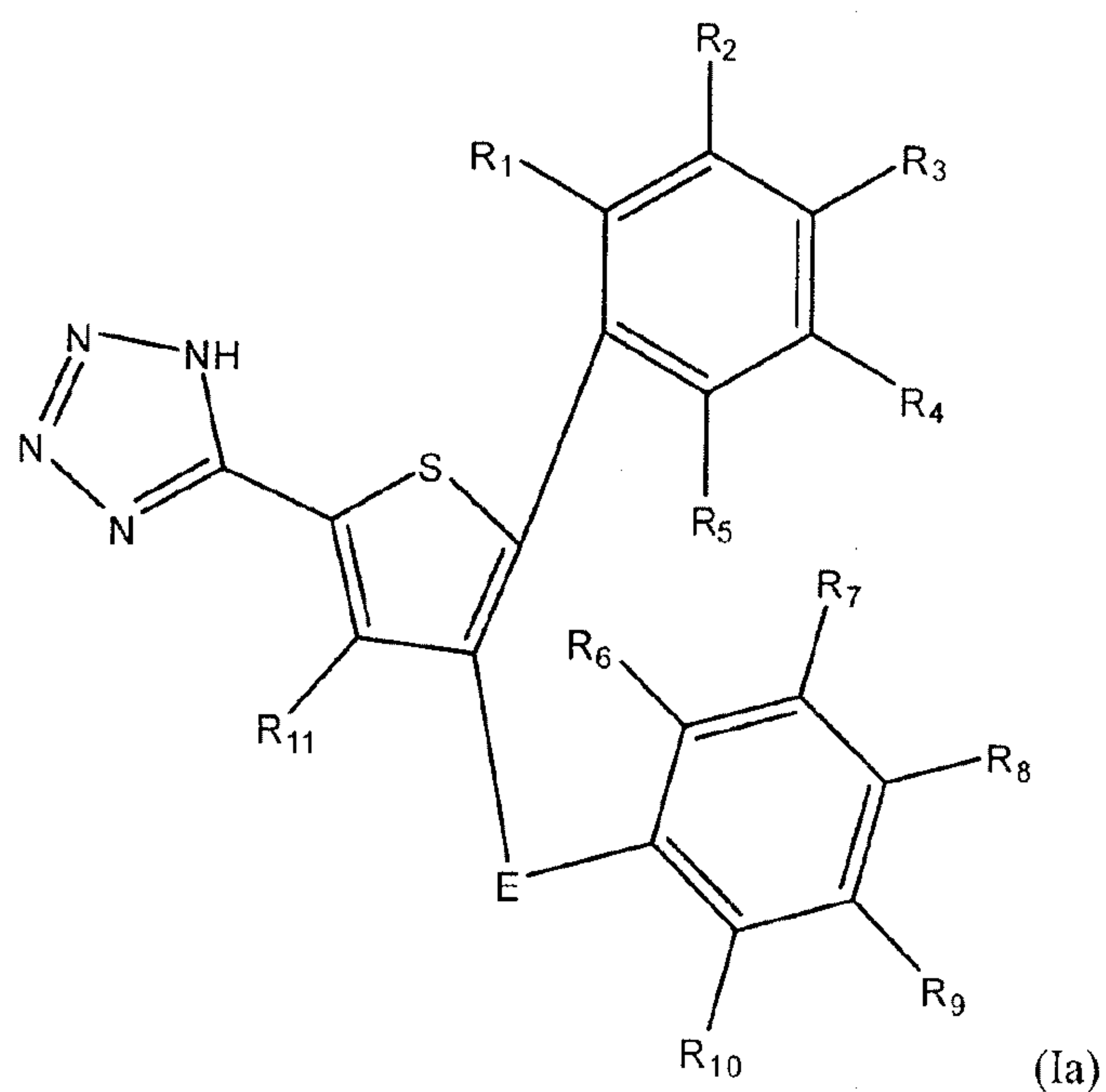
in which E is $-\text{CH}_2-$ or is absent such that thiophene is directly connected to phenyl; R_1 , R_2 , R_9 , R_{10} , and R_{11} are each independently hydrogen, methyl, ethyl, propyl, cyclopropyl, butyl, cyclobutyl, pentyl, hexyl, isopropyl, isobutyl, neopentyl, methoxy, or ethoxy; additionally, R_1 and R_2 may connect to form a phenyl or benzofuran ring; additionally, R_9 and R_{10} may connect to form a phenyl or benzofuran ring; R_3 and R_8 are each independently hydrogen, methyl, ethyl, propyl, isopropyl, chlorine, fluorine, tert-butyl, methylsulfonyl, methoxy, or ethoxy; R_4 and R_7 are each independently hydrogen, chlorine, methyl ester, ethyl ester, methyl, ethyl, propyl, cyclopropyl, butyl, cyclobutyl, isopropyl, isobutyl, methoxy, or ethoxy; and R_5 and R_6 are each independently hydrogen, cyclopentyl, cyclopropyl, furan, thiophene, trifluoromethyl, trifluoromethyl ether, methylthiol, formaldehyde, chlorine, fluorine, bromine, phenyl, methyl, ethyl, isopropyl, propyl, butyl, cyclobutyl, isobutyl, neopentyl, pentyl, methoxy, or ethoxy.

In general, in an aspect of the invention, a method of treatment of a microbial infection is provided including administering an effective amount of an antimicrobial compound disclosed herein to a patient in need thereof.

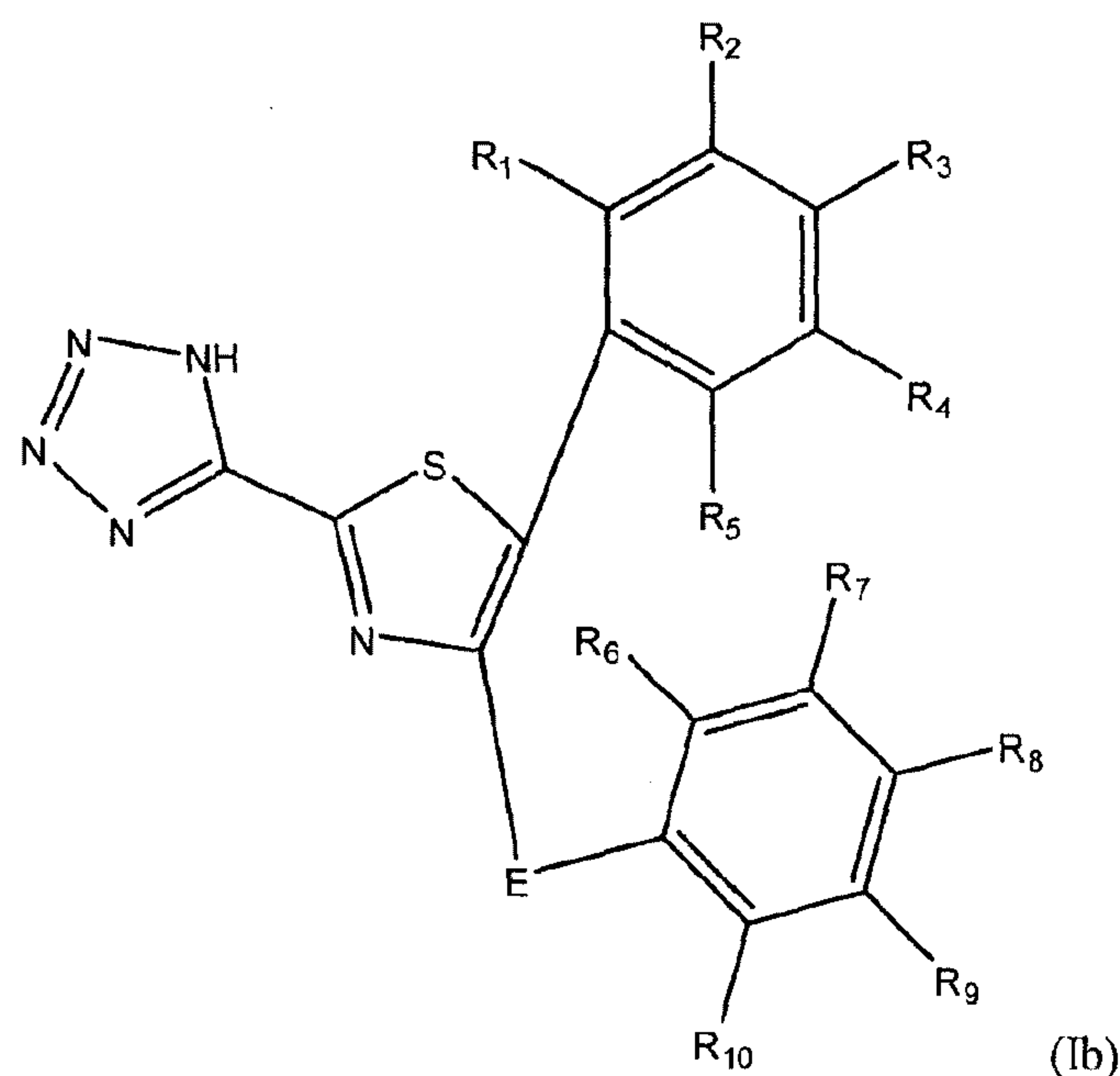
In general, in an aspect of the invention, a method of treatment of a microbial infection is provided including administering an effective amount of an antimicrobial

adjuvant compound disclosed herein and an effective amount of an antimicrobial compound to a patient in need thereof.

According to an aspect of the invention, there is provided a compound having a sulfur-containing ring, or prodrugs or pharmaceutically acceptable salts thereof, of Formula (Ia) or (Ib):



3a



in which

E is $-\text{CH}_2-$ or is absent whereby the sulfur-containing ring is directly connected to phenyl;

R_1 , R_2 , R_9 , R_{10} , and R_{11} are each independently selected from the group consisting of hydrogen, methyl, ethyl, propyl, cyclopropyl, butyl, cyclobutyl, pentyl, hexyl, isopropyl, isobutyl, neopentyl, methoxy, and ethoxy;

additionally, R_1 and R_2 may connect to form a phenyl or benzofuran ring;

additionally, R_9 and R_{10} may connect to form a phenyl or benzofuran ring;

R_3 and R_8 are each independently selected from the group consisting of hydrogen, methyl, ethyl, propyl, isopropyl, chlorine, fluorine, tert-butyl, methoxy, and ethoxy;

R_4 and R_7 are each independently selected from the group consisting of hydrogen, chlorine, methyl ester, ethyl ester, methyl, ethyl, propyl, cyclopropyl, butyl, cyclobutyl, isopropyl, isobutyl, methoxy, and ethoxy;

and R_5 and R_6 are each independently selected from the group consisting of hydrogen, cyclopentyl, cyclopropyl, furan, thiophene, trifluoromethyl, trifluoromethyl ether, methylthiol, formaldehyde, chlorine, fluorine, bromine, phenyl, methyl, ethyl, isopropyl, propyl, butyl, cyclobutyl, isobutyl, neopentyl, pentyl, methoxy, and ethoxy.

According to another aspect of the invention, there is provided use of the antimicrobial compound as described herein for treatment of a microbial infection.

According to another aspect of the invention, there is provided use of the antimicrobial adjuvant compound as described herein and an antimicrobial compound for treatment of a microbial infection.

According to another aspect of the invention, there is provided a pharmaceutical composition comprising a compound as described herein and a pharmaceutically acceptable excipient.

Compounds of other formulae are provided as described in the Detailed Description below.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 depicts thiophene- or thiazole-core compounds and associated compound identifiers of the present invention, along with their respective minimum inhibitory concentrations against MRSA generally following the procedure in Example 9 (“MRSA_MIC” reported in μM).

FIG. 2 depicts phenyl-core compounds and associated compound identifiers of the present invention.

DETAILED DESCRIPTION

Definitions

Unless otherwise defined, terms as used in the specification refer to the following definitions, as detailed below.

The term “acyl” as used herein means an alkyl group, as defined herein, appended to the parent molecular moiety through a carbonyl group, as defined herein.

Representative examples of acyl include, but are not limited to, acetyl, 1-oxopropyl, 2,2-dimethyl-1-oxopropyl, 1-oxobutyl, and 1-oxopentyl.

The term “acyloxy” as used herein means an acyl group, as defined herein, appended to the parent molecular moiety through an oxygen atom. Representative examples of acyloxy include, but are not limited to, acetyloxy, propionyloxy, and isobutyryloxy.

The terms “administration” or “administering” compound should be understood to mean providing a compound of the present invention to an individual in a form that can be introduced into that individual’s body in an amount effective for prophylaxis, treatment, or diagnosis, as applicable. Such forms may include for example oral dosage forms, injectable dosage forms, transdermal dosage forms, inhalation dosage forms, and rectal dosage forms.

The term “alkenyl” as used herein means a straight chain, branched and/or cyclic hydrocarbon having from 2 to 20 (e.g., 2 to 10 or 2 to 6) carbon atoms, and including at

least one carbon-carbon double bond. Representative alkenyl moieties include vinyl, allyl, 1-butenyl, 2-butenyl, isobutylenyl, 1-pentenyl, 2-pentenyl, 3-methyl-1-butenyl, 2-methyl-2-butenyl, 2,3-dimethyl-2-butenyl, 1-hexenyl, 2-hexenyl, 3-hexenyl, 1-heptenyl, 2-heptenyl, 3-heptenyl, 1-octenyl, 2-octenyl, 3-octenyl, 1-nonenyl, 2-nonenyl, 3-nonenyl, 1-decenyl, 2-decenyl and 3-decenyl.

The term “alkoxy” as used herein means an alkyl group, as defined herein, appended to the parent molecular moiety through an oxygen atom. Representative examples of alkoxy include, but are not limited to, methoxy, ethoxy, propoxy, 2-propoxy, butoxy, tert-butoxy, pentyloxy, and hexyloxy.

The term “alkoxyalkoxy” as used herein means an alkoxy group, as defined herein, appended to the parent molecular moiety through another alkoxy group, as defined herein. Representative examples of alkoxyalkoxy include, but are not limited to, tert-butoxymethoxy, 2-ethoxyethoxy, 2-methoxyethoxy, and methoxymethoxy.

The term “alkoxyalkyl” as used herein means an alkoxy group, as defined herein, appended to the parent molecular moiety through an alkyl group, as defined herein. Representative examples of alkoxyalkyl include, but are not limited to, tert-butoxymethyl, 2-ethoxyethyl, 2-methoxyethyl, and methoxymethyl.

The term “alkoxycarbonyl” as used herein means an alkoxy group, as defined herein, appended to the parent molecular moiety through a carbonyl group, as defined herein. Representative examples of alkoxycarbonyl include, but are not limited to, methoxycarbonyl, ethoxycarbonyl, and tert-butoxycarbonyl.

The term “alkoxyimino” as used herein means an alkoxy group, as defined herein, appended to the parent molecular moiety through an imino group, as defined herein. Representative examples of alkoxyimino include, but are not limited to, ethoxy(imino)methyl and methoxy(imino)methyl.

The term “alkoxysulfonyl” as used herein means an alkoxy group, as defined herein, appended to the parent molecular moiety through a sulfonyl group, as defined herein. Representative examples of alkoxysulfonyl include, but are not limited to, methoxysulfonyl, ethoxysulfonyl, and propoxysulfonyl.

The term “alkyl” as used herein means a straight or branched chain hydrocarbon containing from 1 to 20 carbon atoms, preferably from 1 to 10 carbon atoms, more

preferably 1, 2, 3, 4, 5, or 6 carbons. Representative examples of alkyl include, but are not limited to, methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, iso-butyl, tert-butyl, n-pentyl, isopentyl, neopentyl, n-hexyl, 3-methylhexyl, 2,2-dimethylpentyl, 2,3-dimethylpentyl, n-heptyl, n-octyl, n-nonyl, and n-decyl.

The term “alkylamino” as used herein means an alkyl group, as defined herein, appended to the parent molecular moiety through a NH group. Representative examples of alkylamino include, but are not limited to, methylamino, ethylamino, isopropylamino, and butylamino.

The term “alkylcarbonyl” as used herein means an alkyl group, as defined herein, appended to the parent molecular moiety through a carbonyl group, as defined herein. Representative examples of alkylcarbonyl include, but are not limited to, methylcarbonyl, ethylcarbonyl, isopropylcarbonyl, n-propylcarbonyl, and the like.

The term “alkylsulfonyl” as used herein means an alkyl group, as defined herein, appended to the parent molecular moiety through a sulfonyl group, as defined herein. Representative examples of alkylsulfonyl include, but are not limited to, methylsulfonyl and ethylsulfonyl.

The term “alkynyl” as used herein means a straight or branched chain hydrocarbon group containing from 2 to 10 carbon atoms, and preferably 2, 3, 4, or 5 carbons, and containing at least one carbon-carbon triple bond. Representative examples of alkynyl include, but are not limited to, acetylenyl, 1-propynyl, 2-propynyl, 3-butylnyl, 2-pentylnyl, and 1-butylnyl.

The term “amido” as used herein means an amino, alkylamino, or dialkylamino group appended to the parent molecular moiety through a carbonyl group, as defined herein. Representative examples of amido include, but are not limited to, aminocarbonyl, methylaminocarbonyl, dimethylaminocarbonyl, and ethylmethylaminocarbonyl.

The term “amino” as used herein means a —NH₂ group.

The term “aryl” as used herein means a monocyclic hydrocarbon aromatic ring system. Representative examples of aryl include, but are not limited to, phenyl.

The term “arylalkyl” as used herein means an aryl group, as defined herein, appended to the parent molecular moiety through an alkyl group, as defined herein.

Representative examples of arylalkyl include, but are not limited to, benzyl, 2-phenylethyl and 3-phenylpropyl.

The term “carbonyl” as used herein means a —C(=O)— group.

The term “carboxy” as used herein means a —COOH group, which may be protected as an ester group: —COO-alkyl .

The term “cyano” as used herein means a —CN group.

The term “cyanophenyl” as used herein means a —CN group appended to the parent molecular moiety through a phenyl group, including, but not limited to, 4-cyanophenyl, 3-cyanophenyl, and 2-cyanophenyl.

The term “cycloalkyl” as used herein means a saturated cyclic hydrocarbon group containing from 3 to 8 carbons. Examples of cycloalkyl include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, and cyclooctyl.

The term “cycloalkylcarbonyl” as used herein means a cycloalkyl group, as defined herein, appended to the parent molecular moiety through a carbonyl group, as defined herein. Representative examples of cycloalkylcarbonyl include, but are not limited to, cyclopropylcarbonyl, cyclopentylcarbonyl, cyclohexylcarbonyl, and cycloheptylcarbonyl.

The term “dialkylamino” as used herein means two independent alkyl groups, as defined herein, appended to the parent molecular moiety through a nitrogen atom. Representative examples of dialkylamino include, but are not limited to, dimethylamino, diethylamino, ethylmethylamino, and butylmethylamino.

The term “fluoro” as used herein means —F .

The term “fluoroalkoxy” as used herein means at least one fluoroalkyl group, as defined herein, appended to the parent molecular moiety through an oxygen group, as defined herein. Representative examples of fluoroalkyl include, but are not limited to, trifluoromethoxy ($\text{CF}_3\text{O—}$), and difluoromethoxy ($\text{CHF}_2\text{O—}$).

The term “fluoroalkyl” as used herein means at least one fluoro group, as defined herein, appended to the parent molecular moiety through an alkyl group, as defined herein. Representative examples of fluoroalkyl include, but are not limited to, fluoromethyl, difluoromethyl, trifluoromethyl, pentafluoroethyl, and 2,2,2-trifluoroethyl.

The term “formyl” as used herein means a —C(O)H group.

The term “halo” or “halogen” as used herein means Cl, Br, I, or F.

The term “haloalkoxy” as used herein means at least one halogen, as defined herein, appended to the parent molecular moiety through an alkoxy group, as defined herein. Representative examples of haloalkoxy include, but are not limited to, 2-fluoroethoxy, trifluoromethoxy, and pentafluoroethoxy.

The term “haloalkyl” as used herein means at least one halogen, as defined herein, appended to the parent molecular moiety through an alkyl group, as defined herein. Representative examples of haloalkyl include, but are not limited to, chloromethyl, 2-fluoroethyl, trifluoromethyl, pentafluoroethyl, and 2-chloro-3-fluoropentyl.

The term “heteroaryl”, as used herein, refers to an aromatic ring containing one or more heteroatoms independently selected from nitrogen, oxygen, or sulfur, or a tautomer thereof. Such rings can be monocyclic or bicyclic as further described herein. Heteroaryl rings are connected to the parent molecular moiety through a carbon or nitrogen atom.

The terms “monocyclic heteroaryl” or “5- or 6-membered heteroaryl ring”, as used herein, refer to 5- or 6-membered aromatic rings containing 1, 2, 3, or 4 heteroatoms independently selected from nitrogen, oxygen, or sulfur, or a tautomer thereof. Examples of such rings include, but are not limited to, a ring wherein one carbon is replaced with an O or atom; one, two, or three N atoms arranged in a suitable manner to provide an aromatic ring; or a ring wherein two carbon atoms in the ring are replaced with one O or S atom and one N atom. Such rings can include, but are not limited to, a six-membered aromatic ring wherein one to four of the ring carbon atoms are replaced by nitrogen atoms, five-membered rings containing a sulfur, oxygen, or nitrogen in the ring; five membered rings containing one to four nitrogen atoms; and five membered rings containing an oxygen or sulfur and one to three nitrogen atoms. Representative examples of 5- to 6-membered heteroaryl rings include, but are not limited to, furyl, imidazolyl, isoxazolyl, isothiazolyl, oxazolyl, pyrazinyl, pyrazolyl, pyridazinyl, pyridinyl, pyrimidinyl, pyrrolyl, tetrazolyl, [1,2,3]thiadiazolyl, [1,2,3]oxadiazolyl, thiazolyl, thienyl, [1,2,3]triazinyl, [1,2,4]triazinyl, [1,3,5]triazinyl, [1,2,3]triazolyl, and [1,2,4]triazolyl.

The term “bicyclic heteroaryl” or “8- to 12-membered bicyclic heteroaryl ring”, as used herein, refers to an 8-, 9-, 10-, 11-, or 12-membered bicyclic aromatic ring containing at least 3 double bonds, and wherein the atoms of the ring include one or more heteroatoms

independently selected from oxygen, sulfur, and nitrogen. Representative examples of bicyclic heteroaryl rings include indolyl, benzothienyl, benzofuranyl, indazolyl, benzimidazolyl, benzothiazolyl, benzoxazolyl, benzoisothiazolyl, benzoisoxazolyl, quinoliny, isoquinoliny, quinazoliny, quinoxaliny, phthalaziny, pteridinyl, puriny, naphthyridiny, cinnoliny, thieno[2,3-d]imidazole, thieno[3,2-b]pyridiny, and pyrrolopyrimidinyl.

The terms “heterocyclic ring” and “heterocycle”, as used herein, refer to a 4- to 12-membered monocyclic or bicyclic ring containing one, two, three, four, or five heteroatoms independently selected from the group consisting of nitrogen, oxygen, and sulfur and also containing either at least one carbon atom attached to four other atoms or one carbon atom substituted with an oxo group and attached to two other atoms. Four- and five-membered rings may have zero or one double bond. Six-membered rings may have zero, one, or two double bonds. Seven- and eight-membered rings may have zero, one, two, or three double bonds. The non-aromatic heterocycle groups of the invention can be attached through a carbon atom or a nitrogen atom. The non-aromatic heterocycle groups may be present in tautomeric form. Representative examples of nitrogen-containing heterocycles include, but are not limited to, azepanyl, azetidiny, aziridinyl, azocanyl, dihydropyridazinyl, dihydropyridiny, dihydropyrimidinyl, morpholinyl, piperazinyl, piperidinyl, pyrrolidinyl, pyrroliny, dihydrothiazolyl, dihydropyridiny, and thiomorpholinyl. Representative examples of non-nitrogen containing non-aromatic heterocycles include, but are not limited to, dioxanyl, dithianyl, tetrahydrofuryl, dihydropyranyl, tetrahydropyranyl, and [1,3]dioxolanyl.

The term “hydroxy” as used herein means an —OH group.

The term “hydroxyalkyl” as used herein means at least one hydroxy group, as defined herein, appended to the parent molecular moiety through an alkyl group, as defined herein. Representative examples of hydroxyalkyl include, but are not limited to, hydroxymethyl, 2-hydroxyethyl, 2-methyl-2-hydroxyethyl, 3-hydroxypropyl, 2,3-dihydroxypentyl, and 2-ethyl-4-hydroxyheptyl.

The term “hydroxy-protecting group” means a substituent which protects hydroxyl groups against undesirable reactions during synthetic procedures. Examples of hydroxy-protecting groups include, but are not limited to, methoxymethyl,

benzyloxymethyl, 2-methoxyethoxymethyl, 2-(trimethylsilyl)ethoxymethyl, benzyl, triphenylmethyl, 2,2,2-trichloroethyl, t-butyl, trimethylsilyl, t-butyldimethylsilyl, t-butyldiphenylsilyl, methylene acetal, acetonide benzylidene acetal, cyclic ortho esters, methoxymethylene, cyclic carbonates, and cyclic boronates. Hydroxy-protecting groups are appended onto hydroxy groups by reaction of the compound that contains the hydroxy group with a base, such as triethylamine, and a reagent selected from an alkyl halide, alkyl triflate, trialkylsilyl halide, trialkylsilyl triflate, aryldialkylsilyltriflate, or an alkylchloroformate, CH_2I_2 , or a dihaloboronate ester, for example with methyl iodide, benzyl iodide, triethylsilyltriflate, acetyl chloride, benzylchloride, or dimethylcarbonate. A protecting group also may be appended onto a hydroxy group by reaction of the compound that contains the hydroxy group with acid and an alkyl acetal.

The term “imino” as defined herein means a —C(=NH)— group.

The term “mercapto” as used herein means a —SH group.

The term “nitro” as used herein means a —NO_2 group.

The term “nitrogen protecting group” as used herein means those groups intended to protect a nitrogen atom against undesirable reactions during synthetic procedures. Nitrogen protecting groups comprise carbamates, amides, N-benzyl derivatives, and imine derivatives. Preferred nitrogen protecting groups are acetyl, benzoyl, benzyl, benzyloxycarbonyl (Cbz), formyl, phenylsulfonyl, pivaloyl, tert-butoxycarbonyl (Boc), tert-butylacetyl, trifluoroacetyl, and triphenylmethyl (trityl). Nitrogen-protecting groups are appended onto primary or secondary amino groups by reacting the compound that contains the amine group with base, such as triethylamine, and a reagent selected from an alkyl halide, an alkyl triflate, a dialkyl anhydride, for example as represented by $(\text{alkyl-O})_2\text{C=O}$, a diaryl anhydride, for example as represented by $(\text{aryl-O})_2\text{C=O}$, an acyl halide, an alkylchloroformate, or an alkylsulfonylhalide, an arylsulfonylhalide, or halo- CON(alkyl)_2 , for example acetylchloride, benzoylchloride, benzylbromide, benzyloxycarbonylchloride, formylfluoride, phenylsulfonylchloride, pivaloylchloride, $(\text{tert-butyl-O—C=O})_2\text{O}$, trifluoroacetic anhydride, and triphenylmethylchloride.

The term “oxo” as used herein means $(=\text{O})$.

Unless otherwise indicated, the term “prodrug” encompasses pharmaceutically acceptable esters, carbonates, thiocarbonates, N-acyl derivatives, N-acyloxyalkyl

derivatives, quaternary derivatives of tertiary amines, N-Mannich bases, Schiff bases, aminoacid conjugates, phosphate esters, metal salts and sulfonate esters of compounds disclosed herein. Examples of prodrugs include compounds that comprise a biohydrolyzable moiety (e.g., a biohydrolyzable amide, biohydrolyzable carbamate, biohydrolyzable carbonate, biohydrolyzable ester, biohydrolyzable phosphate, or biohydrolyzable ureide analog). Prodrugs of compounds disclosed herein are readily envisioned and prepared by those of ordinary skill in the art. See, e.g., Design of Prodrugs, Bundgaard, A. Ed., Elsevier, 1985; Bundgaard, hours., "Design and Application of Prodrugs," A Textbook of Drug Design and Development, Krosgaard-Larsen and hours. Bundgaard, Ed., 1991, Chapter 5, p. 113-191; and Bundgaard, hours., Advanced Drug Delivery Review, 1992, 8, 1-38.

Unless otherwise indicated, the term "protecting group" or "protective group," when used to refer to part of a molecule subjected to a chemical reaction, means a chemical moiety that is not reactive under the conditions of that chemical reaction, and which may be removed to provide a moiety that is reactive under those conditions. Protecting groups are well known in the art. See, e.g., Greene, T. W. and Wuts, P.G.M., Protective Groups in Organic Synthesis (3rd ed., John Wiley & Sons: 1999); Larock, R. C., Comprehensive Organic Transformations (2nd ed., John Wiley & Sons: 1999). Some examples include benzyl, diphenylmethyl, trityl, Cbz, Boc, Fmoc, methoxycarbonyl, ethoxycarbonyl, and phthalimido. Protecting groups include, for example, nitrogen protecting groups and hydroxy-protecting groups.

The term "sulfonyl" as used herein means a $\text{—S(O)}_2\text{—}$ group.

The term "thioalkoxy" as used herein means an alkyl group, as defined herein, appended to the parent molecular moiety through a sulfur atom. Representative examples of thioalkoxy include, but are not limited to, methylthio, ethylthio, and propylthio.

Certain compounds of the present invention may exist as stereoisomers wherein, asymmetric or chiral centers are present. These stereoisomers are "R" or "S" depending on the configuration of substituents around the chiral carbon atom. The terms "R" and "S" used herein are configurations as defined in IUPAC 1974 Recommendations for Section E, Fundamental Stereochemistry, in Pure Appl. Chem., 1976, 45: 13-30. The invention contemplates various stereoisomers and mixtures thereof and these are

specifically included within the scope of this invention. Stereoisomers include enantiomers and diastereomers, and mixtures of enantiomers or diastereomers. Individual stereoisomers of compounds of the invention may be prepared synthetically from commercially available starting materials which contain asymmetric or chiral centers or by preparation of racemic mixtures followed by resolution well known to those of ordinary skill in the art. These methods of resolution are exemplified by (1) attachment of a mixture of enantiomers to a chiral auxiliary, separation of the resulting mixture of diastereomers by recrystallization or chromatography and optional liberation of the optically pure product from the auxiliary as described in Furniss, Hannaford, Smith, and Tatchell, "Vogel's Textbook of Practical Organic Chemistry", 5th edition (1989), Longman Scientific & Technical, Essex CM20 2JE, England.

Certain compounds of the present invention may exist as cis or trans isomers, wherein substituents on a ring may be attached in such a manner that they are on the same side of the ring (cis) relative to each other, or on opposite sides of the ring relative to each other (trans). Such methods are well known to those of ordinary skill in the art, and may include separation of isomers by recrystallization or chromatography. It should be understood that the compounds of the invention may possess tautomeric forms, as well as geometric isomers, and that these also constitute an aspect of the invention.

It should be noted that a chemical moiety that forms part of a larger compound may be described herein using a name commonly accorded it when it exists as a single molecule or a name commonly accorded its radical. For example, the terms "pyridine" and "pyridyl" are accorded the same meaning when used to describe a moiety attached to other chemical moieties. Thus, for example, the two phrases "XOH, wherein X is pyridyl" and "XOH, wherein X is pyridine" are accorded the same meaning, and encompass the compounds pyridin-2-ol, pyridin-3-ol and pyridin-4-ol.

It should also be noted that names of compounds having one or more chiral centers that do not specify the stereochemistry of those centers encompass pure stereoisomers and mixtures thereof. Moreover, any atom shown in a drawing with

unsatisfied valences is assumed to be attached to enough hydrogen atoms to satisfy the valences. In addition, chemical bonds depicted with one solid line parallel to one dashed line encompass both single and double (e.g., aromatic) bonds, if valences permit.

The term “pharmaceutically acceptable excipient”, as used herein, means a non-toxic, inert solid, semi-solid or liquid filler, diluent, encapsulating material or formulation auxiliary of any type. Some examples of materials which can serve as pharmaceutically acceptable carriers are sugars such as lactose, glucose and sucrose; starches such as corn starch and potato starch; cellulose and its derivatives such as sodium carboxymethyl cellulose, ethyl cellulose and cellulose acetate; powdered tragacanth; malt; gelatin; talc; cocoa butter and suppository waxes; oils such as peanut oil, cottonseed oil, safflower oil, sesame oil, olive oil, corn oil and soybean oil; glycols; such a propylene glycol; esters such as ethyl oleate and ethyl laurate; agar; buffering agents such as magnesium hydroxide and aluminum hydroxide; alginic acid; pyrogen-free water; isotonic saline; Ringer's solution; ethyl alcohol, and phosphate buffer solutions, as well as other non-toxic compatible lubricants such as sodium lauryl sulfate and magnesium stearate, as well as coloring agents, releasing agents, coating agents, sweetening, flavoring and perfuming agents, preservatives and antioxidants can also be present in the composition, according to the judgment of one skilled in the art of formulations.

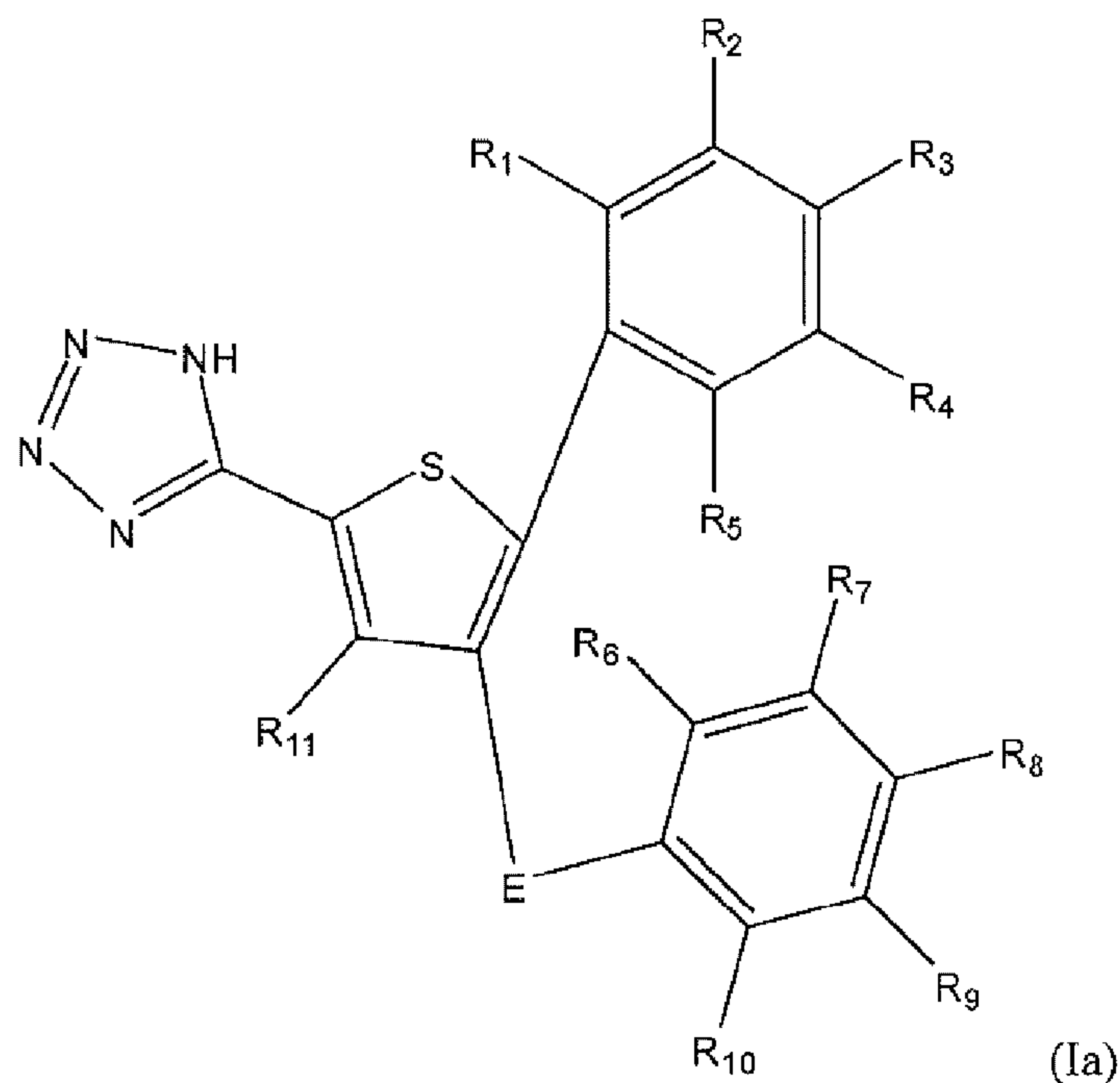
Unless otherwise indicated, a “therapeutically effective amount” of a compound is an amount sufficient to treat a disease or condition, or one or more symptoms associated with the disease or condition. In some embodiments, “treatment” may be determined by comparison to an untreated control.

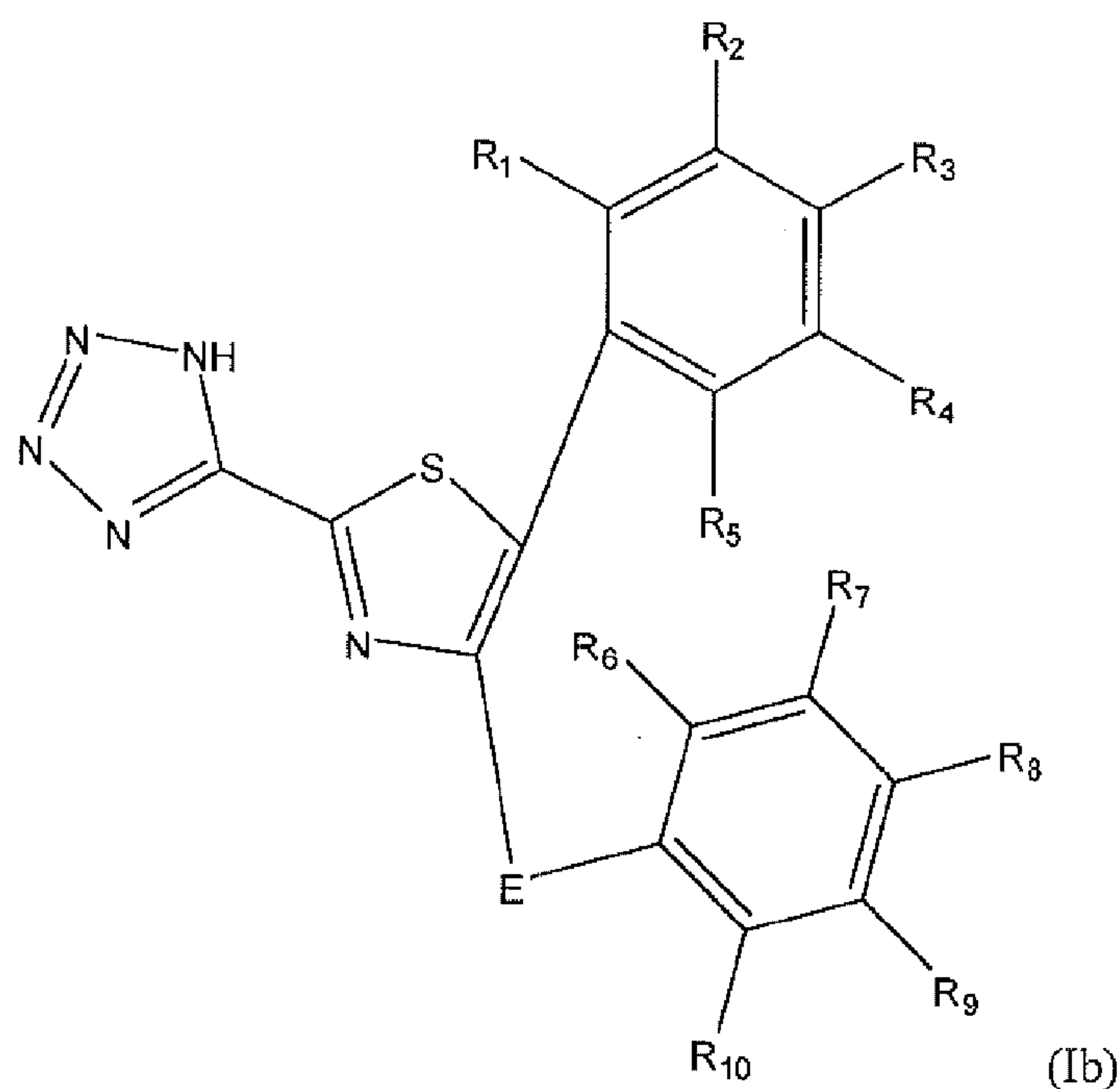
The term “subject” is intended to include living organisms in which disease may occur. Examples of subjects include humans, monkeys, cows, sheep, goats, dogs, cats, mice, rats, and transgenic species thereof.

The present invention is based, at least in part, on the design of compounds that inhibit acyl carrier protein (ACP) synthase (AcpS), the enzyme responsible for converting apo-ACP into holo-ACP. AcpS is present not only in Gram-positive and -negative bacteria, but also in acid-fast bacteria such as *Mycobacterium tuberculosis*, and even in protozoa such as *Plasmodium falciparum*. Accordingly, AcpS inhibitors are expected to have deleterious effects on the viability of many microbes. AcpS inhibitors are be

expected to have deleterious effects on the maintenance of microbial cell function, including, for example, increased porosity of cell membranes and dysfunction of efflux pumps in such membranes. The spectrum of activity demonstrated for compounds of the present invention includes many Gram-positive bacteria including Methicillin-resistant *S. aureus*, with selected compounds retaining activity against Gram-negative pathogens such as *Ps. aeruginosa*, *Ac. baumannii*, and *S. maltophilia*, and the like. Compounds of the present invention with low or no antimicrobial potency against, for example, *Ps. aeruginosa*, may have antimicrobial adjuvant (“adjuvant” or “pro-antibiotic”) effects when co-administered with antimicrobial compounds such as, for example, azithromycin, erythromycin, or ampicillin, or with antimicrobial compounds of the present invention. Though the utility of the compounds disclosed herein does not depend *per se* on their being AcpS inhibitors, the design effects toward that goal resulted, at least in part, in the discovery of the compounds of the present invention.

According to an embodiment, a compound, or prodrug or pharmaceutically acceptable salt thereof, is provided according to one of Formulas I or has as structure as set forth in one of Formulas I:

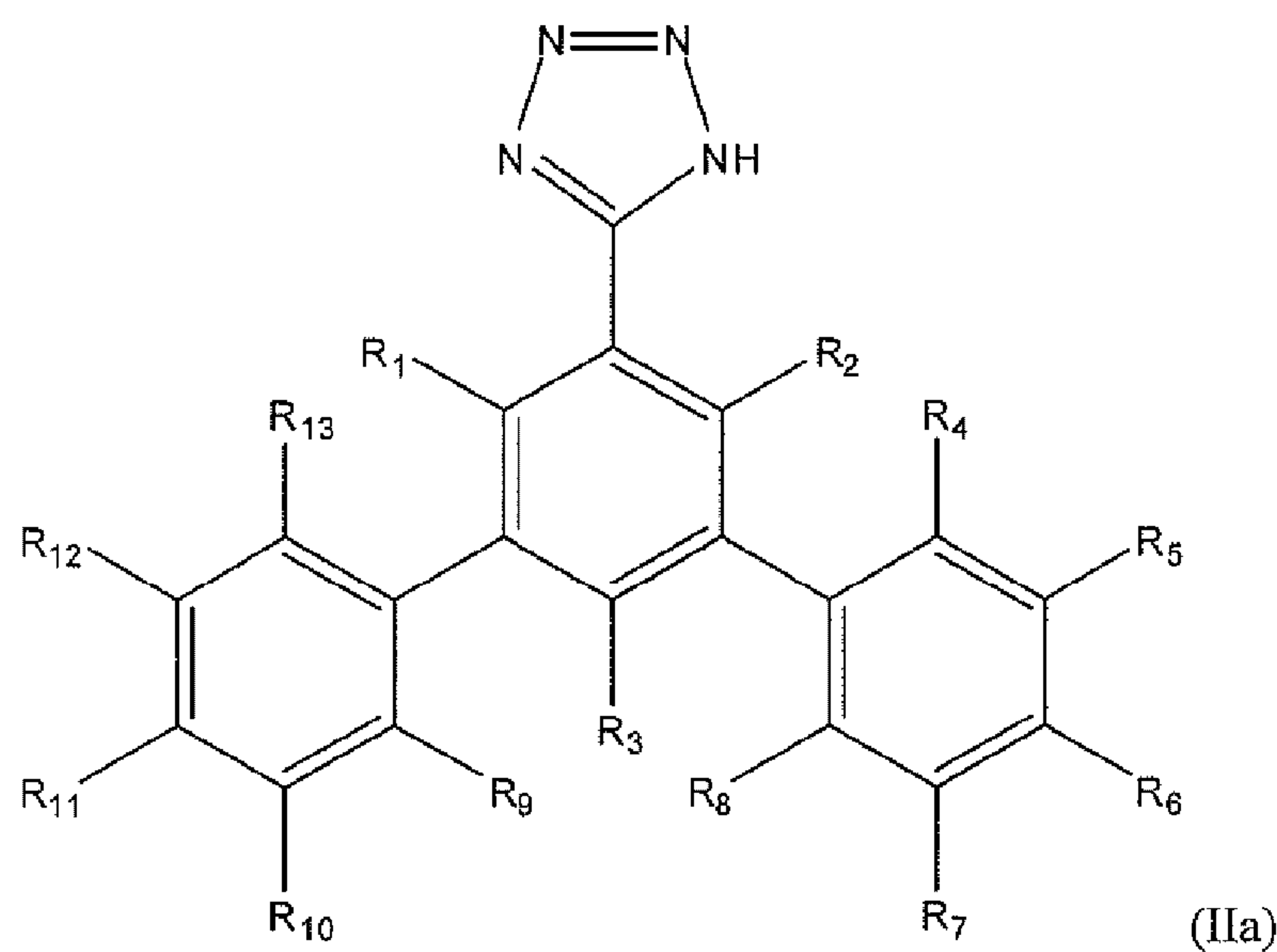


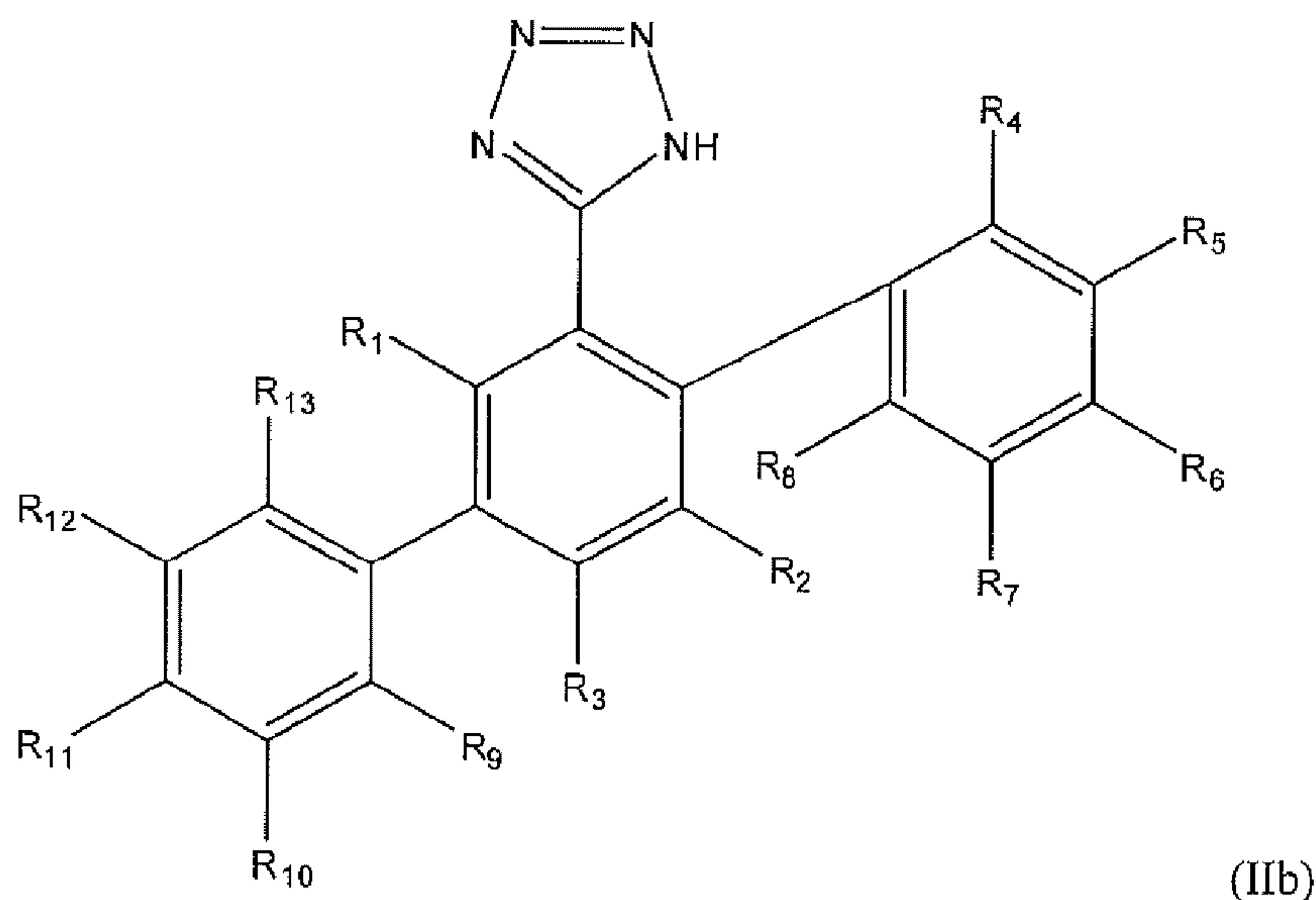


in which E is $-\text{CH}_2-$ or is absent whereby thiophene is directly connected to phenyl;
 R_1 , R_2 , R_9 , R_{10} , and R_{11} (if present) are each independently selected from the group consisting of hydrogen, methyl, ethyl, propyl, cyclopropyl, butyl, cyclobutyl, pentyl, hexyl, isopropyl, isobutyl, neopentyl, methoxy, and ethoxy;
 additionally, R_1 and R_2 may connect to form a phenyl or benzofuran ring;
 additionally, R_9 and R_{10} may connect to form a phenyl or benzofuran ring;
 R_3 and R_8 are each independently selected from the group consisting of hydrogen, methyl, ethyl, propyl, isopropyl, chlorine, fluorine, tert-butyl, methylsulfonyl, methoxy, and ethoxy;
 R_4 and R_7 are each independently selected from the group consisting of hydrogen, chlorine, methyl ester, ethyl ester, methyl, ethyl, propyl, cyclopropyl, butyl, cyclobutyl, isopropyl, isobutyl, methoxy, and ethoxy;
 and R_5 and R_6 are each independently selected from the group consisting of hydrogen, cyclopentyl, cyclopropyl, furan, thiophene, trifluoromethyl, trifluoromethyl ether, methylthiol, formaldehyde, chlorine, fluorine, bromine, phenyl, methyl, ethyl, isopropyl, propyl, butyl, cyclobutyl, isobutyl, neopentyl, pentyl, methoxy, and ethoxy.

In some embodiments, R_1 and R_2 are either independently selected from the group consisting of hydrogen and methyl, or form a phenyl ring whereby the ring system is naphthyl; R_9 and R_{10} are either independently selected from the group consisting of hydrogen and methyl, or form a phenyl ring whereby the ring system is naphthyl; R_{11} is hydrogen; R_3 and R_8 are each independently selected from the group consisting of hydrogen, methyl, chlorine, fluorine, isopropyl, tert-butyl, methoxy, and methylsulfonyl; R_4 and R_7 are each independently selected from the group consisting of hydrogen, methyl, chlorine, and ethyl ester; and R_5 and R_6 are each independently selected from the group consisting of methyl, ethyl, phenyl, hydrogen, chlorine, isopropyl, cyclopentyl, bromine, cyclopropyl, trifluoromethyl, trifluoromethyl ether, methylthiol, formaldehyde, furan, and thiophene. In some embodiments, E is absent. In some embodiments, R_1 , R_2 , R_4 , R_7 , R_9 , and R_{10} are each hydrogen. In some embodiments, R_3 and R_8 are each chlorine; and R_5 and R_6 are selected from the group consisting of hydrogen, methyl, and isopropyl. In a preferred embodiment, the compound is DNM0488. In a preferred embodiment, the compound is DNM0548. In a preferred embodiment, the compound is DNM0606. In a preferred embodiment, the compound is DNM0631. (These compound identifiers are given according to FIG. 1.) In a preferred embodiment, the compound is selected from the group consisting of those compounds listed in FIG. 1.

According to an embodiment, a compound, or prodrug or pharmaceutically acceptable salt thereof, is provided according to one of Formulas II:





in which

R_1 , R_2 , R_3 , R_5 , and R_{12} are each independently selected from the group consisting of hydrogen, methyl, ethyl, propyl, cyclopropyl, butyl, cyclobutyl, pentyl, hexyl, isopropyl, isobutyl, neopentyl, methoxy, and ethoxy;

R_4 , and R_{13} are each independently selected from the group consisting of hydrogen, methyl, ethyl, propyl, cyclopropyl, butyl, cyclobutyl, pentyl, hexyl, isopropyl, isobutyl, neopentyl, methoxy, ethoxy, and dialkylamine;

additionally, R_4 and R_5 may connect to form a phenyl ring;

additionally, R_{12} and R_{13} may connect to form a phenyl ring;

R_6 and R_{11} are each independently selected from the group consisting of hydrogen, chlorine, fluorine, hydroxy, phenyl ether, methyl, ethyl, propyl, isopropyl, tert-butyl, methoxy, and ethoxy;

R_7 and R_{10} are each independently selected from the group consisting of hydrogen, chlorine, methyl, ethyl, propyl, isopropyl, tert-butyl, methoxy, and ethoxy;

and R_8 and R_9 are each independently selected from the group consisting of hydrogen, halogen, methyl, ethyl, propyl, isopropyl, tert-butyl, methoxy, ethoxy, naphthyl optionally substituted with methyl, and phenyl optionally substituted with chlorine, bromine, carboxylic acid, and alkyl.

In some embodiments, R_6 and R_{11} are each independently selected from the group consisting of hydrogen, chlorine, fluorine, hydroxy, phenyl ether, and alkyl; R_7 and R_{10} are each independently selected from the group consisting of hydrogen, chlorine, and alkyl; and R_8 and R_9 are each independently selected from the group consisting of hydrogen, halogen, methyl, isopropyl, naphthyl optionally substituted with methyl, and phenyl optionally substituted with chlorine, bromine, carboxylic acid, and alkyl. In some embodiments, the compound is according to Formula IIa. In some embodiments, the compound is a compound according to Formula IIb. In a preferred embodiment, the compound is selected from the group consisting of those compounds listed in FIG. 2.

In a preferred embodiment of the invention, a compound is selected from the group consisting of 5-(4,5-Bis(4-chloro-2-methylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0488), 5-(4,5-Bis(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0486), 5-(4,5-Bis(4-chlorophenyl)thiophen-2-yl)-1H-tetrazole (DNM0487), 5-(4,5-Di(biphenyl-2-yl)thiophen-2-yl)-1H-tetrazole (DNM0489), 5-(4,5-Bis(3-chloro-4-methylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0504), 5-(4,5-Bis(5-chloro-2-methylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0508), 5-(4,5-Bis(3,4-dimethylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0509), 5-(4,5-Bis(4-isopropylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0512), 5-(4,5-Bis(2-methylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0531), 5-(4,5-Bis(2-isopropylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0534), 5-(4,5-Bis(2-phenoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0536), 5-(4,5-Bis(4-fluoronaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0537), 5-(4,5-Bis(2-chlorophenyl)thiophen-2-yl)-1H-tetrazole (DNM0538), 5-(4,5-Bis(2-ethylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0541), 5-(4,5-Bis(dibenzo[b,d]furan-4-yl)thiophen-2-yl)-1H-tetrazole (DNM0542), 5-(4,5-Di(benzofuran-2-yl)thiophen-2-yl)-1H-tetrazole (DNM0543), 5-(4,5-Bis(2-methoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0544), 5-(4,5-Bis(2,3-dimethoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0545), 5-(4,5-Bis(4-tert-butylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0546), 5-(4,5-Bis(4-chloro-2-isopropylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0548), 5-(4,5-Bis(2-(trifluoromethyl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0549), 5-(4,5-Bis(2-(trifluoromethoxy)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0550), 5-(4,5-Bis(2,4-

dimethoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0552), 5-(4,5-Bis(2,6-dimethoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0553), (2,2'-(5-(1H-tetrazol-5-yl)thiophene-2,3-diyl)bis(2,1-phenylene))dimethanol (DNM0555), 2,2'-(5-(1H-tetrazol-5-yl)thiophene-2,3-diyl)dibenzaldehyde (DNM0556), 5-(4,5-Di(furan-3-yl)thiophen-2-yl)-1H-tetrazole (DNM0557), 5-(4,5-Di(thiophen-3-yl)thiophen-2-yl)-1H-tetrazole (DNM0558), 5-(4,5-Bis(2-(thiophen-3-yl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0559), 5-(4,5-Bis(2-(furan-3-yl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0560), 5-(4,5-Bis(2-chloro-4-methylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0563), 5-(4,5-Bis(4-methoxy-3,5-dimethylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0564), 5-(4,5-Bis(3-chloro-4-methoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0565), Diethyl 3,3'-(5-(1H-tetrazol-5-yl)thiophene-2,3-diyl)dibenzoate (DNM0593), 1,1'-(3,3'-(5-(1H-tetrazol-5-yl)thiophene-2,3-diyl)bis(3,1-phenylene))dibutan-1-one (DNM0599), Diethyl 5,5'-(5-(1H-tetrazol-5-yl)thiophene-2,3-diyl)bis(3-hydroxybenzoate), 5-(4,5-Bis(3-butylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0608), 5-(4,5-bis(3-(cyclopentylmethyl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0612), 5-(4-(4-Chloro-2-methylphenyl)-5-(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0576), 5-(4-(4-Chlorophenyl)-5-(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0572), 5-(4-(5-Chlorophenyl)-4-(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0575), 5-(4-(4-Fluorophenyl)-5-(4-(methylsulfonyl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0592), Ethyl 3-(2-(4-methylnaphthalen-1-yl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)benzoate (DNM0596), Ethyl 3-(2-(4-chloro-2-methylphenyl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)benzoate (DNM0597), 4,5-Bis(4-chloro-2-methylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0574), 4,5-Bis(5-chloro-2-methylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0567), 4,5-Bis(3-chloro-4-methylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0568), 4,5-Bis(4-methylnaphthalen-1-yl)-2-(1H-tetrazol-5-yl)thiazole (DNM0569), 4,5-Bis(4-chlorophenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0573), 4,5-Bis(4-fluoronaphthalen-1-yl)-2-(1H-tetrazol-5-yl)thiazole (DNM0578), 4,5-Bis(4-biphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0581), 4,5-Bis(4-t-butylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0582), 4,5-Bis(3,4-dimethylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0583), 4,5-Bis(4-chloro-2-isopropylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0584), 5-(5-(4-Chlorobenzyl)-4-(4-methylnaphthalen-1-yl)thiophen-2-

yl)-1H-tetrazole (DNM0577), 5-(5-(4-Chlorobenzyl)-4-(4-chlorophenyl)thiophenyl)-1H-tetrazole (DNM0579), 5-(5-(4-Chlorobenzyl)-4-(4-chloro-2-isopropylphenyl)thiophenyl)-1H-tetrazole (DNM0580), 5-(5-(4-Chlorobenzyl)-4-(4-fluoronaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0587), 5-(4-(Biphenyl-2-yl)-5-(4-chlorobenzyl)thiophen-2-yl)-1H-tetrazole (DNM0588), Ethyl 3-(2-(4-chlorobenzyl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)benzoate (DNM0595), 1-(3-(2-(4-Chlorobenzyl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)phenyl)butan-1-one (DNM0600), 5-(4-(3-Butylphenyl)-5-(4-chlorobenzyl)thiophen-2-yl)-1H-tetrazole (DNM0606), Ethyl 3-(2-(4-chlorobenzyl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)-5-hydroxybenzoate (DNM0609), 5-(5-(4-Chlorobenzyl)-4-(3-(cyclopentylmethyl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0610), 3-(2-(4-Chlorobenzyl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)phenol (DNM0613), 5-(5-(4-Chlorobenzyl)-4-(3-methoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0615), 5-(5-(4-Chlorobenzyl)-4-(3-butoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0616), 5-(5-(4-Chlorobenzyl)-4-(3-ethoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0617), 5-(5-(4-Chlorobenzyl)-4-(3-propoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0618), 5-(3,5-Bis(4-methylnaphthalen-1-yl)phenyl)-2H-tetrazole (DNM0461), 5-(2,5-Bis(4-methylnaphthalen-1-yl)phenyl)-1H-tetrazole (DNM0446), 5-(2,5-Bis(4-chloro-2-methylphenyl)phenyl)-1H-tetrazole (DNM0447), 5-(3,5-Bis(4-chlorophenyl)phenyl)-2H-tetrazole (DNM0470), 5-(4'-Chloro-5-(4-methylnaphthalen-1-yl)biphenyl-3-yl)-1H-tetrazole (DNM0480), 5-(3,5-Bis(4-fluoronaphthalen-1-yl)phenyl)-2H-tetrazole (DNM0539), 4,5-Bis(4-chloro-2-isopropylphenyl)thiophene-2-carboxylic acid (DNM0566), 4,5-Bis(4-biphenyl)thiophene-2-carboxylic acid (DNM0497), 4,5-Bis(4-chlorophenyl)thiophene-2-carboxylic acid (DNM0498), 4,5-Bis(5-chloro-2-methylphenyl)thiophene-2-carboxylic acid (DNM0501), 4,5-Bis(3-chlorophenyl)thiophene-2-carboxylic acid (DNM0502), 4,5-Bis(2,4-dimethylphenyl)thiophene-2-carboxylic acid (DNM0503), 4,5-Bis(4-chloro-2-methylphenyl)thiophene-2-carboxylic acid (DNM0561), 5-(4,5-Bis(4-chloro-2-isopropylphenyl)-3-methylthiophen-2-yl)-1H-tetrazole (DNM0631), 5-(4,5-bis(4-chloro-2-methylphenyl)-3-methylthiophen-2-yl)-1H-tetrazole (DNM0614), 5-(4,5-Bis(4-methylnaphthalen-1-yl)-3-methylthiophen-2-yl)-1H-tetrazole (DNM0620), 5-(4,5-Bis(3-

butylphenyl)-3-methylthiophen-2-yl)-1H-tetrazole (DNM0627), and 5-(4,5-Bis(4-fluoronaphthalen-1-yl)-3-methylthiophen-2-yl)-1H-tetrazole (DNM0628).

According to an embodiment of the invention, a method of treatment of a microbial infection is provided comprising administering an effective amount of an antimicrobial compound as described herein to a patient in need thereof. Such a patient may be, for example, a human or other mammal that is infected with a pathogenic bacterium. In some embodiments, the microbial infection is substantially caused by Gram-positive bacteria. In some embodiments, the microbial infection is substantially caused by *Enterococcus* sp. In some embodiments, the microbial infection is substantially caused by *Staphylococcus* sp. In some embodiments, the microbial infection is substantially caused by *Bacillus* sp. In some embodiments, the microbial infection is substantially caused by *Staphylococcus epidermidis*, *Staphylococcus aureus* (including methicillin-resistant *Staphylococcus aureus* [MRSA]), *Enterococcus* sp. (including vancomycin-resistant *Enterococcus* [VRE]), *Streptococcus* sp., or *Bacillus* sp. To say that a microbial infection is “substantially caused” by a particular bacterium or species thereof indicates that the given bacterial genus or species is thought to be primarily responsible for the pathology, epidemiology, or symptom profile of the microbial infection and does not rule out the presence of other bacterial species (e.g., benignly colonizing bacteria). In some embodiments, the microbial infection is skin and skin structure infection of ulcers, wound infections, diabetic foot infections, osteomyelitis, pneumonia, anthrax infection, impetigo or secondarily-acquired traumatic lesions, gastroenteritis, meningitis, pneumonia, gonorrhea, peptic ulcers, nosocomial infections, or blood-stream infection, among others. In some embodiments, the described antimicrobial agents are used as medicinal compounds, for example, for treating humans, or as veterinary compounds, for example, for treating animals, poultry, livestock and the like, as well as in aquaculture and agricultural applications.

According to an embodiment of the invention, a method of treatment of a microbial infection is provided comprising administering an effective amount of an antimicrobial adjuvant compound as described herein and an effective amount of an antimicrobial compound to a patient in need thereof. Such a patient may be, for example, a human or other mammal that is infected with a pathogenic bacterium. In some

embodiments, the antimicrobial adjuvant compound is DNM0487. In some embodiments, the antimicrobial adjuvant compound is DNM0488. In some embodiments, the antimicrobial adjuvant compound is DNM0548. In some embodiments, the antimicrobial adjuvant compound is itself antimicrobial to some extent. Thus combinations are possible, not only of compounds of the present invention with each other, but also between a compound of the present invention and a known antibacterial compound. In some embodiments, the microbial infection is skin and skin structure infection of ulcers, wound infections, diabetic foot infections, osteomyelitis, pneumonia, impetigo or secondarily-acquired traumatic lesions, gastroenteritis, meningitis, pneumonia, septicaemia, urinary tract infections, gonorrhea, peptic ulcers, nosocomial infections, blood-stream infection, brucellosis, campylobacteriosis, Cat Scratch fever, cholera, legionellosis, leptospirosis, Lyme disease, melioidosis, meningitis, pertussis, plague, salmonellosis, shigellosis, syphilis, tularemia, typhoid fever, or urinary tract infection. An effective amount of one or more of the above-described antimicrobials may be used in the preparation of a medicament as described above for the treatment of a disease, disorder or condition caused by a pathogenic bacteria selected from the group including but by no means limited to Escherichia, Salmonella, Pseudomonas, Neisseria, Legionella, Haemophilus, Campylobacter, Helicobacter and Shigella.

In another embodiment of the invention, there is provided a method of manufacturing a medicament for treating a microbial infection comprising admixing an antimicrobial compound as described herein with a suitable excipient.

In other embodiments, there is provided the use of an antimicrobial compound as described herein for treating a microbial infection.

In another embodiment of the invention, there is provided a method of manufacturing a medicament for treating a microbial infection comprising admixing an antimicrobial adjuvant as described herein with a suitable antimicrobial compound.

In other embodiments, there is provided the use of an antimicrobial adjuvant as described herein for treating a microbial infection. In some embodiments, the antimicrobial adjuvant is used with or coadministered with an antimicrobial compound.

According to an embodiment, a pharmaceutical composition is provided comprising a compound of the present invention and a pharmaceutically acceptable excipient.

The microbial infection may be substantially caused by one or more Gram-positive bacteria.

The microbial infection may comprise a Staphylococcal infection.

The microbial infection may comprise Enterococcal infection.

The microbial infection may comprise Bacillus infection.

The microbial infection may be substantially caused by a bacterial species selected from the group consisting of *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Enterococcus faecalis*, *Enterococcus faecium*, *Bacillus cereus*, and *Streptococcus* sp.

Alternatively, the microbial infection is substantially caused by Gram-negative bacteria.

The microbial infection may be polymicrobial.

The microbial infection may be substantially caused by *Pseudomonas aeruginosa*.

The antimicrobial adjuvant compound may be selected from the group consisting of DNM0487, DNM0488, and DNM0548.

It is of note that the antimicrobials or antimicrobial adjuvants may be prepared to be administered in a variety of ways, for example, topically, orally, intravenously, intramuscularly, subcutaneously, intraperitoneally, intranasally or by local or systemic intravascular infusion using means known in the art and as discussed below. Compounds of the present invention may be used, for example, to treat infections caused by Gram negative bacteria such as *E. coli* and/or Gram positive bacteria such as *S. aureus*. In some embodiments, compounds have antimicrobial effects against antibiotic-resistant strains such as, for example, methicillin-resistant *S. aureus* (MRSA). In some embodiments, compounds have antimicrobial effects against *Mycobacterium tuberculosis*.

The antimicrobial or antimicrobial adjuvant compounds may be arranged to be delivered at a concentration of about 1 nM to about 50 mM; or 10 nM to about 50 mM; or 100 nM to about 50mM; or 1 μ M to about 50 mM; or 10 μ M to 50 mM or 100 μ M to 50 mM. As will be appreciated by one of skill in the art, this may be the "effective amount,"

that is, a sufficient dosage is administered such that a concentration within one of the envisioned ranges is attained at the required site. In some antimicrobial embodiments, the effective amount will be informed at least in part by the minimum inhibitory concentration of the compound required to exhibit bacteriostatic or bacteriocidal effects against the pathogen of interest. In some antimicrobial adjuvant embodiments, the effective amount will be informed at least in part by the approximate minimum concentration required to produce the desired adjuvant effect with a predetermined known antibiotic against the pathogen of interest. In some embodiments, the effective amount will be calibrated so as to produce a serum level of over ten times the MIC, or over five times the MIC, or over three times the MIC, or at the MIC in a subject suffering from an infection. In some embodiments, the effective amount will be calibrated so as to produce an in situ concentration of over ten times the MIC, or over five times the MIC, or over three times the MIC, or at the MIC.

An effective amount of one of the compounds of the invention can be employed in pure form or, where such forms exist, in pharmaceutically acceptable salt form. Alternatively, the compound can be administered as a pharmaceutical composition containing the compound of interest in combination with one or more pharmaceutically acceptable carriers. It will be understood, however, that the total daily usage of the compounds and compositions of the invention will be decided by the attending physician within the scope of sound medical judgment. The specific effective dose level for any particular patient will depend upon a variety of factors including the disorder being treated and the severity of the disorder; activity of the specific compound employed; the specific composition employed; the age, body weight, general health, sex and diet of the patient; the time of administration, route of administration, and rate of excretion of the specific compound employed; the duration of the treatment; the risk/benefit ratio; drugs used in combination or coincidental with the specific compound employed; and like factors well known in the medical arts. For example, it is well within the skill of the art to start doses of the compound at levels lower than required to achieve the desired therapeutic effect and to gradually increase the dosage until the desired effect is achieved.

The total daily dose of the compounds of the present invention as administered to a human or lower animal may range from about 0.0003 to about 30 mg/kg of body

weight. For purposes of oral administration, more preferable doses can be in the range of from about 0.0003 to about 1 mg/kg body weight. If desired, the effective daily dose can be divided into multiple doses for purposes of administration; consequently, single dose compositions may contain such amounts or submultiples thereof to make up the daily dose. For oral administration, the compositions of the invention are preferably provided in the form of tablets containing about 1.0, about 5.0, about 10.0, about 15.0, about 25.0, about 50.0, about 100, about 250, or about 500 milligrams of the active ingredient.

For best results, whether a particular compound is antimicrobial or an antimicrobial adjuvant with respect to the pathogen of interest (and in the case of adjuvants, with respect to the antimicrobial compound being used) would generally be ascertained by a number of microbiological methods known in the art, including for example, the methods disclosed in the Examples. It is well understood in the art that while every "antimicrobial" compound has an antimicrobial effect against at least one pathogen at one or more effective amounts, antimicrobial compounds vary as to their spectrum and/or potency of activity. Moreover, while every "antimicrobial adjuvant" compound has an adjuvant effect in conjunction with at least one antimicrobial compound against at least one pathogen at one or more effective amounts of both antimicrobial compound and adjuvant, antimicrobial adjuvant compounds vary as to their spectrum, potency of activity, and/or compatibility with particular antimicrobial compounds. As will be apparent to one knowledgeable in the art, the total dosage will vary according to many factors, including but by no means limited to the weight, age and condition of the individual or patient.

In some embodiments, one or more of the antimicrobial compounds may be co-administered with one or more known antibiotics. In some embodiments, one or more of the antimicrobial adjuvant compounds may be co-administered with one or more antimicrobial compounds; in which case the total effective amount of antimicrobial compound may be less than would otherwise be required in the absence of antimicrobial adjuvant, e.g. ~8 times less, or ~16 times less, or ~32 times less, or ~64 times less, or ~125 times less, or ~250 times less. In some embodiments, the antimicrobial adjuvant compounds are not themselves antimicrobial. In some embodiments, the antimicrobial adjuvant compounds are themselves antimicrobial. In some embodiments, one or more

of the antimicrobial adjuvant compounds may be combined with one or more antimicrobial compounds in a single dosage form. In some embodiments, the antimicrobial compound is an antimicrobial compound of the present invention. In some embodiments, the antimicrobial compound is a known antimicrobial compound such as, for example, almecillin, amdinocillin, amikacin, amoxicillin, amphotycin, amphotericin B, ampicillin, azacitidine, azaserine, azithromycin, azlocillin, aztreonam, artemisinin, allopurinol, ampicillin, aminoglycosides, amphotericin B, ampicillin, ansamycins, anthracyclines, antimycotics, azithromycin, bacampicillin, bacitracin, benzyl penicilloyl-polylysine, bleomycin, brefeldin A, butoconazole, candicidin, capreomycin, carbenicillin, cefaclor, cefadroxil, cefamandole, cefazoline, cefdinir, cefepime, cefixime, cefinenoxime, cefinetazole, cefodizime, cefonicid, cefoperazone, ceforanide, cefotaxime, cefotetan, cefotiam, cefoxitin, cefpiramide, cefpodoxime, cefprozil, cefsulodin, ceftazidime, ceftibuten, ceftizoxime, ceftriaxone, cefuroxime, cephradine, cephaloglycin, cephaloridine, cephalothin, cephapirin, cephradine, chloramphenicol, cilastatin, cinnamycin, ciprofloxacin, clarithromycin, clavulanic acid, clindamycin, clioquinol, cloxacillin, colistimethate, colistin, cyclacillin, cycloserine, cyclosporine, cyclo-(Leu-Pro), camptothecin, cefataxime, cephalixin, cephalosporins, chalcomycin, chartreusin, chlorotetracyclines, chlorothricin, chrymutasins, chrysomicin M, chrysomicin V, clomocyclines, dactinomycin, dalbavancin, dalfopristin, daptomycin, daunorubicin, demeclocycline, detorubicin, dicloxacillin, dihydrostreptomycin, dirithromycin, doxorubicin, doxycycline, ellipticines, elsamicin, epirubicin, erythromycin, eveminomycin, filipins, fluconazoles, fungichromins, fusidic acid, floxacillin, fosfomycin, gentamycin, gilvocarin, griseofulvin, griseoviridin, guamecyclines, gemifloxacin, gramicidin, hetacillin, idarubicin, imipenem, iseganan, ivermectin, ilosamides, itraconazoles, kanamycin, laspartomycin, linezolid, loracarbef, lankamycin, lincomycin, magainin, meclocycline, meropenem, methacycline, mezlocillin, minocycline, mitomycin, moenomycin, moxalactam, moxifloxacin, mycophenolic acid, macrolides, methicillins, mitoxantrone, nafcillin, natamycin, neomycin, netilmicin, niphimycin, nitrofurantoin, novobiocin, nalidixic acid, norfloxacin, nystatin, nystatins, ofloxacin, oleanomycin, oxytetracycline, paromomycin, penicillamine, phenethicillin, piperacillin, plicamycin, pristnamycin, pecilocin, penicillins, pesticides, phosphomycin,

pimarcin, platensimycin, polyenes, polymyxin B, polymyxin E, quinupristin, quinolones, ravidomycin, reserpines, rifamycin, ristocetins A and B, rifabutin, rifampin, rifamycin, rolitetracycline, sisomycin, spiramycin, spironolactone, sulfacetamide sodium, sulphonamide, spectrinomycin, streptomycin, streptozocin, sulbactam, sultamicillin, tacrolimus, tazobactam, teicoplanin, telithromycin, teramycins, tetracyclines, thiamphenicols, thiolutins, tobramycin, tyrothricin, ticarcillin, tigecycline, tobramycin, troleandomycin, tunicamycin, tyrthricin, vancomycin, vidarabine, viomycin, virginiamycin, and wortmannins; the presence of a plural item in the foregoing list meaning to refer to one or more members of a family of antibiotics known in the art by that name. Which compound or compounds should be co-administered or compounded in combination with compounds of the present invention depends on a number of factors, including but not necessarily limited to the efficacy of the agent or agents in the absence of antimicrobial adjuvant compounds, the mechanism of action of the compound(s), the identity of the pathogen causing or potentiating the sick condition, and/or the severity of the sick condition in the subject.

The pharmaceutical compositions can be formulated for oral administration in solid or liquid form, for parenteral intravenous, subcutaneous, intramuscular, intraperitoneal, intra-arterial, or intradermal injection, for or for vaginal, nasal, topical, or rectal administration. Pharmaceutical compositions of the present invention suitable for oral administration can be presented as discrete dosage forms, e.g., tablets, chewable tablets, caplets, capsules, liquids, and flavored syrups. Such dosage forms contain predetermined amounts of active ingredients, and may be prepared by methods of pharmacy well known to those skilled in the art. See generally, Remington's Pharmaceutical Sciences, 18th ed., Mack Publishing, Easton Pa. (1990).

Parenteral dosage forms can be administered to patients by various routes including subcutaneous, intravenous (including bolus injection), intramuscular, and intraarterial. Because their administration typically bypasses patients' natural defenses against contaminants, parenteral dosage forms are specifically sterile or capable of being sterilized prior to administration to a patient. Examples of parenteral dosage forms include solutions ready for injection, dry products ready to be dissolved or suspended in a pharmaceutically acceptable vehicle for injection, suspensions ready for injection, and

emulsions. Pharmaceutical compositions for parenteral injection comprise pharmaceutically acceptable sterile aqueous or nonaqueous solutions, dispersions, suspensions or emulsions and sterile powders for reconstitution into sterile injectable solutions or dispersions. Examples of suitable aqueous and nonaqueous carriers, diluents, solvents or vehicles include water, ethanol, polyols (propylene glycol, polyethylene glycol, glycerol, and the like, and suitable mixtures thereof), vegetable oils (such as olive oil) and injectable organic esters such as ethyl oleate, or suitable mixtures thereof. Suitable fluidity of the composition may be maintained, for example, by the use of a coating such as lecithin, by the maintenance of the required particle size in the case of dispersions, and by the use of surfactants. These compositions may also contain adjuvants such as preservative agents, wetting agents, emulsifying agents, and dispersing agents. Prevention of the action of microorganisms may be ensured by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, and the like. It may also be desirable to include isotonic agents, for example, sugars, sodium chloride and the like. Prolonged absorption of the injectable pharmaceutical form may be brought about by the use of agents delaying absorption, for example, aluminum monostearate and gelatin.

In some cases, in order to prolong the effect of a drug, it is often desirable to slow the absorption of the drug from subcutaneous or intramuscular injection. This may be accomplished by the use of a liquid suspension of crystalline or amorphous material with poor water solubility. The rate of absorption of the drug then depends upon its rate of dissolution which, in turn, may depend upon crystal size and crystalline form. Alternatively, delayed absorption of a parenterally administered drug form is accomplished by dissolving or suspending the drug in an oil vehicle.

Suspensions, in addition to the active compounds, may contain suspending agents, for example, ethoxylated isostearyl alcohols, polyoxyethylene sorbitol and sorbitan esters, microcrystalline cellulose, aluminum metahydroxide, bentonite, agar-agar, tragacanth, and mixtures thereof. If desired, and for more effective distribution, the compounds of the invention can be incorporated into slow-release or targeted-delivery systems such as polymer matrices, liposomes, and microspheres. They may be sterilized, for example, by filtration through a bacteria-retaining filter or by incorporation of

sterilizing agents in the form of sterile solid compositions, which may be dissolved in sterile water or some other sterile injectable medium immediately before use.

Injectable depot forms are made by forming microencapsulated matrices of the drug in biodegradable polymers such as polylactide-polyglycolide. Depending upon the ratio of drug to polymer and the nature of the particular polymer employed, the rate of drug release can be controlled. Examples of other biodegradable polymers include poly(orthoesters) and poly(anhydrides). Depot injectable formulations also are prepared by entrapping the drug in liposomes or microemulsions which are compatible with body tissues. The injectable formulations can be sterilized, for example, by filtration through a bacterial-retaining filter or by incorporating sterilizing agents in the form of sterile solid compositions which can be dissolved or dispersed in sterile water or other sterile injectable medium just prior to use.

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

Solid dosage forms for oral administration include capsules, tablets, pills, powders, and granules. In such solid dosage forms, one or more compounds of the invention is mixed with at least one inert pharmaceutically acceptable carrier such as sodium citrate or dicalcium phosphate and/or a) fillers or extenders such as starches, lactose, sucrose, glucose, mannitol, and salicylic acid; b) binders such as carboxymethylcellulose, alginates, gelatin, polyvinylpyrrolidinone, sucrose, and acacia; c) humectants such as glycerol; d) disintegrating agents such as agar-agar, calcium carbonate, potato or tapioca starch, alginic acid, certain silicates, and sodium carbonate; e) solution retarding agents such as paraffin; f) absorption accelerators such as quaternary

ammonium compounds; g) wetting agents such as cetyl alcohol and glycerol monostearate; h) absorbents such as kaolin and bentonite clay; and i) lubricants such as talc, calcium stearate, magnesium stearate, solid polyethylene glycols, sodium lauryl sulfate, and mixtures thereof. In the case of capsules, tablets and pills, the dosage form may also comprise buffering agents.

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

Dosage forms for topical administration may include powders, sprays, ointments and inhalants. A compound of the present invention can be mixed under sterile conditions with a pharmaceutically acceptable carrier and any needed preservatives, buffers or propellants which may be required. Ophthalmic formulations, eye ointments, powders and solutions are contemplated as being within the scope of this invention. Aqueous liquid compositions comprising compounds of the invention also are contemplated.

Liquid dosage forms for oral administration include pharmaceutically acceptable emulsions, microemulsions, solutions, suspensions, syrups and elixirs. In addition to the active compounds, the liquid dosage forms may contain inert diluents commonly used in the art such as, for example, water or other solvents, solubilizing agents and emulsifiers such as ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene glycol, dimethylformamide, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor, and sesame oils), glycerol, tetrahydrofurfuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof.

Besides inert diluents, the oral compositions can also include adjuvants such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, and perfuming

agents. Dosage forms for topical or transdermal administration of a compound of this invention include ointments, pastes, creams, lotions, gels, powders, solutions, sprays, inhalants or patches. A desired compound of the invention is admixed under sterile conditions with a pharmaceutically acceptable carrier and any needed preservatives or buffers as may be required. Ophthalmic formulation, ear drops, eye ointments, powders and solutions are also contemplated as being within the scope of this invention. The ointments, pastes, creams and gels may contain, in addition to an active compound of this invention, animal and vegetable fats, oils, waxes, paraffins, starch, tragacanth, cellulose derivatives, polyethylene glycols, silicones, bentonites, silicic acid, talc and zinc oxide, or mixtures thereof.

Powders and sprays can contain, in addition to the compounds of this invention, lactose, talc, silicic acid, aluminum hydroxide, calcium silicates and polyamide powder, or mixtures of these substances. Sprays can additionally contain customary propellants such as chlorofluorohydrocarbons.

Compounds of the invention may also be administered in the form of liposomes. As is known in the art, liposomes are generally derived from phospholipids or other lipid substances. Liposomes are formed by mono- or multi-lamellar hydrated liquid crystals that are dispersed in an aqueous medium. Any non-toxic, physiologically acceptable and metabolizable lipid capable of forming liposomes may be used. The present compositions in liposome form may contain, in addition to the compounds of the invention, stabilizers, preservatives, and the like. The preferred lipids are the natural and synthetic phospholipids and phosphatidylcholines (lecithins) used separately or together. Methods to form liposomes are known in the art. See, for example, Prescott, Ed., *Methods in Cell Biology*, Volume XIV, Academic Press, New York, N.Y., (1976), p 33 et seq.

In some embodiments, one or more of the antimicrobials or antimicrobial adjuvants at concentrations or dosages discussed above may be combined with a pharmaceutically or pharmacologically acceptable carrier, excipient or diluent, either biodegradable or non-biodegradable. Exemplary examples of carriers include, but are by no means limited to, for example, poly(ethylene-vinyl acetate), copolymers of lactic acid and glycolic acid, poly(lactic acid), gelatin, collagen matrices, polysaccharides, poly(D,L lactide), poly(malic acid), poly(caprolactone), celluloses, albumin, starch, casein, dextran,

polyesters, ethanol, methacrylate, polyurethane, polyethylene, vinyl polymers, glycols, mixtures thereof and the like. Standard excipients include gelatin, casein, lecithin, gum acacia, cholesterol, tragacanth, stearic acid, benzalkonium chloride, calcium stearate, glyceryl monostearate, cetostearyl alcohol, cetomacrogol emulsifying wax, sorbitan esters, polyoxyethylene alkyl ethers, polyoxyethylene castor oil derivatives, polyoxyethylene sorbitan fatty acid esters, polyethylene glycols, polyoxyethylene stearates, colloidal silicon dioxide, phosphates, sodium dodecylsulfate, carboxymethylcellulose calcium, carboxymethylcellulose sodium, methylcellulose, hydroxyethylcellulose, hydroxypropylcellulose, hydroxypropylmethylcellulose phthalate, noncrystalline cellulose, magnesium aluminum silicate, triethanolamine, polyvinyl alcohol, polyvinylpyrrolidone, sugars and starches.

As will be apparent to one knowledgeable in the art, specific carriers and carrier combinations known in the art may be selected based on their properties and release characteristics in view of the intended use. Specifically, the carrier may be pH-sensitive, thermo-sensitive, thermo-gelling, arranged for sustained release or a quick burst. In some embodiments, carriers of different classes may be used in combination for multiple effects, for example, a quick burst followed by sustained release.

In other embodiments, one or more of the antimicrobials or antimicrobial adjuvants at concentrations or dosages described above may be encapsulated for delivery. Specifically, the compounds may be encapsulated in biodegradable microspheres, microcapsules, microparticles, or nanospheres. The delivery vehicles may be composed of, for example, hyaluronic acid, polyethylene glycol, poly(lactic acid), gelatin, poly(ϵ -caprolactone), or a poly(lactic-glycolic) acid polymer. Combinations may also be used, as, for example, gelatin nanospheres may be coated with a polymer of poly(lactic-glycolic) acid. As will be apparent to one knowledgeable in the art, these and other suitable delivery vehicles may be prepared according to protocols known in the art and utilized for delivery of the compounds.

It is of note that the above described antimicrobials may be combined with permeation enhancers known in the art for improving delivery. Examples of permeation enhancers include, but are by no means limited to those compounds described in U.S. Pat. Nos. 3,472,931; 3,527,864; 3,896,238; 3,903,256; 3,952,099; 4,046,886; 4,130,643;

4,130,667; 4,299,826; 4,335,115; 4,343,798; 4,379,454; 4,405,616; 4,746,515; 4,788,062; 4,820,720; 4,863,738; 4,863,970; and 5,378,730; British Pat. No. 1,011,949; and Idson, 1975, J. Pharm. Sci. 64:901-924.

A “pharmaceutically acceptable salt” includes a salt that retains the desired biological activity of the parent antimicrobial or antimicrobial adjuvant compound and does not impart any undesired toxicological effects. Examples of such salts are salts of acids such as hydrochloric acid, hydrobromic acid, sulfuric acid, phosphoric acid, nitric acid, and the like; acetic acid, oxalic acid, tartaric acid, succinic acid, malic acid, benzoic acid, pamoic acid, alginic acid, methanesulfonic acid, naphthalenesulfonic acid, and the like. Also included are salts of cations such as sodium, potassium, lithium, zinc, copper, barium, bismuth, calcium, and the like; or organic cations such as trialkylammonium. Combinations of the above salts are also useful. It is to be understood that a compound disclosed herein in a salt-free form and analogous compound in a pharmaceutically acceptable salt form are both compounds of the present invention. Additionally, prodrugs, e.g. esters of the compounds disclosed herein, are compounds of the present invention. The preparation and use of acid addition salts, carboxylate salts, amino acid addition salts, and zwitterion salts of compounds of the present invention may also be considered pharmaceutically acceptable if they are, within the scope of sound medical judgment, suitable for use in contact with the tissues of humans and lower animals without undue toxicity, irritation, allergic response, and the like, are commensurate with a reasonable benefit/risk ratio, and are effective for their intended use. Such salts may also include various solvates and hydrates of the compound of the present invention.

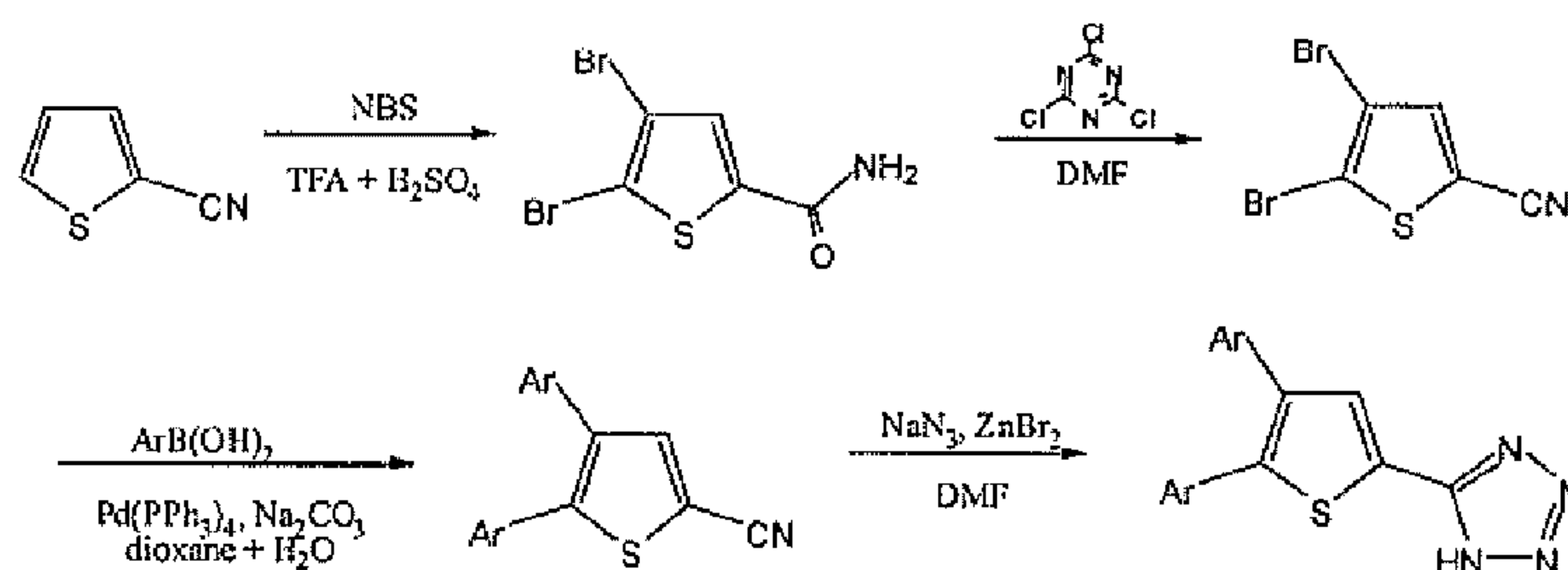
In some embodiments, the described antimicrobial compounds used as medicinal compounds, for example, for treating humans, or as veterinary compounds, for example, for treating animals, poultry, livestock and the like, as well as in aquaculture and agricultural applications.

While various embodiments of the invention have been described above, it will be recognized and understood that modifications may be made therein, and the appended claims are intended to cover all such modifications which may fall within the spirit and scope of the invention.

Certain embodiments of the invention will now be illustrated using examples.

Example 1

Synthesis of DNM0488 and analogues



4,5-Dibromothiophene-2-carboxamide Thiophene-2-carbonitrile (3.27 g, 30.0 mmol) was dissolved in a mixture of H_2SO_4 (10 mL) and TFA (20 mL). NBS (11.75 g, 66.0 mmol) was added in portion in 20 min. After complete addition, the reaction mixture was further stirred for 4h, and then poured onto 200 g of crushed ice. A white solid was formed, which was collected, washed with water, and dried together with phosphorous pentoxide under vacuum to afford 8.50 g (99 %) of product.

4,5-Dibromothiophene-2-carbonitrile An oven-dried round-bottomed flask was charged with 4,5-dibromothiophene-2-carboxamide (4.28g, 15.0 mmol) and 20 mL of DMF under an argon atmosphere. The solution was cooled on an ice-water bath, and cyanuric chloride (1.81 g, 9.8 mmol) was then added in one portion. After stirring at 0 °C for 1 h, the reaction mixture was warmed to room temperature, and stirred for a further 3h. 100 mL of water was added. A white solid was formed, which was collected through suction filtration, washed with water, and dried together with phosphorous pentoxide under vacuum to afford 3.70 g (92 %) of product.

4,5-Bis(4-chloro-2-methylphenyl)thiophene-2-carbonitrile A round-bottomed flask was charged with 4,5-dibromothiophene-2-carbonitrile (534 mg, 2.00 mmol), 4-chloro-2-methylphenylboronic acid (818 mg, 4.80 mmol) and Pd(PPh₃)₄ (136 mg, 0.10 mmol). After degassed, dioxane (10 mL) and aqueous sodium carbonate (5 mL, 2M, 10 mmol) was added. The reaction mixture was heated to 90 °C. The progress of the reaction was monitored by TLC. After the reaction was complete, 50 mL of water was added, and the reaction mixture was extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: CH₂Cl₂ = 2: 1). 0.60 g (84 %) of product was obtained as clear oil.

5-(4,5-Bis(4-chloro-2-methylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0488)

A round-bottomed flask was charged with 4,5-bis(4-chloro-2-methylphenyl)thiophene-2-carbonitrile (600 mg, 1.67 mmol), zinc bromide (945 mg, 4.20 mmol) and sodium azide (273 mg, 4.20 mmol). After degassed, DMF (5 mL) was added. The reaction mixture was heated to 110 °C and stirred at this temperature until complete. The reaction was cooled to rt, and 30 mL of 0.1 N aqueous HCl was added. The reaction mixture was extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: EtOAc: AcOH = 30: 10: 1). 603 mg (90 %) of product was obtained as a white solid, ¹H NMR (DMSO, 500 MHz) δ 7.82 (s, 1H), 7.36 (d, *J* = 2.04 Hz, 1H), 7.34 (d, *J* = 1.94 Hz, 1H), 7.31 (d, *J* = 8.25 Hz, 1H), 7.28 (dd, *J*₁ = 8.26 Hz, *J*₂ = 1.99 Hz, 1H), 7.17 (dd, *J*₁ = 8.20 Hz, *J*₂ = 2.05 Hz, 1H), 7.02 (d, *J* = 8.28 Hz, 1H), 2.17 (s, 3H), 2.03 (s, 3H); ¹³C NMR (DMSO,

125 MHz) δ 140.58, 139.14, 139.12, 138.19, 133.59, 133.39, 132.94, 132.47, 131.71, 131.17, 130.57, 130.17, 130.11, 126.00, 125.80, 19.69, 19.57.

The following compounds were also prepared using an analogous method:

5-(4,5-Bis(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0486)

^1H NMR (DMSO, 500 MHz) δ 8.00 (d, $J = 8.49$ Hz, 1H), 7.98 - 7.90 (m, 3H), 7.88 (d, $J = 8.49$ Hz, 1H), 7.57 - 7.50 (m, 2H), 7.50 - 7.42 (m, 2H), 7.33 (t, $J = 7.47$ Hz, 1H), 7.29 (d, $J = 7.36$ Hz, 1H), 7.19 (d, $J = 7.22$ Hz, 1H), 7.13 (d, $J = 7.22$ Hz, 1H), 2.57 (s, 3H), 2.52 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 141.36, 135.65, 134.20, 132.18, 132.13, 131.98, 131.68, 131.30, 130.95, 129.21, 127.85, 127.50, 126.30, 126.22, 126.12, 125.95, 125.89, 125.81, 125.75, 124.55, 124.50, 19.07, 18.97.

5-(4,5-Bis(4-chlorophenyl)thiophen-2-yl)-1H-tetrazole (DNM0487)

^1H NMR (DMSO, 500 MHz) δ 7.90 (s, 1H), 7.50 - 7.45 (m, 4H), 7.38 - 7.31 (m, 4H); ^{13}C NMR (DMSO, 125 MHz) δ 140.14, 137.85, 133.55, 133.45, 132.63, 131.58, 131.15, 130.74, 130.54, 129.19, 128.94, 124.74.

5-(4,5-Di(biphenyl-2-yl)thiophen-2-yl)-1H-tetrazole (DNM0489)

^1H NMR (DMSO, 500 MHz) δ 7.48 (s, 1H), 7.35 (td, $J_1 = 7.55$ Hz, $J_2 = 1.00$ Hz, 1H), 7.30 (td, $J_1 = 7.55$ Hz, $J_2 = 1.00$ Hz, 1H), 7.21 - 7.03 (m, 10H), 6.72 - 6.65 (m, 2H), 6.65 - 6.58 (m, 3H), 6.55 (d, $J = 7.45$ Hz, 1H); ^{13}C NMR (DMSO, 125 MHz) δ 141.91, 140.83, 140.46, 140.19, 139.33, 132.94, 132.02, 131.21, 130.32, 130.23, 130.20, 129.88, 128.63, 128.46, 128.45, 127.95, 127.88, 127.70, 127.45, 127.34, 126.61, 126.34.

5-(4,5-Bis(3-chloro-4-methylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0504)

^1H NMR (DMSO, 500 MHz) δ 7.89 (s, 1H), 7.41 (d, $J = 1.70$ Hz, 1H), 7.39 (d, $J = 1.75$ Hz, 1H), 7.37 (d, $J = 8.05$ Hz, 1H), 7.35 (d, $J = 8.00$ Hz, 1H), 7.18 (dd, $J_1 = 7.85$ Hz, $J_2 =$

1.80 Hz, 1H), 7.12 (dd, $J_1 = 7.83$ Hz, $J_2 = 1.73$ Hz, 1H), 2.34 (s, 6H); ^{13}C NMR (DMSO, 125 MHz) δ 139.77, 137.40, 136.19, 135.06, 134.02, 133.71, 133.55, 131.80, 131.68, 131.60, 131.54, 128.79, 128.69, 127.71, 127.43, 19.38, 19.32.

5-(4,5-Bis(5-chloro-2-methylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0508)

^1H NMR (DMSO, 500 MHz) δ 7.84 (s, 1H), 7.41 (d, $J = 2.25$ Hz, 1H), 7.36 (dd, $J_1 = 8.23$ Hz, $J_2 = 2.28$ Hz, 1H), 7.31 - 7.23 (m, 3H), 7.11 (s, 1H), 2.13 (s, 3H), 2.01 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 140.36, 139.01, 136.27, 135.74, 134.71, 133.43, 132.26, 132.23, 131.07, 130.59, 130.15, 130.01, 129.56, 128.95, 19.26, 19.16.

5-(4,5-Bis(3,4-dimethylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0509)

^1H NMR (DMSO, 500 MHz) δ 7.84 (s, 1H), 7.21 (s, 1H), 7.19 (s, 1H), 7.12 - 7.06 (m, 2H), 6.98 (dd, $J_1 = 8.28$ Hz, $J_2 = 1.63$ Hz, 1H), 6.94 (dd, $J_1 = 7.67$ Hz, $J_2 = 1.48$ Hz, 1H), 2.22 (s, 6H), 2.20 (s, 3H), 2.19 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 141.17, 138.26, 136.90, 136.80, 136.57, 135.65, 132.51, 131.95, 130.14, 129.86, 129.68, 129.65, 129.54, 126.21, 126.06, 19.41, 19.33, 19.14, 19.11.

5-(4,5-Bis(4-isopropylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0512)

^1H NMR (DMSO, 500 MHz) δ 7.84 (s, 1H), 7.30 - 7.23 (m, 8H), 2.90 (sep, $J = 6.88$ Hz, 1H), 1.24 - 1.18 (m, 12H); ^{13}C NMR (DMSO, 125 MHz) δ 148.87, 147.77, 141.11, 138.25, 132.48, 132.01, 130.15, 128.75, 128.55, 126.93, 126.67, 33.11, 33.08, 23.76, 23.65.

5-(4,5-Bis(2-methylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0531)

^1H NMR (DMSO, 500 MHz) δ 7.81 (s, 1H), 7.33 - 7.16 (m, 6H), 7.02 (t, $J = 7.35$ Hz, 1H), 7.02 (t, $J = 7.44$ Hz, 1H), 2.16 (s, 3H), 2.02 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 141.77,

140.03, 136.57, 135.51, 134.73, 131.87, 131.48, 131.26, 130.42, 130.39, 130.10, 128.93, 127.89, 125.89, 125.72, 19.91, 19.75.

5-(4,5-Bis(2-isopropylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0534) ^1H NMR (CDCl_3 , 500 MHz) δ 7.75 (s, 1H), 7.29 - 7.19 (m, 5H), 7.14 - 7.08 (m, 1H), 7.07 - 7.00 (m, 2H), 3.10 - 2.95 (m, 2H), 1.04 (s, 6H), 0.95 (d, $J = 6.80$ Hz, 6H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 148.48, 147.51, 140.43, 132.28, 131.09, 129.46, 128.43, 126.23, 126.15, 125.72, 125.66, 30.36, 10.15, 24.46.

5-(4,5-Bis(2-phenoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0536) ^1H NMR (DMSO, 500 MHz) δ 7.91 (s, 1H), 7.39 - 7.22 (m, 8H), 7.16 - 7.05 (m, 4H), 6.79 (d, $J = 7.90$ Hz, 1H), 6.75 (d, $J = 7.65$ Hz, 1H), 6.66 - 6.61 (m, 4H); ^{13}C NMR (DMSO, 125 MHz) δ 155.83, 155.76, 154.04, 153.87, 138.02, 136.48, 131.75, 131.63, 131.33, 130.42, 129.91, 129.86, 129.50, 126.43, 124.08, 123.68, 123.64, 123.46, 123.24, 118.95, 118.70, 118.37, 117.81.

5-(4,5-Bis(4-fluoronaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0537) ^1H NMR (DMSO, 500 MHz) δ 8.05 - 7.95 (m, 4H), 7.85 (d, $J = 8.50$ Hz, 1H), 7.66 - 7.56 (m, 3H), 7.53 (t, $J = 7.53$ Hz, 1H), 7.40 (t, $J = 7.55$ Hz, 1H), 7.34 - 7.26 (m, 2H), 7.15 (dd, $J_1 = 10.55$ Hz, $J_2 = 8.00$ Hz, 1H); ^{13}C NMR (DMSO, 125 MHz) δ 159.20, 158.48, 157.19, 156.48, 140.42, 139.24, 132.83, 132.79, 132.44, 132.40, 132.00, 129.91, 129.84, 128.92, 128.89, 127.97, 127.90, 127.80, 127.75, 127.02, 126.85, 125.89, 125.85, 125.53, 125.51, 125.41, 125.39, 122.86, 122.75, 122.73, 122.62, 120.25, 120.23, 120.21, 120.19, 109.42, 109.28, 109.26, 109.12.

5-(4,5-Bis(2-chlorophenyl)thiophen-2-yl)-1H-tetrazole (DNM0538) ^1H NMR (CDCl_3 , 500 MHz) δ 8.07 (s, 1H), 7.36 (d, $J = 8.05$ Hz, 1H), 7.31 (d, $J = 7.91$ Hz, 1H),

7.29 - 7.22 (m, 2H), 7.18 (dt, $J_1 = 1.06$ Hz, $J_2 = 7.50$ Hz, 1H), 7.15 - 7.09 (m, 1H), 7.08 - 7.01 (m, 2H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 142.02, 139.64, 134.55, 134.27, 133.64, 133.21, 132.59, 132.11, 131.78, 130.56, 130.40, 130.23, 129.57, 127.08, 126.97, 124.30.

5-(4,5-Bis(2-ethylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0541) ^1H NMR (DMSO, 500 MHz) δ 7.77 (s, 1H), 7.33 - 7.20 (m, 5H), 7.17 (t, $J = 7.43$ Hz, 1H), 7.08 (dt, $J_1 = 1.10$ Hz, $J_2 = 7.33$ Hz, 1H), 7.03 (d, $J = 7.50$ Hz, 1H), 2.50 (q, $J = 7.50$ Hz, 2H), 2.43 (q, $J = 7.50$ Hz, 2H), 1.06 (t, $J = 7.50$ Hz, 3H), 0.96 (t, $J = 7.50$ Hz, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 142.74, 141.68, 141.58, 139.90, 134.00, 131.53, 131.48, 130.97, 130.33, 129.16, 128.69, 128.45, 128.11, 125.71, 125.56, 123.74, 25.51, 25.38, 15.09, 15.01.

5-(4,5-Bis(dibenzo[b,d]furan-4-yl)thiophen-2-yl)-1H-tetrazole (DNM0542) ^1H NMR (DMSO, 500 MHz) δ 8.26 (s, 1H), 8.15 - 8.07 (m, 3H), 8.04 (dd, $J_1 = 7.63$ Hz, $J_2 = 0.98$ Hz, 1H), 7.50 - 7.40 (m, 4H), 7.40 - 7.34 (m, 2H), 7.34 - 7.22 (m, 4H); ^{13}C NMR (DMSO, 125 MHz) δ 155.30, 155.22, 152.65, 152.36, 137.03, 135.52, 131.54, 128.15, 127.93, 127.75, 127.68, 124.22, 124.05, 123.36, 123.34, 123.20, 123.16, 123.12, 121.82, 121.36, 121.28, 120.90, 119.86, 117.22, 111.38, 111.25.

5-(4,5-Di(benzofuran-2-yl)thiophen-2-yl)-1H-tetrazole (DNM0543) ^1H NMR (DMSO, 500 MHz) δ 8.23 (s, 1H), 7.74 (d, $J = 7.75$ Hz, 2H), 7.67 (t, $J = 7.28$ Hz, 2H), 7.49 (s, 1H), 7.45 - 7.37 (m, 3H), 7.33 (dt, $J_1 = 2.20$ Hz, $J_2 = 7.40$ Hz, 2H); ^{13}C NMR (DMSO, 125 MHz) δ 154.12, 153.91, 149.67, 147.67, 130.34, 130.05, 128.48, 128.36, 128.21, 125.92, 125.38, 123.75, 123.53, 121.93, 121.68, 111.27, 111.26, 107.06, 106.01.

5-(4,5-Bis(2-methoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0544) ^1H NMR (DMSO, 500 MHz) δ 7.82 (s, 1H), 7.35 - 7.28 (m, 2H), 7.10 (dd, $J_1 = 7.55$ Hz, $J_2 = 1.50$

Hz, 1H), 7.04 (d, $J = 8.35$ Hz, 2H), 6.98 (dd, $J_1 = 7.50$ Hz, $J_2 = 1.35$ Hz, 1H), 6.90 – 6.80 (m, 2H), 3.62 (s, 3H), 3.59 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 156.29, 156.25, 138.75, 137.01, 131.72, 130.91, 130.30, 130.09, 129.16, 124.59, 121.73, 120.37, 120.29, 111.85, 111.60, 55.28, 55.22.

5-(4,5-Bis(2,3-dimethoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0545) ^1H NMR (DMSO, 500 MHz) δ 7.82 (s, 1H), 7.03 (dt, $J_1 = 1.20$ Hz, $J_2 = 8.00$ Hz, 2H), 6.98 (d, $J = 7.70$ Hz, 1H), 6.94 (d, $J = 8.00$ Hz, 1H), 6.67 (dd, $J_1 = 7.75$ Hz, $J_2 = 1.40$ Hz, 1H), 6.63 (dd, $J_1 = 7.58$ Hz, $J_2 = 1.58$ Hz, 1H), 3.82 (s, 6H), 3.63 (s, 3H), 3.57 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 152.73, 146.13, 146.07, 138.01, 136.68, 131.51, 129.53, 126.64, 123.88, 122.59, 122.43, 113.24, 112.63, 60.12, 59.96, 55.72, 55.67.

5-(4,5-Bis(4-*tert*-butylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0546) ^1H NMR (DMSO, 500 MHz) δ 7.84 (s, 1H), 7.53 - 7.37 (m, 4H), 7.30 (d, $J = 8.41$ Hz, 2H), 7.27 (d, $J = 8.41$ Hz, 2H), 1.29 (s, 9H), 1.28 (s, 9H); ^{13}C NMR (DMSO, 125 MHz) δ 151.15, 150.07, 141.08, 132.17, 132.12, 129.84, 128.46, 128.28, 125.80, 125.53, 34.46, 34.37, 31.09, 30.99.

5-(4,5-Bis(4-chloro-2-*iso*-propylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0548) ^1H NMR (DMSO, 500 MHz) δ 7.75 (s, 1H), 7.43 - 7.39 (m, 2H), 7.31 - 7.26 (m, 2H), 7.30 (dd, $J_1 = 2.24$ Hz, $J_2 = 8.30$ Hz, 1H), 7.06 (d, $J = 8.30$ Hz, 1H), 2.97 - 2.82 (m, 2H), 1.04 (broad, 6H), 0.95 (d, $J = 6.80$ Hz, 6H); ^{13}C NMR (DMSO, 125 MHz) δ 150.00, 149.20, 140.39, 138.88, 134.47, 133.44, 133.30, 132.20, 131.71, 131.19, 128.76, 126.16, 126.04, 125.97, 125.76, 29.95, 29.77, 23.54 (broad).

5-(4,5-Bis(2-(trifluoromethyl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0549)

¹H NMR (DMSO, 500 MHz) δ 7.88 - 7.78 (m, 3H), 7.66 - 7.58 (m, 2H), 7.56 - 7.49 (m, 2H), 7.41 (broad, 1H), 7.23 - 7.15 (m, 1H); ¹³C NMR (DMSO, 125 MHz) δ

5-(4,5-Bis(2-(trifluoromethoxy)phenyl)thiophen-2-yl)-1H-tetrazole

(DNM0550) ¹H NMR (DMSO, 500 MHz) δ 7.90 (s, 1H), 7.57 - 7.51 (m, 1H), 7.51 - 7.46 (m, 1H), 7.45 - 7.34 (m, 5H), 7.32 (dd, $J_1 = 7.50$ Hz, $J_2 = 1.70$ Hz, 1H); ¹³C NMR (DMSO, 125 MHz) δ 145.44, 136.94, 135.8, 132.48, 131.7, 131.17, 130.98, 130.22, 127.82, 127.62, 127.4, 125.37, 120.88, 120.54, 118.85, 118.81.

5-(4,5-Bis(2,4-dimethoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0552)

¹H NMR (DMSO, 500 MHz) δ 7.75 (s, 1H), 6.99 (d, $J = 8.45$ Hz, 1H), 6.87 (d, $J = 8.45$ Hz, 1H), 6.64 - 6.58 (m, 2H), 6.46 (dd, $J_1 = 8.50$ Hz, $J_2 = 2.25$ Hz, 1H), 6.43 (dd, $J_1 = 8.50$ Hz, $J_2 = 2.25$ Hz, 1H), 3.764 (s, 3H), 3.756 (s, 3H), 3.66 (s, 3H), 3.65 (s, 3H); ¹³C NMR (DMSO, 125 MHz) δ 160.84, 160.13, 157.52, 157.46, 138.46, 136.36, 131.91, 131.62, 130.91, 117.24, 114.29, 105.25, 104.89, 98.82, 98.79, 55.49, 55.40, 55.29, 55.19.

5-(4,5-Bis(2,6-dimethoxyphenyl)thiophen-2-yl)-1H-tetrazole (DNM0553)

¹H NMR (DMSO, 500 MHz) δ 7.68 (s, 1H), 7.22 (t, $J = 8.38$ Hz, 1H), 7.16 (d, $J = 8.33$ Hz, 1H), 6.57 (d, $J = 8.40$ Hz, 2H), 6.55 (d, $J = 8.35$ Hz, 1H), 3.49 (s, 6H), 3.47 (s, 6H); ¹³C NMR (DMSO, 125 MHz) δ 157.67, 157.29, 134.19, 132.23, 130.01, 128.89, 113.22, 110.53, 103.80, 103.73, 55.26, 55.10.

(2,2'-(5-(1H-tetrazol-5-yl)thiophene-2,3-diyl)bis(2,1-phenylene))dimethanol

(DNM0555) ¹H NMR (DMSO, 500 MHz) δ 7.85 (s, 1H), 7.51 (d, $J = 7.60$ Hz, 1H), 7.48 (d, $J = 7.70$ Hz, 1H), 7.37 (dt, $J_1 = 1.47$ Hz, $J_2 = 7.45$ Hz, 1H), 7.33 - 7.21 (m, 3H), 7.13 (dt, $J_1 = 1.00$ Hz, $J_2 = 7.49$ Hz, 1H), 7.02 (dd, $J_1 = 1.00$ Hz, $J_2 = 7.60$ Hz, 1H), 4.36 (s,

2H), 4.23 (s, 2H); ^{13}C NMR (DMSO, 125 MHz) δ 141.19, 140.84, 140.12, 139.48, 133.01, 131.45, 131.19, 130.04, 129.89, 128.87, 127.85, 127.65, 127.26, 126.65, 126.59, 60.71, 60.44.

2,2'-(5-(1H-tetrazol-5-yl)thiophene-2,3-diyl)dibenzaldehyde (DNM0556) ^1H NMR (CDCl_3 , 500 MHz) δ 9.91 (s, 1H), 9.80 (s, 1H), 7.93 (s, 1H), 7.75 (d, $J = 7.80$ Hz, 2H), 7.59 (dt, $J_1 = 1.35$ Hz, $J_2 = 7.55$ Hz, 1H), 7.49 - 7.41 (m, 3H), 7.34 (t, $J = 7.53$ Hz, 1H), 7.18 (d, $J = 7.50$ Hz, 1H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 192.30, 191.20, 153.22, 140.91, 139.47, 137.51, 134.79, 134.72, 134.66, 134.40, 134.04, 133.00, 132.44, 132.21, 130.28, 129.89, 129.76, 129.32, 126.53.

5-(4,5-Di(furan-3-yl)thiophen-2-yl)-1H-tetrazole (DNM0557) ^1H NMR (DMSO, 500 MHz) δ 8.03 (dd, $J_1 = 0.93$ Hz, $J_2 = 1.38$ Hz, 1H), 7.93 (dd, $J_1 = 0.90$ Hz, $J_2 = 1.30$ Hz, 1H), 7.87 (s, 1H), 7.83 (t, $J = 1.60$ Hz, 1H), 7.77 (t, $J = 1.70$ Hz, 1H), 6.63 (dd, $J_1 = 0.83$ Hz, $J_2 = 1.83$ Hz, 1H), 6.59 (dd, $J_1 = 0.80$ Hz, $J_2 = 1.80$ Hz, 1H); ^{13}C NMR (DMSO, 125 MHz) δ 144.46, 143.86, 141.52, 140.76, 131.73, 130.93, 130.30, 119.66, 117.66, 110.91, 110.38.

5-(4,5-Di(thiophen-3-yl)thiophen-2-yl)-1H-tetrazole (DNM0558) ^1H NMR (DMSO, 500 MHz) δ 7.89 (s, 1H), 7.68 (dd, $J_1 = 1.33$ Hz, $J_2 = 2.88$ Hz, 1H), 7.65 (dd, $J_1 = 2.95$ Hz, $J_2 = 4.95$ Hz, 1H), 7.61 (dd, $J_1 = 2.95$ Hz, $J_2 = 4.90$ Hz, 1H), 7.59 (dd, $J_1 = 1.28$ Hz, $J_2 = 2.88$ Hz, 1H), 7.03 (dd, $J_1 = 1.18$ Hz, $J_2 = 4.93$ Hz, 1H); ^{13}C NMR (DMSO, 125 MHz) δ 135.88, 135.23, 133.66, 132.73, 131.40, 127.61, 127.59, 127.52, 126.80, 125.14, 123.88.

5-(4,5-Bis(2-(thiophen-3-yl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0559) ^1H NMR (DMSO, 500 MHz) δ 7.65 (s, 1H), 7.40 - 7.35 (m, 2H), 7.32 (dt, $J_1 = 1.15$ Hz,

$J_2 = 7.51$ Hz, 1H), 7.29 - 7.23 (m, 3H), 7.16 - 7.00 (m, 2H), 6.90 (dd, $J_1 = 1.23$ Hz, $J_2 = 2.88$ Hz, 1H), 6.85 (dd, $J_1 = 1.23$ Hz, $J_2 = 2.88$ Hz, 1H), 6.73 (d, $J = 7.65$ Hz, 1H), 6.64 (d, $J = 7.65$ Hz, 1H), 6.58 (dd, $J_1 = 1.20$ Hz, $J_2 = 4.95$ Hz, 1H), 6.53 (dd, $J_1 = 1.20$ Hz, $J_2 = 4.95$ Hz, 1H); ^{13}C NMR (DMSO, 125 MHz) δ 142.01, 140.99, 140.62, 139.74, 135.76, 135.02, 132.86, 131.72, 130.96, 130.16, 129.91, 129.73, 129.37, 128.68, 127.94, 127.81, 127.73, 127.16, 127.06, 125.56, 125.39, 123.16, 122.78.

5-(4,5-Bis(2-(furan-3-yl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0560) ^1H NMR (DMSO, 500 MHz) δ 7.61 (s, 1H), 7.59 - 7.56 (m, 2H), 7.38 - 7.31 (m, 3H), 7.30 - 7.25 (m, 2H), 7.25 - 7.22 (m, 1H), 7.19 - 7.14 (m, 1H), 7.12 (dt, $J_1 = 1.30$ Hz, $J_2 = 7.58$ Hz, 1H), 6.96 (d, $J = 7.54$ Hz, 1H), 6.85 (dd, $J_1 = 0.95$ Hz, $J_2 = 7.66$ Hz, 1H), 6.20 (dd, $J_1 = 0.83$ Hz, $J_2 = 1.78$ Hz, 1H), 6.12 (dd, $J_1 = 0.80$ Hz, $J_2 = 1.75$ Hz, 1H); ^{13}C NMR (DMSO, 125 MHz) δ 142.01, 140.99, 140.62, 139.74, 135.76, 135.02, 132.86, 131.72, 130.96, 130.16, 129.91, 129.73, 129.37, 128.68, 127.94, 127.81, 127.73, 127.16, 127.06, 125.56, 125.39, 123.16, 122.78.

5-(4,5-Bis(2-chloro-4-methylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0563) ^1H NMR (DMSO, 500 MHz) δ 7.85 (s, 1H), 7.36 - 7.32 (m, 2H), 7.29 (d, $J = 7.80$ Hz, 1H), 7.06 (d, $J = 7.74$ Hz, 1H), 7.09-7.02 (m, 2H), 2.30 (s, 3H), 2.28 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 141.00, 139.73, 138.42, 132.59, 132.54, 131.88, 131.38, 131.08, 130.57, 130.19, 130.03, 128.06, 127.87, 127.82, 20.39, 10.37.

5-(4,5-Bis(4-methoxy-3,5-dimethylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0564) ^1H NMR (DMSO, 500 MHz) δ 7.83 (s, 1H), 7.03 (s, 2H), 6.99 (s, 2H), 3.67 (s, 6H), 2.172 (s, 6H), 2.166 (s, 6H); ^{13}C NMR (DMSO, 125 MHz) δ 156.89, 156.12,

140.69, 137.89, 131.78, 130.86, 130.45, 130.27, 129.19, 128.99, 127.91, 59.43, 59.42, 15.78, 15.74.

5-(4,5-Bis(3-chloro-4-methoxyphenyl)thiophen-2-yl)-1H-tetrazole

(DNM0565) ^1H NMR (DMSO, 500 MHz) δ 7.87 (s, 1H), 7.41 (d, $J = 2.05$ Hz, 1H), 7.39 (d, $J = 2.00$ Hz, 1H), 7.30 (dd, $J_1 = 2.15$ Hz, $J_2 = 8.65$ Hz, 1H), 7.22 (dd, $J_1 = 2.08$ Hz, $J_2 = 8.58$ Hz, 1H), 7.20 (d, $J = 8.70$ Hz, 1H), 7.17 (d, $J = 8.65$ Hz, 1H), 3.89 (s, 3H), 3.88 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 172.03, 154.75, 154.03, 139.42, 136.95, 131.63, 130.00, 129.84, 129.19, 128.70, 127.88, 125.48, 121.39, 121.18, 113.24, 113.01, 56.29, 56.18.

Diethyl 3,3'-(5-(1H-tetrazol-5-yl)thiophene-2,3-diyl)dibenzoate (DNM0593)

^1H NMR (CDCl_3 , 500 MHz) δ 8.17 (s, 1H), 8.14 (s, 1H), 8.06 (s, 1H), 8.03 (d, $J = 7.75$ Hz, 1H), 7.98 (d, $J = 7.75$ Hz, 1H), 7.48 (d, $J = 7.90$ Hz, 1H), 7.44 - 7.37 (m, 3H), 7.34 (t, $J = 7.75$ Hz, 1H), 4.44 - 4.35 (m, 4H), 1.42 - 1.35 (m, 6H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 167.33, 166.35, 142.50, 138.70, 135.47, 133.75, 133.73, 133.17, 132.49, 131.28, 131.27, 130.90, 130.44, 130.20, 129.85, 129.20, 128.99, 128.97, 124.48, 61.88, 61.64, 14.39.

1,1'-(3,3'-(5-(1H-tetrazol-5-yl)thiophene-2,3-diyl)bis(3,1-phenylene))dibutan-1-one (DNM0599)

^1H NMR (CDCl_3 , 500 MHz) δ 8.13 (s, 1H), 8.08 (s, 1H), 7.98 - 7.89 (m, 3H), 7.54 (d, $J = 7.80$ Hz, 1H), 7.46 (t, $J = 7.60$ Hz, 1H), 7.40 (t, $J = 7.70$ Hz, 1H), 2.94 (t, $J = 7.28$ Hz, 2H), 2.85 (t, $J = 7.30$ Hz, 2H), 1.80 - 1.67 (m, 4H), 0.99 (t, $J = 7.35$ Hz, 3H), 0.98 (t, $J = 7.35$ Hz, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 200.52, 139.04, 137.96, 137.80, 136.06, 134.09, 134.00, 133.71, 132.47, 129.80, 129.51, 129.44, 129.04, 128.58, 128.04, 41.20, 41.06, 18.23, 18.18, 14.28.

Diethyl 5,5'-(5-(1H-tetrazol-5-yl)thiophene-2,3-diyl)bis(3-hydroxybenzoate)

(DNM0607) ^1H NMR (DMSO, 500 MHz) δ 10.12 (s, 1H), 9.99 (s, 1H), 7.87 (s, 1H), 7.43 - 7.29 (m, 4H), 6.97 (s, 1H), 6.93 (s, 1H), 4.35 - 4.17 (m, 4H), 1.33 - 1.20 (m, 6H); ^{13}C NMR (DMSO, 125 MHz) δ 165.34, 165.07, 157.89, 157.75, 139.98, 138.09, 136.36, 133.97, 131.78, 131.60, 131.02, 120.17, 120.10, 120.01, 115.86, 115.11, 60.91, 60.81, 14.07, 14.00.

5-(4,5-Bis(3-butylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0608) ^1H NMR

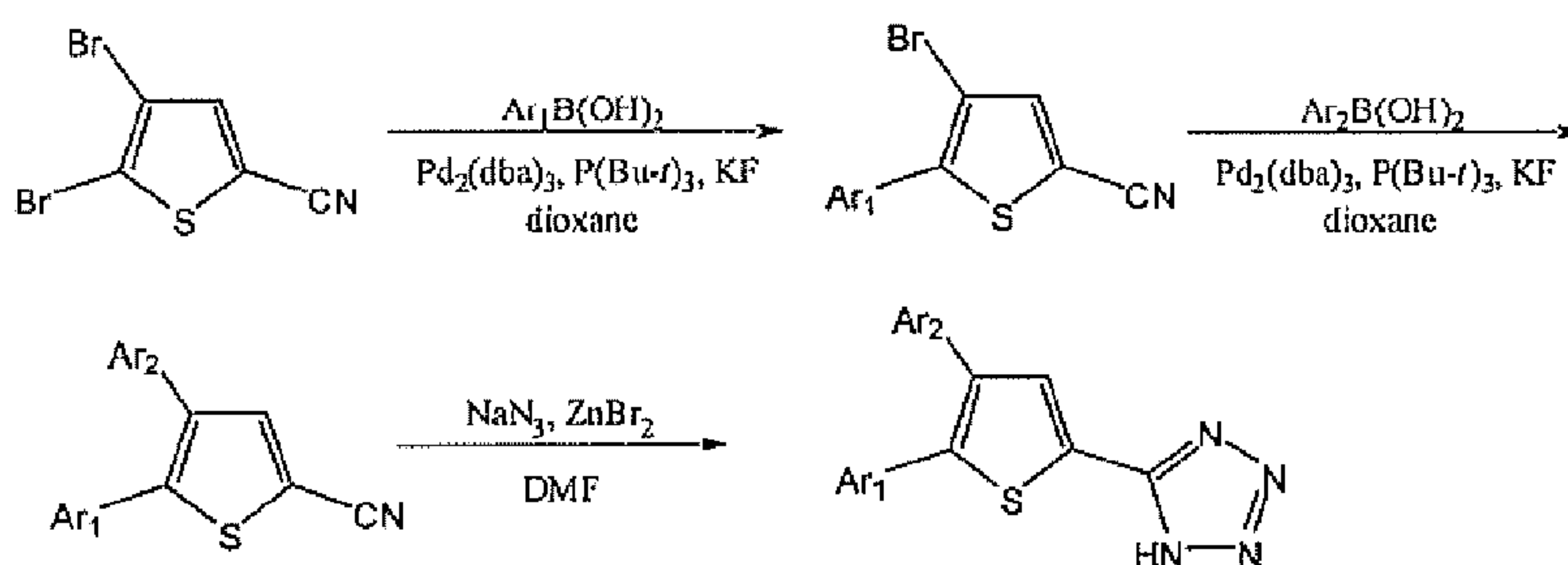
(CDCl_3 , 500 MHz) δ 7.44 (s, 1H), 6.91 - 6.56 (m, 8H), 8.06 (s, 1H), 2.31 - 2.05 (m, 4H), 1.29 - 1.16 (m, 4H), 1.16 - 1.00 (m, 4H), 0.81 - 0.67 (m, 6H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 142.80, 142.62, 139.91, 138.91, 136.26, 134.07, 129.86, 129.58, 129.54, 128.54, 127.63, 127.02, 126.88, 126.61, 35.70, 35.68, 33.79, 33.68, 22.66, 22.63, 14.33.

5-(4,5-bis(3-(cyclopentylmethyl)phenyl)thiophen-2-yl)-1H-tetrazole

(DNM0612) ^1H NMR (CDCl_3 , 500 MHz) δ 8.00 (s, 1H), 7.24 - 7.17 (m, 2H), 7.17 - 7.09 (m, 4H), 7.09 - 7.04 (m, 2H), 2.54 - 2.48 (m, 4H), 2.00 - 1.87 (m, 2H), 1.69 - 1.54 (m, 8H), 1.54 - 1.41 (m, 4H), 1.17 - 1.00 (m, 4H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 152.84, 144.09, 143.03, 142.82, 139.94, 135.22, 133.02, 132.94, 129.97, 129.77, 129.12, 128.70, 128.57, 128.14, 126.76, 126.41, 122.42, 42.08, 41.99, 32.56, 25.06.

Example 2

Synthesis of DNM0576 and analogues



4-Bromo-5-(4-methylnaphthalen-1-yl)thiophene-2-carbonitrile A round-bottomed flask was charged with 4,5-dibromothiophene-2-carbonitrile (536 mg, 2.00 mmol), 4-methylnaphthalen-1-ylboronic acid (409 mg, 2.20 mmol), Pd₂(dba)₃ (18.3 mg, 0.020 mmol) and KF (383 mg, 6.60). After degassed, dioxane (5 mL) and P(Bu-*t*)₃ (0.24 mL, 0.2M, 0.048 mmol) was added. The reaction mixture was stirred at rt until complete. 30 mL of water was added, and the reaction mixture was extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: CH₂Cl₂ = 3: 1). 0.58 g (88 %) of product was obtained as a white solid.

4-(4-Chloro-2-methylphenyl)-5-(4-methylnaphthalen-1-yl)thiophene-2-carbonitrile A round-bottomed flask was charged with 4-bromo-5-(4-methylnaphthalen-1-yl)thiophene-2-carbonitrile (203 mg, 0.62 mmol), 4-chloro-2-methylphenylboronic acid (119 mg, 0.70 mmol), Pd₂(dba)₃ (9.2 mg, 0.010 mmol) and KF (126 mg, 2.17). After degassed, dioxane (2.0 mL) and P(Bu-*t*)₃ (0.15 mL, 0.2M, 0.03 mmol) was added. The reaction mixture was stirred at rt until complete. 20 mL of water was added, and the reaction mixture was extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: CH₂Cl₂ = 3: 1). 0.21 g (90.6 %) of product was obtained as a white solid.

5-(4-(4-Chloro-2-methylphenyl)-5-(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0576) A round-bottomed flask was charged with 4-(4-chloro-2-methylphenyl)-5-(4-methylnaphthalen-1-yl)thiophene-2-carbonitrile (209 mg, 0.56 mmol), zinc bromide (338 mg, 1.50 mmol) and sodium azide (97.5 mg, 1.50 mmol).

After degassed, DMF (3 mL) was added. The reaction mixture was heated to 110 °C and stirred at this temperature until complete. The reaction was cooled to rt, and 30 mL of 0.1 N aqueous HCl was added. The reaction mixture was extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: EtOAc: AcOH = 30: 10: 1). 196 mg (84 %) of product was obtained as a white solid, ¹H NMR (DMSO, 500 MHz) δ 8.03 (d, *J* = 8.40 Hz, 1H), 7.88 (s, 1H), 7.80 (d, *J* = 8.05 Hz, 1H), 7.55 (t, *J* = 7.68 Hz, 1H), 7.48 (t, *J* = 7.65 Hz, 1H), 7.45 (d, *J* = 7.19 Hz, 1H), 7.37 (d, *J* = 7.30 Hz, 1H), 7.23 (d, *J* = 1.95 Hz, 1H), 7.09 (d, *J* = 8.25 Hz, 1H), 7.04 (dd, *J*₁ = 8.25 Hz, *J*₂ = 2.06 Hz, 1H), 2.65 (s, 3H), 2.17 (s, 3H); ¹³C NMR (DMSO, 125 MHz) δ 172.05, 141.01, 139.65, 138.35, 135.93, 133.73, 132.18, 132.10, 131.64, 131.31, 131.26, 129.80, 129.23, 127.62, 126.45, 126.26, 126.02, 125.53, 125.51, 124.67, 21.08, 19.82.

The following compounds were also prepared using an analogous method:

5-(4-(4-Chlorophenyl)-5-(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0572) ¹H NMR (CDCl₃, 500 MHz) δ 8.09 (d, *J* = 8.39 Hz, 1H), 7.84 (s, 1H), 7.82 (d, *J* = 8.46 Hz, 1H), 7.56 (t, *J* = 7.32 Hz, 1H), 7.44 (t, *J* = 7.84 Hz, 1H), 7.31 (d, *J* = 7.25 Hz, 1H), 7.23 (d, *J* = 7.24 Hz, 1H), 7.17-7.09 (m, 4H), 2.76 (s, 3H); ¹³C NMR (CDCl₃, 125 MHz) δ 152.64, 142.65, 138.24, 135.00, 134.09, 133.65, 133.08, 132.16, 131.91, 131.87, 129.76, 128.93, 127.95, 126.54, 126.37, 126.30, 126.11, 124.78, 124.46, 19.80.

5-(4-(5-Chlorophenyl)-4-(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0575) ¹H NMR (DMSO, 500 MHz) δ 8.11 (s, 1H), 8.09 (d, *J* = 8.44 Hz, 1H), 7.65 (d, *J* = 8.11 Hz, 1H), 7.58 - 7.53 (m, 2H), 7.49 - 7.42 (m, 2H), 7.28 - 7.20 (m,

4H), 2.72 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 139.74, 139.15, 136.18, 133.66, 132.29, 132.15, 131.14, 130.40, 129.40, 129.23, 128.61, 127.69, 126.69, 126.36, 126.28, 125.47, 124.77, 19.23.

5-(4-(4-Fluorophenyl)-5-(4-(methylsulfonyl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0592) ^1H NMR (DMSO, 500 MHz) δ 7.96 (s, 1H), 7.94 (d, $J = 8.45$ Hz, 2H), 7.57 (d, $J = 8.45$ Hz, 2H), 7.45 - 7.38 (m, 2H), 7.28 (t, $J = 8.80$ Hz, 2H), 3.27 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 163.32, 161.36, 141.61, 139.83, 139.71, 137.14, 131.45, 131.38, 131.32, 129.58, 129.42, 128.44, 128.42, 127.46, 124.88, 116.37, 116.19, 43.36.

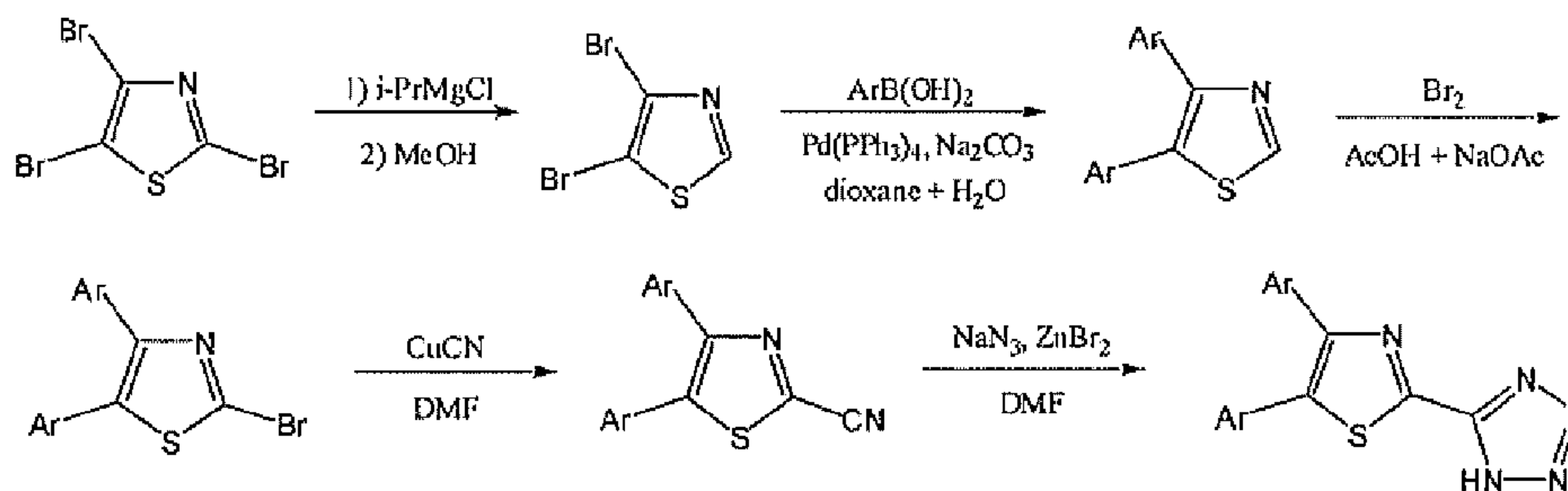
Ethyl 3-(2-(4-methylnaphthalen-1-yl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)benzoate (DNM0596) ^1H NMR (CDCl_3 , 500 MHz) δ 8.00 (d, $J = 8.40$ Hz, 1H), 7.96 (t, $J = 1.64$ Hz, 1H), 7.87 (s, 1H), 7.83 (dt, $J_1 = 7.85$ Hz, $J_2 = 1.35$ Hz, 1H), 7.73 (d, $J = 8.36$ Hz, 1H), 7.35 (t, $J = 7.60$ Hz, 1H), 7.28 (d, $J = 7.79$ Hz, 1H), 7.22 (d, $J = 7.74$ Hz, 1H), 7.17 (d, $J = 7.10$ Hz, 1H), 7.14 (t, $J = 7.85$ Hz, 1H), 4.24 (q, $J = 7.07$ Hz, 2H), 2.68 (s, 3H), 1.24 (t, $J = 7.15$ Hz, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 166.77, 143.43, 138.88, 135.13, 134.17, 133.51, 133.05, 132.84, 132.03, 131.41, 130.72, 129.59, 129.31, 128.91, 127.95, 126.46, 126.36, 126.14, 124.71, 123.55, 61.60, 19.76, 14.21.

Ethyl 3-(2-(4-chloro-2-methylphenyl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)benzoate (DNM0597) ^1H NMR (CDCl_3 , 500 MHz) δ 8.01 - 7.95 (m, 2H), 7.78 (s, 1H), 7.41 - 7.33 (m, 2H), 7.23 (s, 1H), 7.19 (dd, $J_1 = 8.22$ Hz, $J_2 = 1.50$ Hz, 1H), 7.14 (d, $J = 8.22$ Hz, 1H), 4.38 (q, $J = 7.15$ Hz, 2H), 2.04 (s, 3H), 1.40 (t, $J = 7.14$ Hz, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 166.58, 142.77, 138.62, 138.53, 134.15, 133.77, 133.52,

132.76, 132.50, 131.59, 131.14, 130.70, 129.59, 129.35, 129.24, 126.57, 124.34, 61.74, 20.16, 14.39.

Example 3

Synthesis of DNM0574 and analogues



4,5-Dibromothiazole To a solution of 2,4,5-triibromothiazole (3.12 g, 9.67 mmol) in anhydrous THF (25 mL) was added *i*-PrMgCl (4.84 mL, 2M in THF, 9.67 mmol) at ice-salt bath temperature under argon. After complete addition, the reaction was stirred for 1h at ice-salt bath temperature, and then quenched with methanol (2 mL). The reaction was worked up with a typical procedure, and the crude product was purified by flash chromatography (30 % of DCM in hexane) to afford 1.45 g of product.

4,5-Bis(4-chloro-2-methylphenyl)thiazole A round-bottomed flask was charged with 4,5-dibromothiazole (160 mg, 0.66 mmol), 4-chloro-2-methylphenylboronic acid (269 mg, 1.58 mmol) and Pd(PPh₃)₄ (38.1 mg, 0.033 mmol). After degassed, dioxane (5 mL) and aqueous sodium carbonate (3 mL, 2M, 6 mmol) was added. The reaction mixture was heated to 90 °C. The progress of the reaction was monitored by TLC. After the reaction was complete, 50 mL of water was added, and the reaction mixture was extracted with ethyl acetate. The organic phase was dried over anhydrous

sodium sulphate and then concentrated. The residue was purified by flash chromatography to afford 170 mg of product as clear oil.

2-Bromo-4,5-bis(4-chloro-2-methylphenyl)thiazole A solution of 4,5-Bis(4-chloro-2-methylphenyl)thiazole (170 mg, 0.51 mmol), NBS (100 mg, 0.56 mmol) and NaOAc (82 mg, 1.0 mmol) in AcOH (5 mL) and DCM (3 mL) was stirred overnight at rt, and then quenched with water (25 mL) and extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography to afford 196 mg of product.

4,5-Bis(4-chloro-2-methylphenyl)thiazole-2-carbonitrile A round-bottomed flask was charged with 2-Bromo-4,5-bis(4-chloro-2-methylphenyl)thiazole (196 mg, 0.47 mmol) and CuCN (84.2 mg, 0.94 mmol). After degassed, 3 mL of DMF was added. The reaction mixture was heated to 150 °C overnight. After cooled to room temperature, the reaction was quenched with 25 mL of water, and extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography to afford 150 mg of product.

4,5-Bis(4-chloro-2-methylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0574) A round-bottomed flask was charged with 4,5-bis(4-chloro-2-methylphenyl)thiazole-2-carbonitrile (150 mg, 0.42 mmol), zinc bromide (189 mg, 0.84 mmol) and sodium azide (45.5 mg, 0.84 mmol). After degassed, DMF (3 mL) was added. The reaction mixture was heated to 150 °C overnight. After cooled to rt, the reaction was quenched with 30 mL of 0.1 N aqueous HCl, and extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: EtOAc: AcOH = 30: 10: 1). 120 mg of product was obtained as

a white solid, ^1H NMR (DMSO, 500 MHz) δ 7.93 (d, $J = 8.41$ Hz, 1H), 7.57 (d, $J = 1.90$ Hz, 1H), 7.49 - 7.44 (m, 2H), 7.33 - 7.28 (m, 2H), 2.63 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 166.07, 153.61, 139.50, 138.74, 134.92, 133.48, 132.53, 131.87, 131.42, 130.27, 129.98, 126.64, 125.67, 21.13, 19.51.

The following compounds were also prepared using an analogous method:

4,5-Bis(5-chloro-2-methylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0567)

^1H NMR (DMSO, 500 MHz) δ 7.95 (d, $J = 2.17$ Hz, 1H), 7.54 (dd, $J_1 = 8.25$ Hz, $J_2 = 1.80$ Hz, 1H), 7.48 (d, $J = 8.25$ Hz, 1H), 7.45 (dd, $J_1 = 8.23$ Hz, $J_2 = 2.33$ Hz, 1H), 7.41 - 7.36 (m, 2H), 2.61 (s, 3H), 2.11 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 165.31, 152.99, 135.93, 135.54, 135.31, 133.72, 133.07, 132.04, 130.99, 130.09, 129.94, 129.64, 128.79, 128.72, 20.82, 19.03.

4,5-Bis(3-chloro-4-methylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0568)

^1H NMR (DMSO, 500 MHz) δ 8.09 (d, $J = 1.30$ Hz, 1H), 7.92 (dd, $J_1 = 7.93$ Hz, $J_2 = 1.38$ Hz, 1H), 7.79 (d, $J = 1.20$ Hz, 1H), 7.57 - 7.50 (m, 2H), 7.43 (d, $J = 7.95$ Hz, 1H), 2.42 (s, 3H), 2.39 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 166.30, 153.18, 138.95, 136.51, 134.29, 133.22, 132.68, 132.20, 131.49, 131.20, 129.01, 127.53, 126.22, 125.36, 19.68, 19.50.

4,5-Bis(4-methylnaphthalen-1-yl)-2-(1H-tetrazol-5-yl)thiazole (DNM0569)

^1H NMR (DMSO, 500 MHz) δ 9.99 (d, $J = 7.91$ Hz, 1H), 8.16 (t, $J = 9.52$ Hz, 2H), 8.04 (d, $J = 7.35$ Hz, 1H), 7.86 (d, $J = 8.41$ Hz, 1H), 7.47 - 7.49 (m, 6H), 7.47 (d, $J = 7.30$ Hz, 1H), 2.764 (s, 3H), 2.761 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 167.71, 154.55, 138.21, 135.74, 132.61, 132.41, 131.55, 129.79, 129.58, 129.06, 128.26, 127.48, 127.41, 126.69, 126.34, 126.23, 126.13, 126.04, 125.93, 125.83, 124.78, 124.59, 19.52, 19.23.

4,5-Bis(4-chlorophenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0573) ^1H NMR (DMSO, 500 MHz) δ 8.10 (d, $J = 8.43$ Hz, 2H), 7.74 (d, $J = 8.44$ Hz, 2H), 7.64 (d, $J = 7.50$ Hz, 2H), 5.3 (d, $J = 8.50$ Hz, 2H); ^{13}C NMR (DMSO, 125 MHz) δ 166.61, 153.57, 135.94, 133.87, 132.11, 130.85, 130.74, 129.52, 128.50, 128.29.

4,5-Bis(4-fluoronaphthalen-1-yl)-2-(1H-tetrazol-5-yl)thiazole (DNM0578) ^1H NMR (DMSO, 500 MHz) δ 9.02-8.95 (m, 1H), 8.24-8.16 (m, 3H), 7.88 (d, $J = 8.49$ Hz, 1H), 7.79-7.73 (m, 1H), 7.73-7.67 (m, 2H), 7.62 (t, $J = 7.80$ Hz, 1H), 7.58 (dd, $J_1 = 8.21$ Hz, $J_2 = 10.14$ Hz, 1H), 7.47 (dd, $J_1 = 7.96$ Hz, $J_2 = 10.54$ Hz, 1H); ^{13}C NMR (DMSO, 125 MHz) δ 166.76, 160.47, 159.60, 158.43, 157.59, 153.30, 132.99, 132.96, 131.08, 130.07, 129.99, 129.08, 128.99, 128.92, 127.82, 127.58, 126.92, 125.63, 123.39, 123.26, 123.23, 123.10, 120.54, 120.49, 120.35, 120.30, 109.92, 109.75, 109.55, 109.40.

4,5-Bis(4-biphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0581) ^1H NMR (DMSO, 500 MHz) δ 8.17 (d, $J = 8.32$ Hz, 2H), 7.89 (d, $J = 8.32$ Hz, 2H), 7.84-7.72 (m, 8H), 7.56-7.47 (m, 4H), 7.47-7.38 (m, 2H); ^{13}C NMR (DMSO, 125 MHz) δ 167.64, 154.70, 142.75, 140.67, 139.37, 138.93, 132.38, 131.10, 129.43, 129.12, 129.05, 128.23, 127.84, 127.60, 127.17, 126.79, 126.70, 126.68.

4,5-Bis(4-*t*-butylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0582) ^1H NMR (DMSO, 500 MHz) δ 7.99 (d, $J = 8.25$ Hz, 2H), 7.60 (d, $J = 8.25$ Hz, 4H), 7.48 (d, $J = 8.30$ Hz, 2H), 1.34 (s, 9H), 1.32 (s, 9H); ^{13}C NMR (DMSO, 125 MHz) δ 167.93, 155.03, 154.21, 151.65, 130.58, 129.56, 128.52, 126.35, 126.27, 125.27, 34.77, 34.51, 31.02, 30.87.

4,5-Bis(3,4-dimethylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0583) ^1H NMR (DMSO, 500 MHz) δ 7.85 (s, 1H), 7.79 (dd, $J_1 = 1.65$, $J_2 = 7.80$ Hz, 1H), 7.47 (s,

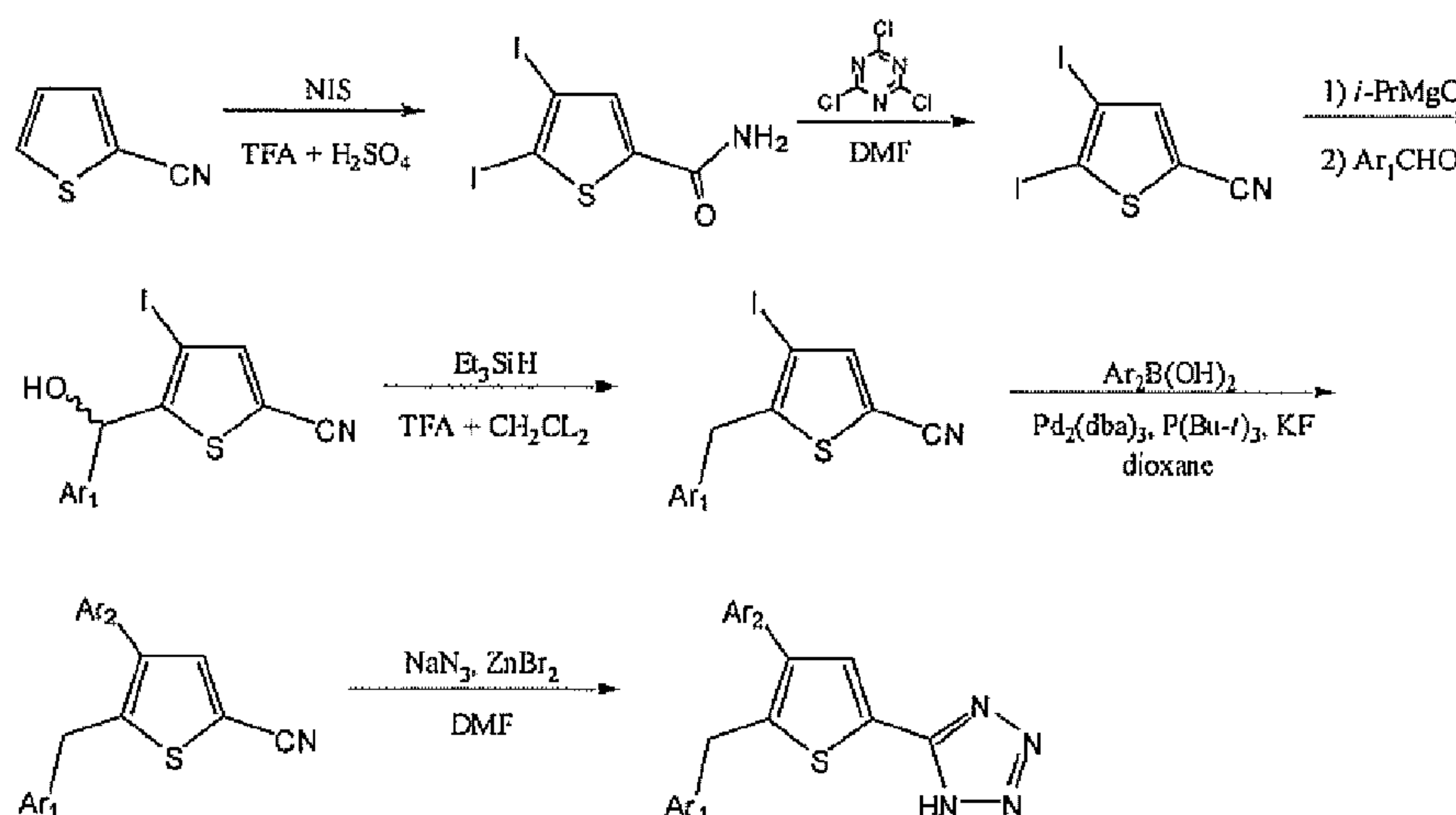
1H), 7.34 (d, $J = 7.95$ Hz, 1H), 7.29 (d, $J = 7.70$ Hz, 1H), 7.19 (d, $J = 7.85$ Hz, 1H), 2.34 (s, 3H), 2.31 (s, 3H), 2.28 (s, 3H), 2.25 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 168.65, 155.73, 140.64, 138.00, 137.85, 136.73, 131.33, 130.85, 130.32, 130.17, 129.93, 127.70, 126.54, 124.49, 19.91, 19.87, 19.75, 19.71.

4,5-Bis(4-chloro-2-isopropylphenyl)-2-(1H-tetrazol-5-yl)thiazole (DNM0584)

^1H NMR (DMSO, 500 MHz) δ 7.73 (d, $J = 8.35$ Hz, 1H), 7.62 (d, $J = 2.20$ Hz, 1H), 7.52 (d, $J = 2.10$ Hz, 1H), 7.47 (dd, $J_1 = 2.18$, $J_2 = 8.33$ Hz, 1H), 7.30 (dd, $J_1 = 2.13$, $J_2 = 8.23$ Hz, 1H), 7.25 (d, $J = 8.20$ Hz, 1H), 3.77 (sep, $J = 6.85$ Hz, 1H), 2.93 (sep, $J = 6.83$ Hz, 1H), 1.21 (d, $J = 6.85$ Hz, 6H), 1.11 (d, $J = 6.80$ Hz, 6H); ^{13}C NMR (DMSO, 125 MHz) δ 166.64, 154.25, 150.51, 150.06, 136.15, 134.62, 132.72, 132.50, 131.94, 129.84, 127.13, 126.93, 126.22, 126.16, 30.57, 29.36, 23.72, 23.59.

Example 4

Synthesis of DNM0577 and analogues



4,5-Diiodothiophene-2-carboxamide Thiophene-2-carbonitrile (5.39 g, 49.39

mmol) was dissolved in a mixture of H_2SO_4 (10 mL) and TFA (30 mL). NIS (23.34 g,

103.74 mmol) was added in portion in 30 min. After complete addition, the reaction

mixture was further stirred for 4h, and then poured onto 300 g of crushed ice. A white solid was formed, which was collected, washed with water, and dried together with phosphorous pentoxide under vacuum to afford 17.8 g (95 %) of product.

4,5-Diiodothiophene-2-carbonitrile An oven-dried round-bottomed flask was charged with 4,5-diiodothiophene-2-carboxamide (5.68 g, 15.0 mmol) and 20 mL of DMF under an argon atmosphere. The solution was cooled on an ice-water bath, and cyanuric chloride (1.81 g, 9.8 mmol) was then added in one portion. After stirring at 0 °C for 1 h, the reaction mixture was warmed to room temperature, and stirred for a further 3h. 100 mL of water was added. A white solid was formed, which was collected through suction filtration, washed with water, and dried together with phosphorous pentoxide under vacuum to afford 4.87 g (90 %) of product.

5-((4-Chlorophenyl)(hydroxy)methyl)-4-iodothiophene-2-carbonitrile An oven-dried round-bottomed flask was charged with 4,5-diiodothiophene-2-carbonitrile (1.80 g, 5.0 mmol). After degassed, anhydrous THF (15 mL) was added through syringe. After cooled to -78 °C, *i*-PrMgCl (3 mL, 2.0 M, 6.0 mmol) was added dropwise. The reaction was further stirred for 30 min at -78 °C after complete addition. 4-chlorobenzaldehyde (0.98 g, 7.0 mmol) in 5 mL THF was then added. After stirring for 10 min at -78 °C for 1 h, the reaction mixture was warmed to room temperature. 50 mL of saturated aqueous NH₄Cl was added. The reaction mixture was extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: EtOAc: CH₂CL₂ = 30: 3: 10). 1.39 g (74 %) of product was obtained as a white solid.

5-(4-Chlorobenzyl)-4-iodothiophene-2-carbonitrile A round-bottomed flask was charged with 5-((4-chlorophenyl)(hydroxy)methyl)-4-iodothiophene-2-carbonitrile (1.67 g, 4.45 mmol). After degassed, dichloromethane (8 mL), TFA (4 mL) and triethylsilane (1.1 mL, 6.9 mmol) was added sequentially through syringe. The reaction was further stirred at rt until complete, and then concentrated. The residue was purified by flash chromatography (hexane: CH₂Cl₂ = 2: 1). 1.36 g (85 %) of product was obtained as a white solid.

5-(4-Chlorobenzyl)-4-(4-methylnaphthalen-1-yl)thiophene-2-carbonitrile A round-bottomed flask was charged with 5-(4-chlorobenzyl)-4-iodothiophene-2-carbonitrile (180 mg, 0.50 mmol), 4-methylnaphthalen-1-ylboronic acid (102 mg, 0.55 mmol), Pd₂(dba)₃ (9.2 mg, 0.010 mmol) and KF (126 mg, 2.17). After degassed, dioxane (2.0 mL) and P(Bu-*t*)₃ (0.15 mL, 0.2M, 0.03 mmol) was added. The reaction mixture was stirred at rt until complete. 20 mL of water was added, and the reaction mixture was extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (5 % ethyl acetate in hexane). 0.17 g (91 %) of product was obtained as a white solid.

5-(5-(4-Chlorobenzyl)-4-(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0577) A round-bottomed flask was charged with 5-(4-chlorobenzyl)-4-(4-methylnaphthalen-1-yl)thiophene-2-carbonitrile (170 mg, 0.45 mmol), zinc bromide (338 mg, 1.50 mmol) and sodium azide (97.5 mg, 1.50 mmol). After degassed, DMF (3 mL) was added. The reaction mixture was heated to 110 °C and stirred at this temperature until complete. The reaction was cooled to rt and 30 mL of 0.1 N aqueous HCl was added. The reaction mixture was extracted with ethyl acetate. The organic phase was

dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: EtOAc: AcOH = 30: 10: 1). 161 mg (85 %) of product was obtained as a white solid, ^1H NMR (CDCl_3 , 500 MHz) δ 8.05 (d, $J = 8.46$ Hz, 1H), 7.73 (s, 1H), 7.63 (d, $J = 8.36$ Hz, 1H), 7.53 (t, $J = 7.58$ Hz, 1H), 7.42 (t, $J = 7.53$ Hz, 1H), 7.33 (d, $J = 7.11$ Hz, 1H), 7.23 (d, $J = 7.08$ Hz, 1H), 7.14 (d, $J = 8.25$ Hz, 2H), 6.92 (d, $J = 8.14$ Hz, 2H), 3.86 (ABq, 2H, $\Delta\delta_{\text{AB}} = 0.06$, $J_{\text{AB}} = 15.90$ Hz), 2.70 (s, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 152.61, 145.54, 139.59, 137.96, 135.22, 132.97, 132.76, 132.69, 132.27, 131.09, 130.05, 128.81, 127.55, 126.33, 126.25, 126.20, 126.16, 124.75, 122.29, 34.24, 19.77.

The following compounds were also prepared using an analogous method:

5-(5-(4-Chlorobenzyl)-4-(4-chlorophenyl)thiophenyl)-1H-tetrazole

(DNM0579) ^1H NMR (DMSO, 500 MHz) δ 7.80 (s, 1H), 7.57 (d, $J = 8.70$ Hz, 2H), 7.53 (d, $J = 8.70$ Hz, 2H), 7.40 (d, $J = 8.34$ Hz, 2H), 7.26 (d, $J = 8.34$ Hz, 2H), 4.30 (s, 2H); ^{13}C NMR (DMSO, 125 MHz) δ 143.21, 138.47, 138.38, 133.64, 132.51, 131.51, 130.65, 130.49, 130.24, 128.89, 128.65, 122.97, 32.99.

5-(5-(4-Chlorobenzyl)-4-(4-chloro-2-iso-propylphenyl)thiophenyl)-1H-

tetrazole (DNM0580) ^1H NMR (CDCl_3 , 500 MHz) δ 7.66 (s, 1H), 7.31 (d, $J = 2.05$ Hz, 1H), 7.19 (d, $J = 8.35$ Hz, 2H), 7.16 (dd, $J_1 = 8.12$ Hz, $J_2 = 2.10$ Hz, 1H), 6.99 (d, $J = 8.20$ Hz, 1H), 7.23 (d, $J = 78.35$ Hz, 2H), 3.89 (ABq, 2H, $\Delta\delta_{\text{AB}} = 0.04$, $J_{\text{AB}} = 14.13$ Hz), 2.76 (sep, $J = 6.85$ Hz, 1H), 1.10 - 0.97 (m, 6H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 152.60, 149.93, 144.93, 139.52, 137.57, 134.85, 132.95, 131.97, 131.93, 131.70, 130.02, 129.01, 126.41, 126.15, 122.28, 30.02, 30.85, 24.57, 23.42.

5-(5-(4-Chlorobenzyl)-4-(4-fluoronaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0587) ^1H NMR (DMSO, 500 MHz) δ 8.17 (d, J = 8.25 Hz, 1H), 7.75 - 7.69 (m, 2H), 7.69 - 7.62 (m, 2H), 7.53 - 7.42 (m, 2H), 7.30 - 7.25 (m, 2H), 7.11 - 7.06 (m, 2H), 4.10 - 3.91 (m, 2H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 158.86, 156.86, 144.75, 138.33, 137.42, 132.85, 132.81, 131.60, 131.28, 130.30, 128.78, 128.75, 128.41, 127.93, 127.85, 127.78, 126.99, 125.40, 125.38, 123.10, 122.97, 120.43, 120.39, 109.53, 109.37, 33.01, 21.07.

5-(4-(Biphenyl-2-yl)-5-(4-chlorobenzyl)thiophen-2-yl)-1H-tetrazole (DNM0588) ^1H NMR (DMSO, 500 MHz) δ 7.58 - 7.52 (m, 1H), 7.52 - 7.46 (m, 3H), 7.43 (d, J = 7.60 Hz, 2H), 7.33 - 7.24 (m, 5H), 7.20 - 7.13 (m, 2H), 6.89 (d, J = 8.33 Hz, 2H), 3.73 (s, 2H); ^{13}C NMR (DMSO, 125 MHz) δ 143.34, 140.80, 140.48, 139.40, 138.13, 133.20, 131.66, 131.37, 130.76, 130.42, 130.30, 129.03, 128.69, 128.42, 128.23, 127.71, 127.03, 122.21, 33.01.

Ethyl 3-(2-(4-chlorobenzyl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)benzoate (DNM0595) ^1H NMR (DMSO, 500 MHz) δ 8.09-7.93 (m, 2H), 7.87 (s, 1H), 7.80 (d, J = 7.24 Hz, 1H), 7.66 (t, J = 7.71 Hz, 1H), 7.40 (d, J = 7.86 Hz, 2H), 7.26 (d, J = 7.86 Hz, 2H), 4.52 - 4.14 (m, 4H), 1.31 (t, J = 7.07 Hz, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 165.42, 143.15, 138.63, 138.45, 135.17, 133.07, 131.49, 130.65, 130.48, 130.40, 129.46, 128.79, 128.64, 128.37, 123.12, 60.94, 32.96, 14.11.

1-(3-(2-(4-Chlorobenzyl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)phenyl)butan-1-one (DNM0600) ^1H NMR (DMSO, 500 MHz) δ 8.00 - 7.97 (m, 2H), 7.88 (s, 1H), 7.77 (d, J = 7.70 Hz, 1H), 7.65 (t, J = 7.95 Hz, 1H), 7.39 (d, J = 8.40 Hz, 2H), 7.26 (d, J = 8.40 Hz, 2H), 4.32 (s, 2H), 2.98 (t, J = 7.15 Hz, 2H), 1.63 (sex, J = 7.30 Hz, 1H), 0.93 (t,

$J = 7.35$ Hz, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 199.80, 142.91, 138.94, 138.55, 137.20, 135.19, 132.80, 131.50, 130.68, 130.42, 129.40, 128.66, 127.75, 127.08, 123.27, 39.85, 32.99, 17.17, 13.61.

5-(4-(3-Butylphenyl)-5-(4-chlorobenzyl)thiophen-2-yl)-1H-tetrazole

(DNM0606) ^1H NMR (DMSO, 500 MHz) δ 7.81 (s, 1H), 7.42 - 7.34 (m, 3H), 7.32 - 7.26 (m, 2H), 7.26 - 7.21 (m, 3H), 4.30 (s, 2H), 2.62 (t, $J = 7.65$ Hz, 2H), 1.56 (qi, $J = 7.55$ Hz, 2H), 1.31 (sex, $J = 7.54$ Hz, 2H), 0.90 (t, $J = 7.37$ Hz, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 142.95, 139.99, 138.72, 134.71, 131.41, 130.87, 130.39, 128.77, 128.59, 128.58, 128.34, 127.76, 125.68, 122.74, 34.73, 33.04, 21.75, 13.79.

Ethyl 3-(2-(4-chlorobenzyl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)-5-

hydroxybenzoate (DNM0609) ^1H NMR (DMSO, 500 MHz) δ 10.12 (s, 1H), 7.81 (s, 1H), 7.45 (s, 1H), 7.43 - 7.38 (m, 3H), 7.27 (d, $J = 8.35$ Hz, 2H), 7.14 (s, 1H), 4.34 - 4.25 (m, 4H), 1.30 (t, $J = 7.10$ Hz, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 165.41, 157.89, 150.98, 142.84, 138.79, 138.53, 136.37, 131.64, 131.47, 130.45, 130.38, 128.64, 123.18, 119.84, 119.74, 114.99, 60.87, 32.99, 14.11.

5-(5-(4-Chlorobenzyl)-4-(3-(cyclopentylmethyl)phenyl)thiophen-2-yl)-1H-

tetrazole (DNM0610) ^1H NMR (DMSO, 500 MHz) δ 7.81 (s, 1H), 7.41 - 7.43 (m, 3H), 7.30 (d, $J = 7.70$ Hz, 1H), 7.26 (s, 1H), 7.25 - 7.19 (m, 3H), 4.30 (s, 2H), 2.61 (d, $J = 7.45$ Hz, 2H), 2.10 - 2.01 (m, 1H), 1.67 - 1.54 (m, 4H), 1.54 - 1.41 (m, 2H), 1.21 - 1.09 (m, 2H); ^{13}C NMR (DMSO, 125 MHz) δ 150.80, 142.42, 142.22, 140.05, 138.70, 134.61, 131.41, 130.92, 130.34, 128.70, 128.67, 128.58, 128.11, 125.68, 122.65, 41.32, 41.17, 33.01, 31.90, 24.48.

3-(2-(4-Chlorobenzyl)-5-(1H-tetrazol-5-yl)thiophen-3-yl)phenol (DNM0613)

¹H NMR (DMSO, 500 MHz) δ 9.65 (s, 1H), 7.65 (s, 1H), 7.40 (d, *J* = 8.35 Hz, 2H), 7.29 (t, *J* = 7.88 Hz, 1H), 7.26 (d, *J* = 8.40 Hz, 2H), 6.91 (d, *J* = 7.90 Hz, 1H), 6.87 (s, 1H), 6.82 (dd, *J*₁ = 1.79 Hz, *J*₂ = 8.10 Hz, 1H), 4.29 (s, 2H); ¹³C NMR (DMSO, 125 MHz) δ 157.66, 142.45, 139.94, 138.72, 136.01, 131.46, 130.76, 130.44, 129.94, 128.64, 119.11, 115.20, 114.78, 33.07.

5-(5-(4-Chlorobenzyl)-4-(3-methoxyphenyl)thiophen-2-yl)-1H-tetrazole

(DNM0615) ¹H NMR (DMSO, 500 MHz) δ 7.84 (s, 1H), 7.47 - 7.40 (m, 3H), 7.29 (d, *J* = 8.45 Hz, 2H), 7.09 (d, *J* = 7.80 Hz, 1H), 7.06 - 7.04 (m, 1H), 7.02 (dd, *J*₁ = 2.00 Hz, *J*₂ = 8.20 Hz, 1H), 4.34 (s, 2H), 3.81 (s, 3H); ¹³C NMR (DMSO, 125 MHz) δ 159.49, 142.69, 139.68, 138.70, 136.13, 131.45, 130.87, 130.44, 129.99, 128.65, 120.68, 113.83, 113.50, 55.14, 33.06.

5-(5-(4-Chlorobenzyl)-4-(3-butoxyphenyl)thiophen-2-yl)-1H-tetrazole

(DNM0616) ¹H NMR (DMSO, 500 MHz) δ 7.81 (s, 1H), 7.44 - 7.36 (m, 3H), 7.26 (d, *J* = 8.35 Hz, 2H), 7.05 (d, *J* = 7.60 Hz, 1H), 6.99 - 6.95 (m, 2H), 4.31 (s, 2H), 3.95 (t, *J* = 6.50 Hz, 2H), 1.69 (pen, *J* = 6.96 Hz, 2H), 1.43 (sex, *J* = 7.50 Hz, 2H), 0.94 (t, *J* = 7.40 Hz, 2H); ¹³C NMR (DMSO, 125 MHz) δ 158.90, 150.96, 142.40, 139.75, 138.74, 136.10, 131.43, 130.85, 130.39, 129.96, 128.63, 122.80, 120.51, 114.13, 67.14, 33.04, 30.73, 18.72, 13.72.

5-(5-(4-Chlorobenzyl)-4-(3-ethoxyphenyl)thiophen-2-yl)-1H-tetrazole

(DNM0617) ¹H NMR (DMSO, 500 MHz) δ 7.81 (s, 1H), 7.44 - 7.37 (m, 3H), 7.26 (d, *J* = 8.40 Hz, 2H), 7.05 (d, *J* = 7.65 Hz, 1H), 7.01 - 6.95 (m, 2H), 4.31 (s, 2H), 4.04 (q, *J* = 7.00 Hz, 2H), 1.33 (t, *J* = 7.00 Hz, 3H); ¹³C NMR (DMSO, 125 MHz) δ 158.74, 142.67,

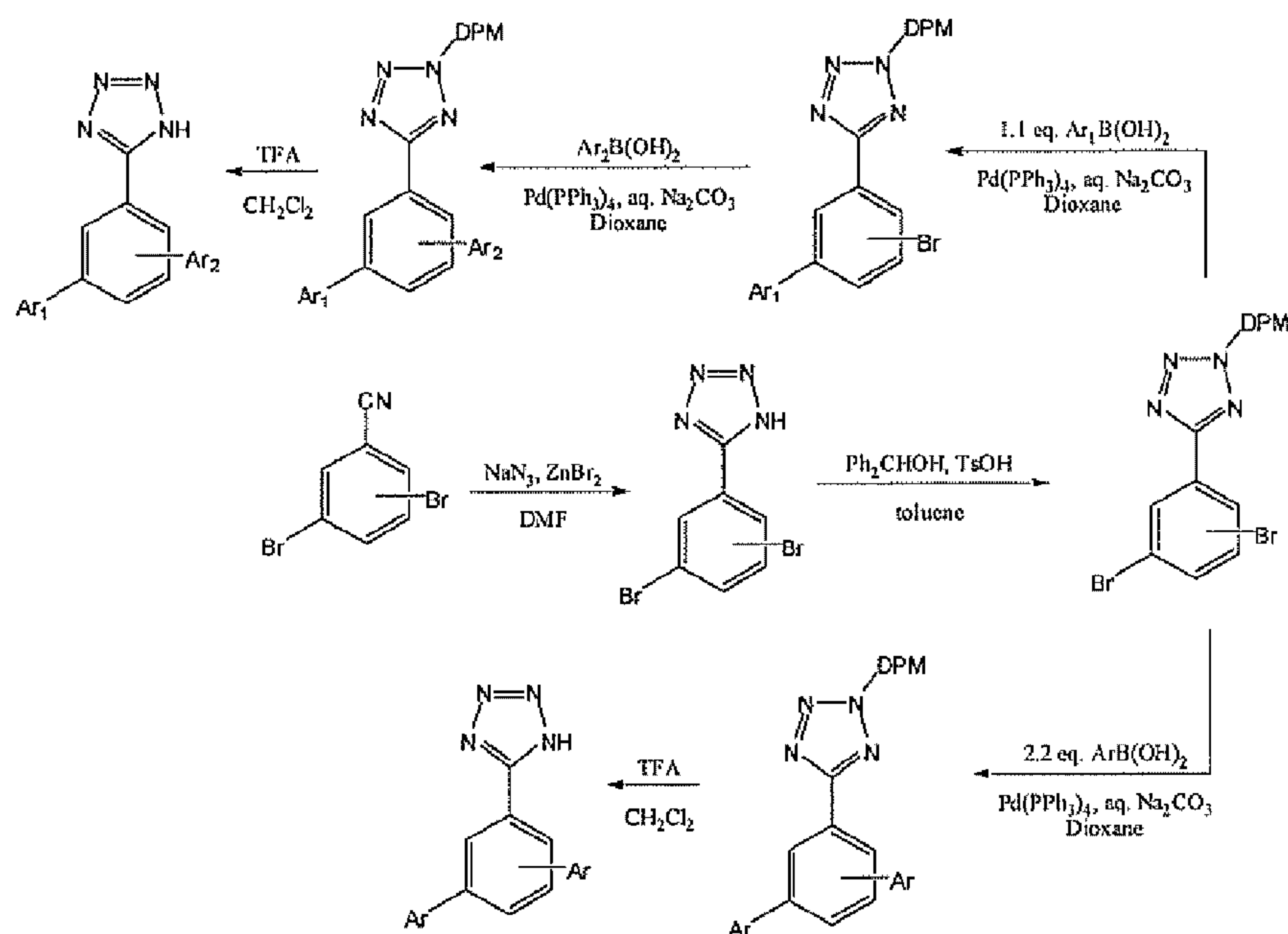
139.70, 138.71, 136.11, 131.44, 130.89, 130.43, 130.01, 128.63, 120.54, 114.20, 114.01, 63.05, 33.05, 14.63.

5-(5-(4-Chlorobenzyl)-4-(3-propoxyphenyl)thiophen-2-yl)-1H-tetrazole

(DNM0618) ^1H NMR (DMSO, 500 MHz) δ 7.82 (s, 1H), 7.43 - 7.36 (m, 3H), 7.26 (d, J = 8.40 Hz, 2H), 7.05 (d, J = 7.65 Hz, 1H), 7.00 - 6.95 (m, 2H), 4.31 (s, 2H), 3.91 (t, J = 6.60 Hz, 2H), 1.73 (sex, 7.06, 2H), 0.98 (t, J = 7.40 Hz, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 158.88, 142.50, 139.74, 138.73, 136.09, 131.43, 130.91, 130.39, 129.97, 128.63, 122.72, 120.51, 114.14, 68.92, 33.04, 22.02, 10.37.

Example 5

Synthesis of DNM0461 and analogues



5-(3,5-Dibromophenyl)-1H-tetrazole A round-bottomed flask was charged with 3,5-dibromobenzonitrile (15.65 g, 60.00 mmol), sodium azide (7.80 g, 120.00 mmol) and zinc bromide (27.00 g, 120.00 mmol). After degassed, DMF (100 mL) was added. The reaction mixture was heated to 120 °C and stirred at this temperature until complete. The

reaction was cooled to rt and then in an ice-water bath. 300 mL of 1N aqueous HCl was added. The white precipitate formed was collected by suction filtration, washed with water, and dried together with phosphorous pentoxide under vacuum to afford 17.32 g (95 %) of product.

2-Benzhydryl-5-(3,5-dibromophenyl)-2H-tetrazole A suspension of 5-(3,5-dibromophenyl)-1H-tetrazole (6.08 g, 20.00 mmol), diphenylmethanol (3.68 g, 20.00 mmol) and TsOH.H₂O (0.38 g, 2.00 mmol) in toluene (50.0 mL) was heated to 100 °C until a clear solution was obtained. The solution was cooled to rt, and filtered. The filtration was concentrated, and the residue was purified by recrystallization in ether and hexane to afford 8.00 g (85 %) of product as a white solid.

2-Benzhydryl-5-(3,5-bis(4-methylnaphthalen-1-yl)phenyl)-2H-tetrazole A round-bottomed flask was charged with 2-benzhydryl-5-(3,5-dibromophenyl)-2H-tetrazole (282 mg, 0.60 mmol), 4-methylnaphthalen-1-ylboronic acid (251 mg, 1.32 mmol) and Pd(PPh₃)₄ (35 mg, 0.03 mmol). After degassed, dioxane (5 mL) and aqueous sodium carbonate (3 mL, 2M, 6.0 mmol) was added. The reaction mixture was heated to 90 °C until the reaction was complete. 30 mL of water was added, and the reaction mixture was extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: CH₂Cl₂ = 2: 1) to afford 0.32 g (90 %) of product as a white solid.

5-(3,5-Bis(4-methylnaphthalen-1-yl)phenyl)-2H-tetrazole (DNM0461) 2-Benzhydryl-5-(3,5-bis(4-methylnaphthalen-1-yl)phenyl)-2H-tetrazole (0.32 g, 0.54 mmol) was dissolved in dichloromethane (2 mL). Anisole (0.3 mL, 2.76 mmol) and TFA

(1 mL) were added sequentially. The reaction was stirred overnight, and then concentrated. The residue was purified by flash chromatography (hexane: ethyl acetate: AcOH = 30: 10: 1) to afford 0.22 g (95.5 %) of product as a white solid, ^1H NMR (DMSO, 500 MHz) δ 8.24 (d, $J = 1.55$ Hz, 2H), 8.25 (d, $J = 8.15$ Hz, 2H), 8.03 (d, $J = 8.20$ Hz, 2H), 7.72 (s, 1H), 7.65 (t, $J = 7.58$ Hz, 2H), 7.60 (t, $J = 7.44$ Hz, 2H), 7.56 (d, $J = 7.15$ Hz, 2H), 7.51 (d, $J = 7.29$ Hz, 2H), 2.74 (s, 6H); ^{13}C NMR (DMSO, 125 MHz) δ 141.58, 136.38, 134.51, 133.81, 132.43, 130.72, 127.15, 127.03, 126.51, 126.32, 126.11, 125.61, 124.76, 19.21.

The following compounds were also prepared using an analogous method:

5-(2,5-Bis(4-methylnaphthalen-1-yl)phenyl)-1H-tetrazole (DNM0446) ^1H NMR (DMSO, 500 MHz) δ 8.16 (d, $J = 8.45$ Hz, 1H), 8.06 (d, $J = 8.41$ Hz, 2H), 7.97 (s, 1H), 7.80 (dd, $J_1 = 7.84$ Hz, $J_2 = 1.80$ Hz, 1H), 7.69 - 7.49 (m, 7H), 7.42 (t, $J = 7.56$ Hz, 1H), 7.39 (d, $J = 7.09$ Hz, 1H), 7.28 (d, $J = 7.09$ Hz, 1H), 2.73 (s, 3H), 2.70 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 139.96, 138.93, 136.37, 135.51, 134.38, 133.98, 132.46, 132.21, 132.06, 132.03, 131.37, 130.98, 130.80, 127.11, 127.00, 126.43, 126.34, 126.10, 126.04, 125.89, 125.76, 125.73, 124.73, 124.45, 19.23, 19.14.

5-(2,5-Bis(4-chloro-2-methylphenyl)phenyl)-1H-tetrazole (DNM0447) ^1H NMR (DMSO, 500 MHz) δ 7.79 (s, 1H), 7.65 (d, $J = 7.16$ Hz, 1H), 7.51 - 7.43 (m, 2H), 7.38 (s, 2H), 7.33 (s, 1H), 7.22 (d, $J = 8.09$ Hz, 1H), 7.05 (d, $J = 8.14$ Hz, 1H), 2.33 (s, 3H), 1.97 (s, 3H); ^{13}C NMR (DMSO, 125 MHz) δ 139.71, 138.72, 132.58, 138.20, 138.13, 137.59, 132.41, 132.10, 131.39, 131.20, 131.08, 130.96, 130.10, 130.05, 129.00, 126.06, 125.39, 20.05, 19.56.

5-(3,5-Bis(4-chlorophenyl)phenyl)-2H-tetrazole (DNM0470) ^1H NMR

(DMSO, 500 MHz) δ 8.34 (d, $J = 1.69$ Hz, 2H), 8.16 (d, $J = 1.69$ Hz, 2H), 7.95 - 7.91 (m, 4H), 7.65 - 7.61 (m, 4H); ^{13}C NMR (DMSO, 125 MHz) δ 140.76, 137.76, 133.22, 129.07, 128.94, 127.58, 124.42.

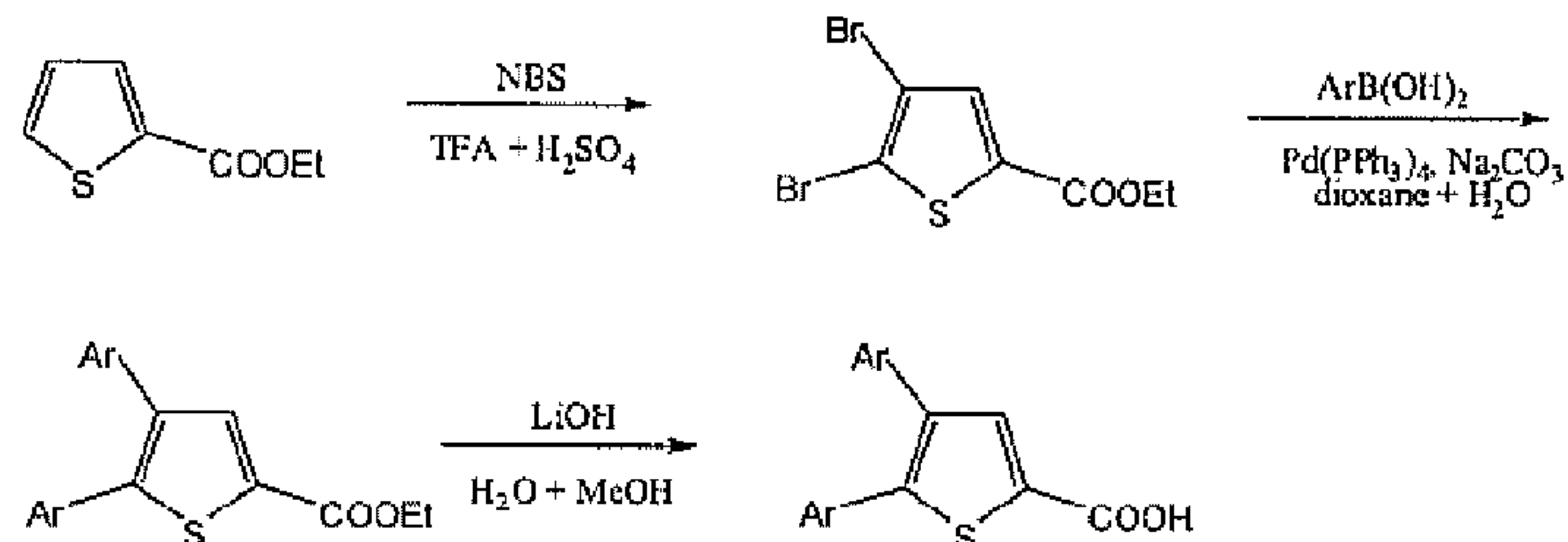
5-(4'-Chloro-5-(4-methylnaphthalen-1-yl)biphenyl-3-yl)-1H-tetrazole

(DNM0480) ^1H NMR (DMSO, 500 MHz) δ 8.42 (t, $J = 1.60$ Hz, 1H), 8.16 (d, $J = 7.98$ Hz, 1H), 8.14 (t, $J = 1.58$ Hz, 1H), 7.95 (t, $J = 1.62$ Hz, 1H), 7.92 (d, $J = 7.90$ Hz, 1H), 7.90 (d, $J = 8.70$ Hz, 2H), 7.67 - 7.63 (m, 1H), 7.61 (d, $J = 8.70$ Hz, 2H), 7.59-7.55 (m, 1H), 7.54 - 7.50 (m, 2H), 2.76 (s, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 143.14, 141.32, 138.28, 137.09, 134.98, 134.46, 133.04, 131.81, 131.53, 129.36, 128.72, 128.11, 127.06, 126.37, 126.31, 126.26, 126.08, 125.13, 124.79, 19.84.

5-(3,5-Bis(4-fluoronaphthalen-1-yl)phenyl)-2H-tetrazole (DNM0539) ^1H

NMR (DMSO, 500 MHz) δ 8.26 (d, $J = 1.55$ Hz, 2H), 8.19 (dd, $J_1 = 8.15$ Hz, $J_2 = 1.87$ Hz, 2H), 8.05 (d, $J = 7.87$ Hz, 2H), 7.77 (t, $J = 1.55$ Hz, 1H), 7.75-7.65 (m, 6H), 7.49 (dd, $J_1 = 10.60$ Hz, $J_2 = 7.95$ Hz, 2H); ^{13}C NMR (DMSO, 125 MHz) δ 158.81, 156.81, 140.71, 134.46, 134.42, 133.80, 132.00, 131.97, 128.67, 127.55, 127.48, 127.46, 126.96, 125.44, 125.42, 123.15, 123.02, 120.46, 120.42, 109.60, 109.44.

Example 6**Synthesis of DNM0566 and analogues**



Ethyl 4,5-dibromothiophene-2-carboxylate To a stirred solution of ethyl thiophene-2-carboxylate (12.62g, 80.8mmol) in 12 mL of sulfuric acid and 40 mL of TFA was added NBS (32.00g, 177.8mmol) in portions during 2~3 hours. After stirred overnight at room temperature, the reaction mixture was poured onto ice. The white precipitate formed was collected by suction filtration, and purified by recrystallization in methanol. 23.38g (92%) of product was obtained as a white solid, mp: 47.0 - 48.0 (lit. mp 48.0 – 49.0 °C, *Bull. Chem. Soc. Jpn.* **1991**, 64 (8), 2566-8).

Ethyl 4,5-bis(4-chloro-2-isopropylphenyl)thiophene-2-carboxylate A round-bottomed flask was charged with ethyl 4,5-dibromothiophene-2-carboxylate (235.5 mg, 0.75 mmol), 4-chloro-2-isopropylphenylboronic acid (327.5 mg, 1.65 mmol) and $\text{Pd(PPh}_3)_4$ (43 mg, 0.0375 mmol). After degassed, dioxane (5 mL) and aqueous sodium carbonate (3 mL, 2M, 6.0 mmol) was added. The reaction mixture was heated to 90 °C until the reaction was complete. After cooled to room temperature, the reaction mixture was diluted with 30 mL of water and then extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: CH_2Cl_2 = 2: 1) to afford 0.28 g (81 %) of product as a white solid.

4,5-Bis(4-chloro-2-isopropylphenyl)thiophene-2-carboxylic acid (DNM0566)

To a solution of ethyl 4,5-bis(4-chloro-2-isopropylphenyl)thiophene-2-carboxylate (280 mg, 0.61 mmol) in THF (3 mL) and MeOH (3 mL) was added a solution of LiOH (72 mg, 3.0 mmol) in water (2 mL). The reaction was stirred at rt until complete, and then concentrated. The residue was re-dissolved in 20 mL of water and acidified with 1N aq. HCl to pH 2. The white precipitate was extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by recrystallization in a mixture solvent of ethyl acetate and hexane to afford 0.24 g (91 %) of product as a white solid, ^1H NMR (CDCl_3 , 500 MHz) δ 7.78 (s, 1H), 7.23 (d, $J = 2.15$ Hz, 1H), 7.22 (d, $J = 1.88$ Hz, 1H), 7.13 - 7.07 (m, 2H), 7.03 (dd, $J_1 = 8.23$ Hz, $J_2 = 2.20$ Hz, 1H), 6.89 (d, $J = 8.26$ Hz, 1H), 2.95 (m, 2H), 1.04 (d, $J = 4.94$ Hz, 6H), 0.98 (d, $J = 6.95$ Hz, 6H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 167.13, 149.87, 149.06, 146.58, 139.45, 137.21, 135.53, 134.39, 132.79, 131.84, 131.57, 131.14, 129.01, 126.43, 126.28, 125.86, 125.77, 30.27, 30.23, 23.93.

The following compounds were also prepared using an analogous method:

4,5-Bis(4-biphenyl)thiophene-2-carboxylic acid (DNM0497) ^1H NMR (CDCl_3 , 500 MHz) δ 13.34 (s, 1H), 7.86 (s, 1H), 7.72 - 7.65 (m, 8H), 7.50 - 7.32 (m, 10H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 162.69, 143.94, 140.16, 139.30, 139.09, 139.00, 138.17, 135.56, 134.08, 133.00, 131.98, 129.46, 129.38, 129.02, 128.98, 127.87, 127.63, 127.12, 126.86, 126.61, 126.53.

4,5-Bis(4-chlorophenyl)thiophene-2-carboxylic acid (DNM0498) ^1H NMR (CDCl_3 , 500 MHz) δ 13.39 (s, 1H), 7.81 (s, 1H), 7.46 (d, $J = 8.40$ Hz, 2H), 7.42 (d, $J = 8.40$ Hz, 2H), 7.32 (d, $J = 8.50$ Hz, 2H), 7.29 (d, $J = 8.42$ Hz, 2H); ^{13}C NMR (CDCl_3 , 125

MHz) δ 162.53, 143.06, 137.68, 135.30, 133.60, 133.47, 133.44, 132.47, 131.46, 130.74, 130.64, 129.13, 128.78.

4,5-Bis(5-chloro-2-methylphenyl)thiophene-2-carboxylic acid (DNM0501) ^1H NMR (CDCl_3 , 500 MHz) δ 13.38 (s, 1H), 7.77 (s, 1H), 7.36 (d, $J = 2.20$ Hz, 1H), 7.34 (dd, $J_1 = 2.20$ Hz, $J_2 = 8.15$ Hz, 1H), 7.26 - 7.22 (m, 3H), 7.05 (s, 1H), 2.01 (s, 3H), 1.96 (s, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 162.63, 143.31, 138.84, 136.36, 135.58, 134.85, 134.75, 133.77, 133.76, 132.18, 132.08, 130.47, 130.07, 129.86, 129.60, 128.88, 127.74, 19.22, 19.09.

4,5-Bis(3-chlorophenyl)thiophene-2-carboxylic acid (DNM0502) ^1H NMR (CDCl_3 , 500 MHz) δ 13.34 (s, 1H), 7.85 (s, 1H), 7.47 (d, $J = 8.10$ Hz, 1H), 7.44 - 7.34 (m, 5H), 7.26 (d, $J = 7.65$ Hz, 1H), 7.20 (d, $J = 7.45$ Hz, 1H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 162.50, 142.92, 137.70, 136.57, 135.23, 134.51, 133.77, 133.50, 133.31, 130.87, 130.48, 128.75, 128.56, 128.53, 127.85, 127.69, 127.63.

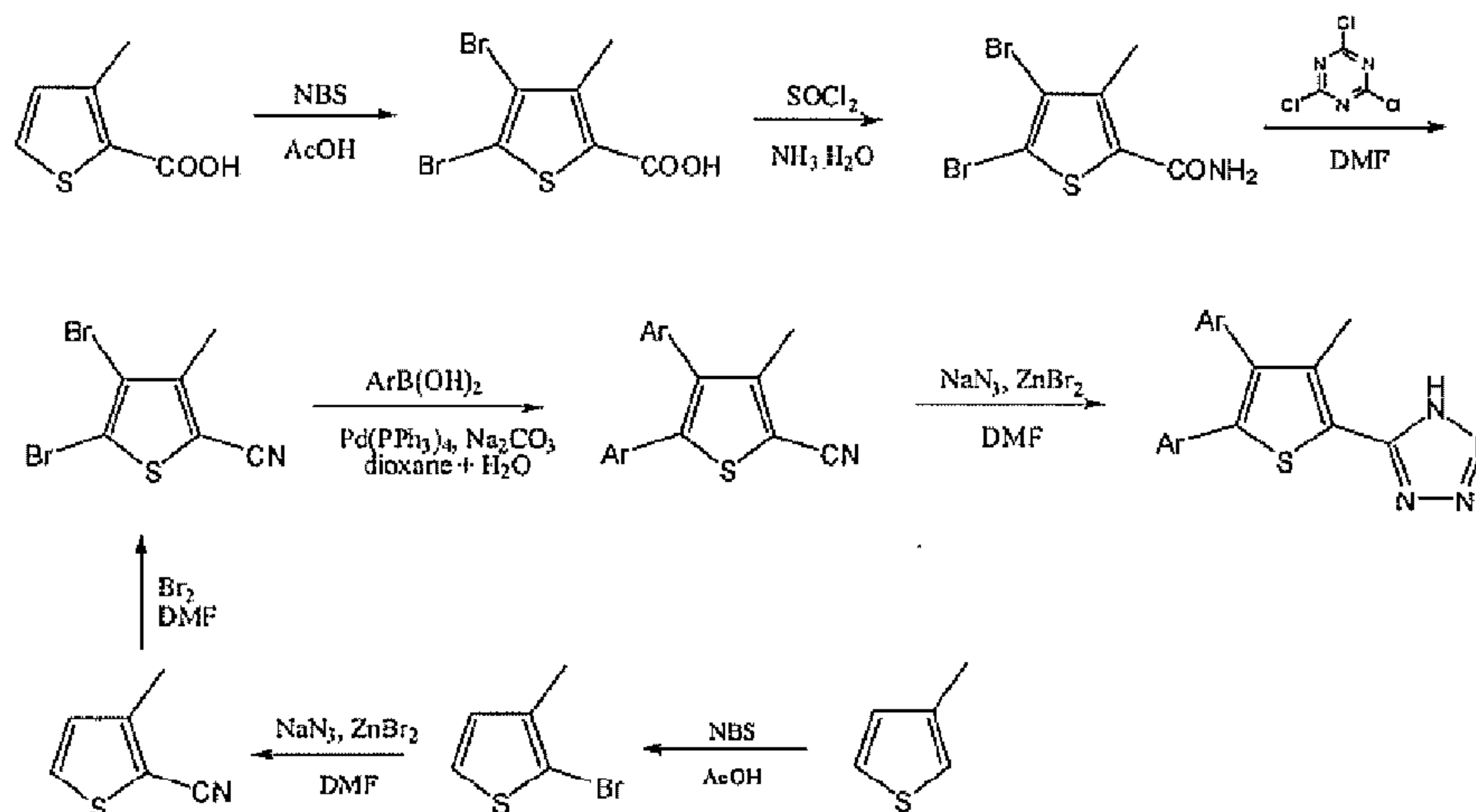
4,5-Bis(2,4-dimethylphenyl)thiophene-2-carboxylic acid (DNM0503) ^1H NMR (CDCl_3 , 500 MHz) δ 13.19 (s, 1H), 7.66 (s, 1H), 7.12 (d, $J = 8.25$ Hz, 1H), 7.03 - 6.95 (m, 3H), 6.87 - 6.81 (m, 2H), 2.24 (s, 3H), 2.22 (s, 3H), 2.07 (s, 3H), 1.93 (s, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 162.82, 144.83, 139.77, 138.16, 136.78, 136.10, 135.28, 135.22, 132.49, 132.04, 130.98, 130.91, 130.02, 129.43, 126.45, 126.27, 20.66, 20.61, 19.78, 19.64.

4,5-Bis(4-chloro-2-methylphenyl)thiophene-2-carboxylic acid (DNM0561) ^1H NMR (CDCl_3 , 500 MHz) δ 7.81 (s, 1H), 7.17 (d, $J = 2.02$ Hz, 1H), 7.14 (s, 1H), 7.13 - 7.11 (m, 2H), 7.03 (dd, $J_1 = 8.24$ Hz, $J_2 = 2.02$ Hz, 1H), 6.87 (d, $J = 8.24$ Hz, 1H), 2.12 (s, 3H), 2.03 (s, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 167.74, 147.16, 140.15, 139.20,

138.26, 137.56, 135.29, 134.06, 133.61, 132.85, 131.97, 131.74, 131.13, 131.03, 130.88, 126.50, 126.43, 20.61, 20.59.

Example 7

Synthesis of DNM0631 and analogues



2-Bromo-3-methylthiophene NBS (8.90 g, 50.0 mmol) was added portion wise to a stirred solution of 3-methylthiophene (4.90 g, 50.0 mmol) in acetic acid (20 mL) at rt. After complete addition, the reaction was stirred at rt until it was complete. The reaction mixture was poured into ice-water, and then extracted with a 3:1 mixture solvent of hexane and ether. The organic layer was washed with 1N aq. NaOH and brine. After dried over anhydrous sodium sulphate, the organic phase was concentrated on vacuum to afford 2-bromo-3-methylthiophene (8.20 g, 92.7 %), which was used directly in the next step without further purification.

3-Methylthiophene-2-carbonitrile A round-bottomed flask was charged with 2-bromo-3-methylthiophene (8.20 g, 46.3 mmol) and CuCN (8.29 g, 92.6 mmol). After degassed, 50 mL of DMF was added. The reaction mixture was heated to 150 °C

overnight. After cooled to room temperature, the reaction was quenched with 250 mL of water, and extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was passed through a short and fat silicon column, and the column was eluted with hexane to afford 5.07g of product.

4,5-Dibromo-3-methylthiophene-2-carbonitrile Bromine (4.25 mL, 82.6 mmol) was added drop wise to a stirred solution of 3-methylthiophene-2-carbonitrile (5.07 g, 41.2 mmol) in DMF (20 mL) at rt. After complete addition, the reaction was heated to 60 °C until it was complete. After cooled to rt, the reaction mixture was poured into ice-water. The light yellow solid formed was collected through suction filtration, and dried together with P₂O₅ under vacuum to afford 9.84 g of 4,5-dibromo-3-methylthiophene-2-carbonitrile.

4,5-Bis(4-chloro-2-isopropylphenyl)-3-methylthiophene-2-carbonitrile A round-bottomed flask was charged with 4,5-dibromo-3-methylthiophene-2-carbonitrile (140.5 mg, 0.50 mmol), 2-(4-chloro-2-isopropylphenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (308.7 mg, 1.10 mmol) and Pd(PPh₃)₄ (29 mg, 0.025 mmol). After degassed, dioxane (5 mL) and aqueous sodium carbonate (3 mL, 2M, 6.0 mmol) was added. The reaction mixture was heated to 95 °C until the reaction was complete. After cooled to room temperature, the reaction mixture was diluted with 30 mL of water and then extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: CH₂Cl₂ = 4: 1) to afford 190.5 mg (89 %) of product as a white solid.

5-(4,5-Bis(4-chloro-2-isopropylphenyl)-3-methylthiophen-2-yl)-1H-tetrazole (DNM0631) A round-bottomed flask was charged with 4,5-bis(4-chloro-2-

isopropylphenyl)-3-methylthiophene-2-carbonitrile (190.5 mg, 0.44 mmol), zinc bromide (338 mg, 1.50 mmol) and sodium azide (97.5 mg, 1.50 mmol). After degassed, DMF (3 mL) was added. The reaction mixture was heated to 130 °C and stirred at this temperature until complete. The reaction was cooled to rt and 30 mL of 0.1 N aqueous HCl was added. The reaction mixture was extracted with ethyl acetate. The organic phase was dried over anhydrous sodium sulphate and then concentrated. The residue was purified by flash chromatography (hexane: EtOAc: AcOH = 30: 10: 1). 188.7 mg (90 %) of product was obtained as a white solid, ¹H NMR (CDCl₃, 500 MHz) δ 7.25 - 7.22 (m, 2H), 7.18 (dd, *J*₁ = 8.18 Hz, *J*₂ = 2.13 Hz, 1H), 7.09 - 7.06 (m, 2H), 7.02 (d, *J* = 8.20 Hz, 1H), 3.04 (sep, *J* = 6.75 Hz, 1H), 2.74 (sep, *J* = 6.80 Hz, 1H), 2.37 (s, 3H), 1.12 (d, *J* = 6.80 Hz, 3H), 1.05 (d, *J* = 6.80 Hz, 6H), 0.90 (d, *J* = 6.80 Hz, 3H); ¹³C NMR (CDCl₃, 125 MHz) δ 150.32, 149.87, 141.11, 140.81, 140.72, 135.33, 134.47, 132.72, 132.02, 131.51, 129.01, 126.30, 126.20, 125.84, 125.52, 30.35, 30.10, 24.76, 23.60, 23.13, 15.78.

The following compounds were also prepared using an analogous method:

5-(4,5-bis(4-chloro-2-methylphenyl)-3-methylthiophen-2-yl)-1H-tetrazole

(DNM0614) ¹H NMR (CDCl₃, 500 MHz) δ 7.15 (s, 1H), 7.11 (s, 1H), 7.08 (d, *J* = 8.20 Hz, 1H), 7.05 - 7.01 (m, 2H), 6.93 (d, *J* = 8.30 Hz, 1H), 2.31 (s, 3H), 2.17 (s, 3H), 2.04 (s, 3H); ¹³C NMR (CDCl₃, 125 MHz) δ 141.47, 140.34, 139.95, 139.41, 139.16, 134.57, 133.83, 133.81, 132.76, 132.20, 131.43, 130.52, 130.42, 126.20, 126.00, 20.81, 20.03, 15.56.

5-(4,5-Bis(4-methylnaphthalen-1-yl)-3-methylthiophen-2-yl)-1H-tetrazole

(DNM0620) ¹H NMR (CDCl₃, 500 MHz) δ 8.04 (d, *J* = 8.30 Hz, 1H), 7.91 (d, *J* = 8.30 Hz, 1H), 7.86 (d, *J* = 8.40 Hz, 1H), 7.77 (dd, *J*₁ = 8.30 Hz, *J*₂ = 1.10 Hz, 1H), 7.48 - 7.37

(m, 3H), 7.32 (t, $J = 7.65$ Hz, 1H), 7.18 (d, $J = 7.20$ Hz, 1H), 7.06 - 7.00 (m, 3H), 2.55 (s, 3H), 2.54 (s, 3H), 2.28 (s, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 142.29, 141.77, 141.39, 135.21, 134.23, 132.73, 132.52, 132.44, 132.35, 131.52, 128.93, 128.72, 127.94, 126.61, 126.30, 126.07, 125.82, 125.74, 125.70, 125.64, 125.52, 124.44, 124.10, 119.63, 19.49, 19.42, 15.54.

5-(4,5-Bis(3-butylphenyl)-3-methylthiophen-2-yl)-1H-tetrazole (DNM0627)

^1H NMR (CDCl_3 , 500 MHz) δ 7.30 (t, $J = 7.53$ Hz, 1H), 7.17 (d, $J = 7.70$ Hz, 1H), 7.15 (t, $J = 7.60$ Hz, 1H), 7.10 - 6.97 (m, 5H), 2.59 (t, $J = 7.58$ Hz, 2H), 2.48 (s, 3H), 2.46 (t, $J = 7.75$ Hz, 2H), 1.57 - 1.49 (m, 2H), 1.45 - 1.37 (m, 2H), 1.33 - 1.18 (m, 4H), 0.90 (t, $J = 7.35$ Hz, 3H), 0.89 (t, $J = 7.30$ Hz, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 143.22, 143.19, 142.95, 141.28, 141.17, 135.74, 133.10, 130.46, 129.16, 128.47, 128.30, 128.15, 127.67, 127.45, 126.23, 125.52, 35.42, 35.36, 33.56, 33.26, 30.31, 22.15, 22.07, 15.64, 13.92,.

5-(4,5-Bis(4-fluoronaphthalen-1-yl)-3-methylthiophen-2-yl)-1H-tetrazole

(DNM0628) ^1H NMR (CDCl_3 , 500 MHz) δ 8.10 - 8.06 (m, 1H), 8.03 (d, $J = 8.30$ Hz, 1H), 7.96 (d, $J = 8.50$ Hz, 1H), 7.76 - 7.71 (m, 1H), 7.56 - 7.44 (m, 3H), 7.39 (t, $J = 7.50$ Hz, 1H), 7.22 (dd, $J_1 = 5.40$ Hz, $J_2 = 7.80$ Hz, 1H), 7.08 (dd, $J_1 = 5.38$ Hz, $J_2 = 7.83$ Hz, 1H), 6.95 - 6.87 (m, 2H), 2.34 (s, 3H); ^{13}C NMR (CDCl_3 , 125 MHz) δ 159.96, 159.45, 157.93, 157.44, 141.79, 141.44, 133.85, 133.81, 133.52, 133.49, 128.95, 128.89, 128.71, 128.67, 128.08, 128.02, 127.36, 127.24, 126.30, 126.20, 125.67, 125.53, 125.39, 123.72, 123.59, 123.56, 123.43, 121.05, 121.01, 120.70, 120.66, 109.03, 108.87, 108.77, 108.61, 15.53.

Example 8

Measurement of AcpS inhibition

Materials

[³H]Acetyl-CoA was mixed as 1 volume of Perkin Elmer NET290 radiolabeled stock (e.g. 0.1 mCi/ml, 3.7 Ci/mmol in Na-acetate, pH 4.5-5.0 = 27 μ M) with 1.2 volumes of 1 mM unlabelled acetyl-CoA (Sigma). Trichloroacetic acid was prepared as a 10% w/v solution. Bovine serum albumin was prepared as a 25 mg/ml solution in water. DTT was prepared as a 50 mM solution in water.

Procedure

1. A standard reaction contained the following in a total volume of 10 μ l:

<u>Stock reagents</u>	<u>Volume (μl)</u>	<u>Final concentration</u>
1 M Na-phosphate, pH 7	0.5	50 mM
0.1 M MgCl ₂	1	10 mM
50 mM DTT	1	5 mM
apo-acyl carrier protein (ACP)	4.4 μ g	50 μ M
AcpS enzyme	~0.06 μ g	
570 μ M [³ H]Acetyl-CoA	1	57 μ M
Test compound e.g. DNM0488	0.5	predetermined μ M e.g. 500 or 50
ddH ₂ O to 10 μ l		

2. Tubes were incubated at RT. [³H]acetyl-CoA was added last to start the reaction. To stop the reaction, 2 μ l was removed to a 1.5-ml microfuge tube containing 800 μ l cold 10% TCA. Up to four time points were collected for each reaction, e.g. at 5 min, 10 min, 30 min, and 60 min.
3. 20 μ l of 25 mg/ml BSA was added to each tube, mixed and incubated on ice for 10 min, then centrifuged at 12,000 g for 5 min to form a pellet. Supernatant was removed using P1000.
4. Each pellet was washed twice with 800 μ l of cold 10% TCA each time, then centrifuged at 12,000 g for 5 min after each wash. The supernatant was discarded. Each pellet was resuspended in 50 μ l of formic acid. The suspension was transferred to a scintillation vial and radioactivity was measured in 2 ml of liquid scintillation cocktail.

The random (stochastic) error in scintillation counting is proportional to the square root of the counts (*not* dpm) accumulated in the counting period; i.e. 10% for 100, 3.3% for 1,000, 1% for 10,000, etc. Provided radioactive counts (dpm)

are in the thousands, the assay provides useful data. Results are reported in terms of % activity with respect to the blank-subtracted counts for working substrate. A % activity of less than about 40% is indicative of AcpS enzyme inhibition by the test compound at that concentration.

For results, see the table in the Example below.

Example 9

Measurement of minimum inhibitory concentrations (MICs)

Susceptibilities to the compounds were determined using the National Committee for Clinical Laboratory Standards (NCCLS) M7-A6 broth microdilution method. Cation-adjusted Mueller-Hinton broth (Ca^{2+} , 25 $\mu\text{g/mL}$; Mg^{2+} , 12.5 $\mu\text{g/mL}$) microdilution panels were prepared to contain antimicrobial doubling dilution concentrations of an appropriate range. DMSO (dimethylsulfoxide) controls were incorporated into the panel to mimic the quantity of DMSO used in dissolving some of the compounds at the higher concentrations. Each final panel well volume was 100 μL with a bacterial inoculum of 5×10^5 CFU (colony forming units) / mL of the relevant bacterium. Panels were read following 16 to 20 h of incubation at 35 degrees Celsius in ambient air. The MIC (minimum inhibitory concentration) was defined as the lowest concentration of antimicrobial inhibiting visible growth.

The following table, as well as FIG. 1, indicates results of experiments of both Examples 8 and 9 where available, demonstrating AcpS inhibition and antimicrobial effects on Methicillin-Resistant *Staph. aureus* (MRSA) and *E. coli* D22:

Compound ID	% AcpS activity @ 500 μM	% AcpS activity at 50 μM	MIC MRSA (μM)	MIC <i>E. coli</i> D22 (μM)
DNM0486	0.16	0.82	2	>125
DNM0487	0.08	3.34	8	>125
DNM0488	0.32	11.49	4	125
DNM0489	0	17.89	2	>125
DNM0504	0.16	7.33	125	125
DNM0508	0.1	44.92	4	>125
DNM0509	0.2	31.07	15	>125
DNM0512	0.7	37.29	8	>125
DNM0531	4.38	96.76	60	>125
DNM0534	0	33.98	8	>125
DNM0535	3.48	92.62	125	>125
DNM0536	0.2	8.25	8	125
DNM0537	0.14	1.28	2	125

DNM0538	0.58	82.18	30	>125
DNM0541	0.3	63.12	30	>125
DNM0542	0.7	9.58	2	>125
DNM0546	5.16	37.21	4	>125
DNM0548	0.1	3.1	4	60
DNM0549	0.48	71.31	30	>125
DNM0550	0.39	47.83	30	>125
DNM0559	0.5	7.01	2	>125
DNM0560	0.06	63.58	15	>125
DNM0563	0.56	15.12	8	125
DNM0564	0.75	47.61	15	>125
DNM0565	0.11	22.91	15	>125
DNM0570	0.19	33.7	15	125
DNM0571	0.11	8.19	8	>125
DNM0575	0.23	5.86	8	>125
DNM0572	0.51	4.41	8	>125
DNM0576	0.15	5.88	4	>125
DNM0577	0.4	5.54	8	>125
DNM0579	3.02	15.74	8	125
DNM0580	0.85	1.62	8	125
DNM0587	0	2.13	8	
DNM0588	0	2.67	8	
DNM0446	25.36		4	>125
DNM0447	0.47	32.56	15	>125
DNM0453	23.76		8	>125
DNM0457	0	1.56	8	60
DNM0461	0.85	13.39	1	>125
DNM0464	0.28	9.03	1	>125
DNM0470	27.69		4	125
DNM0474	0.3	15.08	2	>125
DNM0479	0.1	12.79	2	>125
DNM0480	2.04	7.35	4	125
DNM0493	2.7	25.28	4	>125
DNM0510	0.12	8.4	4	>125
DNM0511	0	14.36	8	>125
DNM0514	0.14	5.73	4	>125
DNM0515	3.44	30.26	2	>125
DNM0516	5	32.01	2	>125
DNM0520	20.86		2	>125
DNM0529	0.16	91.56	30	>125
DNM0532	0.22	30.66	60	>125
DNM0539	39.39		8	>125
DNM0648		60.1		

Example 10

Measurement of combination MICs for evaluation of
antibiotic adjuvant potential in *Ps. aeruginosa*

Generally following the procedure of Example 9, MICs of ampicillin, erythromycin, and azithromycin were determined against *Ps. aeruginosa*. Parallel to this effort, solutions were prepared which were identical. To each of these were added 0.5 μ L of stock solution of a given compound of the present invention, then diluted to produce a final concentration of 125 μ M, 60 μ M, and/or 30 μ M for determination of adjuvant activity. Compounds were determined to be antibiotic adjuvants if the mixture produced a lower MIC than that of the antibiotic agent alone. Results were as follows, demonstrating antimicrobial adjuvant effects:

- DNM0487 at 125 μ M (standalone MIC >2 mM) produced an up to 60-fold lower MIC for erythromycin.
- DNM0487 at 125 μ M produced an up to 60-fold lower MIC for ampicillin.
- DNM0488 at 125 μ M produced an up to 60-fold lower MIC for ampicillin.
- DNM0501 at 60 μ M produced an up to 60-fold lower MIC for erythromycin.
- DNM0501 at 60 μ M produced an up to 250-fold lower MIC for ampicillin.
- DNM0537 at 60 μ M produced an up to 60-fold lower MIC for erythromycin.
- DNM0537 at 30 μ M produced an up to ~7-fold lower MIC for erythromycin.
- DNM0537 at 30 μ M produced an up to 250-fold lower MIC for ampicillin.
- DNM0548 at 125 μ M produced an up to 125-fold lower MIC for erythromycin.
- DNM0548 at 125 μ M produced an up to 125-fold lower MIC for ampicillin.

Example 11

Measurement of MICs for selected compounds against a panel of challenge pathogens

The inocula for each bacterial strain were prepared by picking 5-10 distinct colonies from the culture plates and suspending them in the appropriate broth as per Clinical and Laboratory Standards Institute (CLSI) guidelines M07-A8, M24-A or M11-A7 as appropriate. The inoculum was resuspended by vigorous shaking on a vortex mixer for 15s. The turbidity was then adjusted to McFarland standard 0.5 ($1-5 \times 10^6$ CFU/ml). The inoculum was further diluted in the appropriate media for MIC tests to give a final

inoculum in each well of $2-8 \times 10^5$ CFU/ml. MICs were tested in the appropriate broth in accordance with the appropriate CLSI guidelines.

A stock solution of each compound was prepared at a concentration of 1.28 g/L in DMSO. The stock was further diluted in the appropriate media to give a top starting concentration of 128 mg/L in the assay. 100 μ L of the appropriate media, as per CLSI guidelines, was dispensed into each well in columns 2-12. 200 μ L of the each compound solution (at 256mg/L) was dispensed into each well in column 1. 100 μ L aliquots were pipetted from column 1 wells and dispensed into column 2 with a multichannel pipette ($\pm$ 2% coefficient of variation) thus diluting two-fold. 100 μ L samples were then pipetted from column 2 wells and dispensed into column 3. The process was repeated through to column 10. The final 100 μ L of diluted drug from column 10 was then discarded. Row 11 acted as a positive control (no compound, but organisms added), Row 12 acted as a negative control (no compound, and no organisms added).

100 μ L of the appropriate inoculum suspension in the appropriate media, as per CLSI guidelines, was added to the appropriate wells. This resulted in a well containing 200 μ L final volume (made up of 100 μ L diluted compound or diluents and 100 μ L of inoculum or broth alone). All plates were incubated in the dark under aerobic or anaerobic conditions at 30-37°C for 24-48 hours, according to the appropriate CLSI guideline. Plates were read visually 24-48 hours post inoculation. Endpoints of 100% inhibition were determined (CLSI interpretation endpoints following visual examination).

MIC₅₀, MIC₈₀, and 100% inhibition results are reported below in μ g/mL in the following Tables, indicating each compound tested against a given species and strain:

Compound	<i>Enterococcus faecalis</i> ATCC29212			<i>Bacillus cereus</i> NCTC6349		
	100%	80%	50%	100%	80%	50%
DNM0610	1	1	1	0.5	0.5	0.5
DNM0488	0.5	0.5	0.5	≤ 0.25	≤ 0.25	≤ 0.25
DNM0487	2	2	2	0.5	0.5	0.5
DNM0477	8	4	4	1	1	0.5
DNM0566	0.5	0.5	0.5	≤ 0.25	≤ 0.25	≤ 0.25
DNM0576	1	1	1	0.5	≤ 0.25	≤ 0.25
DNM0466	4	4	2	0.5	≤ 0.25	≤ 0.25

DNM0465	2	2	2	≤0.25	≤0.25	≤0.25
DNM0508	2	2	2	0.5	0.5	0.5
DNM0547	1	1	1	≤0.25	≤0.25	≤0.25
DNM0474	1	1	1	≤0.25	≤0.25	≤0.25
DNM0606	1	1	1	0.5	0.5	0.5
DNM0537	1	1	0.5	≤0.25	≤0.25	≤0.25
DNM0548	0.25	0.25	0.25	≤0.25	≤0.25	≤0.25
Vancomycin	4	4	4	2	2	1

	<i>Staphylococcus epidermidis</i> NRS122			<i>Staphylococcus epidermidis</i> NRS7		
Compound	100%	80%	50%	100%	80%	50%
DNM0610	16	8	4	2	1	1
DNM0488	2	2	1	0.5	0.25	0.25
DNM0487	4	4	4	1	1	0.5
DNM0477	16	16	8	1	0.5	0.25
DNM0566	2	2	1	1	1	1
DNM0576	2	2	2	0.5	0.5	0.25
DNM0466	16	8	4	0.5	0.25	0.25
DNM0465	8	8	4	1	0.25	0.25
DNM0508	8	8	4	1	0.5	0.5
DNM0547	16	8	4	1	1	1
DNM0474	16	8	4	1	1	0.5
DNM0606	4	4	2	1	0.5	0.5
DNM0537	4	4	4	1	1	0.5
DNM0548	1	1	1	0.5	0.5	0.5
Vancomycin	2	1	1	4	4	2

	<i>Staphylococcus aureus</i> NRS2 (ATCC700698)			<i>Staphylococcus aureus</i> ATCC43300		
Compound	100%	80%	50%	100%	80%	50%
DNM0610	0.5	0.5	0.5	0.5	0.5	0.5
DNM0488	0.5	0.5	0.5	0.5	0.5	0.5
DNM0487	2	2	1	1	1	1
DNM0477	2	2	2	2	2	1
DNM0566	0.5	0.5	0.25	≤0.25	≤0.25	≤0.25
DNM0576	0.5	0.5	0.5	0.5	0.5	0.5

DNM0466	1	1	1	1	1	1
DNM0465	1	1	1	1	1	1
DNM0508	1	1	0.5	1	1	1
DNM0547	1	1	0.5	0.5	0.5	0.5
DNM0474	0.5	0.5	0.5	0.5	0.5	0.5
DNM0606	0.5	0.5	0.5	≤0.25	≤0.25	≤0.25
DNM0537	1	1	1	1	1	0.5
DNM0548	0.5	0.5	0.5	≤0.25	≤0.25	≤0.25
Vancomycin	1	1	0.5	0.5	0.5	0.5

Compound	<i>Staphylococcus aureus</i> NRS1 (ATCC700699)			<i>Staphylococcus aureus</i> NRS382		
	100%	80%	50%	100%	80%	50%
DNM0610	≤0.25	≤0.25	≤0.25	0.5	0.5	0.5
DNM0488	≤0.25	≤0.25	≤0.25	0.5	0.5	0.5
DNM0487	0.5	0.5	0.25	1	1	1
DNM0477	1	1	1	2	2	2
DNM0566	≤0.25	≤0.25	≤0.25	0.5	0.5	0.5
DNM0576	0.5	0.5	0.25	0.5	0.5	0.5
DNM0466	1	1	0.5	2	2	1
DNM0465	1	1	1	2	2	2
DNM0508	1	1	0.5	1	1	1
DNM0547	0.5	0.5	0.5	0.5	0.5	0.5
DNM0474	0.5	0.5	0.25	0.5	0.5	0.5
DNM0606	0.5	0.5	0.5	0.5	0.5	0.5
DNM0537	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25
DNM0548	≤0.25	≤0.25	≤0.25	0.5	0.5	0.5
Vancomycin	4	4	2	1	1	1

Compound	<i>Staphylococcus aureus</i> NRS383			<i>Staphylococcus aureus</i> NRS384		
	100%	80%	50%	100%	80%	50%
DNM0610	0.5	0.5	0.5	≤0.25	≤0.25	≤0.25
DNM0488	0.5	0.5	0.5	0.5	0.5	0.5
DNM0487	1	1	1	1	1	1
DNM0477	4	4	2	2	2	2
DNM0566	≤0.25	≤0.25	≤0.25	0.5	0.5	0.5

DNM0576	0.5	0.5	0.5	0.5	0.5	0.5
DNM0466	2	2	1	1	1	1
DNM0465	2	2	1	2	2	1
DNM0508	1	1	1	1	1	1
DNM0547	0.5	0.5	0.5	1	1	1
DNM0474	0.5	0.5	0.5	0.5	0.5	0.5
DNM0606	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25
DNM0537	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25
DNM0548	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25
Vancomycin	0.5	0.5	0.5	1	1	1

Compound	<i>Staphylococcus aureus</i> EUP SAU040			<i>Staphylococcus aureus</i> EUP MRSA004		
	100%	80%	50%	100%	80%	50%
DNM0610	0.5	0.5	0.5	≤0.25	≤0.25	≤0.25
DNM0488	0.5	0.5	0.5	0.5	0.5	0.5
DNM0487	2	1	1	2	2	1
DNM0477	2	2	1	2	2	2
DNM0566	0.5	0.5	0.5	≤0.25	≤0.25	≤0.25
DNM0576	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25
DNM0466	2	1	1	2	2	1
DNM0465	1	1	1	1	1	1
DNM0508	1	1	1	1	1	1
DNM0547	0.5	0.25	0.25	0.5	0.5	0.5
DNM0474	0.25	0.5	0.5	0.5	0.5	0.5
DNM0606	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25
DNM0537	1	1	1	1	1	0.5
DNM0548	0.5	0.5	0.5	0.5	0.5	0.5
Vancomycin	1	1	1	0.5	0.5	0.5

Compound	<i>Staphylococcus aureus</i> EUP MRSA002			<i>Staphylococcus aureus</i> EUP MRSA002		
	100%	80%	50%	100%	80%	50%
DNM0610	0.5	0.5	0.5	0.5	0.5	0.5
DNM0488	1	1	0.5	0.5	0.5	0.5
DNM0487	2	2	1	1	1	1
DNM0477	4	2	2	2	2	1
DNM0566	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25
DNM0576	≤0.25	≤0.25	≤0.25	0.5	0.5	0.5

DNM0466	1	1	1	2	1	1
DNM0465	1	1	1	1	1	0.5
DNM0508	1	1	0.5	1	1	1
DNM0547	1	1	1	0.5	0.5	0.5
DNM0474	1	1	1	0.5	0.5	0.5
DNM0606	0.5	0.5	0.5	≤0.25	≤0.25	≤0.25
DNM0537	1	1	1	1	1	0.5
DNM0548	0.5	0.5	0.5	≤0.25	≤0.25	≤0.25
Vancomycin	0.5	0.5	0.5	0.5	0.5	0.5

	<i>Staphylococcus aureus</i> AUR131 007035			<i>Staphylococcus aureus</i> AUR60 7005		
Compound	100%	80%	50%	100%	80%	50%
DNM0610	0.5	0.5	0.5	0.5	0.5	0.5
DNM0488	0.5	0.5	0.5	0.5	0.5	0.5
DNM0487	1	1	1	1	1	1
DNM0477	2	2	1	2	2	1
DNM0566	≤0.25	≤0.25	≤0.25	0.5	0.5	0.5
DNM0576	0.5	0.5	0.5	0.5	0.5	0.5
DNM0466	1	1	1	1	1	1
DNM0465	2	2	1	1	1	1
DNM0508	1	1	1	1	1	1
DNM0547	1	1	1	1	1	1
DNM0474	0.5	0.5	0.5	0.5	0.5	0.5
DNM0606	0.5	0.5	0.5	0.5	0.5	0.5
DNM0537	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25
DNM0548	0.5	0.5	0.5	0.5	0.5	0.5
Vancomycin	0.5	0.5	0.5	1	1	0.5

	<i>Staphylococcus aureus</i> AUR59 7005			<i>Staphylococcus aureus</i> AUR58 7005		
Compound	100%	80%	50%	100%	80%	50%
DNM0610	0.5	0.5	0.5	2	2	1
DNM0488	0.5	0.5	0.5	1	0.5	0.5
DNM0487	1	1	1	1	1	1
DNM0477	2	2	2	2	2	1
DNM0566	0.5	0.25	0.25	1	1	1
DNM0576	0.5	0.5	0.5	0.5	0.5	0.5
DNM0466	1	1	1	2	1	1

DNM0465	1	1	1	1	1	1
DNM0508	1	1	1	1	1	1
DNM0547	1	1	1	2	2	1
DNM0474	0.5	0.5	0.5	1	1	0.5
DNM0606	0.5	0.5	0.5	1	1	0.5
DNM0537	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25
DNM0548	0.5	0.5	0.5	1	1	1
Vancomycin	1	0.5	0.5	1	1	1

Compound	<i>Enterococcus faecium</i> ATCC700221			<i>Enterococcus faecalis</i> ATCC51299		
	100%	80%	50%	100%	80%	50%
DNM0610	0.5	0.5	0.5	1	1	1
DNM0488	0.5	0.25	0.25	0.5	0.5	0.5
DNM0487	1	1	1	2	2	1
DNM0477	4	4	2	4	4	2
DNM0566	0.5	0.25	0.25	0.5	0.5	0.5
DNM0576	0.5	0.25	0.25	1	1	1
DNM0466	2	2	2	2	2	2
DNM0465	2	1	1	2	2	2
DNM0508	1	1	1	2	2	2
DNM0547	1	1	1	0.5	0.5	0.5
DNM0474	1	1	1	1	1	1
DNM0606	1	1	1	1	1	1
DNM0537	0.5	0.5	0.5	0.5	0.5	0.5
DNM0548	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25	≤0.25
Vancomycin	>16	>16	>16	>16	>16	>16

These results indicate that the compounds of present invention are potently antibacterial against a variety of antibiotic-resistant strains, and in many cases (particularly with respect to VRE), more potent than vancomycin.

Example 12

Measurement of minimum inhibitory concentrations against

Streptococcus pneumoniae Group A

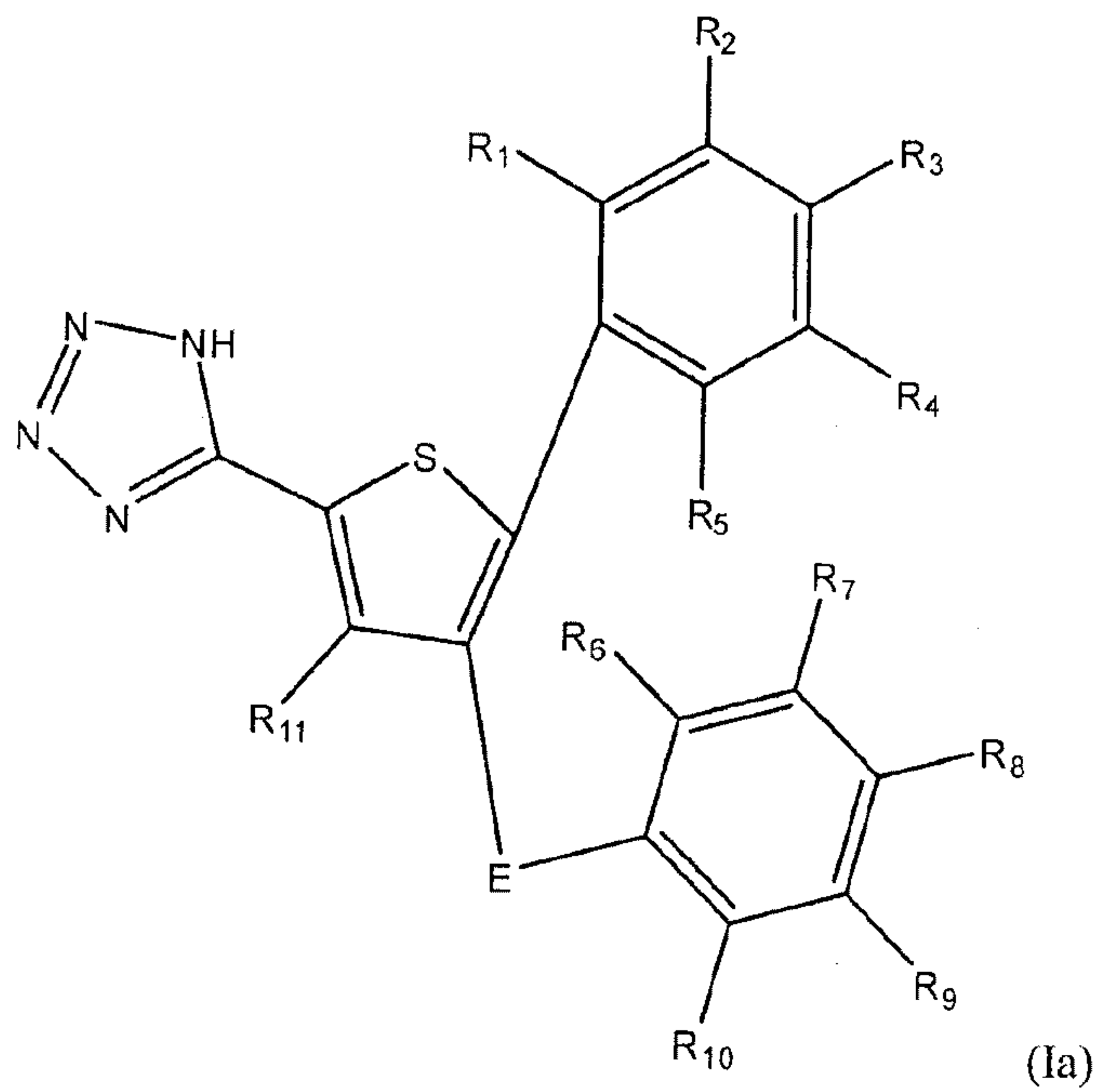
Generally following the procedure of Example 9, but using Todd Hewitt broth (beef heart digest) rather than Mueller-Hinton broth, MICs were initially measured against *Streptococcus pneumoniae* Group A for compounds of the present invention as follows:

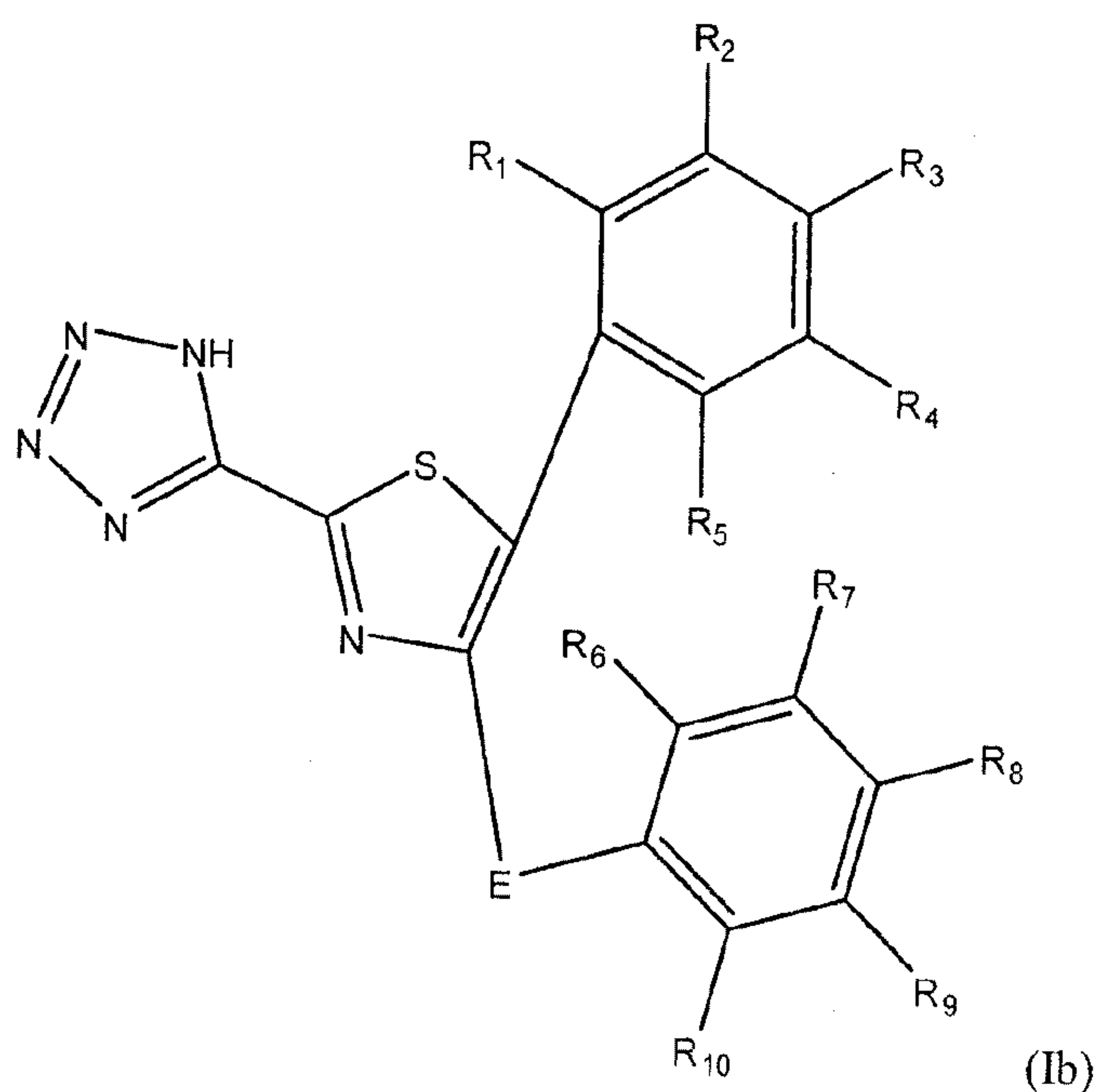
DNM0548	<0.25 μ M
DNM0576	0.5 μ M
DNM0620	<0.25 μ M
DNM0629	<0.25 μ M
DNM0631	<0.25 μ M
DNM0636	0.8 μ M
DNM0640	<0.25 μ M

Repeated measurement of MIC of the above seven compounds in Todd Hewitt broth or in CASO broth (casein, soybean) indicates the MIC range for these compounds is between 125 nM and 8 μ M, the average MIC being 1.6 μ M. These results indicate that the compounds of the present invention have potent antibacterial effects against *Streptococcus*.

CLAIMS

1. A compound having a sulfur-containing ring, or prodrugs or pharmaceutically acceptable salts thereof, of Formula (Ia) or (Ib):





in which

E is $-\text{CH}_2-$ or is absent whereby the sulfur-containing ring is directly connected to phenyl;

5 R_1 , R_2 , R_9 , R_{10} , and R_{11} are each independently selected from the group consisting of hydrogen, methyl, ethyl, propyl, cyclopropyl, butyl, cyclobutyl, pentyl, hexyl, isopropyl, isobutyl, neopentyl, methoxy, and ethoxy;

additionally, R_1 and R_2 may connect to form a phenyl or benzofuran ring;

additionally, R_9 and R_{10} may connect to form a phenyl or benzofuran ring;

10 R_3 and R_8 are each independently selected from the group consisting of hydrogen, methyl, ethyl, propyl, isopropyl, chlorine, fluorine, tert-butyl, methoxy, and ethoxy;

R_4 and R_7 are each independently selected from the group consisting of hydrogen, chlorine, methyl ester, ethyl ester, methyl, ethyl, propyl, cyclopropyl, butyl, cyclobutyl, isopropyl, isobutyl, methoxy, and ethoxy;

15 and R_5 and R_6 are each independently selected from the group consisting of hydrogen, cyclopentyl, cyclopropyl, furan, thiophene, trifluoromethyl, trifluoromethyl ether, methylthiol, formaldehyde, chlorine, fluorine, bromine, phenyl, methyl, ethyl, isopropyl, propyl, butyl, cyclobutyl, isobutyl, neopentyl, pentyl, methoxy, and ethoxy.

2. The compound of claim 1 in which
the compound is according to Formula Ia;
R₁ and R₂ are either independently selected from the group consisting of hydrogen and
methyl, or form a phenyl ring whereby the ring system is naphthyl;
5 R₉ and R₁₀ are either independently selected from the group consisting of hydrogen and
methyl, or form a phenyl ring whereby the ring system is naphthyl;
R₁₁ is hydrogen;
R₃ and R₈ are each independently selected from the group consisting of hydrogen,
methyl, chlorine, fluorine, isopropyl, tert-butyl, and methoxy;
10 R₄ and R₇ are each independently selected from the group consisting of hydrogen,
methyl, chlorine, and ethyl ester;
and R₅ and R₆ are each independently selected from the group consisting of methyl,
ethyl, phenyl, hydrogen, chlorine, isopropyl, cyclopentyl, bromine, cyclopropyl,
trifluoromethyl, trifluoromethyl ether, methylthiol, formaldehyde, furan, and thiophene.
15
3. The compound of claim 2 in which E is absent.
4. The compound of claim 3 in which R₁, R₂, R₄, R₇, R₉, and R₁₀ are each
hydrogen.
20
5. The compound of claim 4 in which R₃ and R₈ are each chlorine; and R₅ and R₆
are selected from the group consisting of hydrogen, methyl, and isopropyl.
6. 5-(4,5-bis(4-chloro-2-methylphenyl)thiophen-2-yl)-1H-tetrazole or a prodrug or
25 pharmaceutically acceptable salt thereof.
7. 5-(4,5-bis(4-chloro-2-isopropylphenyl)thiophen-2-yl)-1H-tetrazole or a prodrug
or pharmaceutically acceptable salt thereof.

8. 5-(4-(3-butylphenyl)-5-(4-chlorobenzyl)thiophen-2-yl)-1H-tetrazole or a prodrug or pharmaceutically acceptable salt thereof.

9. 5-(4,5-bis(4-chloro-2-isopropylphenyl)-3-methylthiophen-2-yl)-1H-tetrazole or
5 a prodrug or pharmaceutically acceptable salt thereof.

10. The compound of claim 1 in which the compound is selected from the group consisting of 5-(4,5-Bis(4-chloro-2-iso-propylphenyl)thiophen-2-yl)-1H-tetrazole (DNM0548), 5-(4,5-Bis(2-(thiophen-3-yl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0559), 5-(4-(4-Chlorophenyl)-5-(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0572), 5-(5-(4-Chlorobenzyl)-4-(4-methylnaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0577), 5-(5-(4-Chlorobenzyl)-4-(4-fluoronaphthalen-1-yl)thiophen-2-yl)-1H-tetrazole (DNM0587), 5-(4-(Biphenyl-2-yl)-5-(4-chlorobenzyl)thiophen-2-yl)-1H-tetrazole (DNM0588), 5-(5-(4-Chlorobenzyl)-4-(3-(cyclopentylmethyl)phenyl)thiophen-2-yl)-1H-tetrazole (DNM0610), 5-(4,5-bis(4-chloro-2-methylphenyl)-3-methylthiophen-2-yl)-1H-tetrazole (DNM0614), 5-(4,5-Bis(3-butylphenyl)-3-methylthiophen-2-yl)-1H-tetrazole (DNM0627), and 5-(4,5-Bis(4-chloro-2-isopropylphenyl)-3-methylthiophen-2-yl)-1H-tetrazole (DNM0631), prodrugs and pharmaceutically acceptable salts thereof.

20 11. Use of the compound of claim 1 for treatment of a microbial infection.

12. The use of claim 11 in which the microbial infection is substantially caused by Gram-positive bacteria.

25 13. The use of claim 12 in which the microbial infection comprises Staphylococcal infection.

14. Use of the compound of claim 1 and an antimicrobial compound for treatment of a microbial infection.

15. The use of claim 14 in which the microbial infection is substantially caused by Gram-negative bacteria.
- 5 16. The use of claim 14 in which the microbial infection is substantially caused by Gram-positive bacteria.
17. The use of claim 14 in which the microbial infection is polymicrobial.
- 10 18. The use of claim 14 in which the microbial infection is substantially caused by *Pseudomonas aeruginosa*.
19. A pharmaceutical composition comprising a compound of claim 1 and a pharmaceutically acceptable excipient.

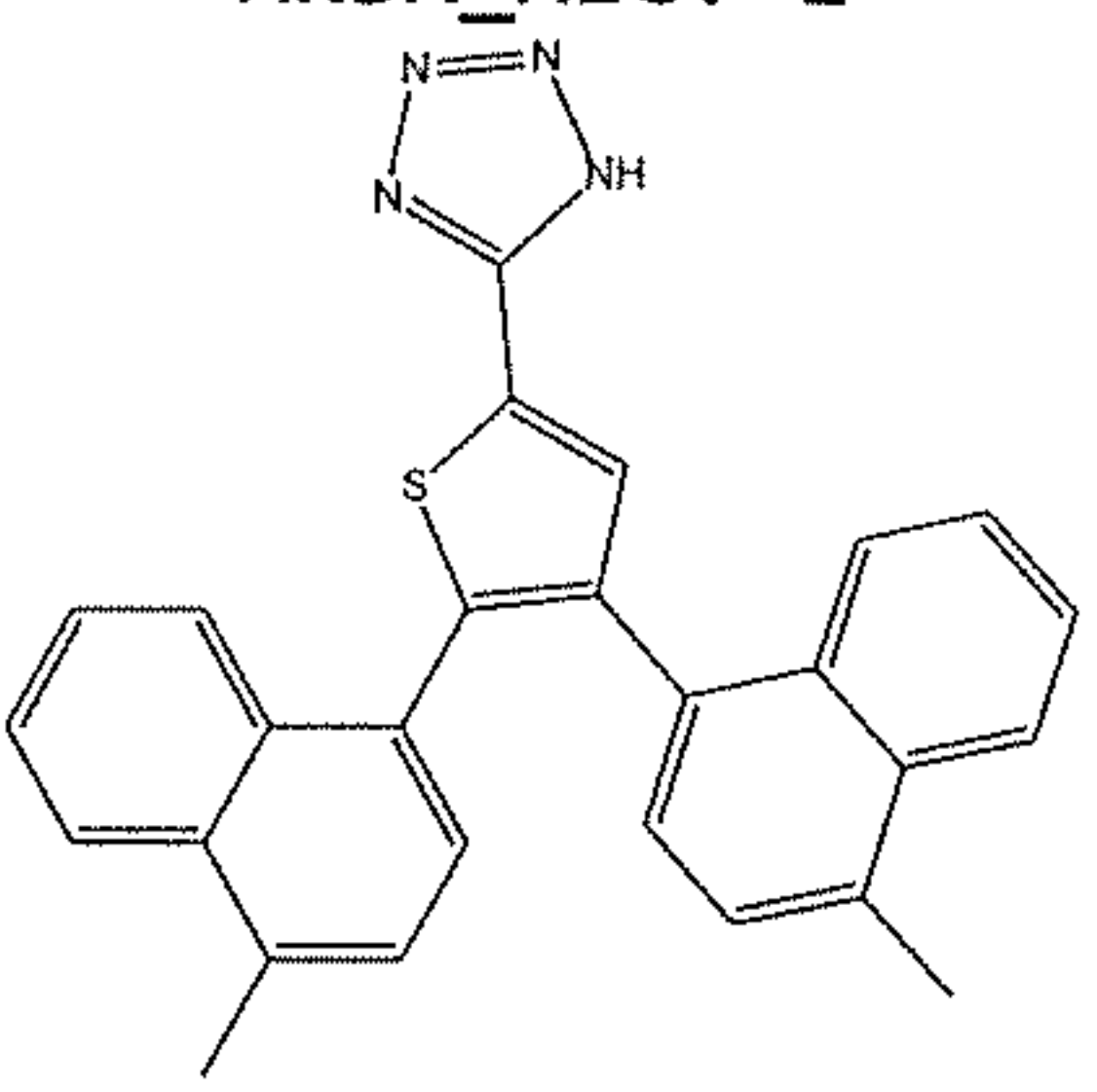
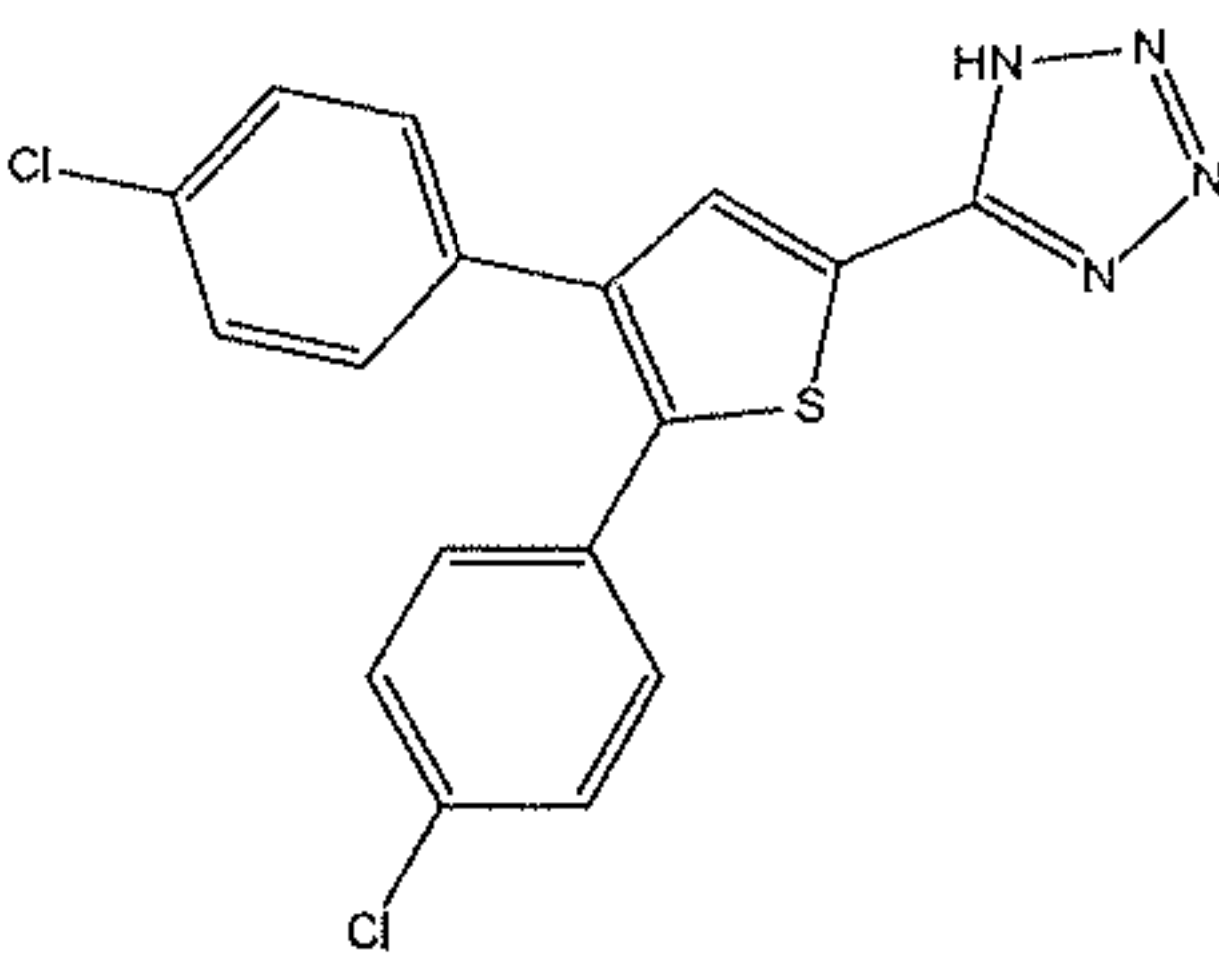
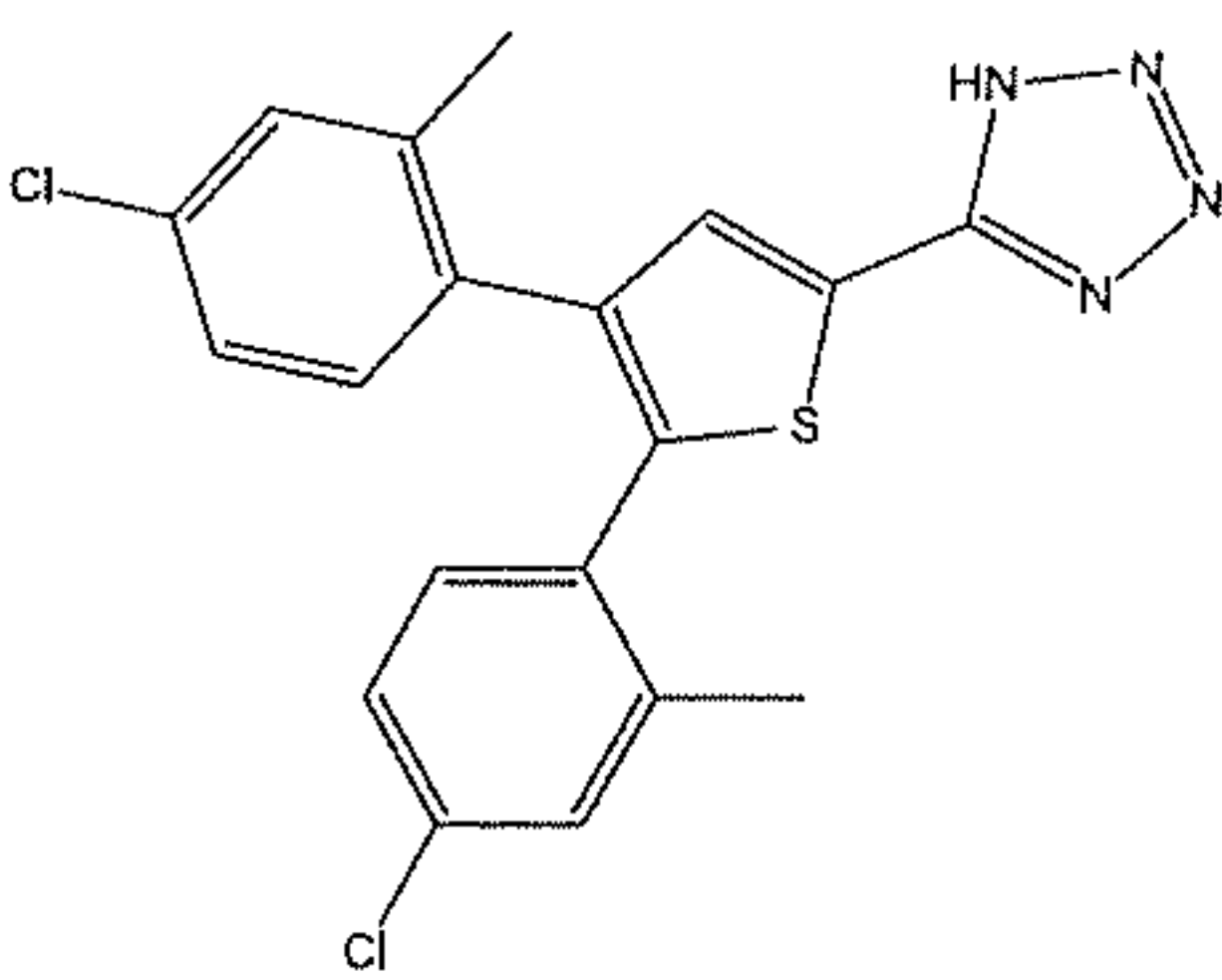
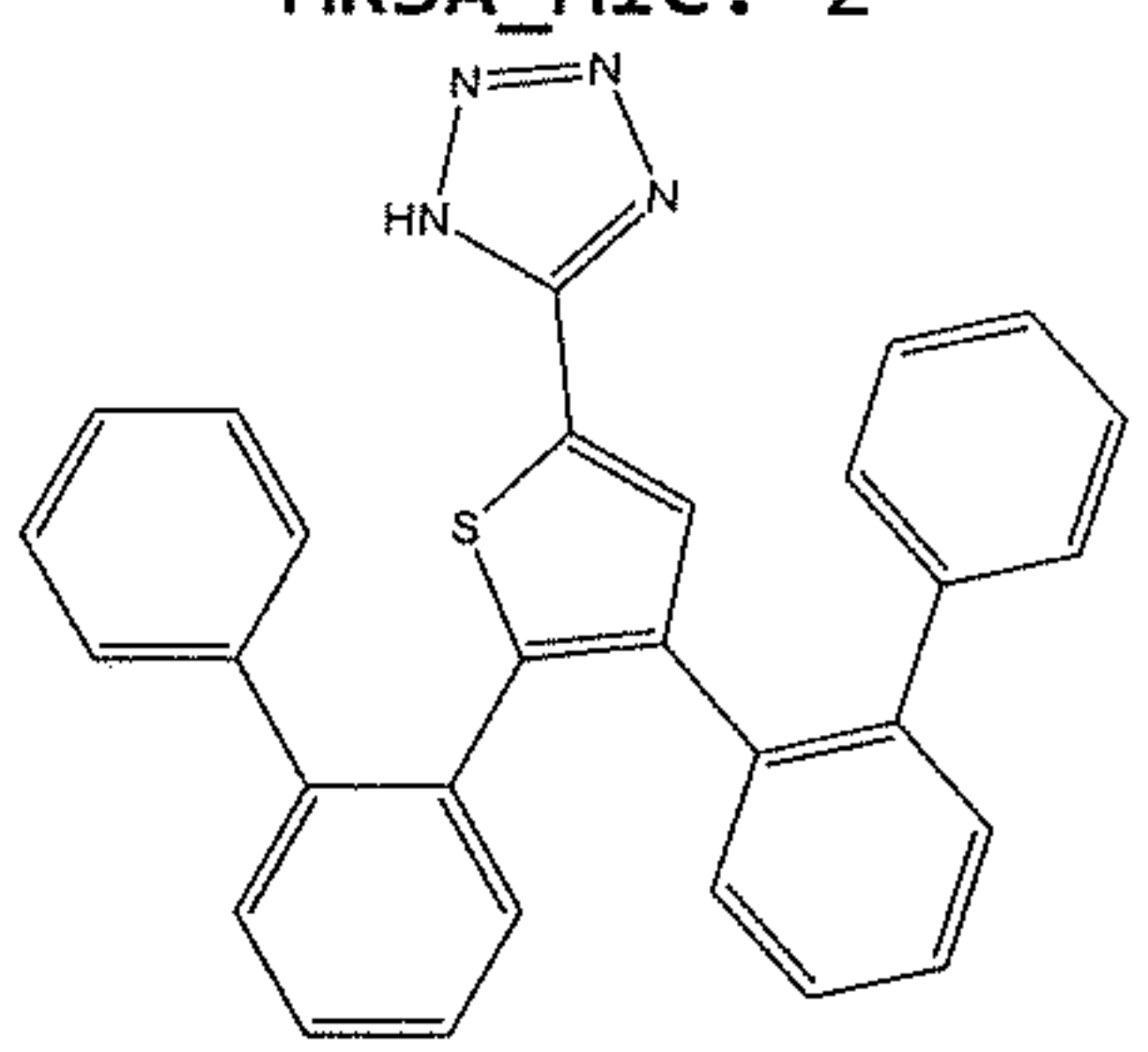
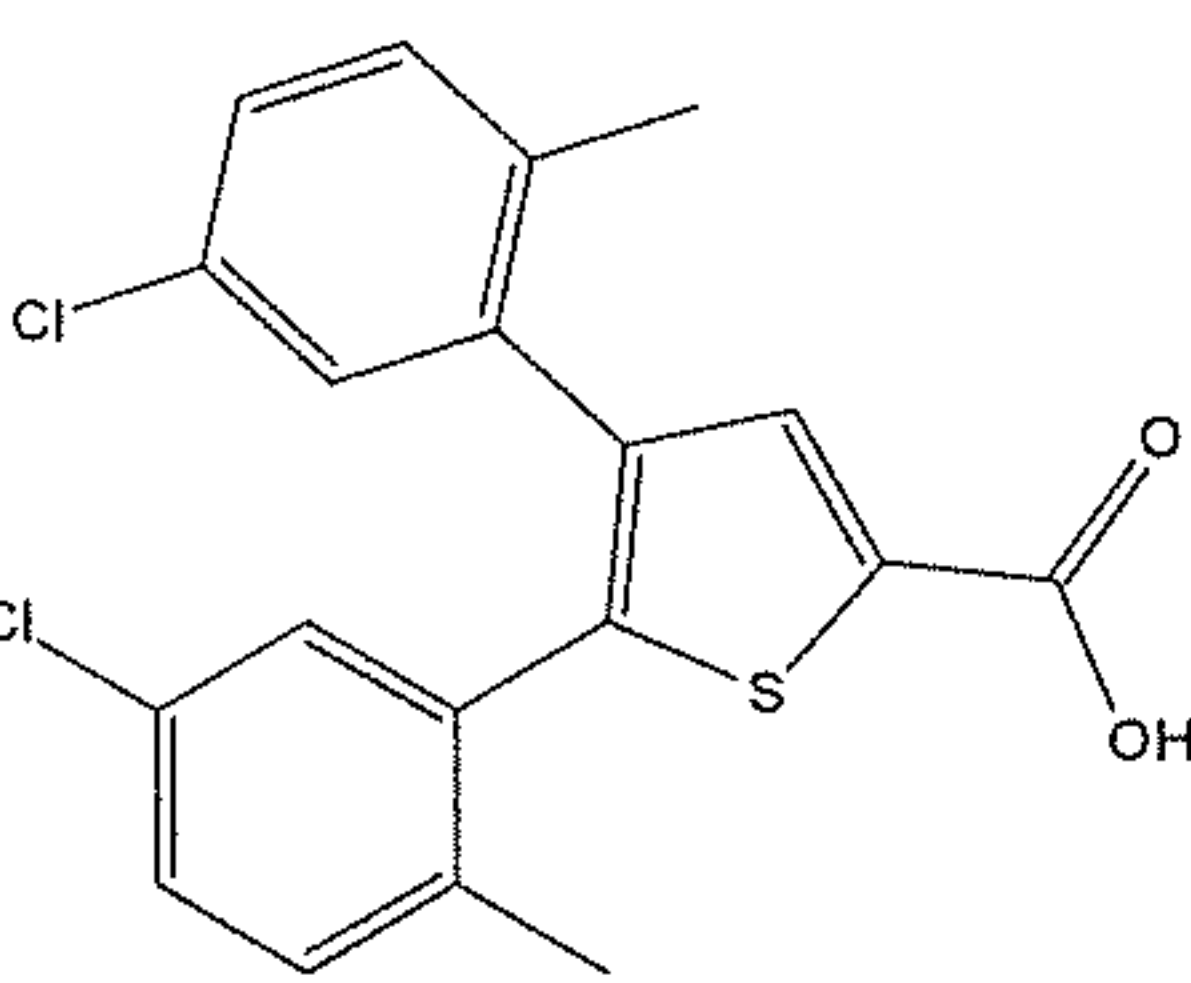
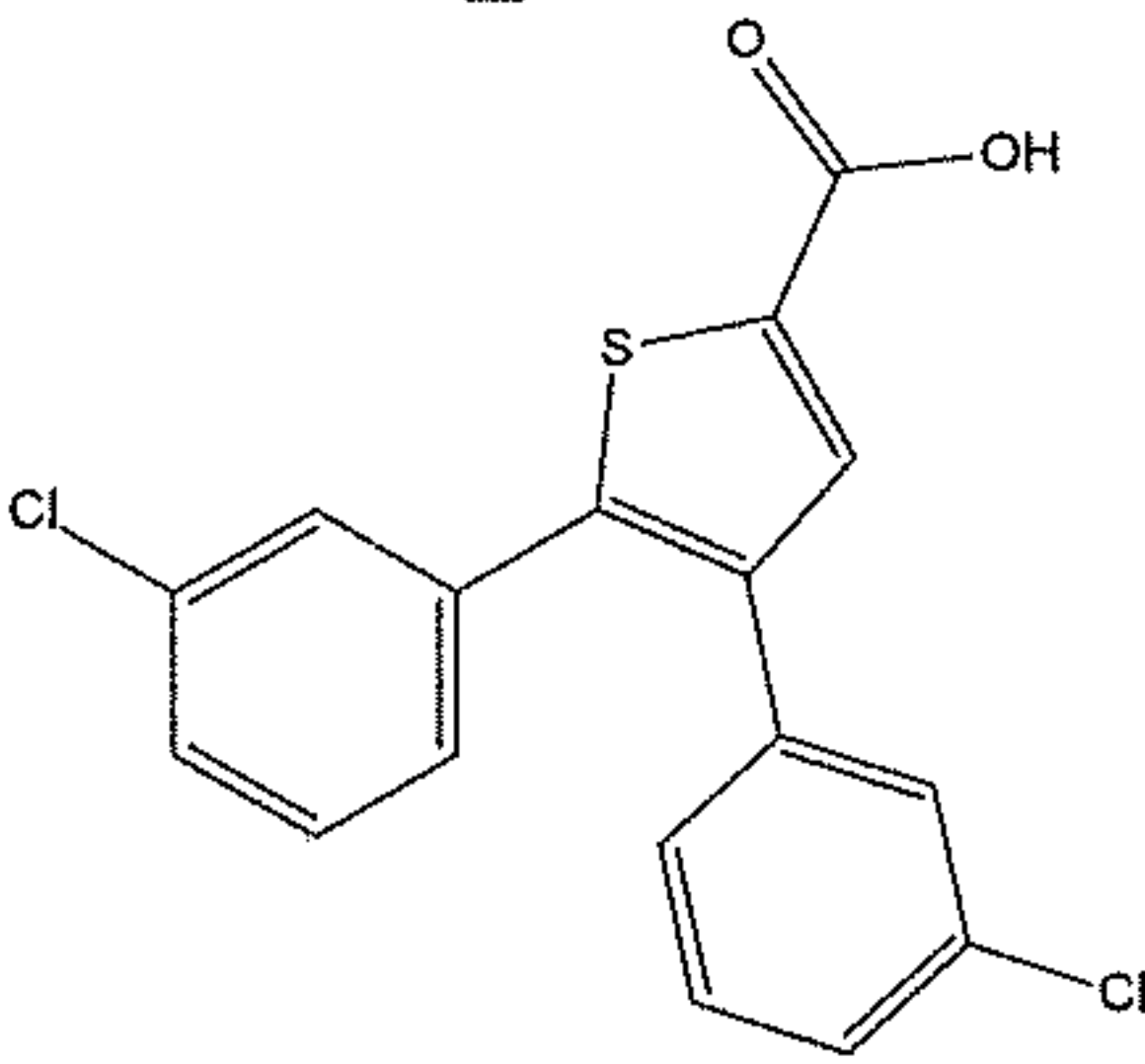
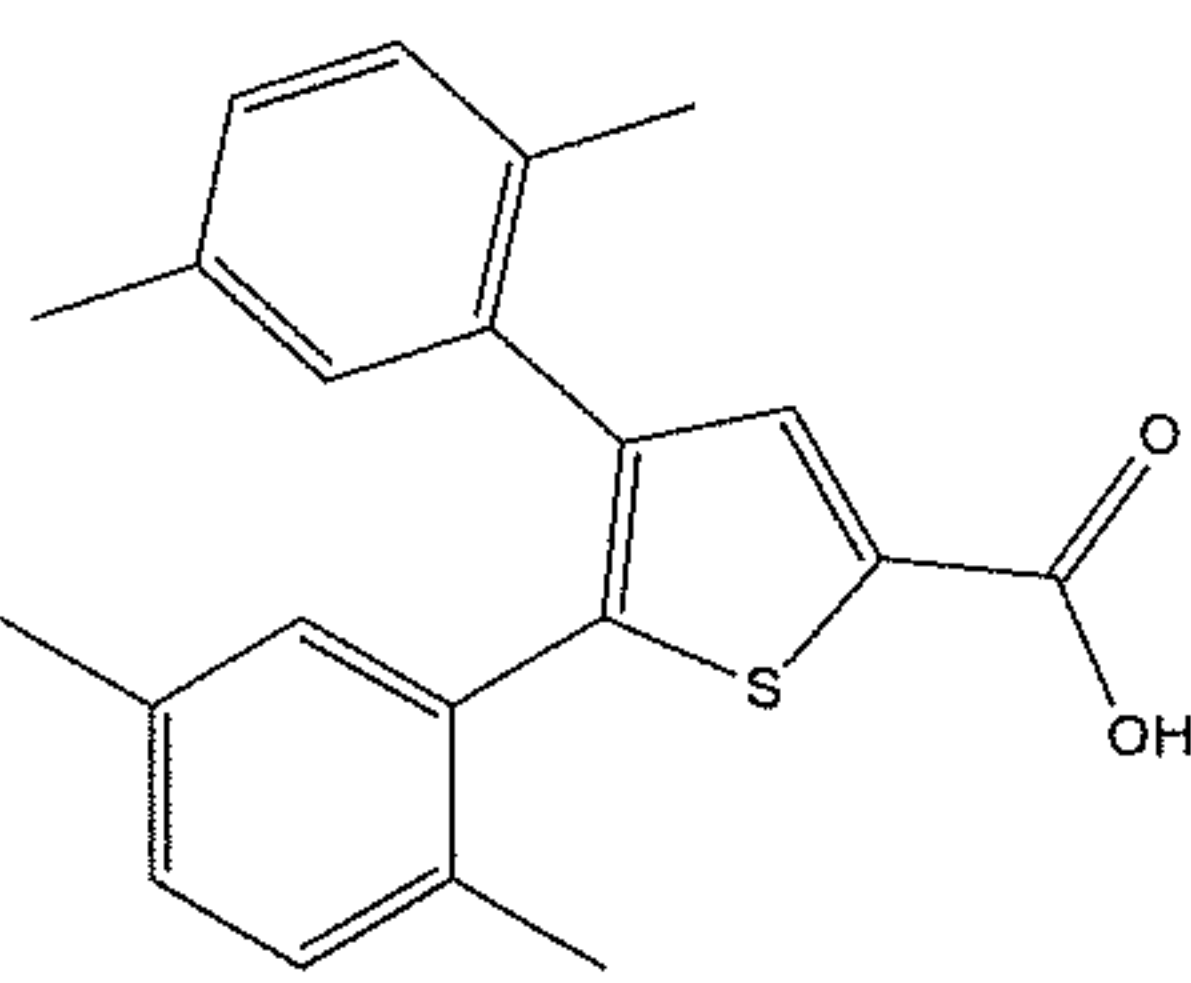
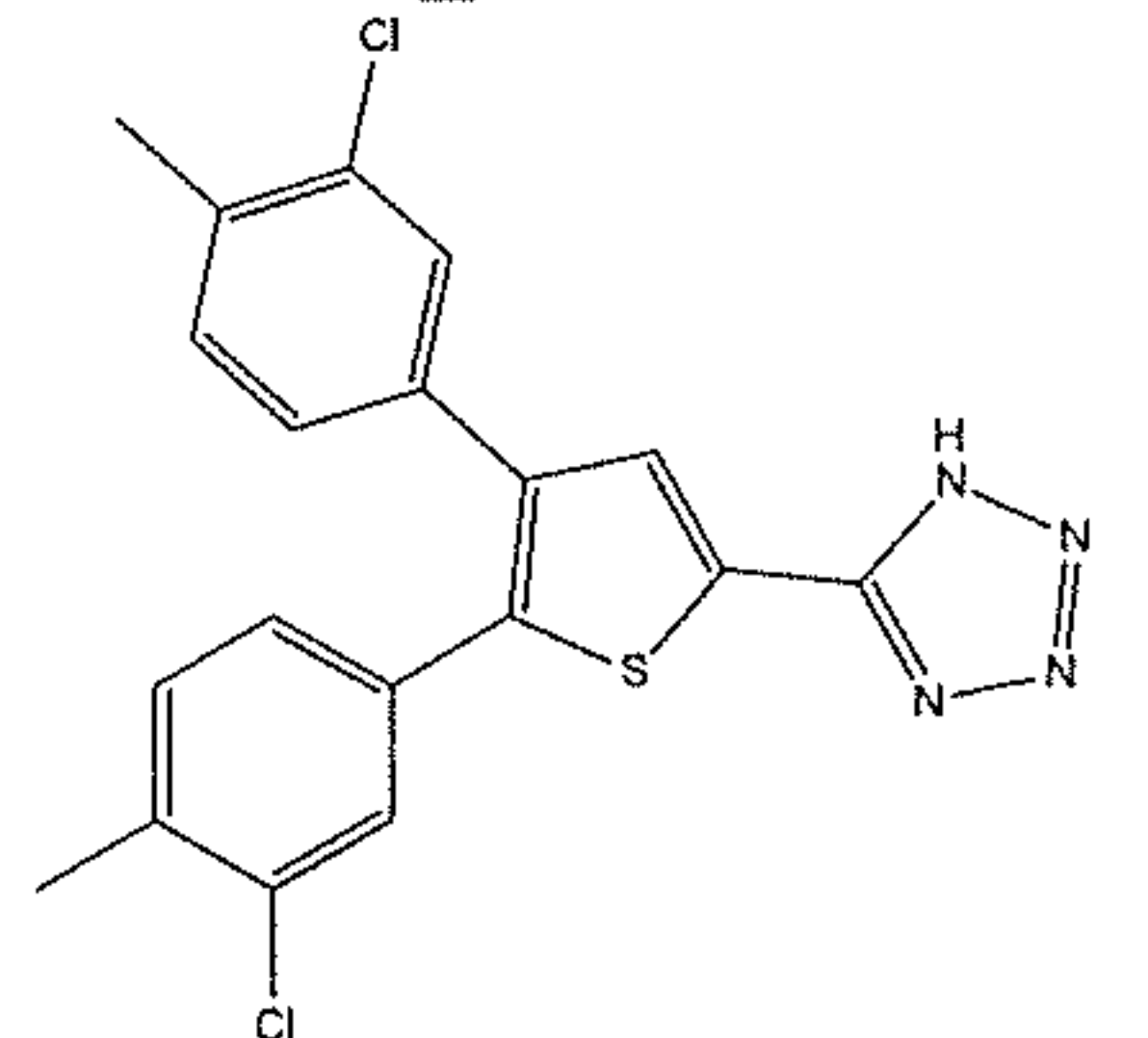
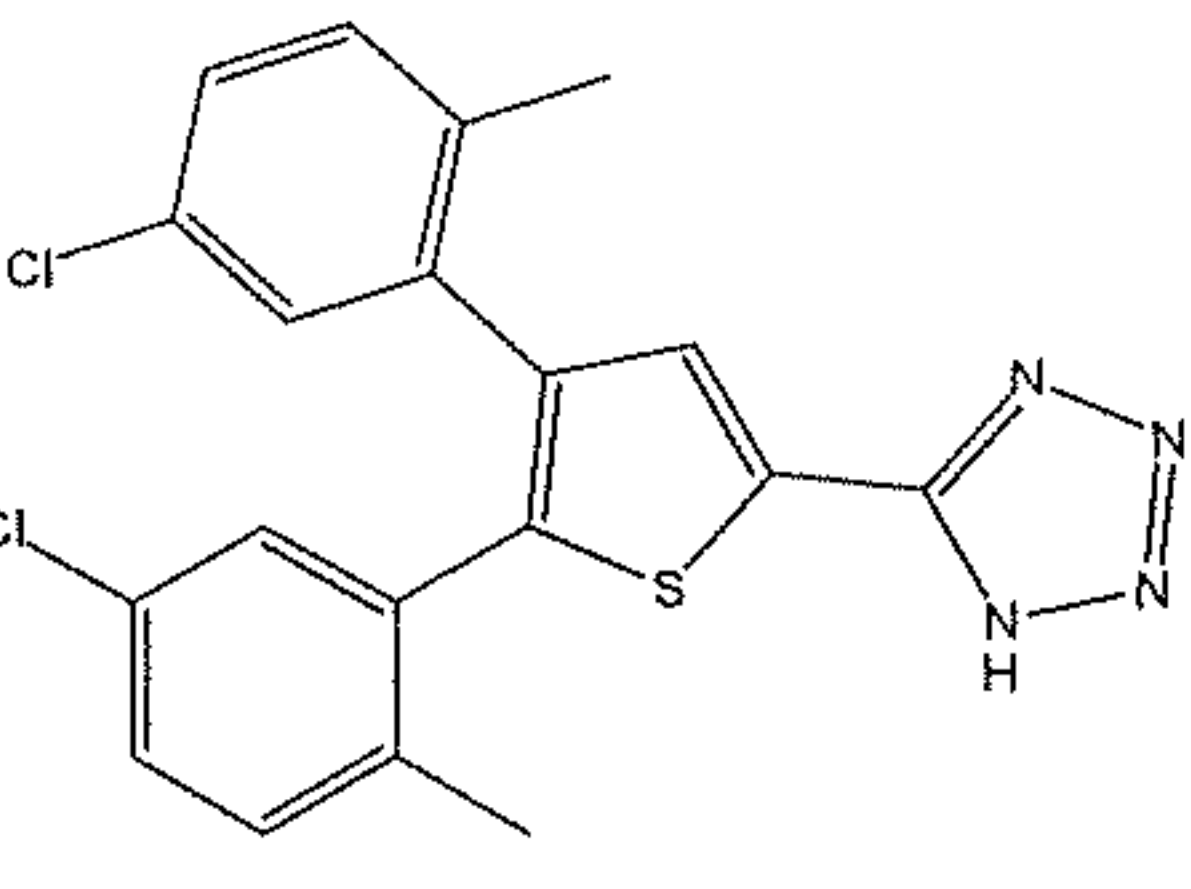
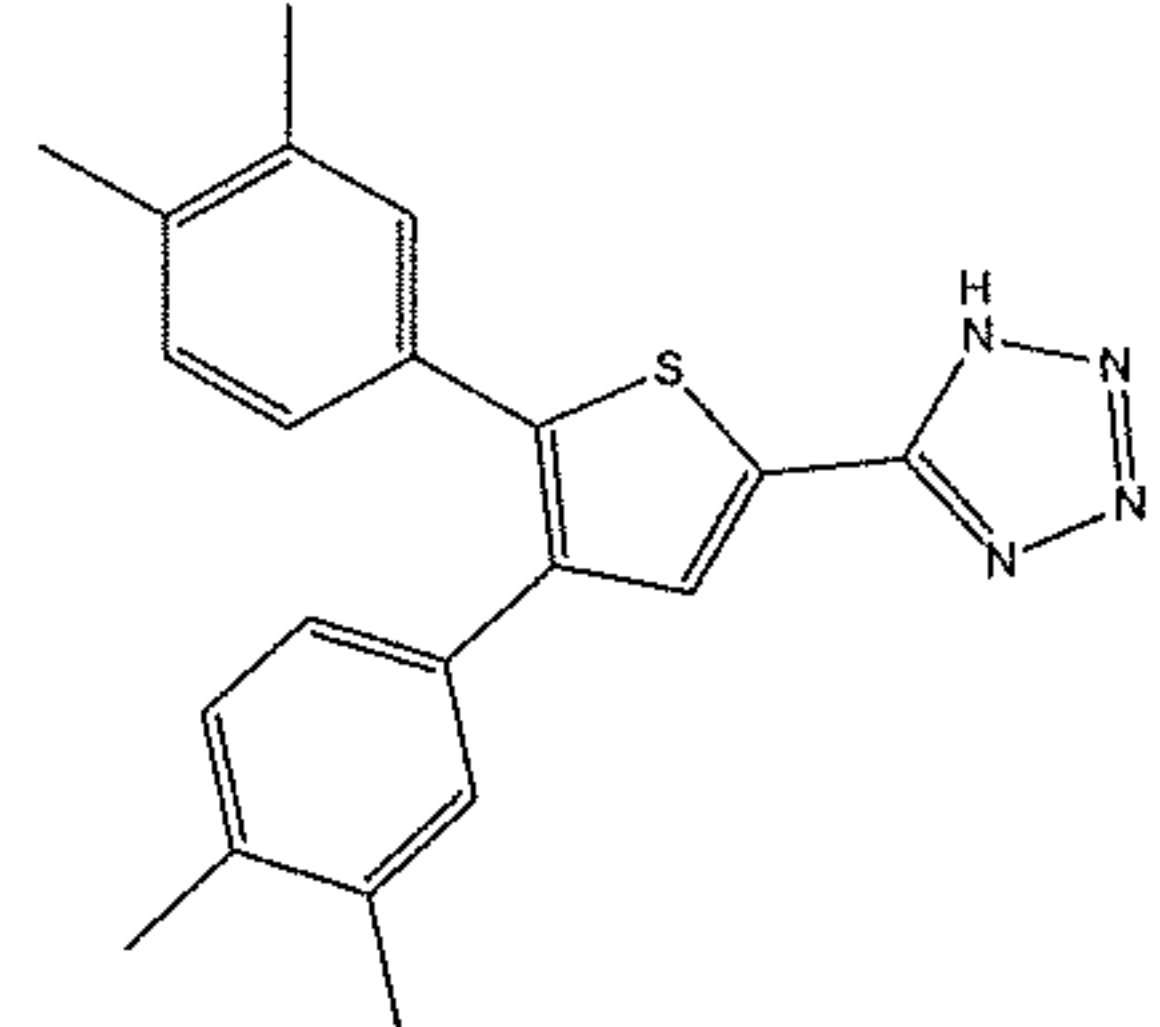
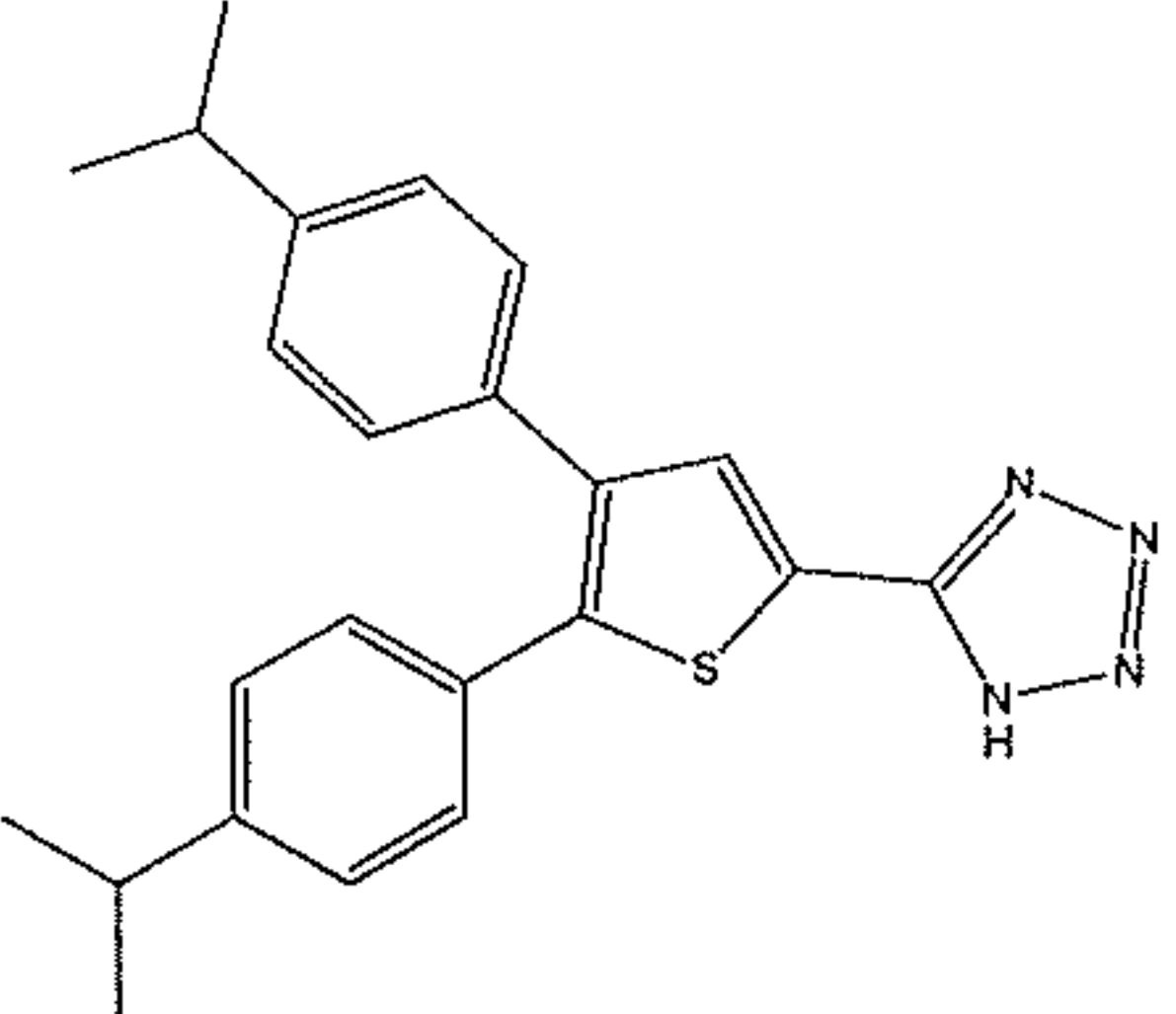
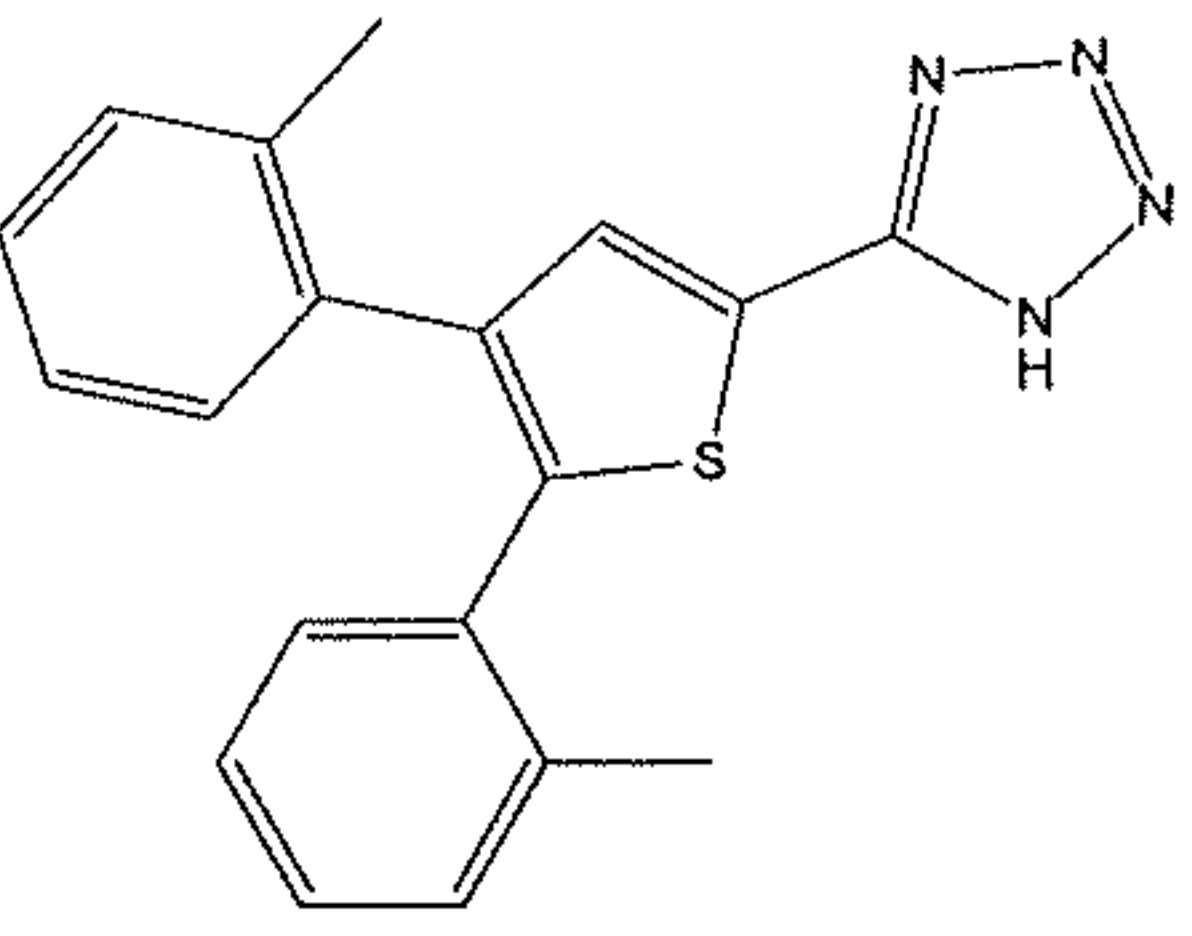
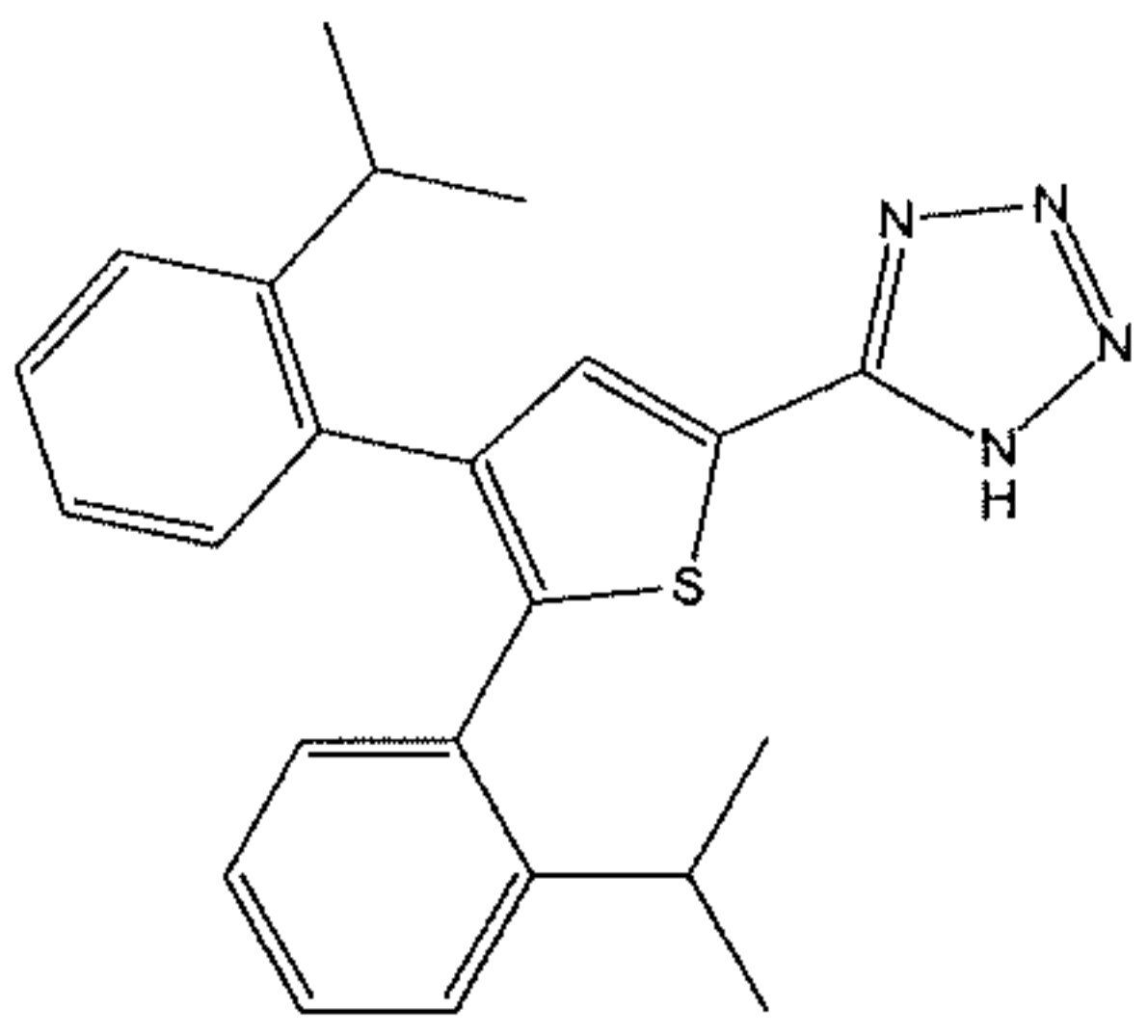
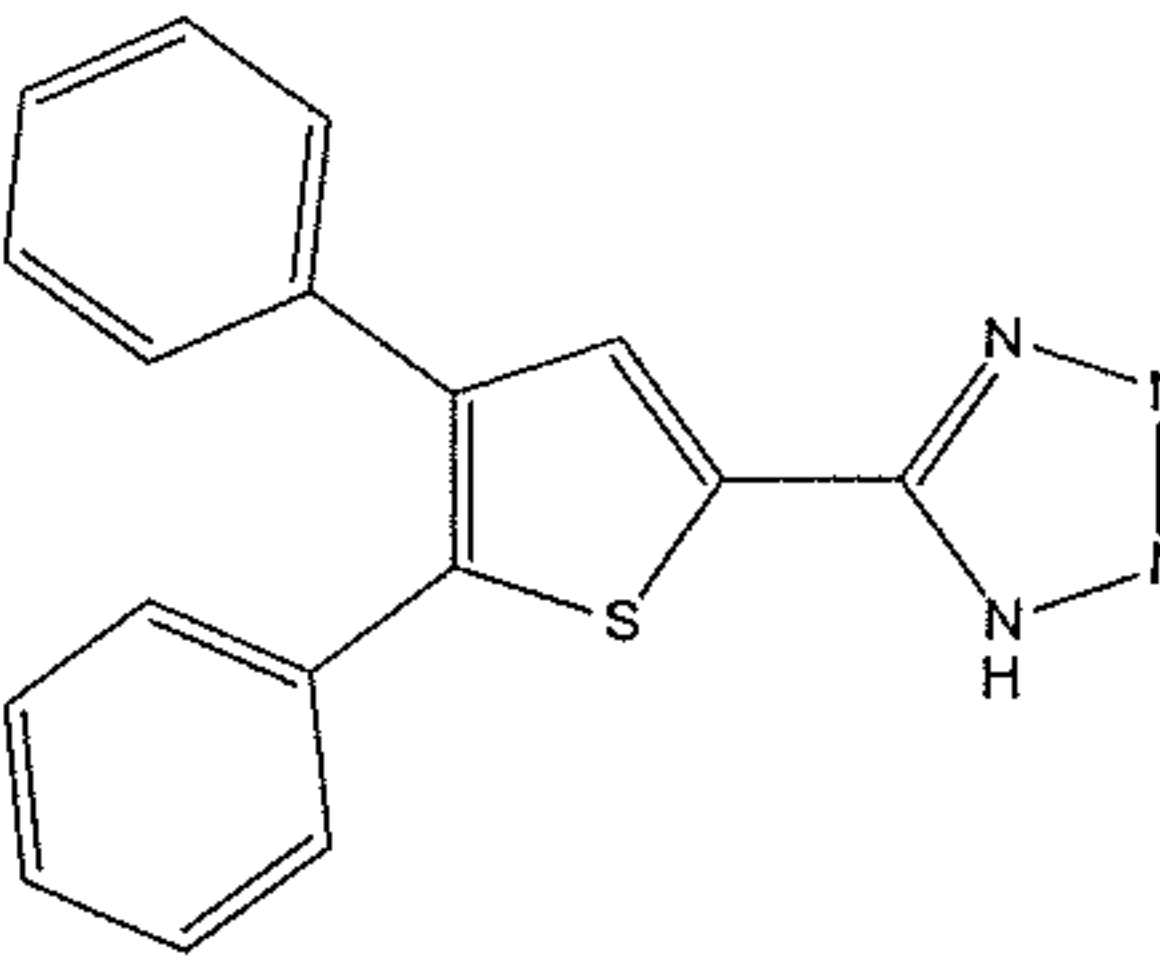
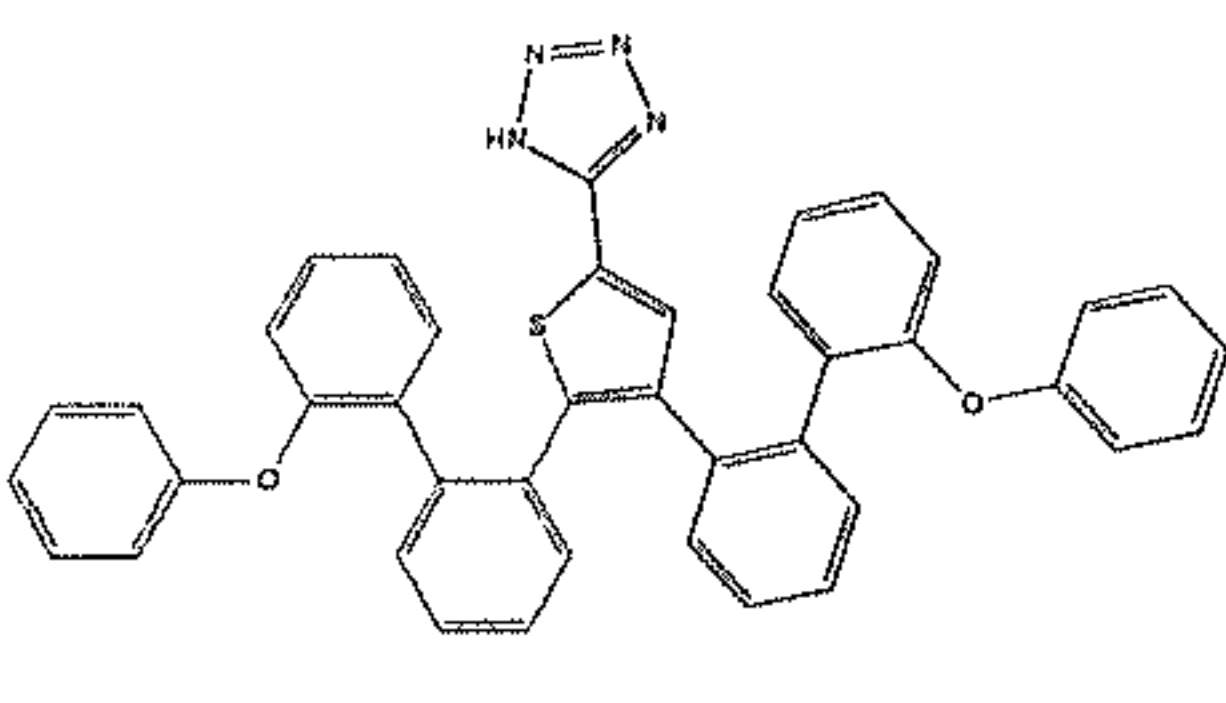
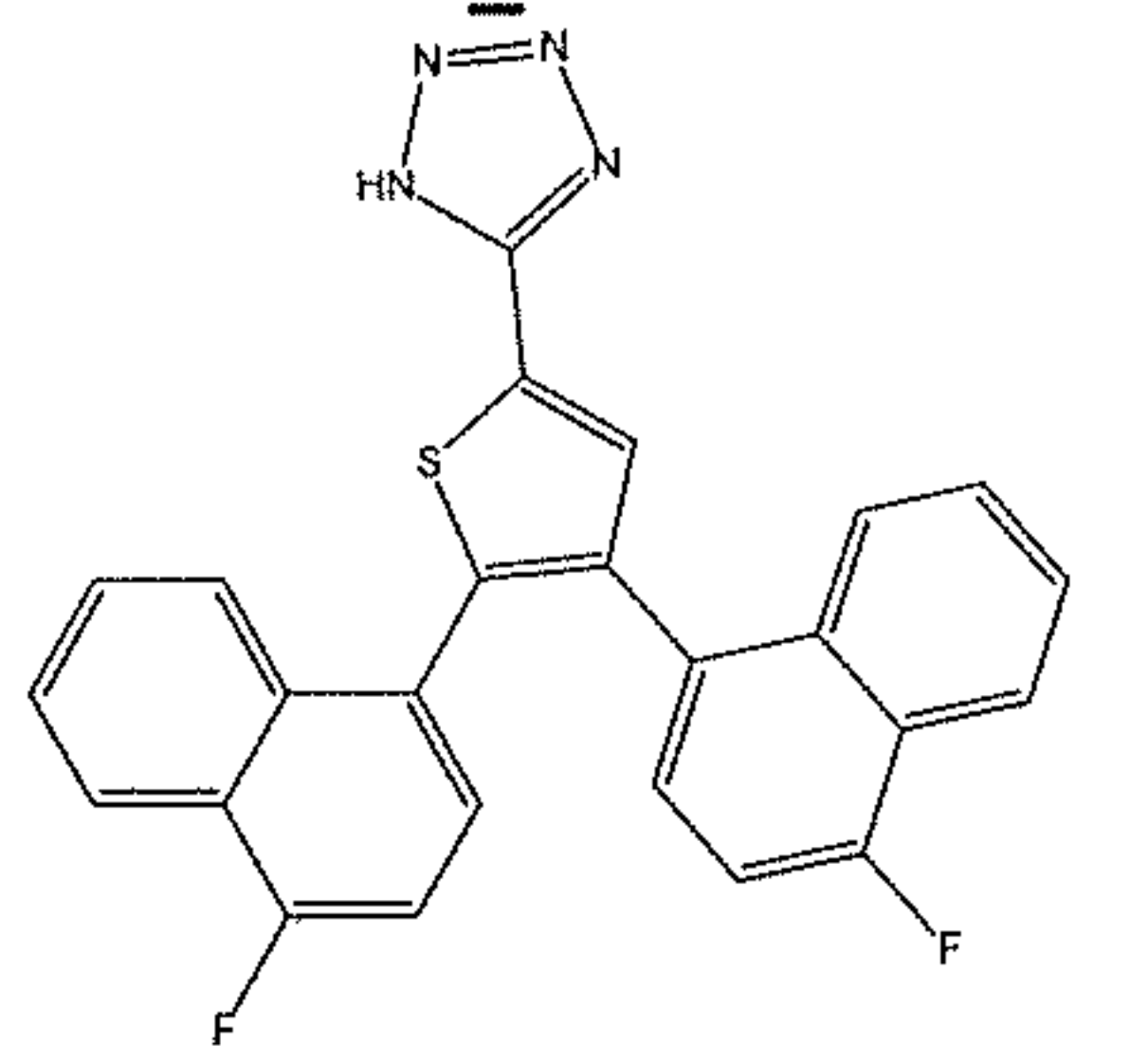
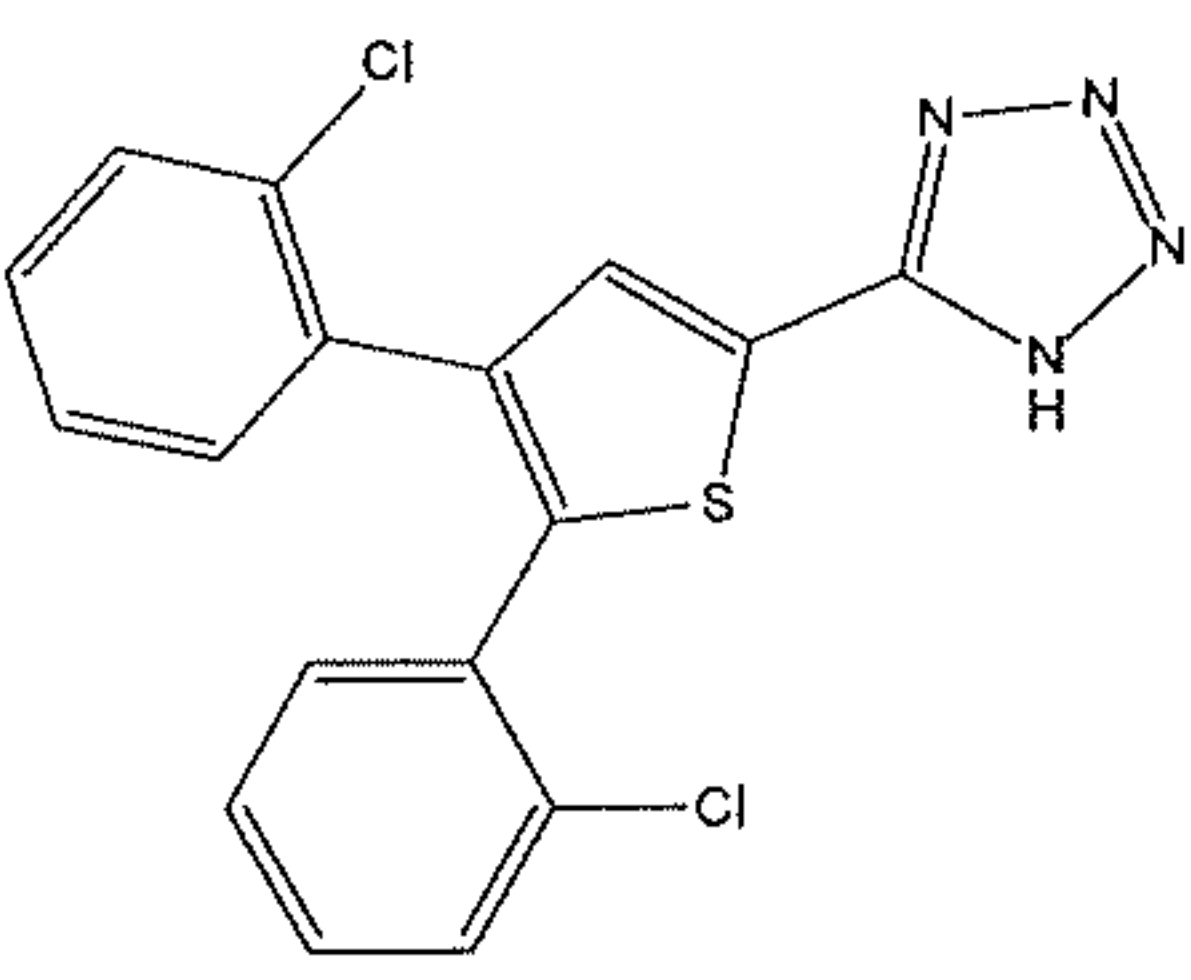
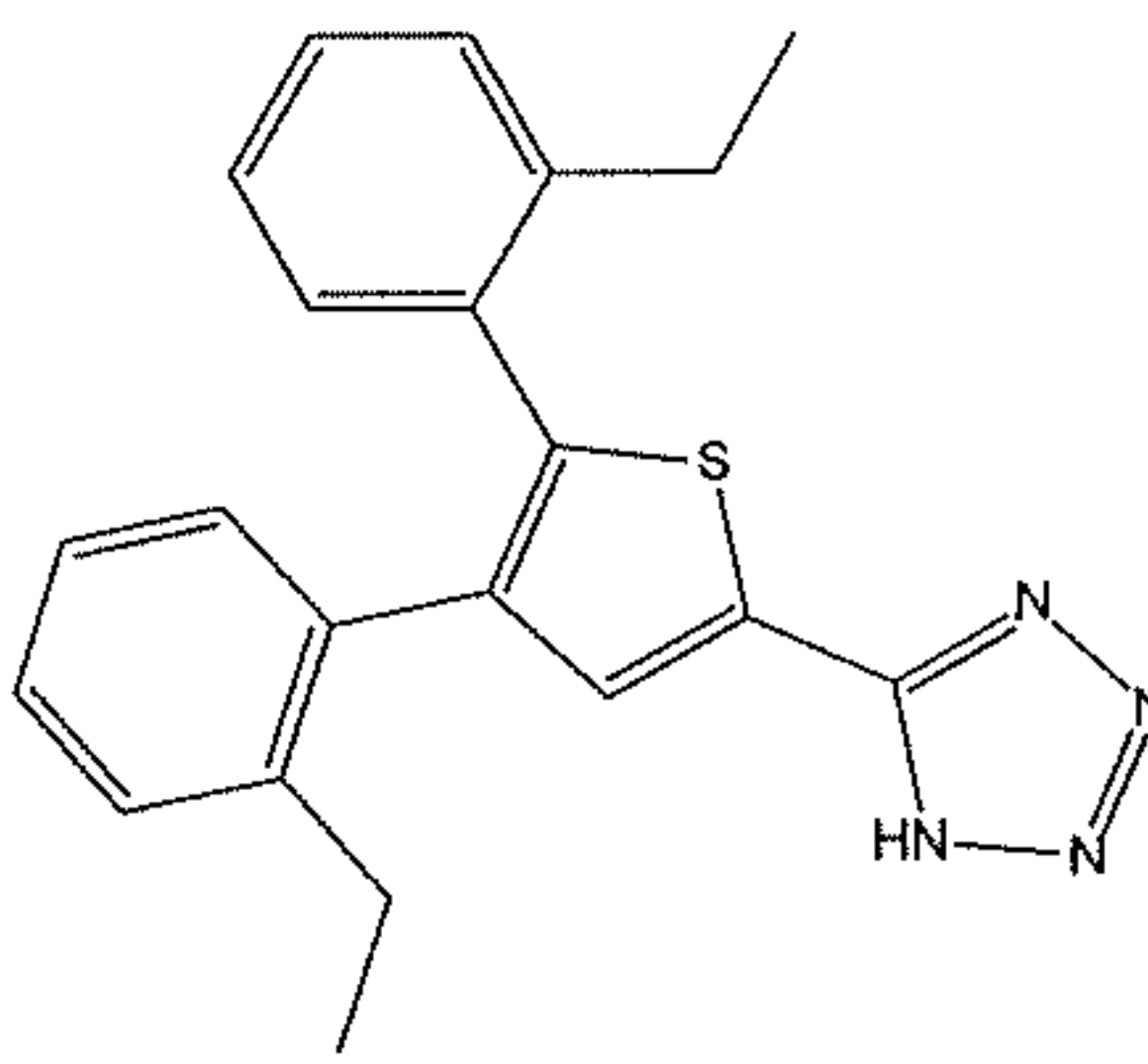
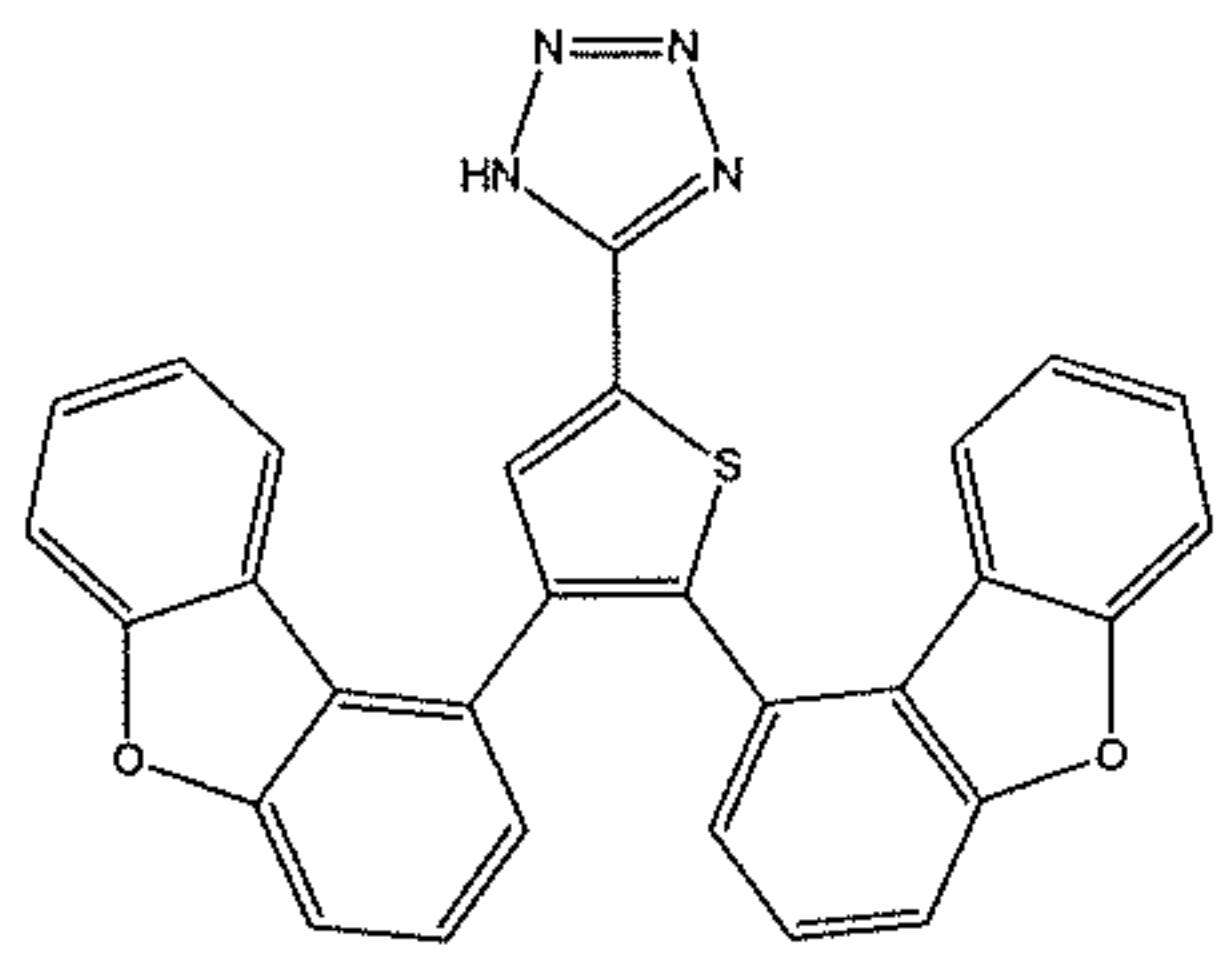
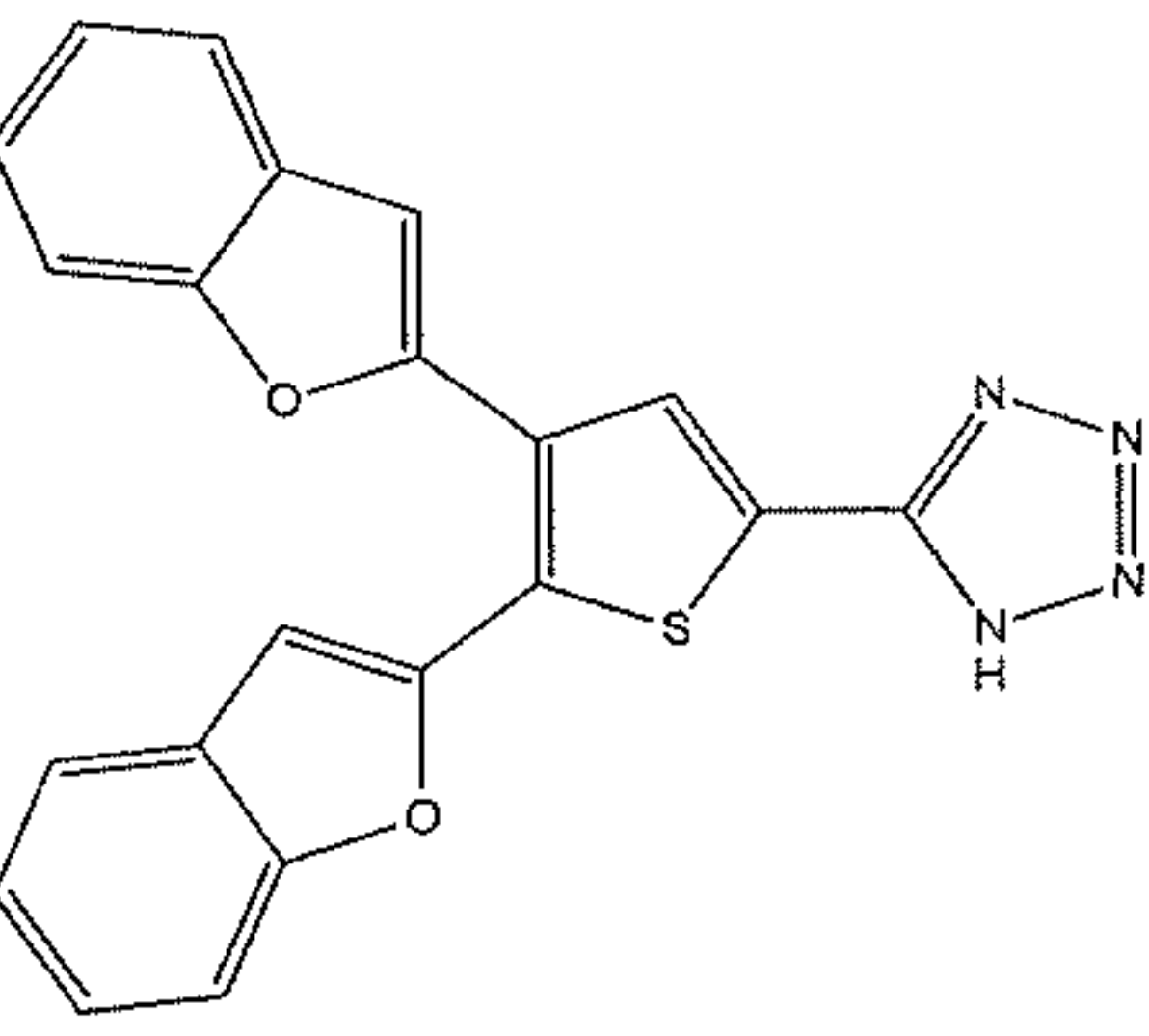
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FIG. 1-1

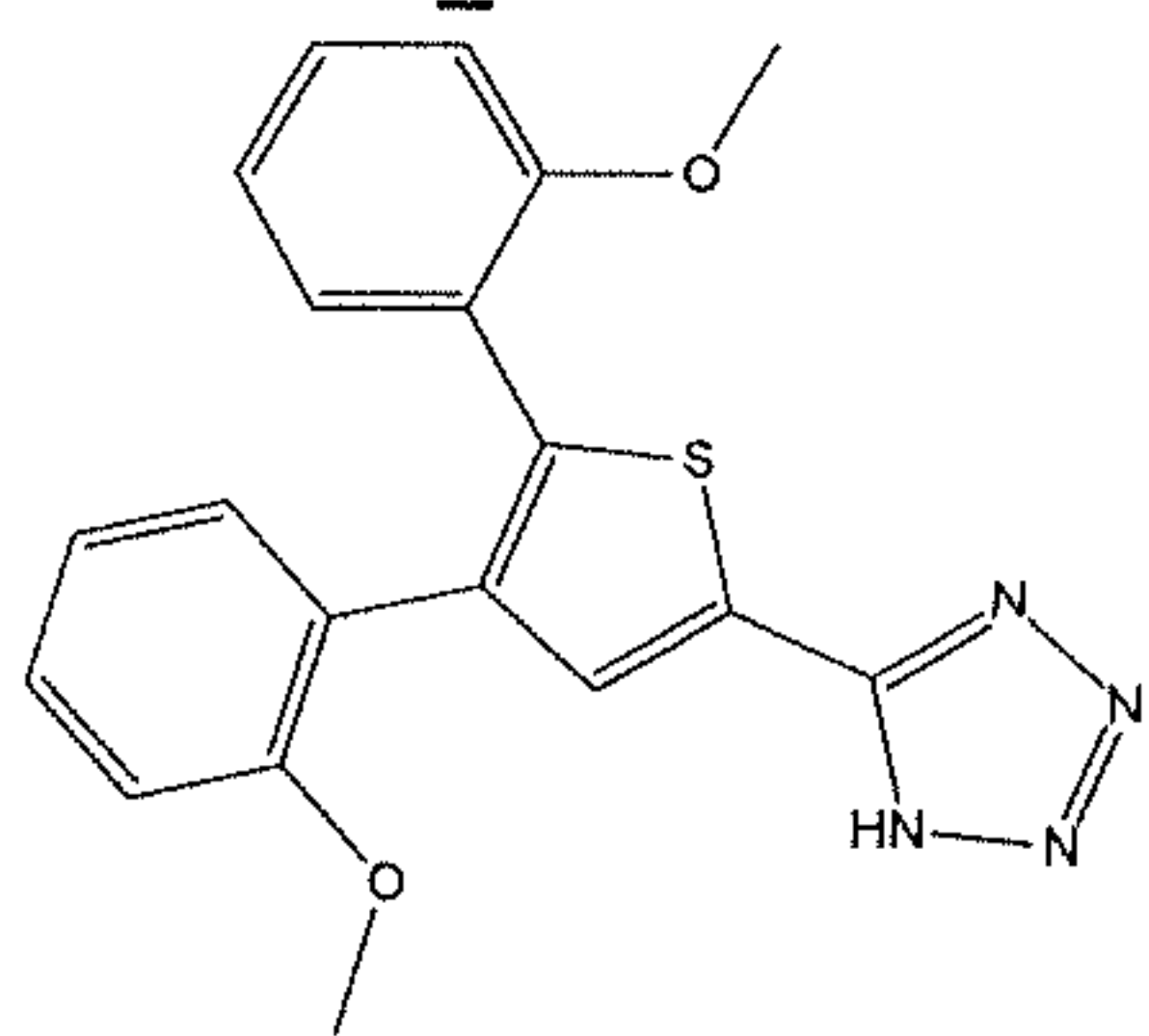
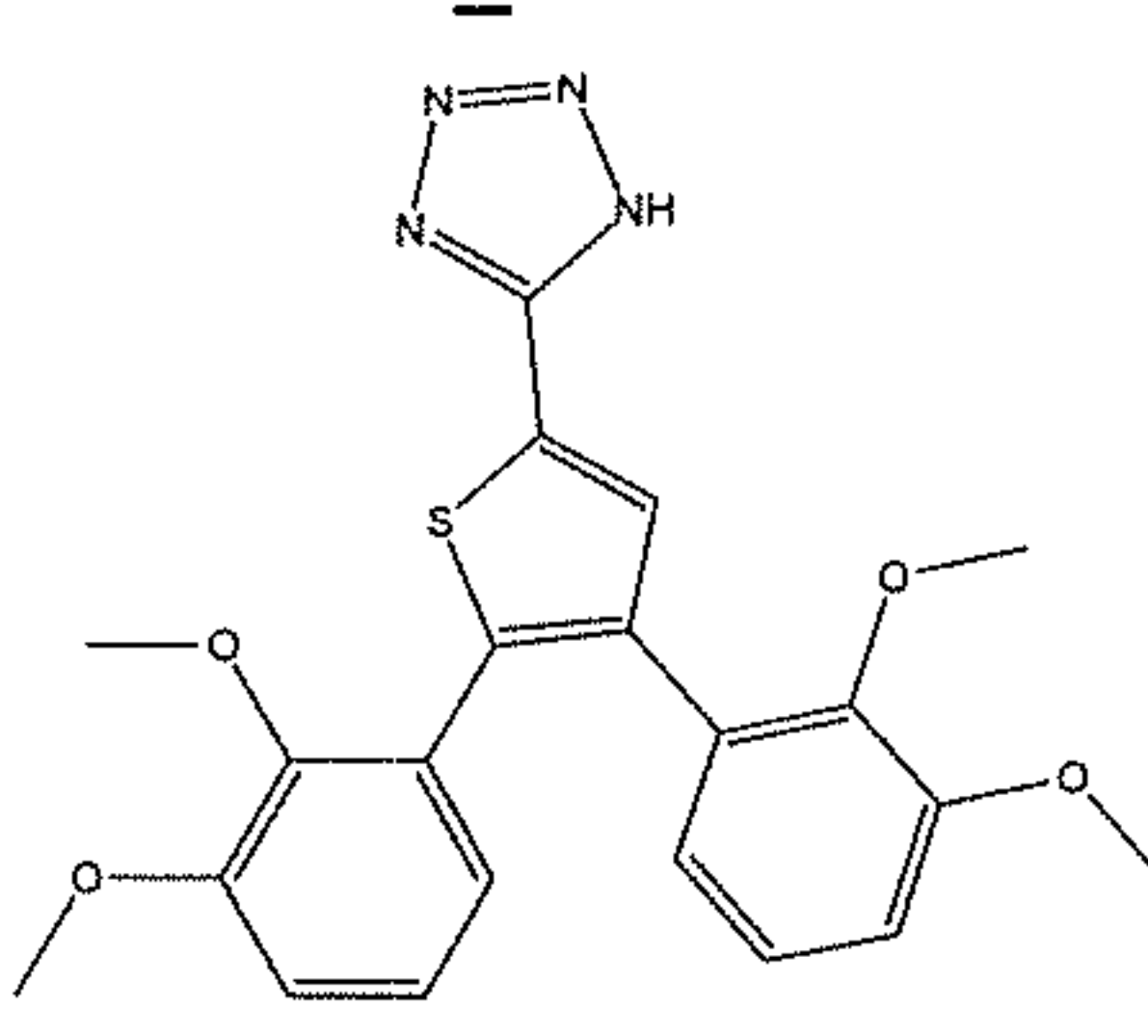
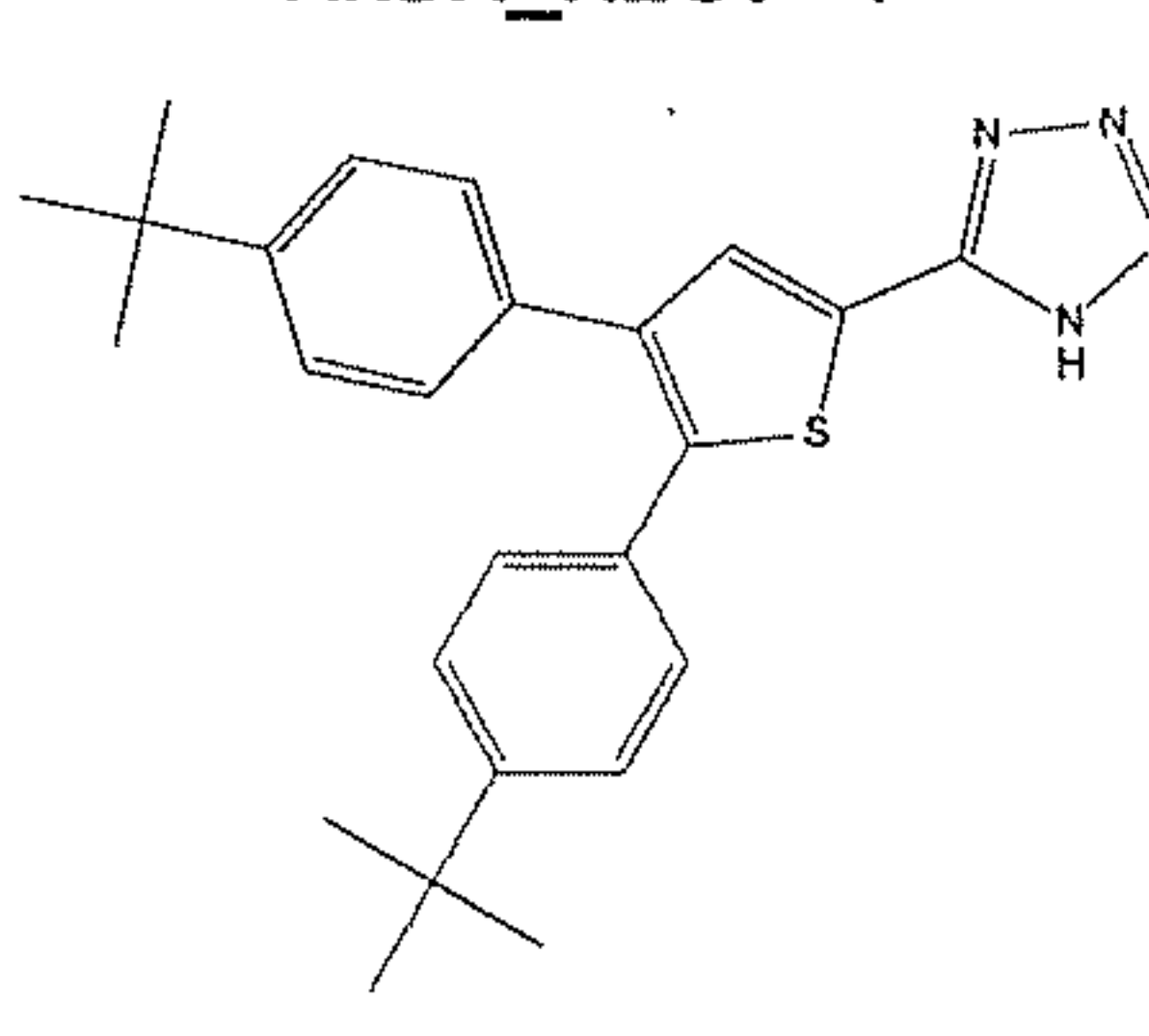
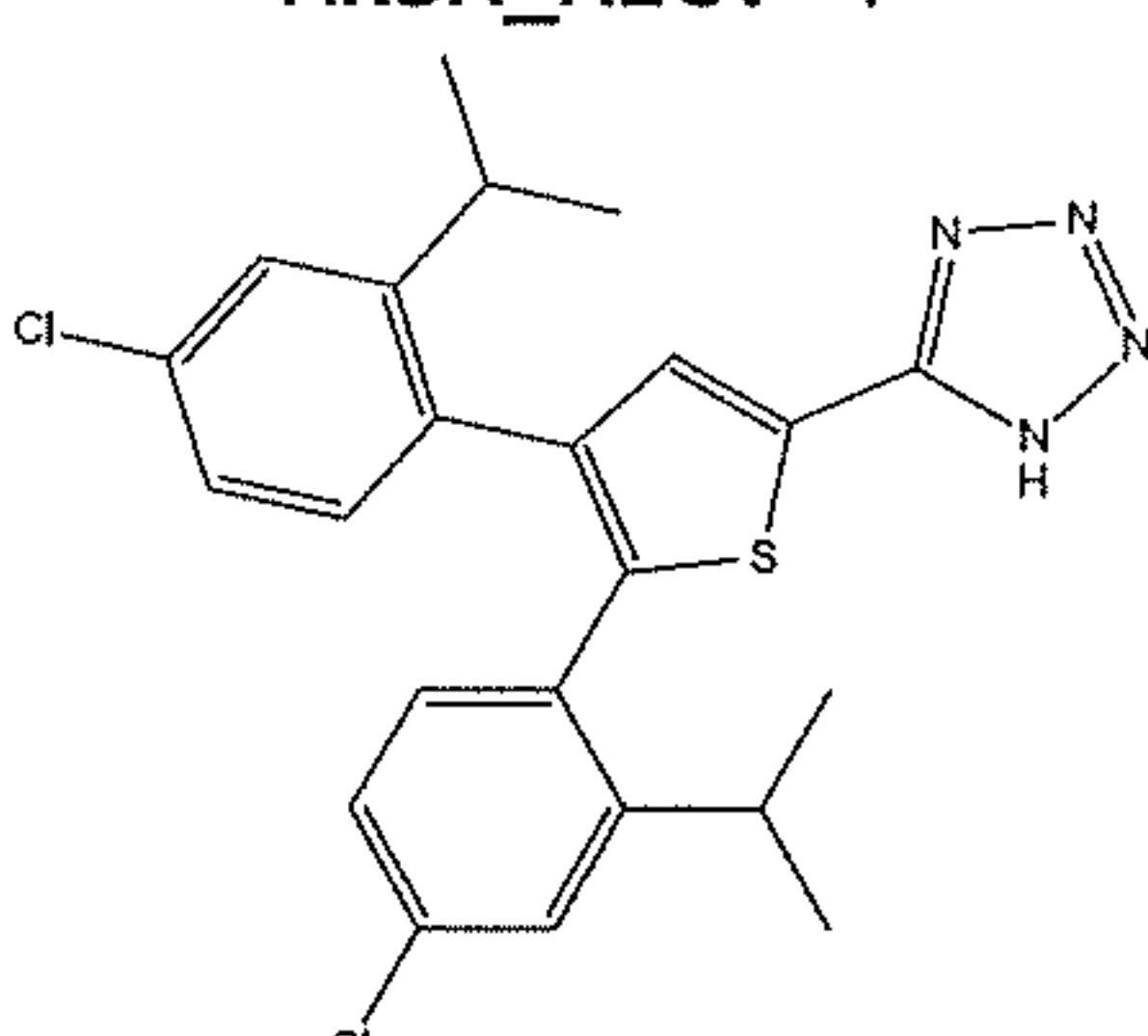
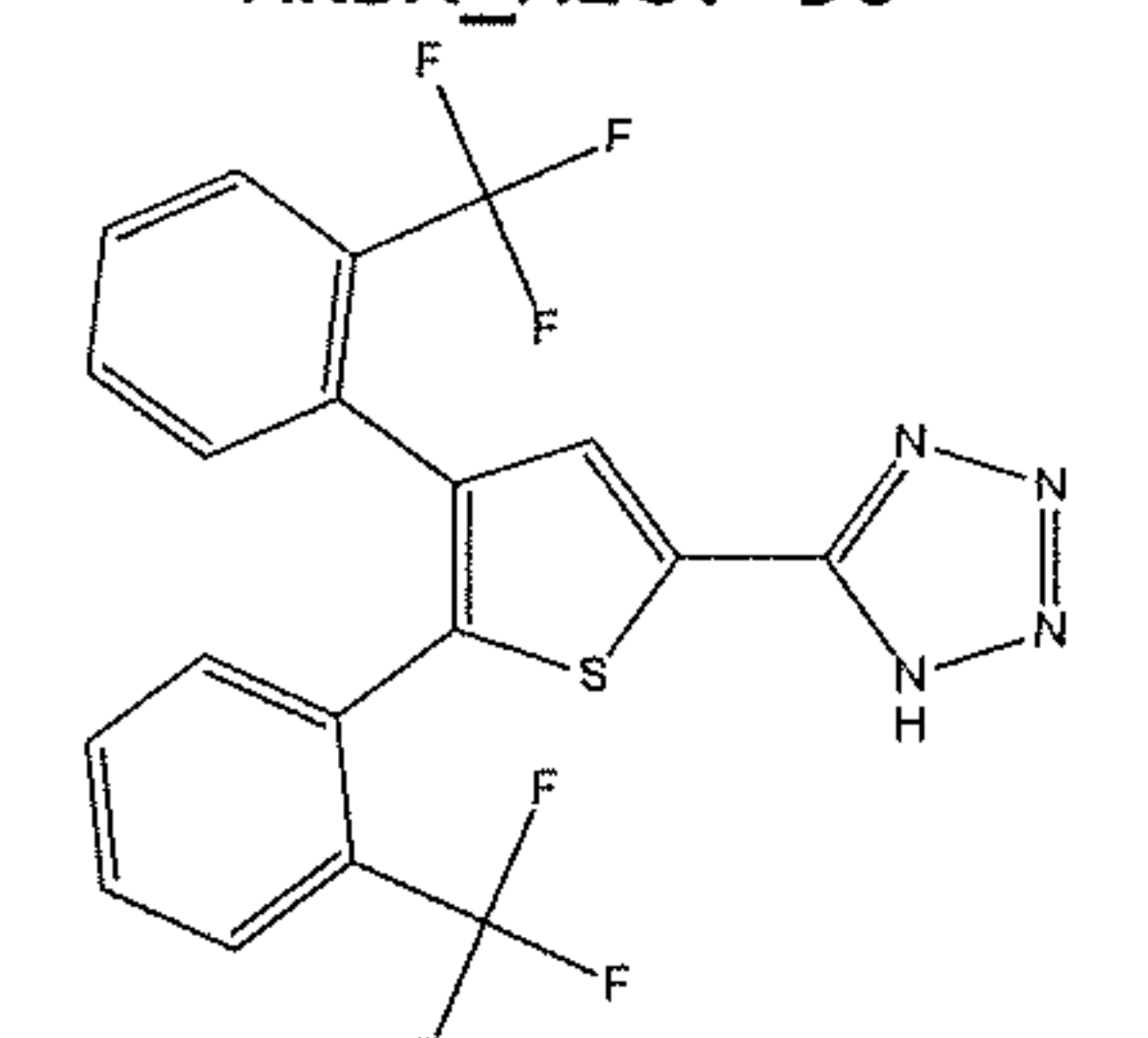
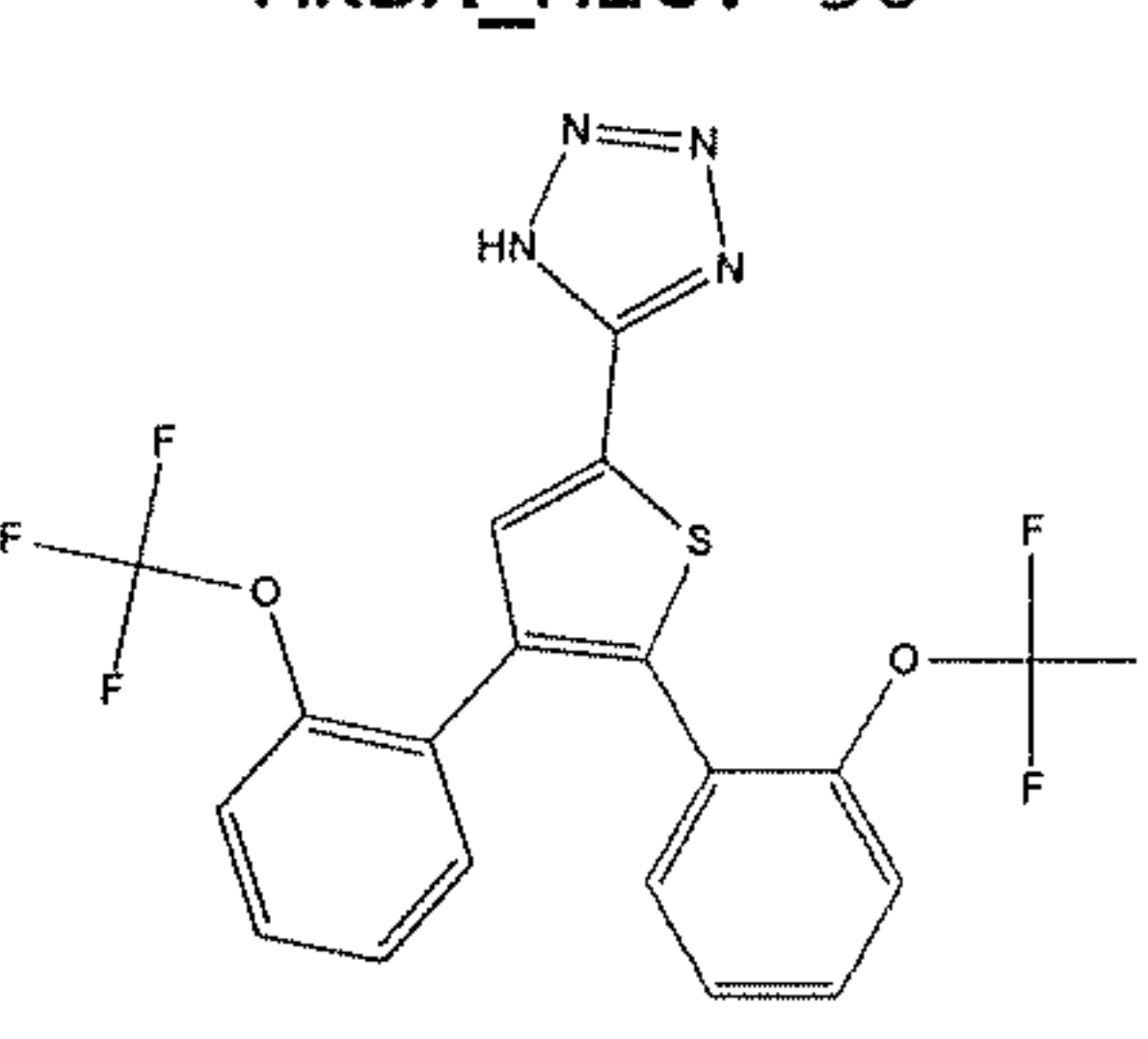
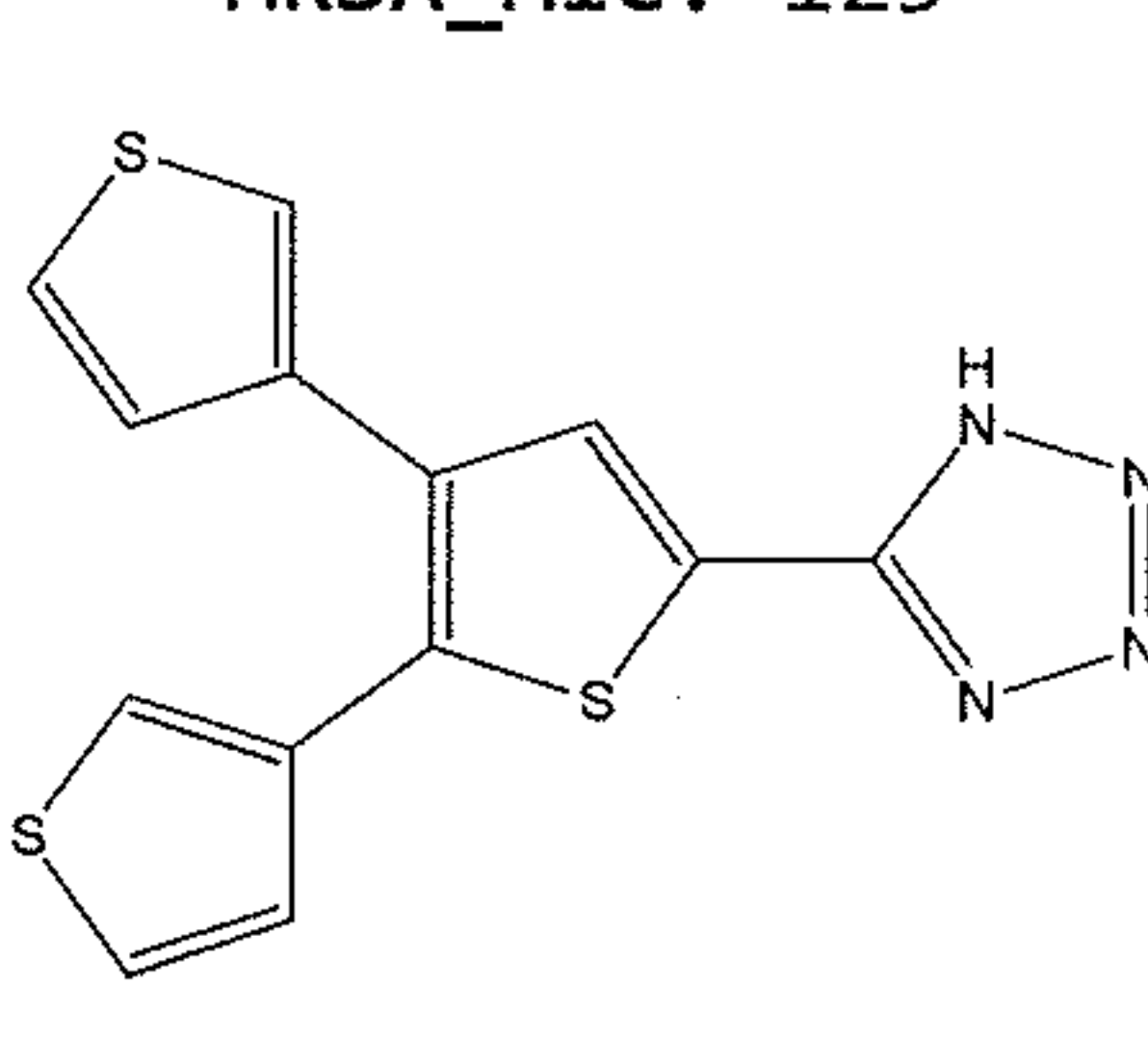
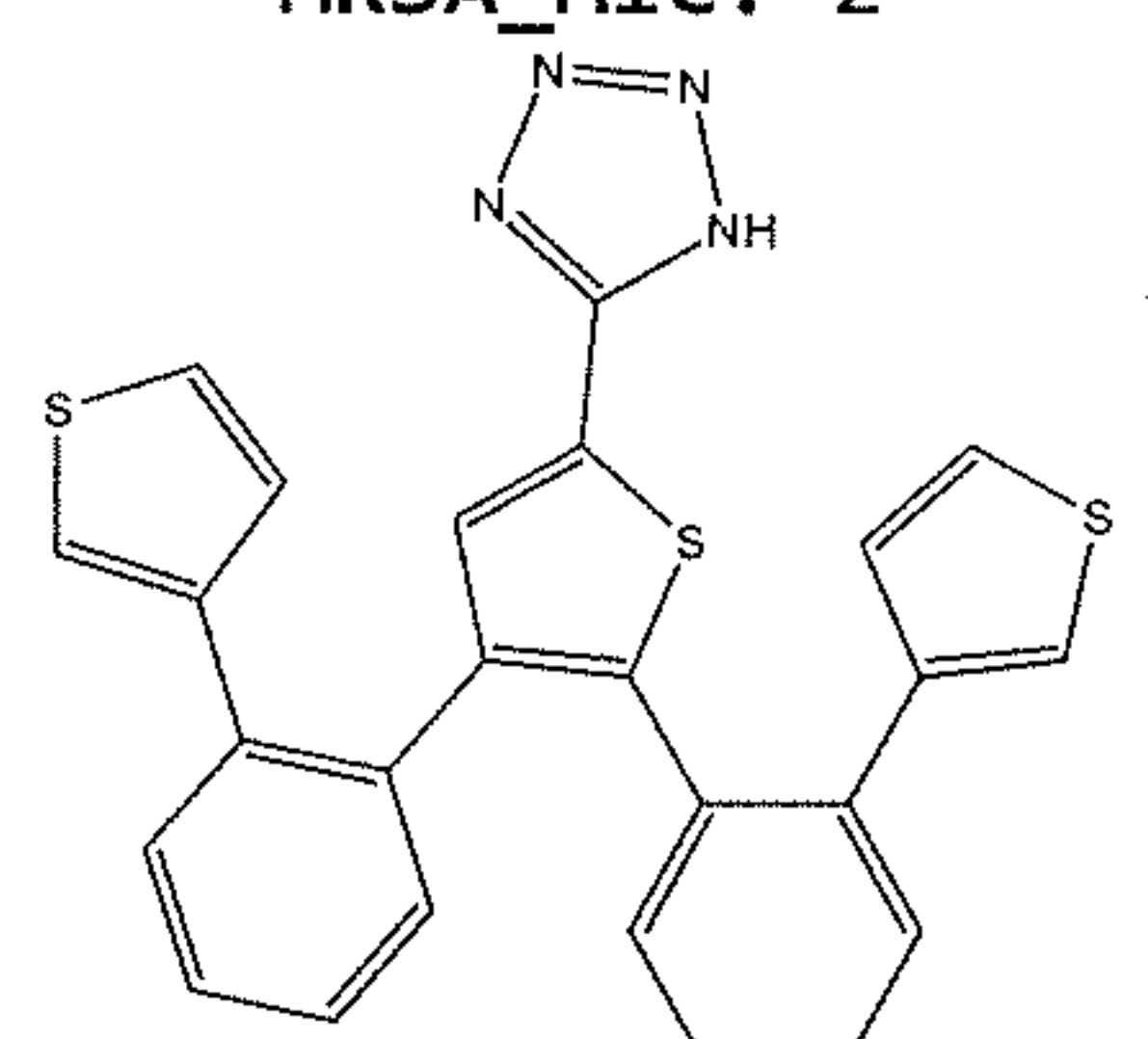
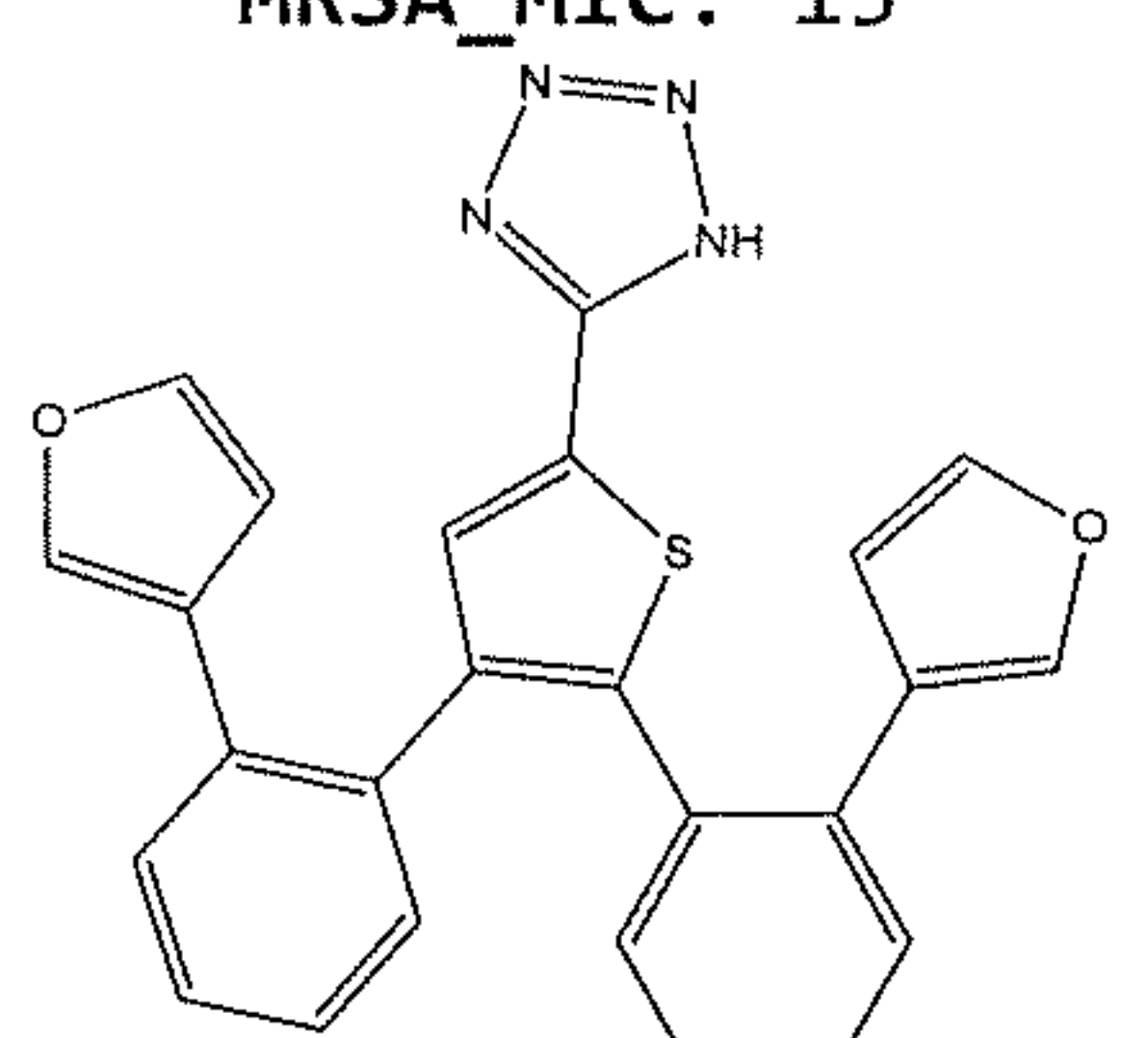
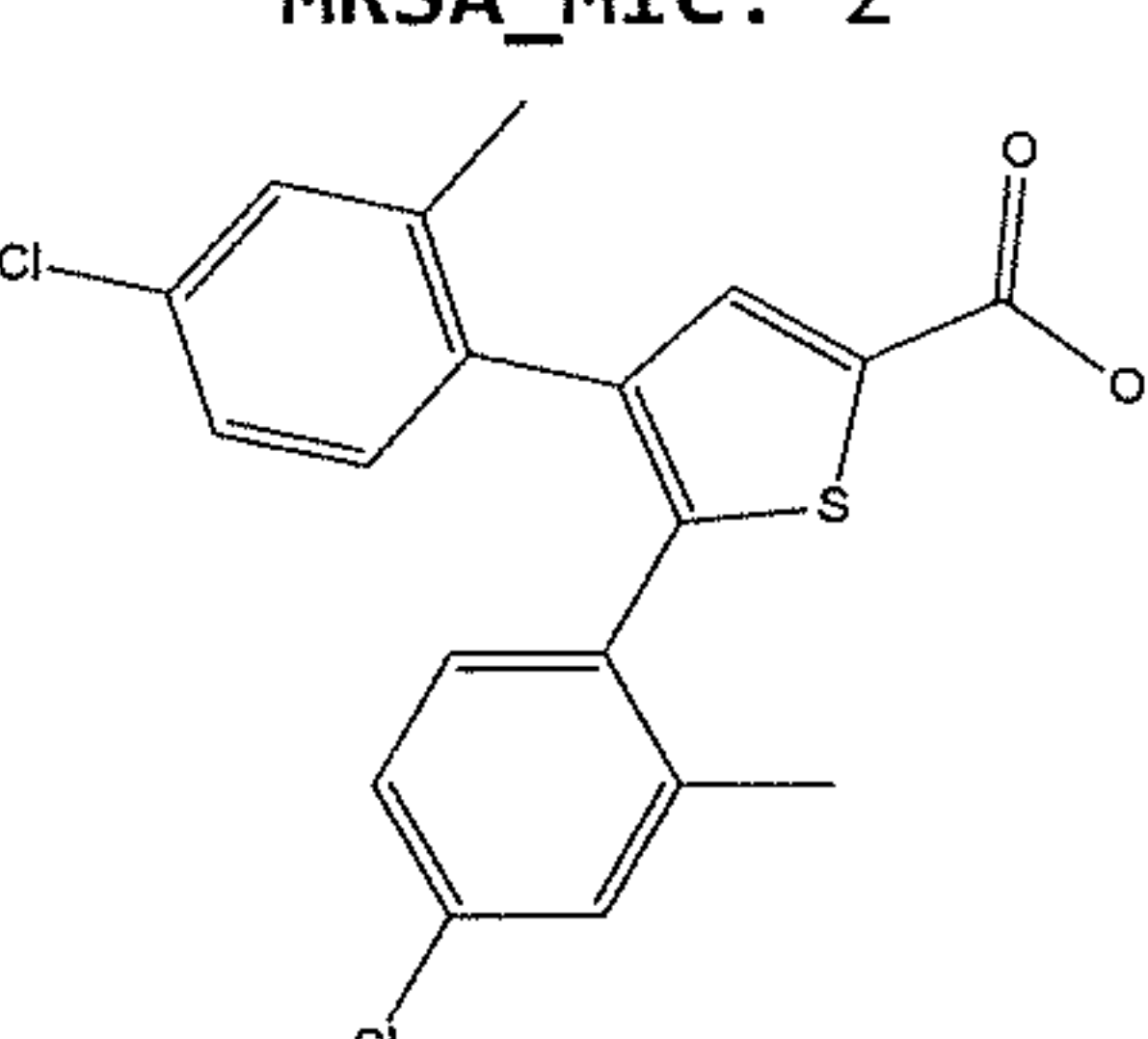
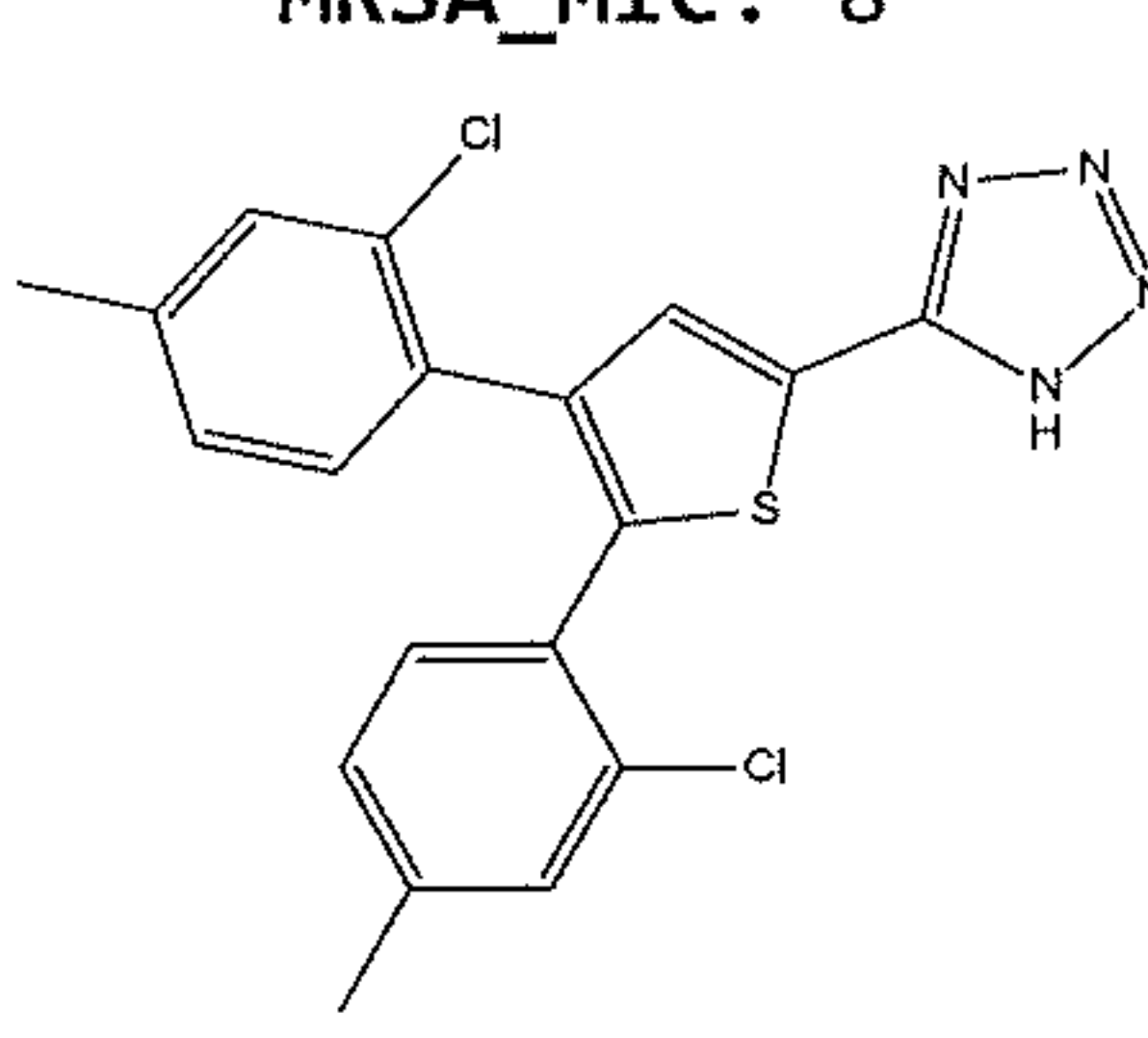
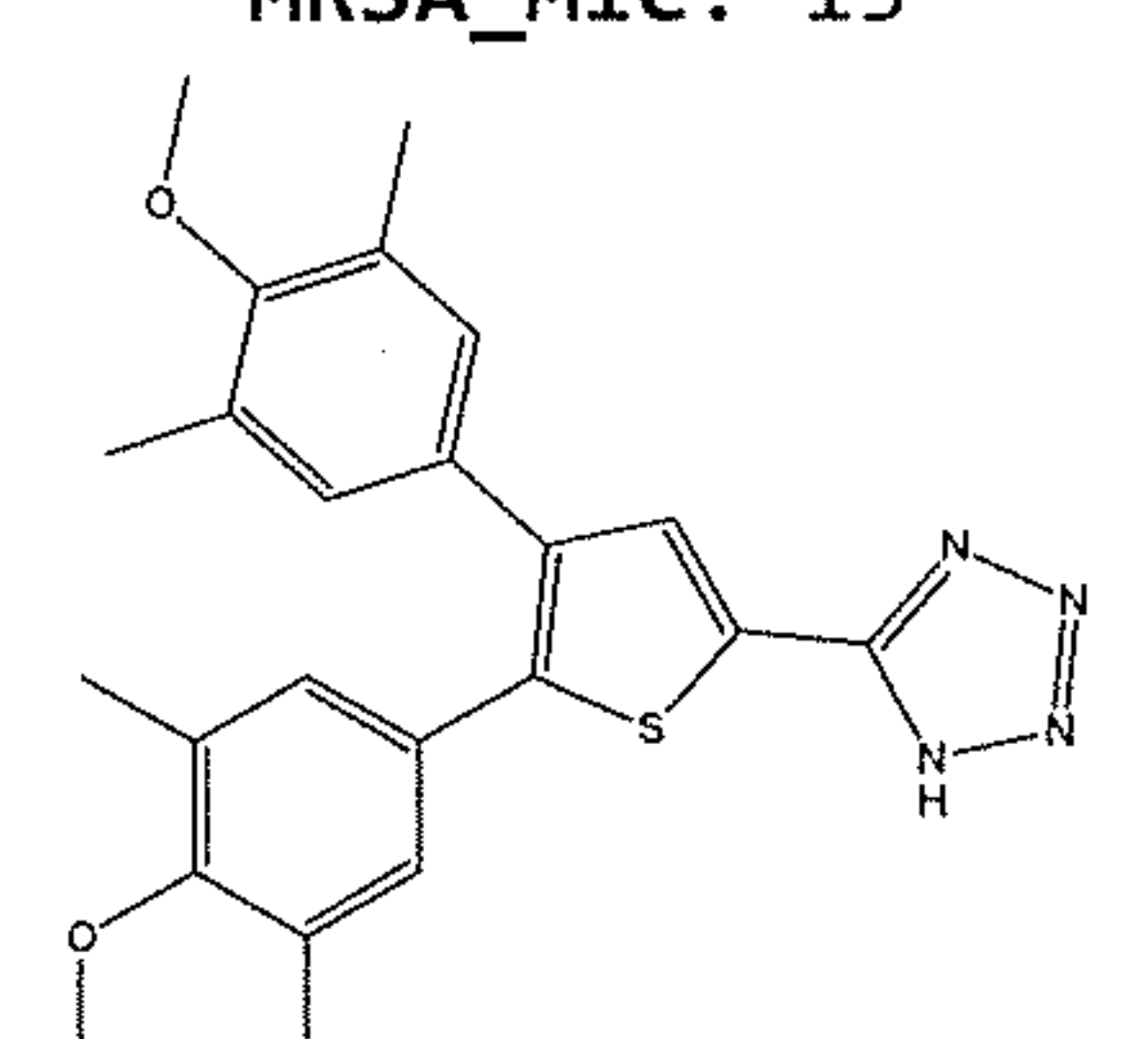
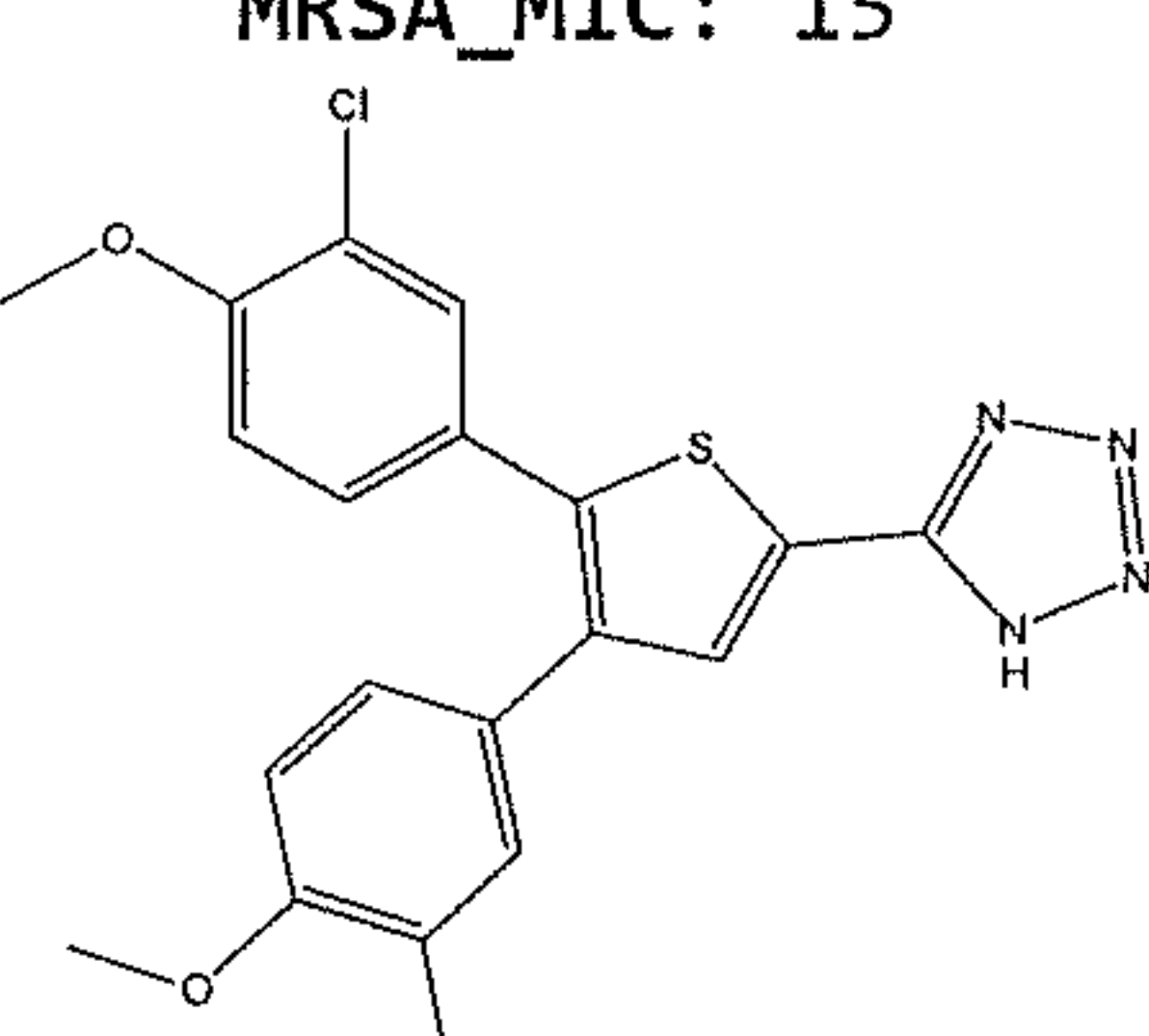
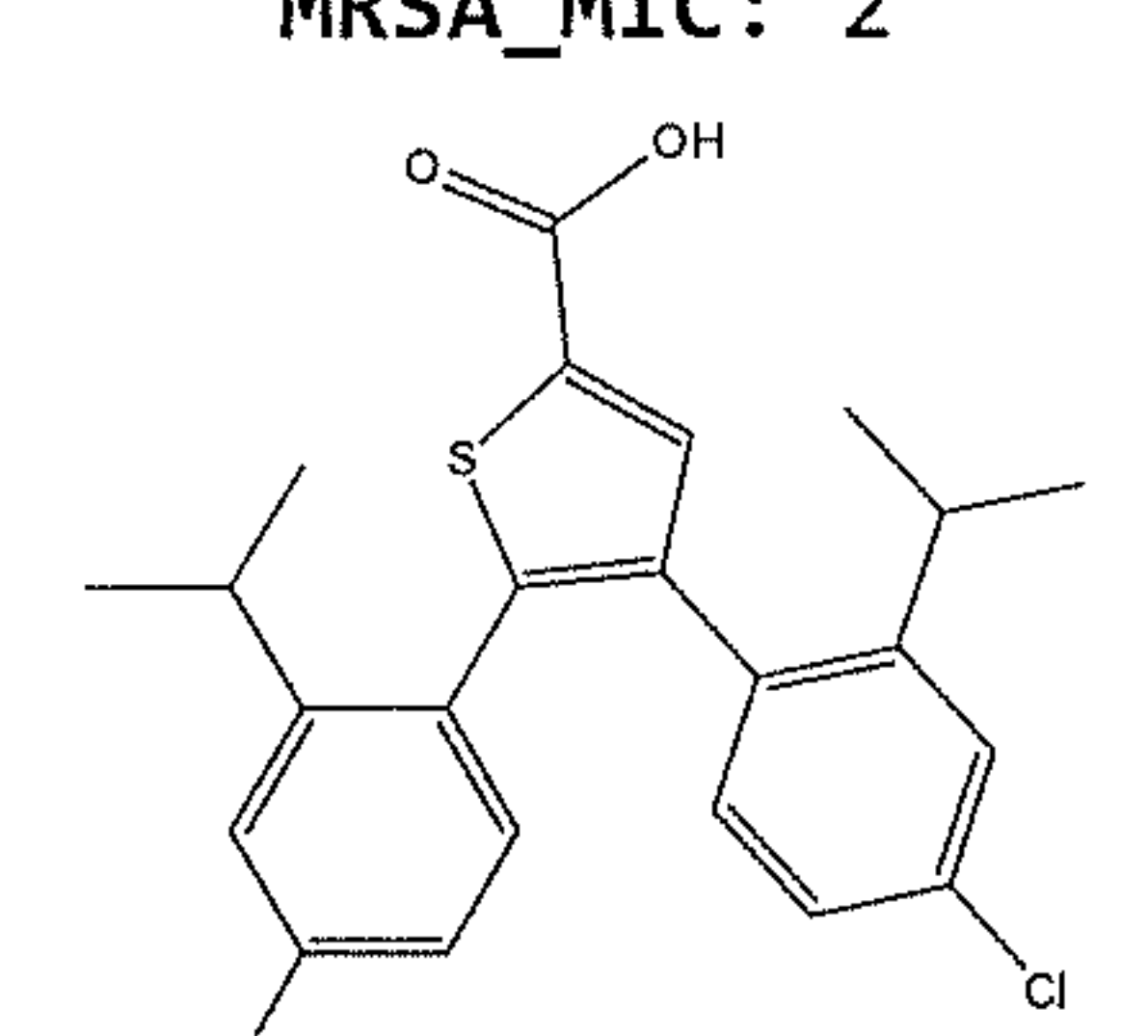
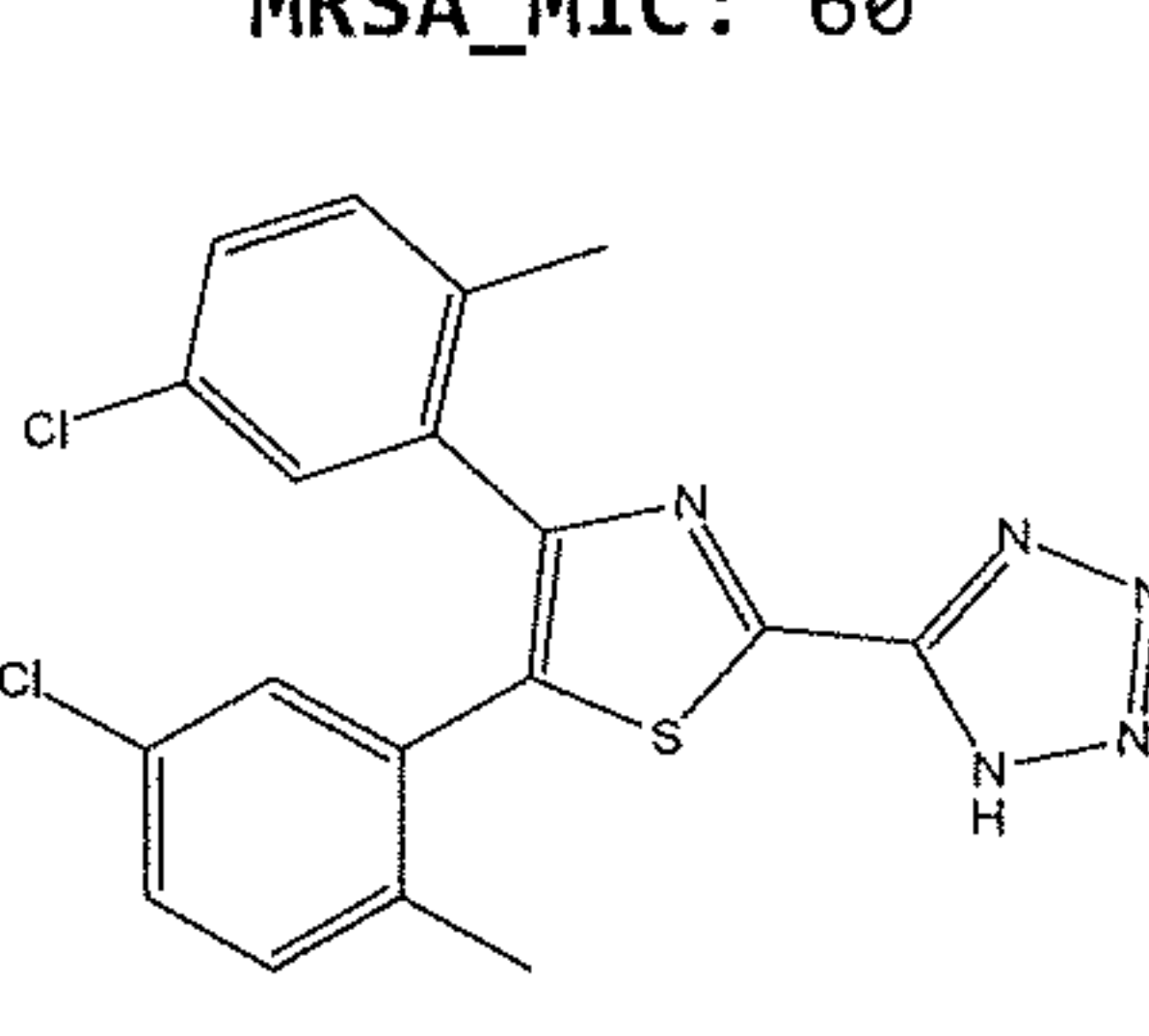
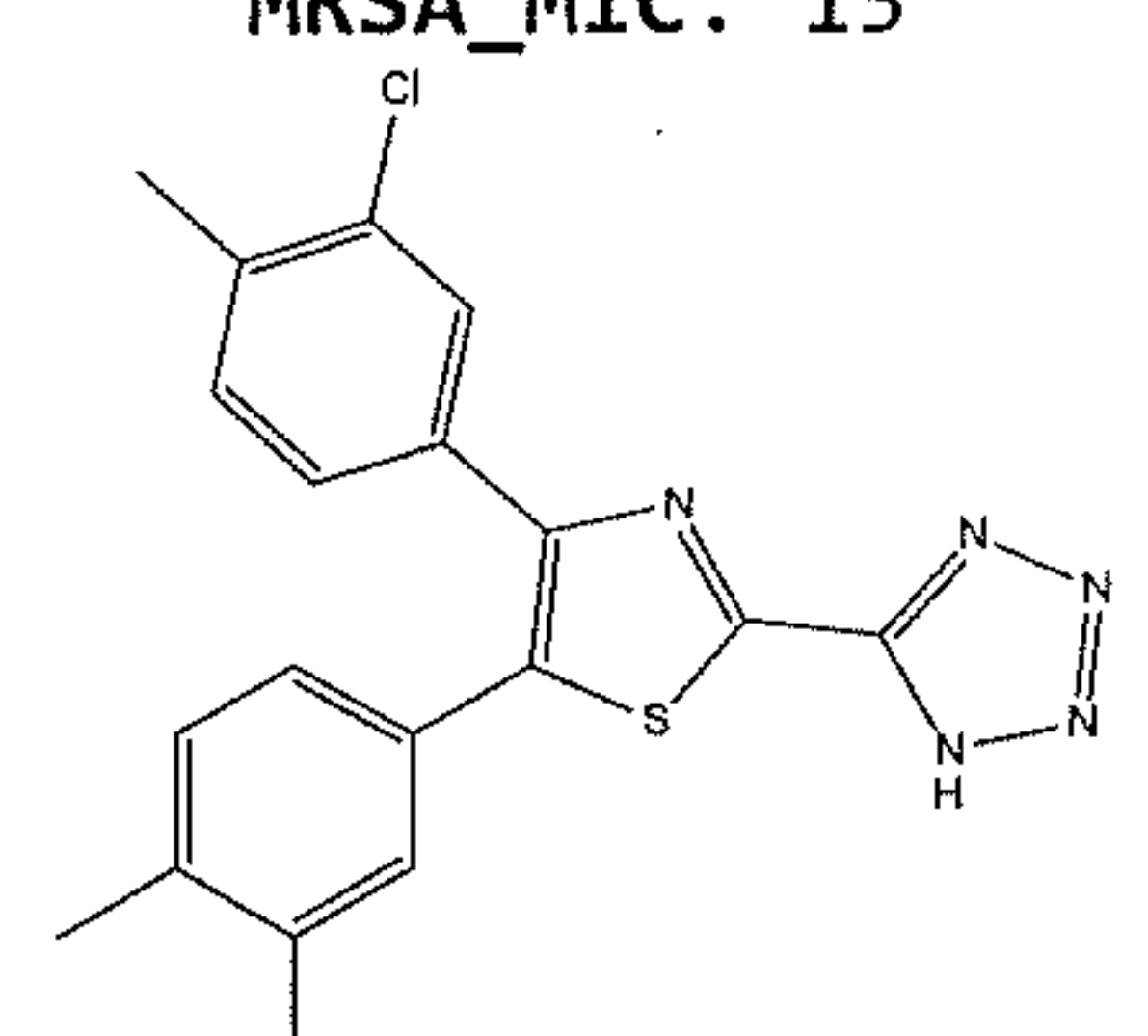
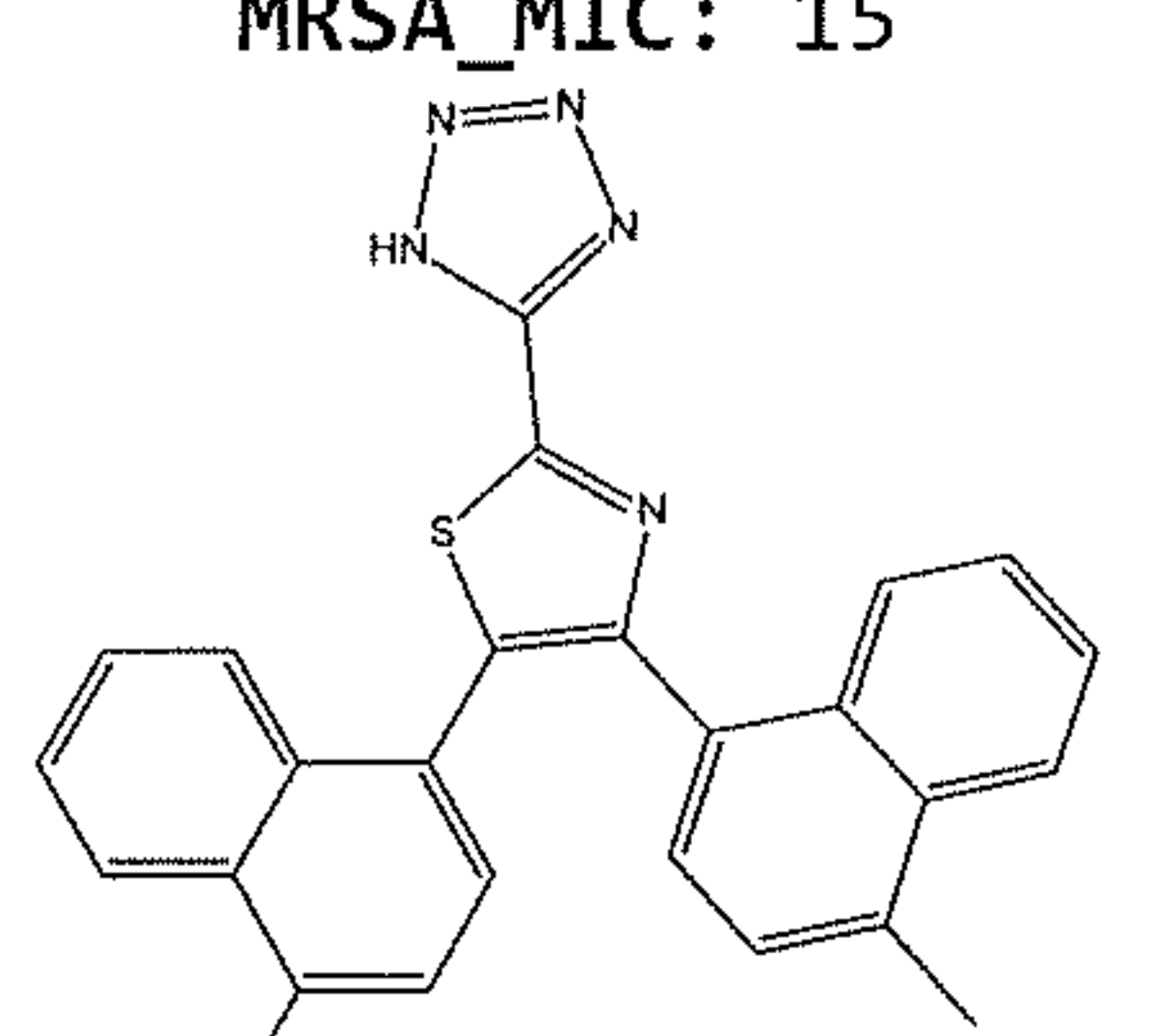
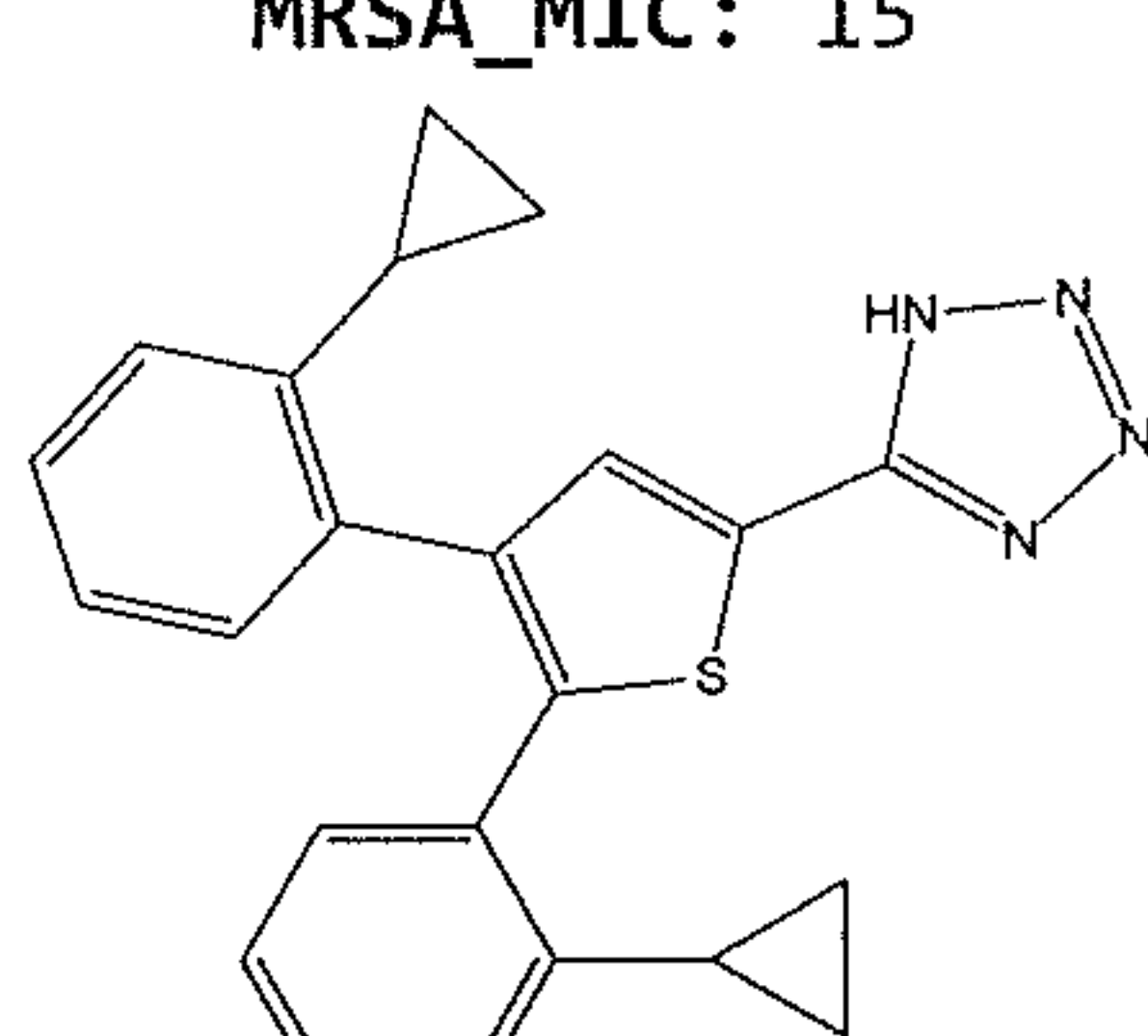
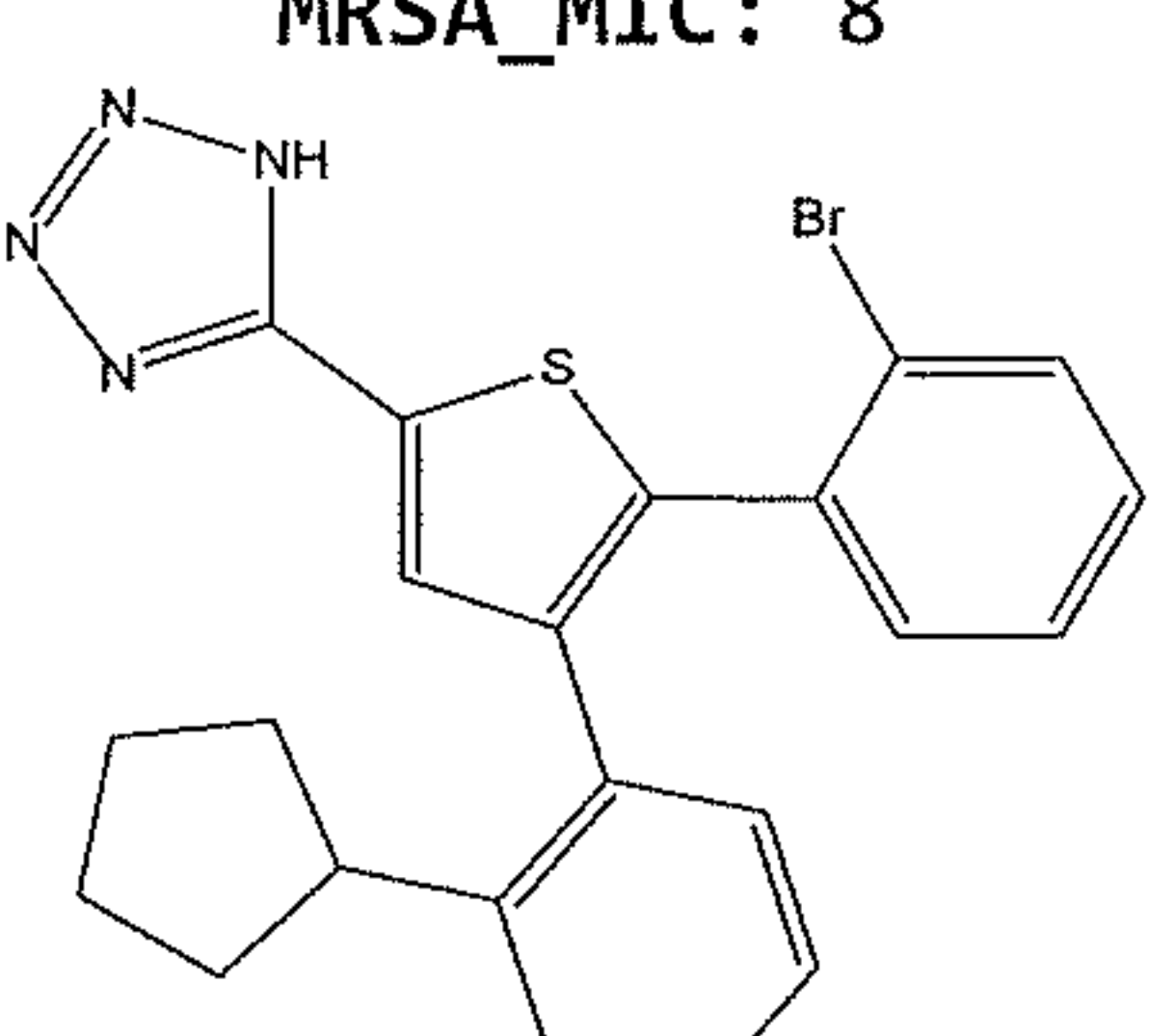
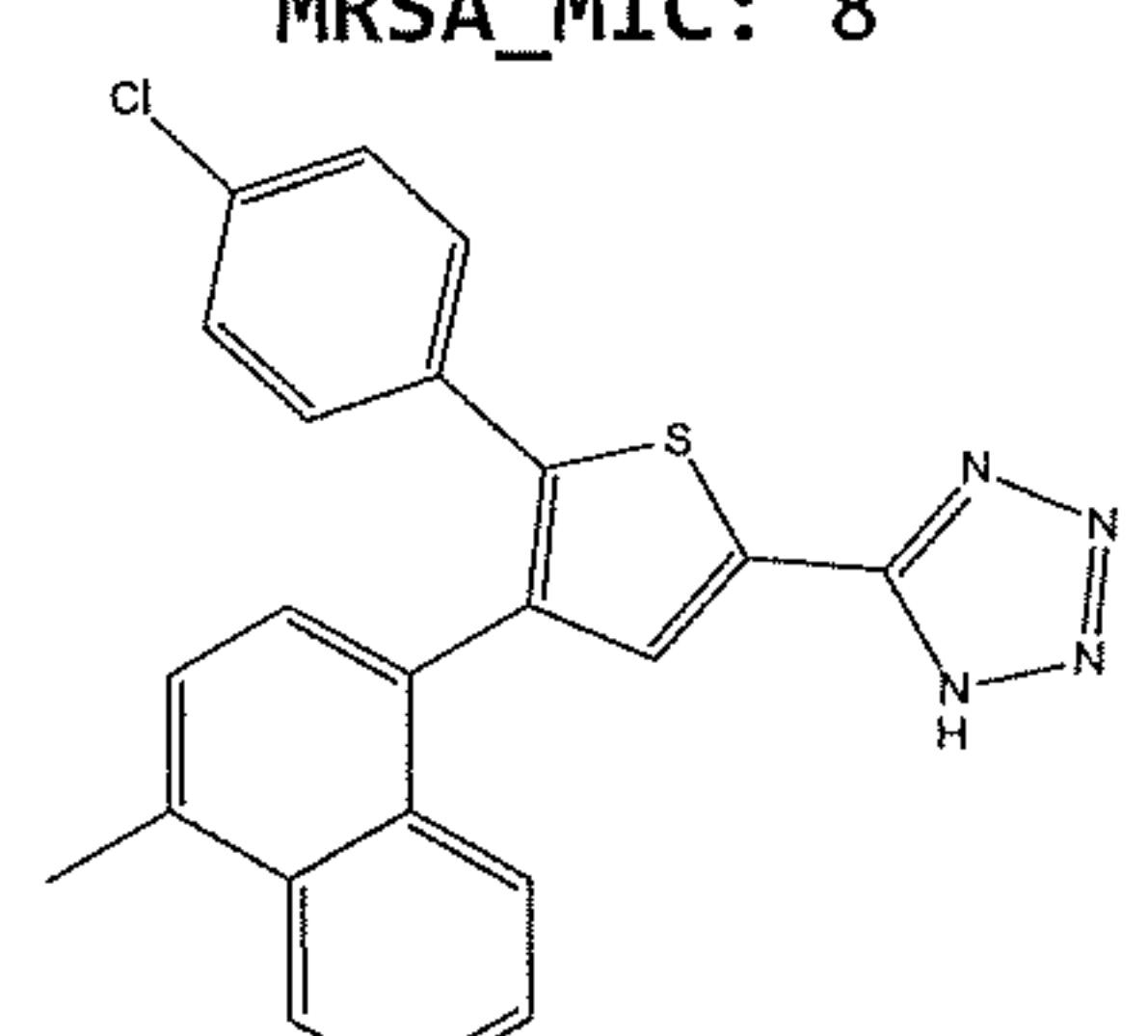
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MRSA_MIC: 15  DNM0560	MRSA_MIC: 2  DNM0561	MRSA_MIC: 8  DNM0563	MRSA_MIC: 15  DNM0564
MRSA_MIC: 15  DNM0565	MRSA_MIC: 2  DNM0566	MRSA_MIC: 60  DNM0567	MRSA_MIC: 15  DNM0568
MRSA_MIC: 15  DNM0569	MRSA_MIC: 15  DNM0570	MRSA_MIC: 8  DNM0571	MRSA_MIC: 8  DNM0572

FIG. 1-2

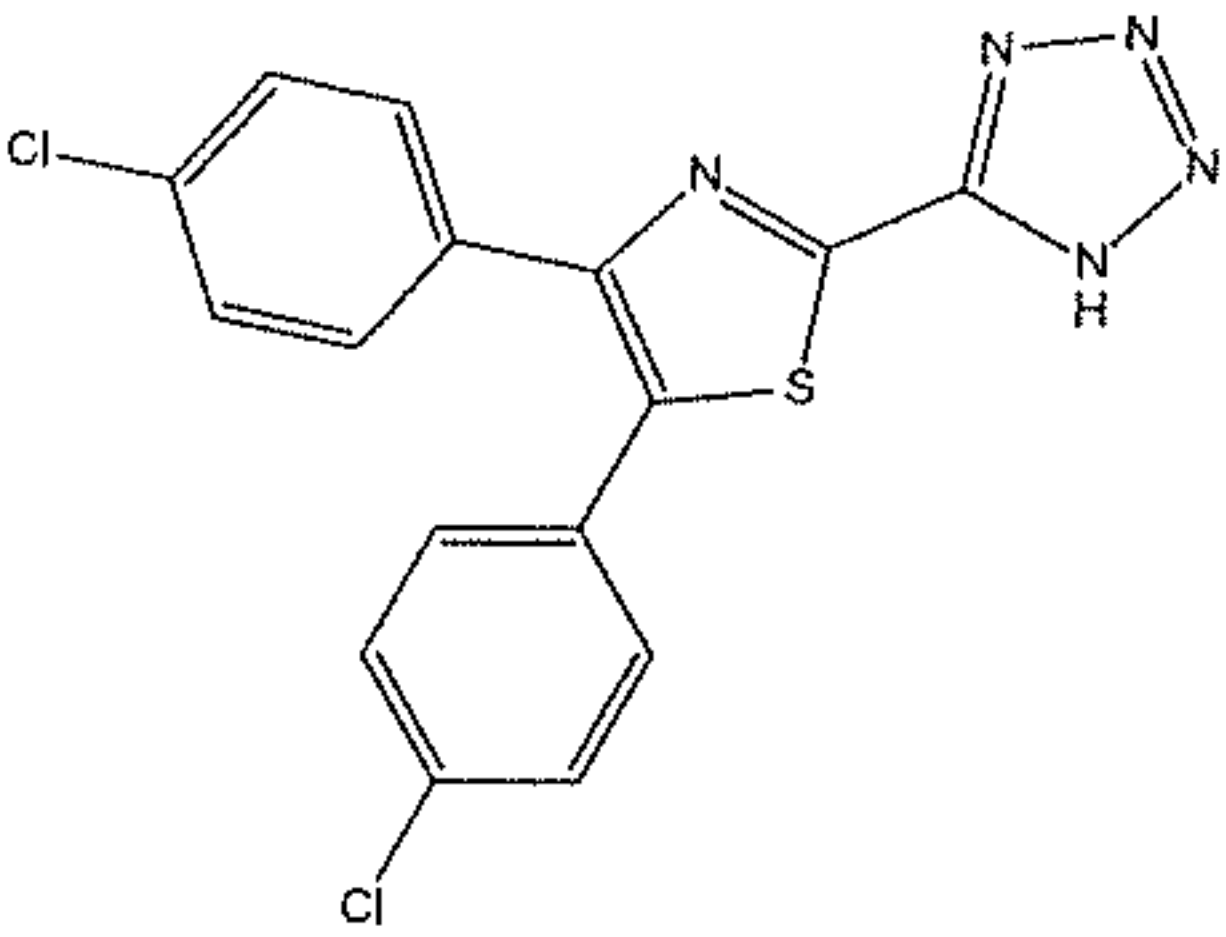
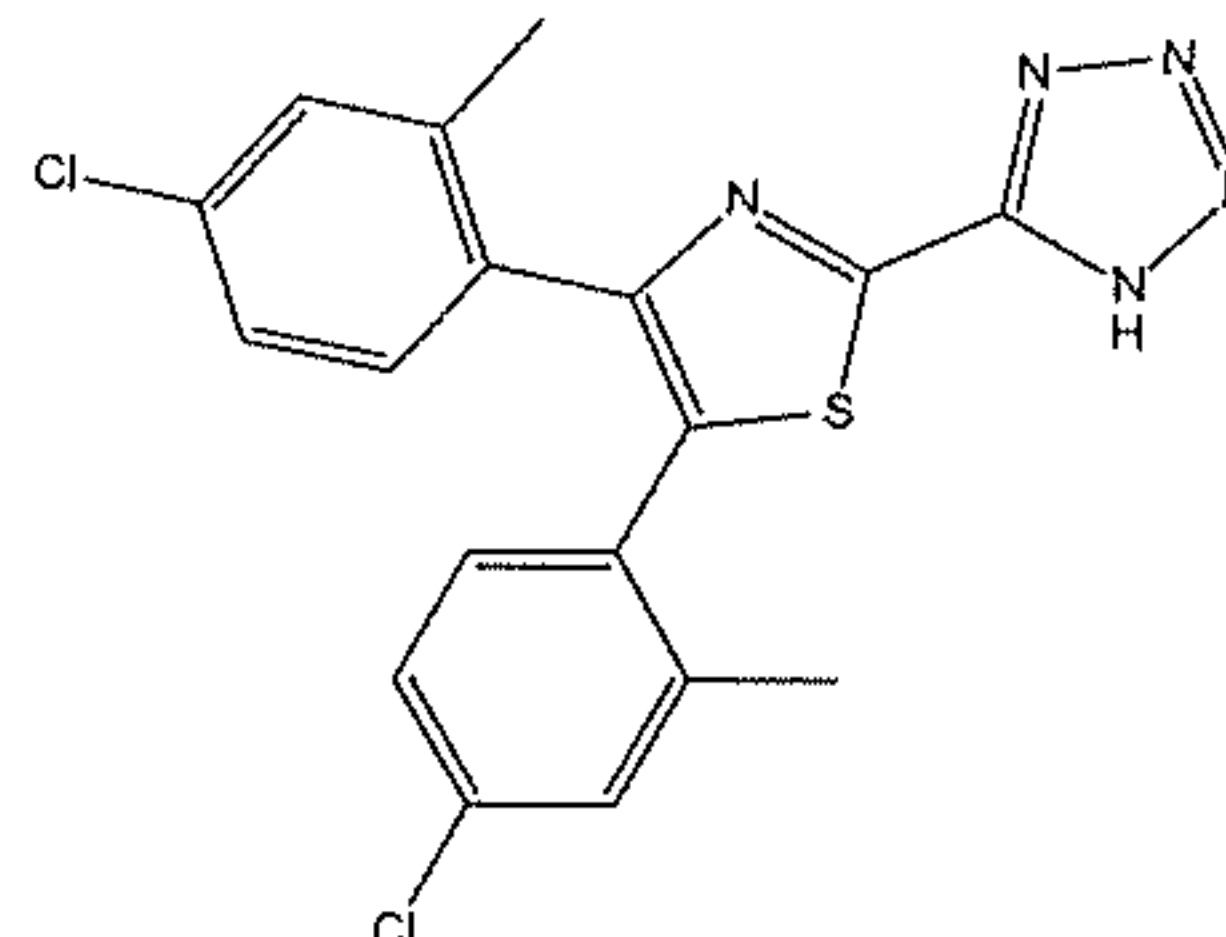
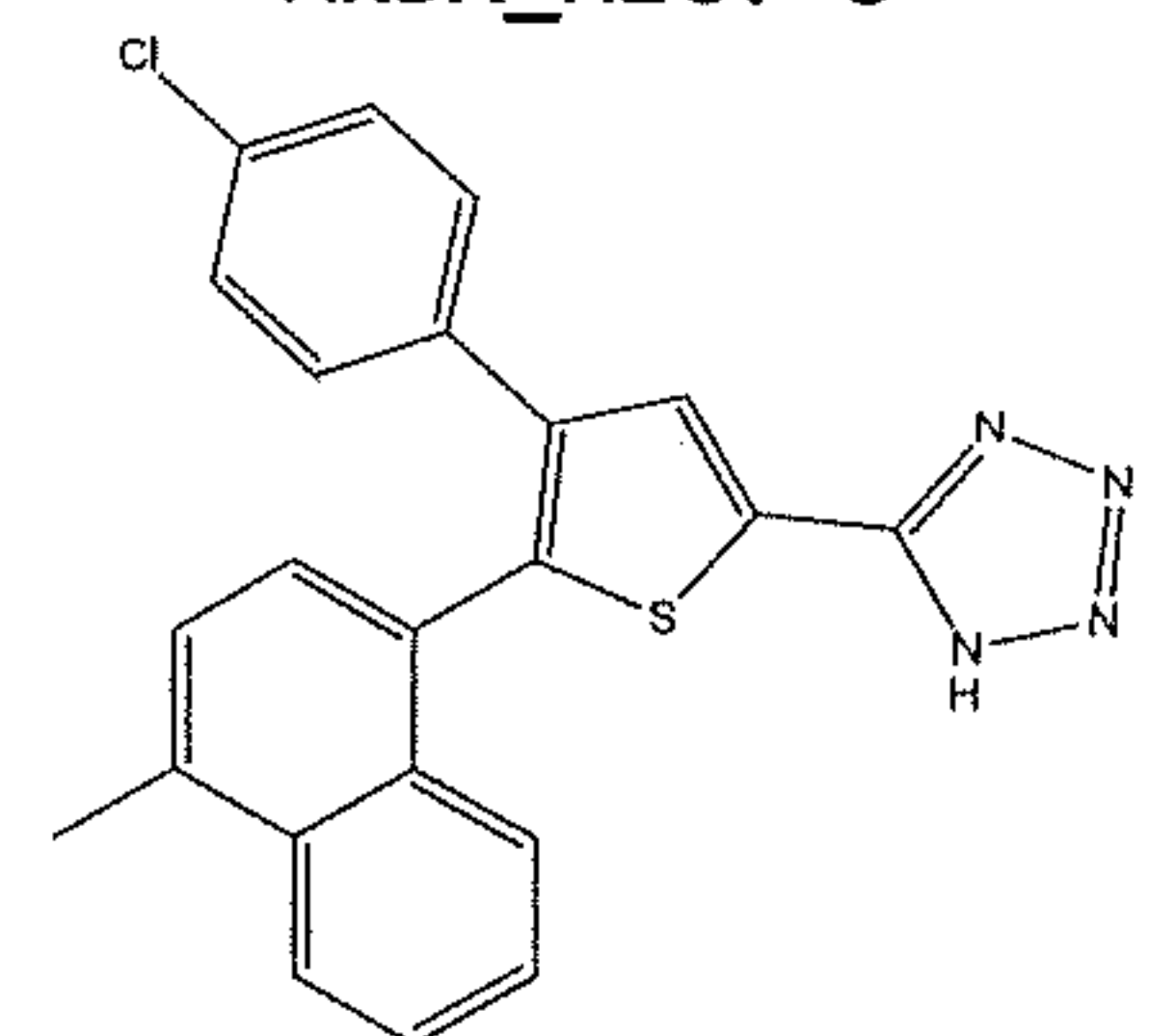
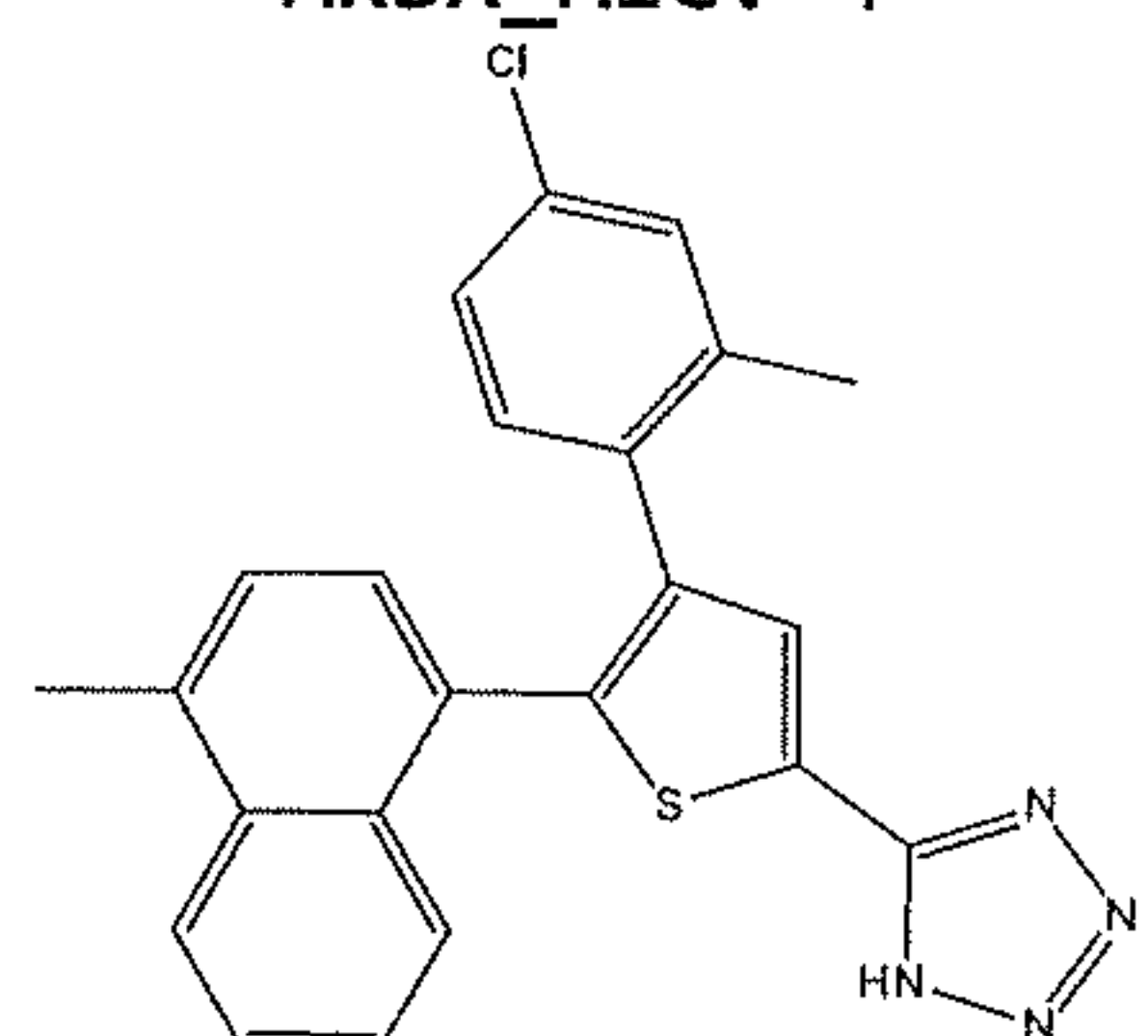
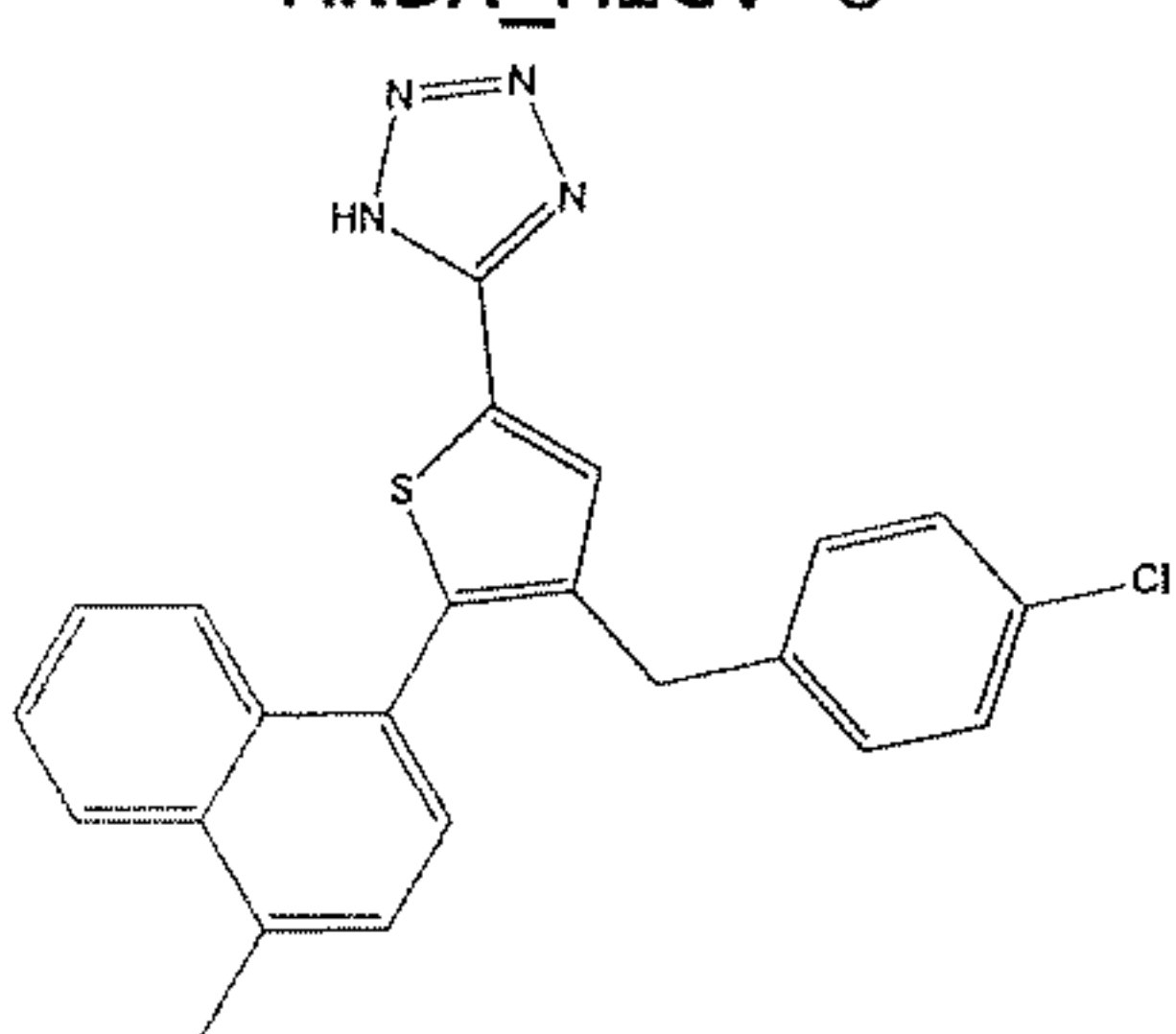
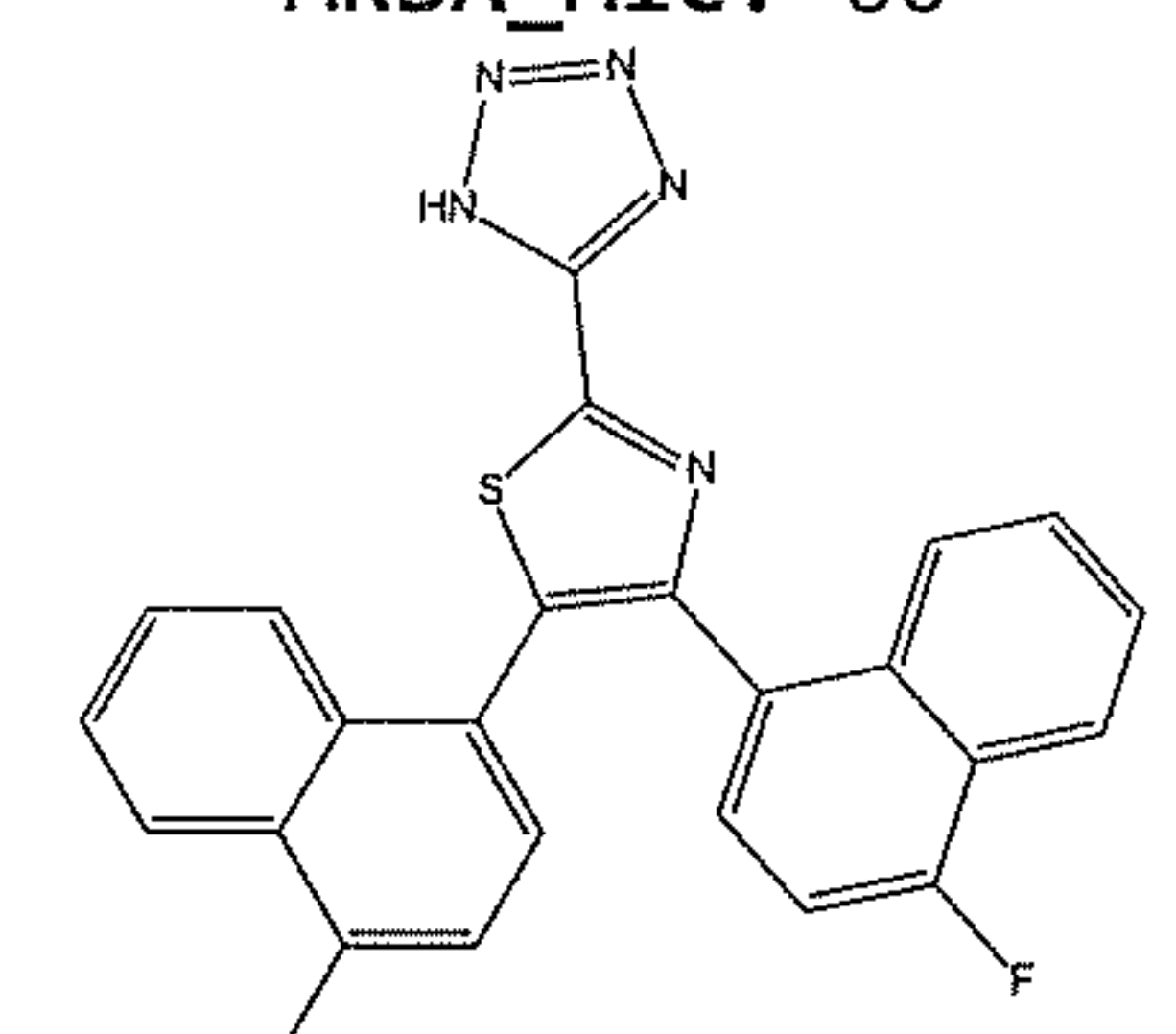
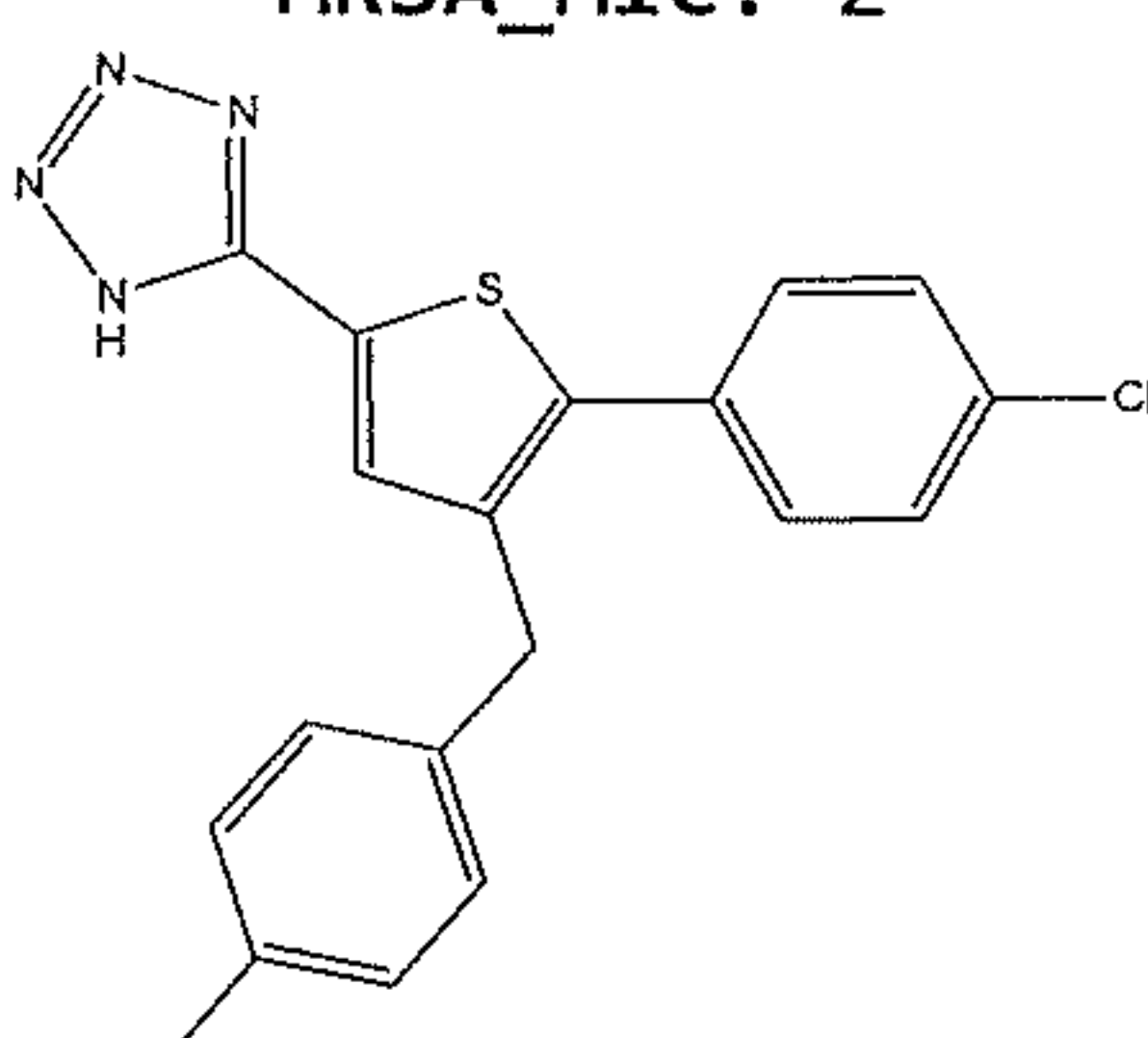
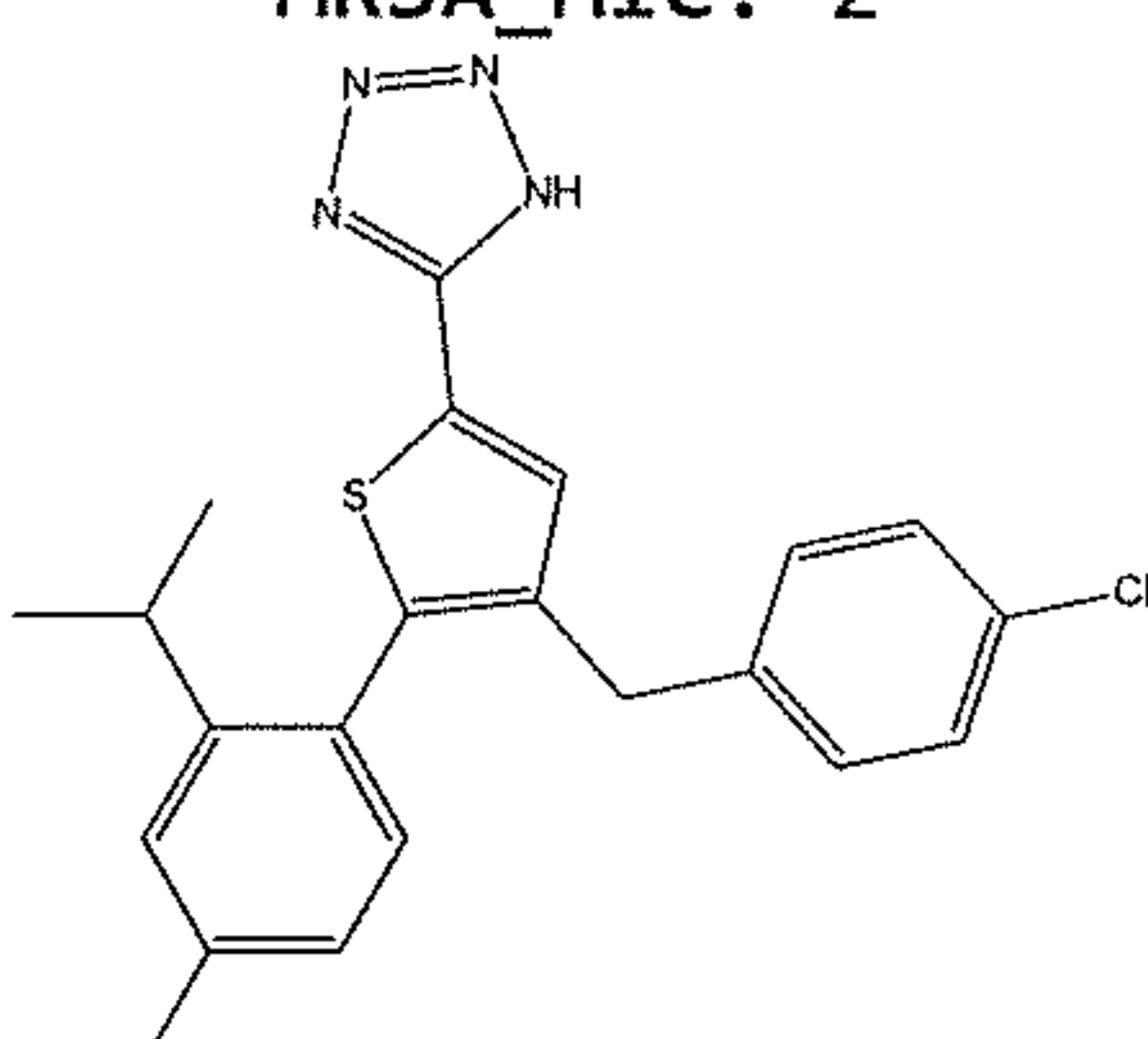
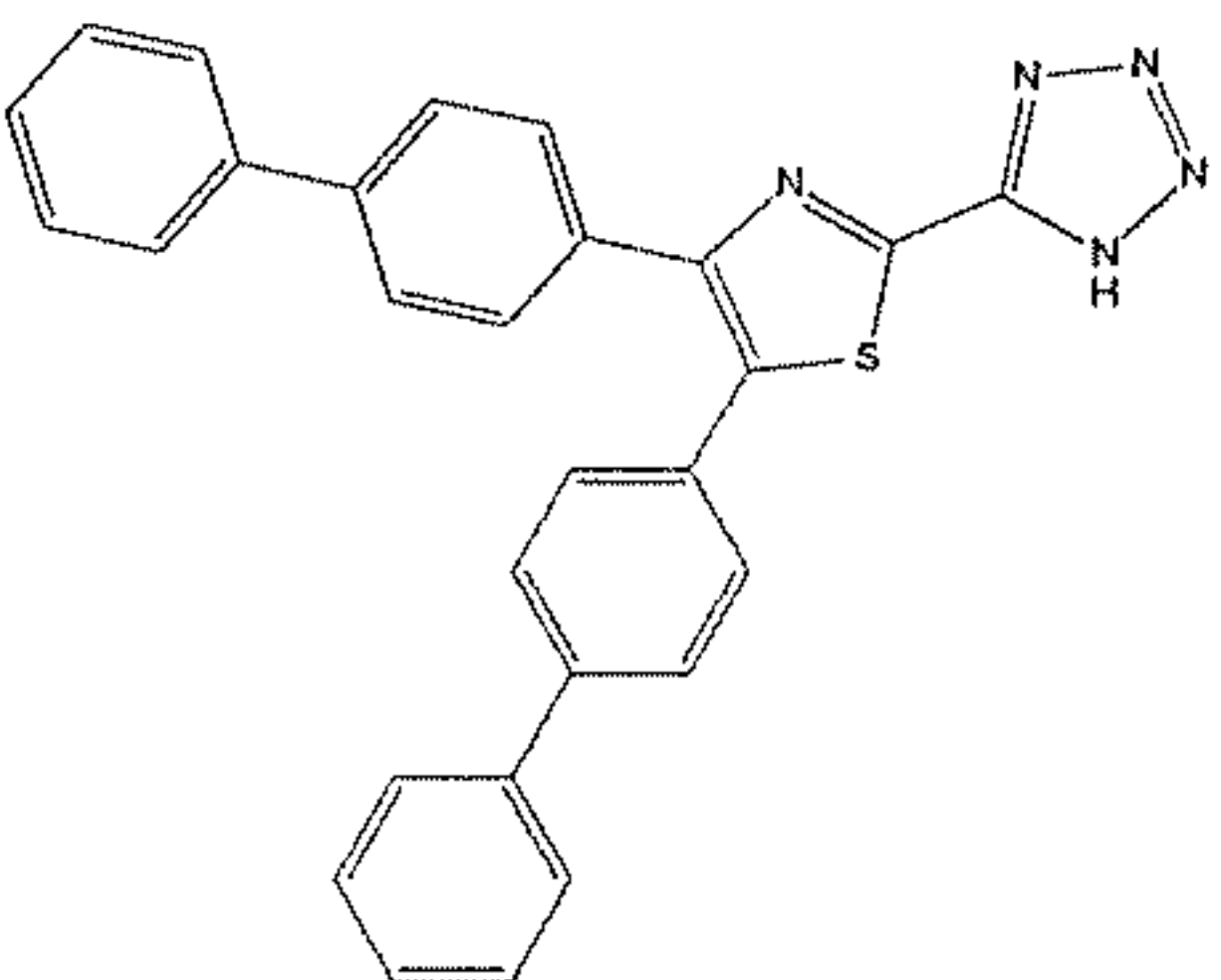
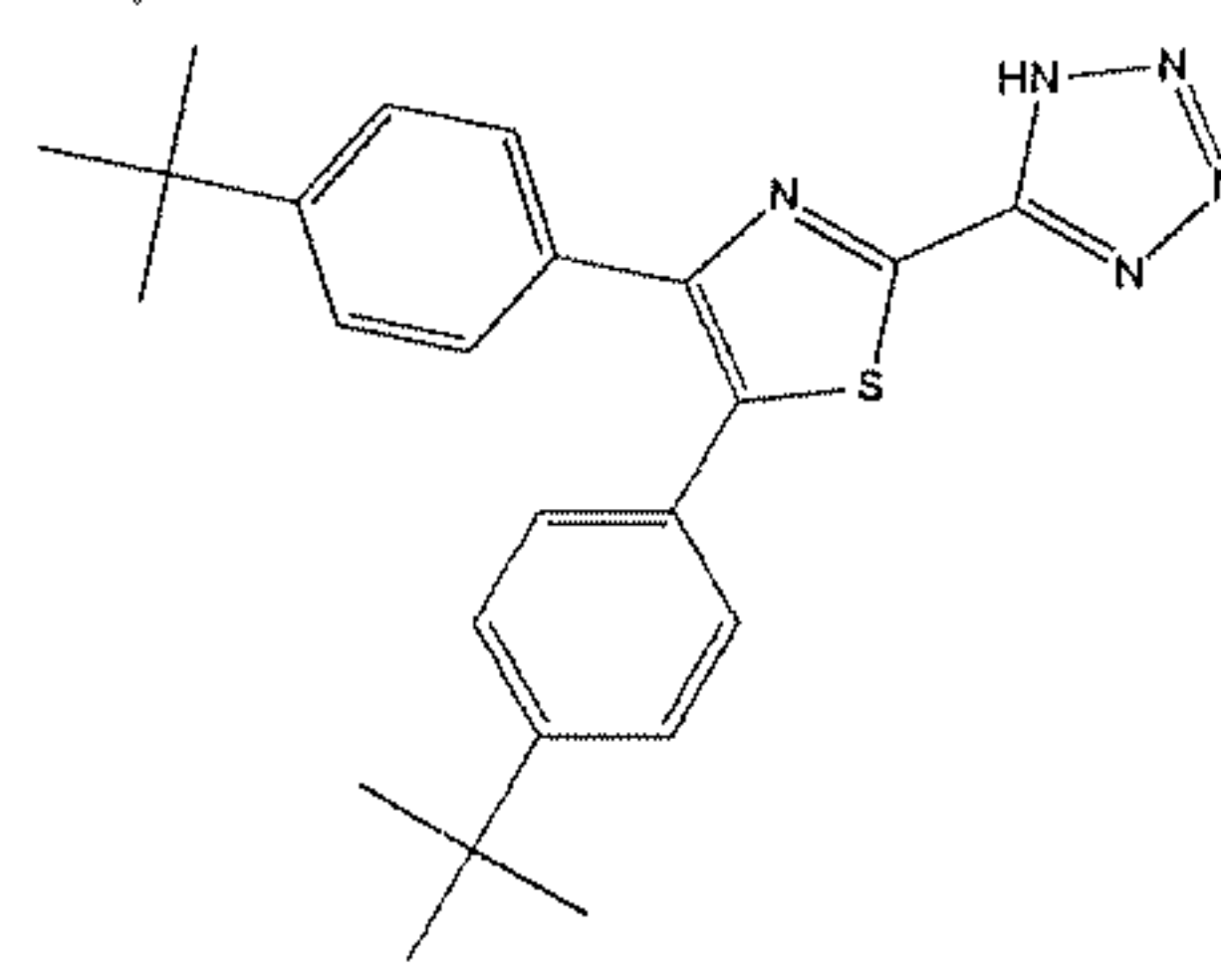
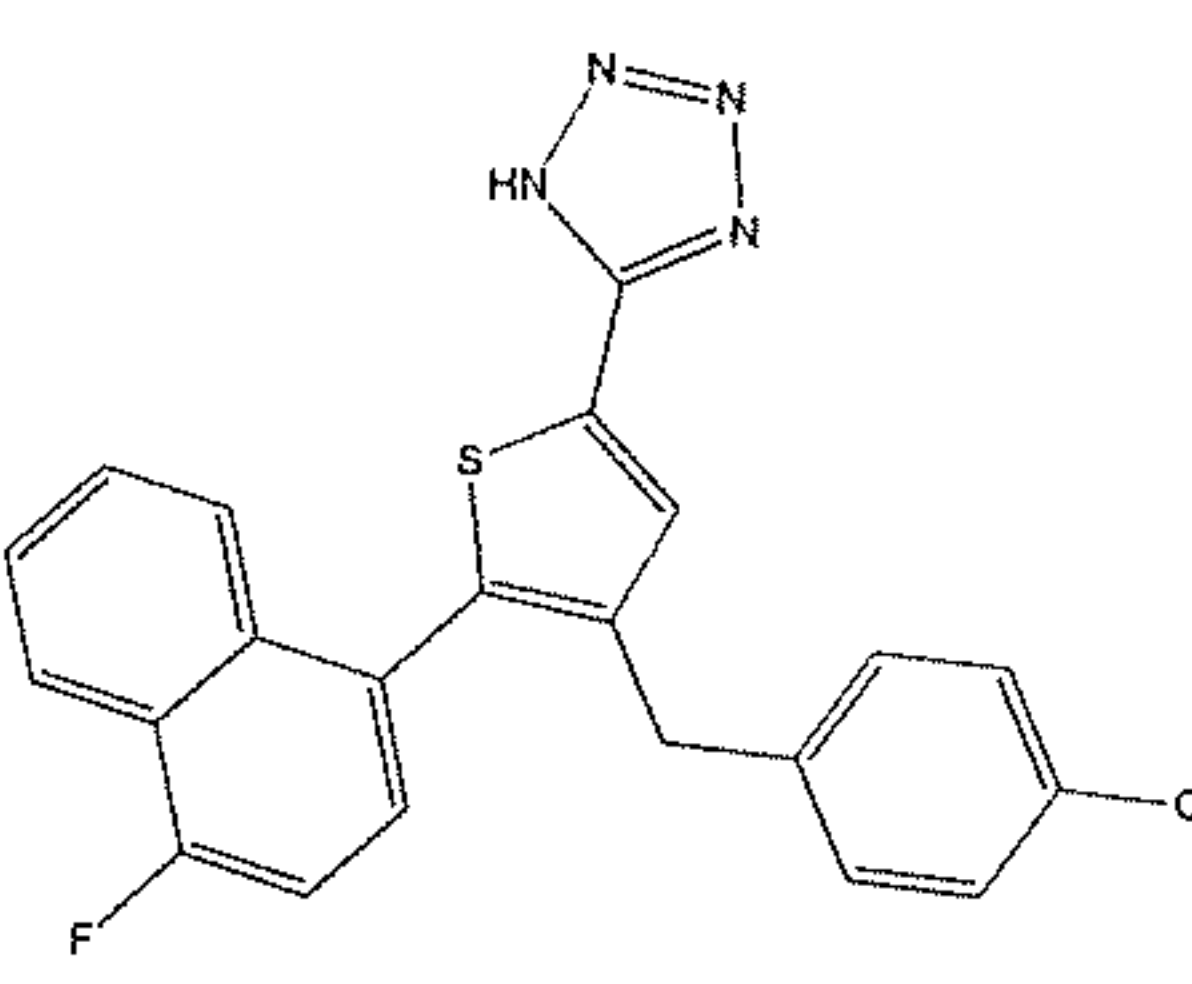
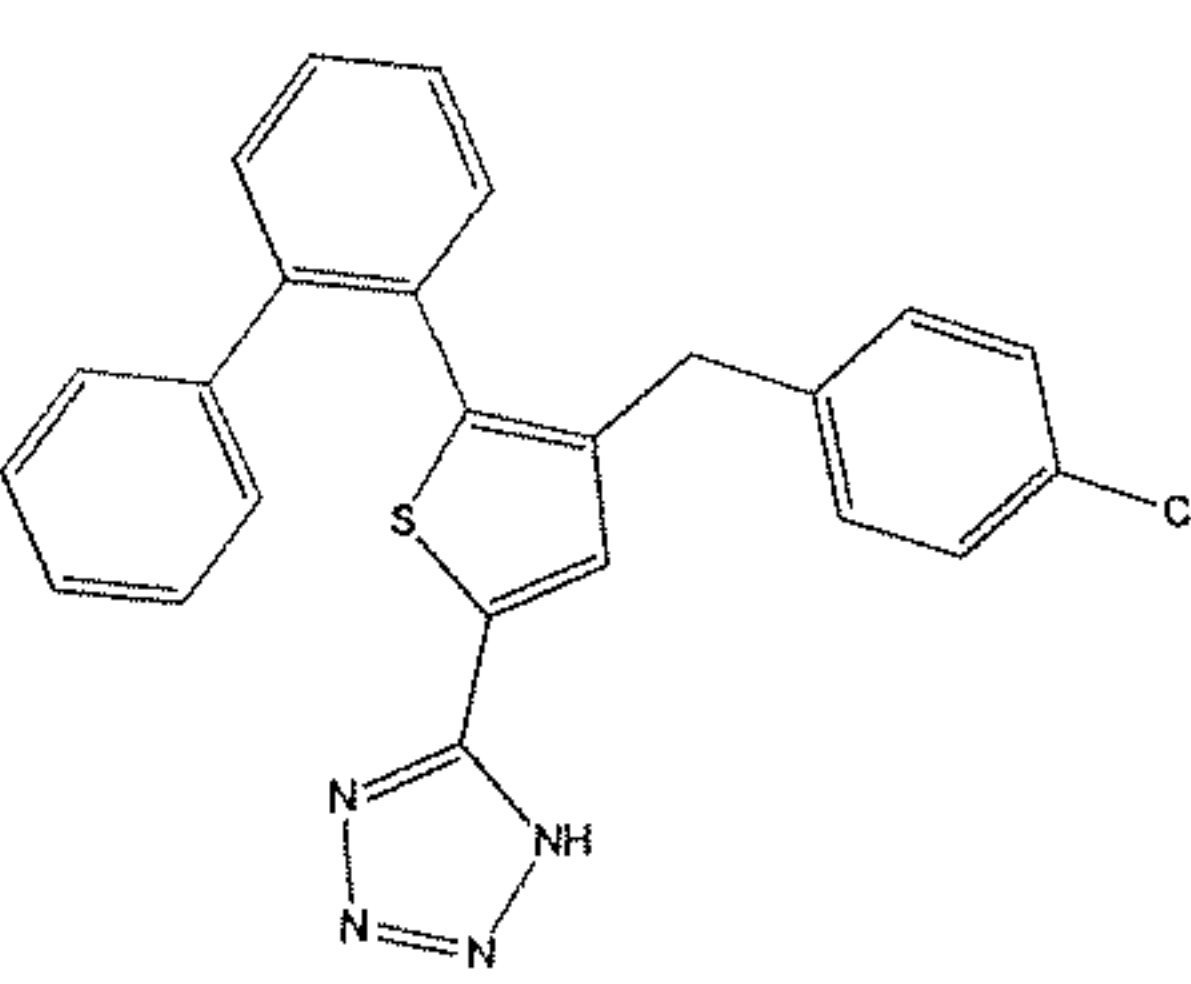
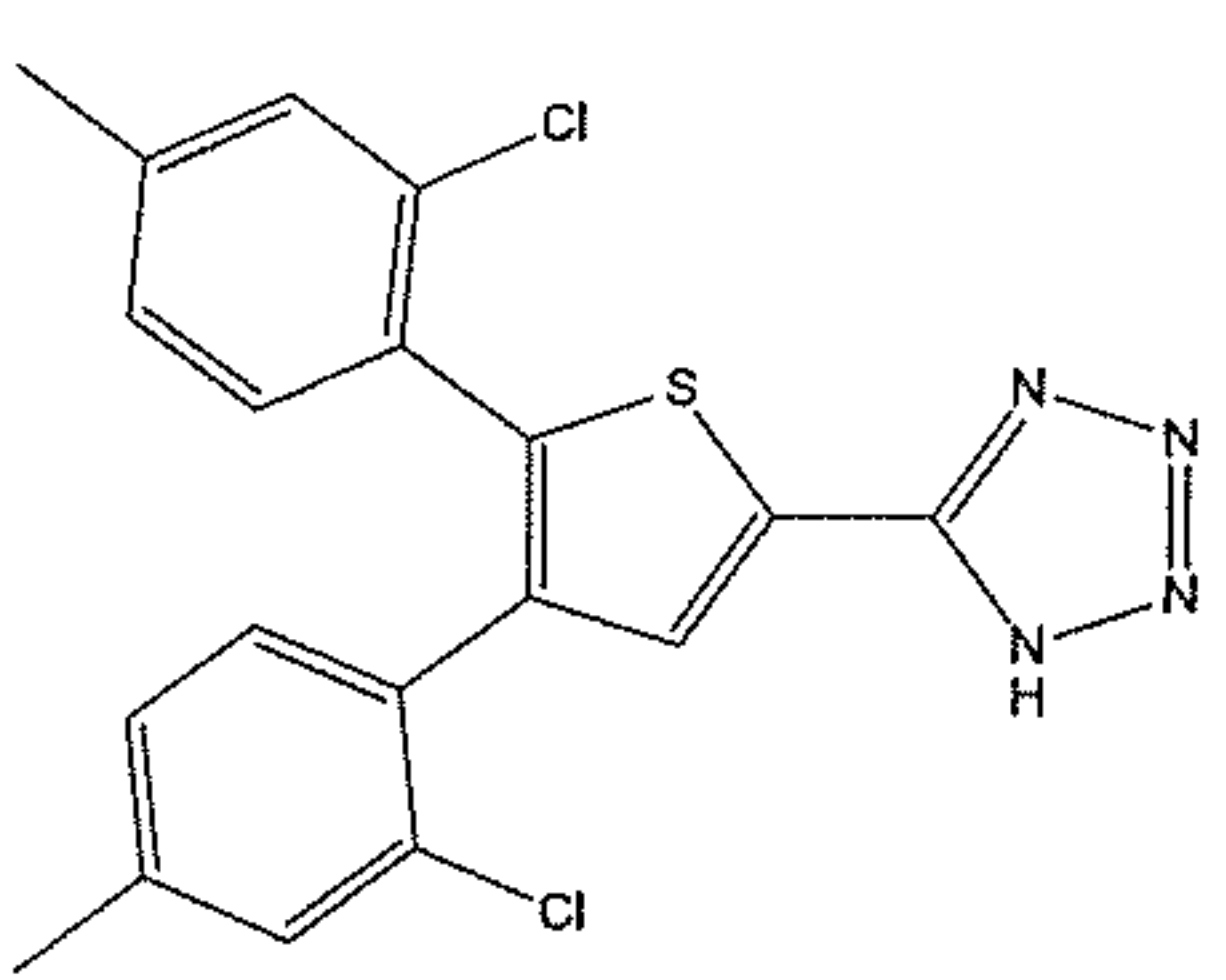
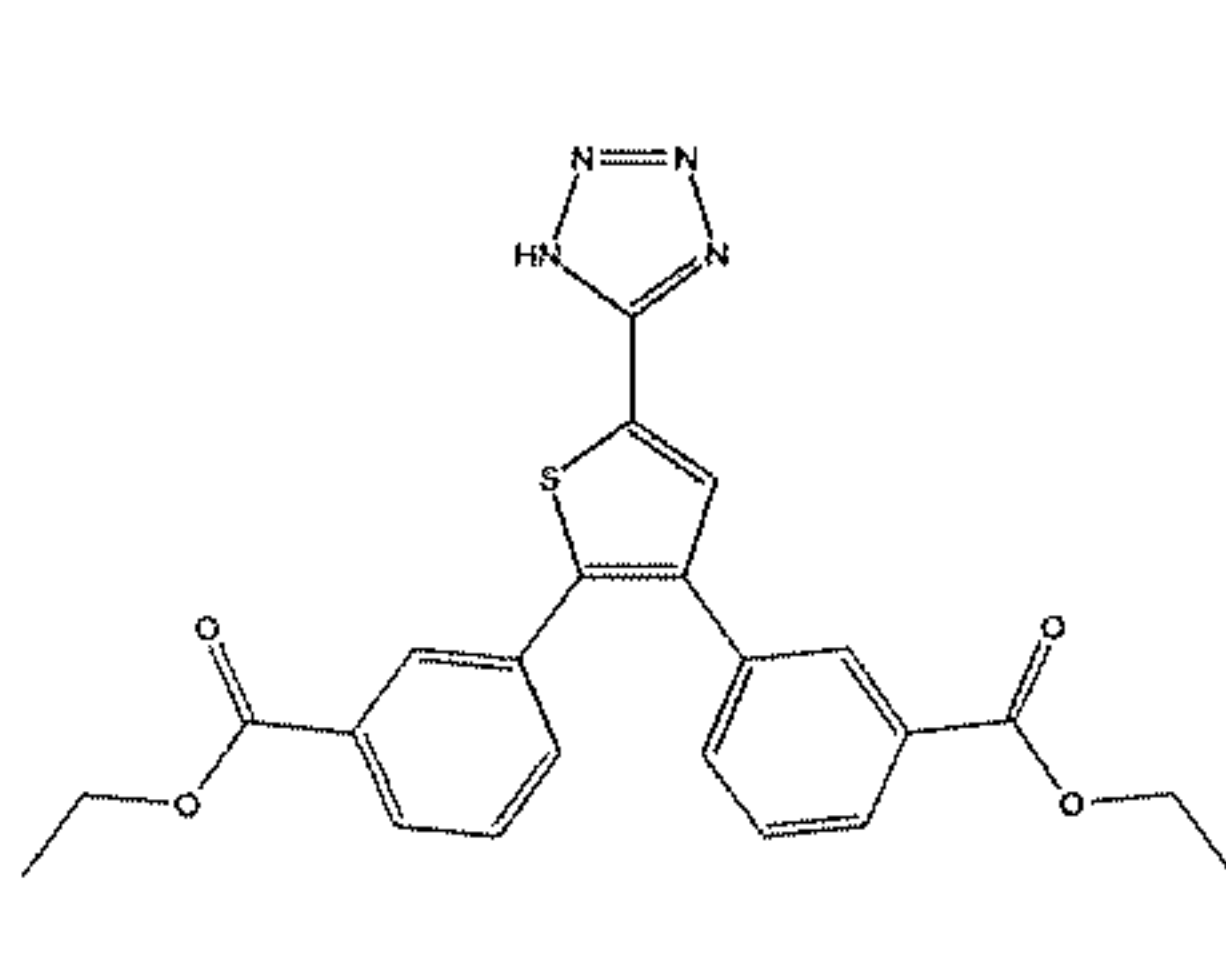
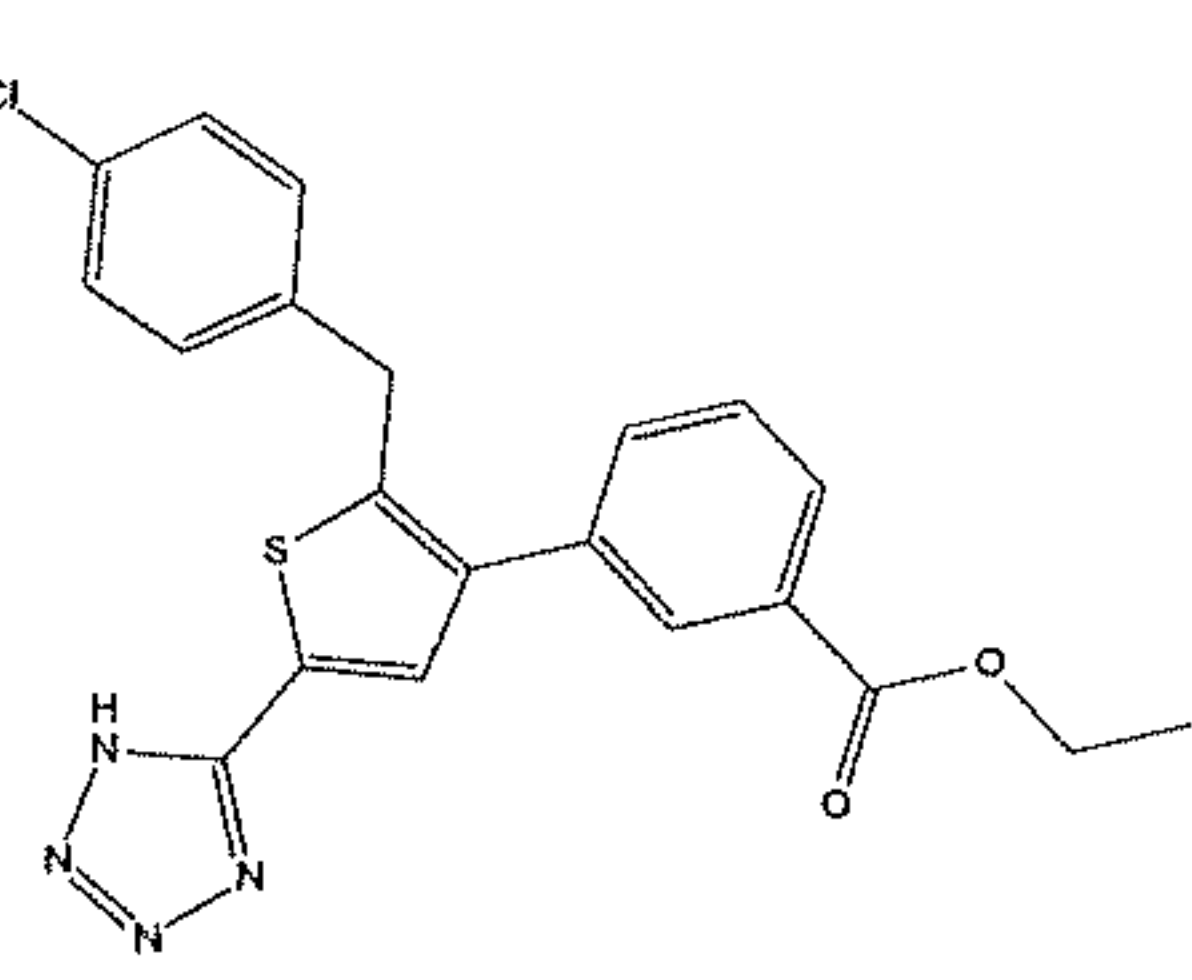
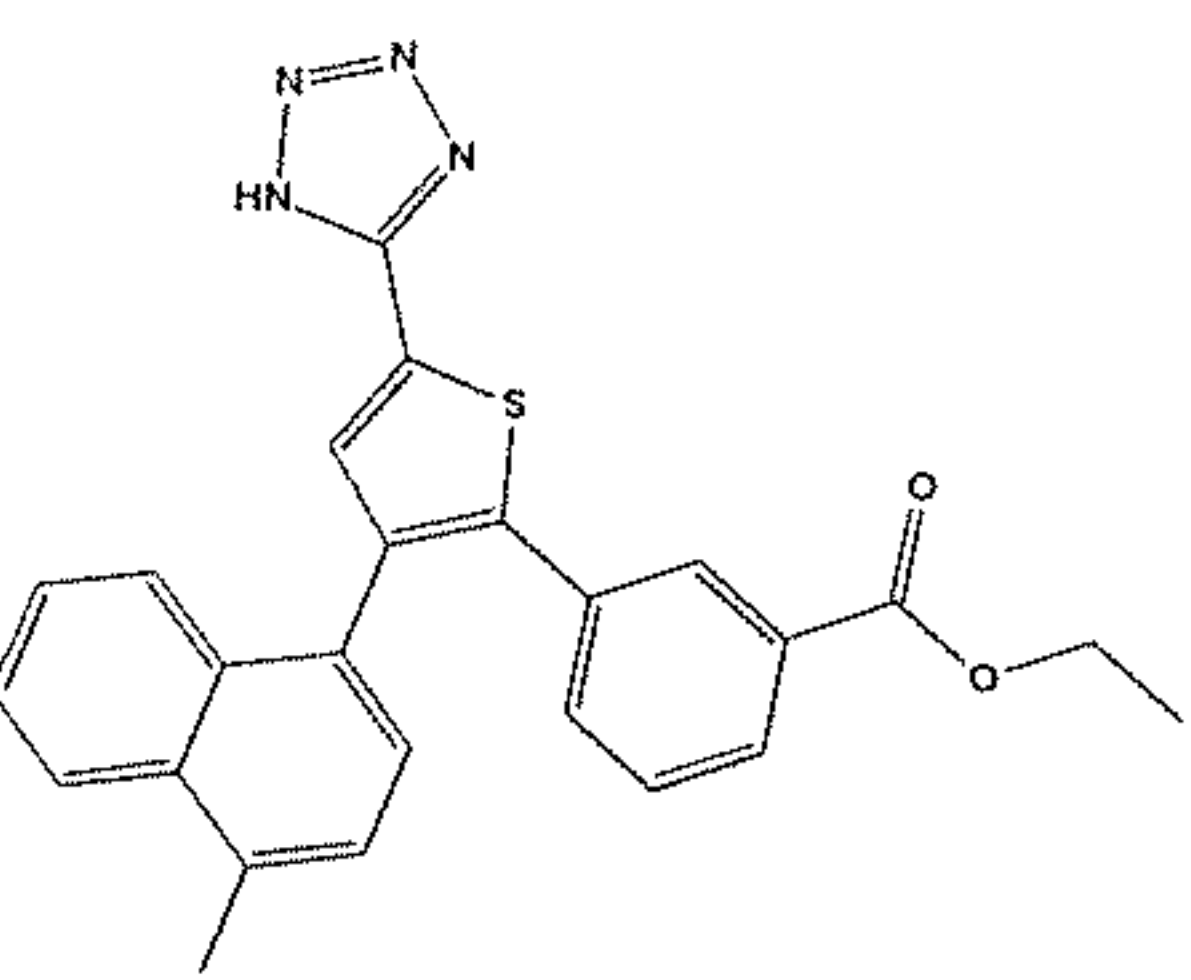
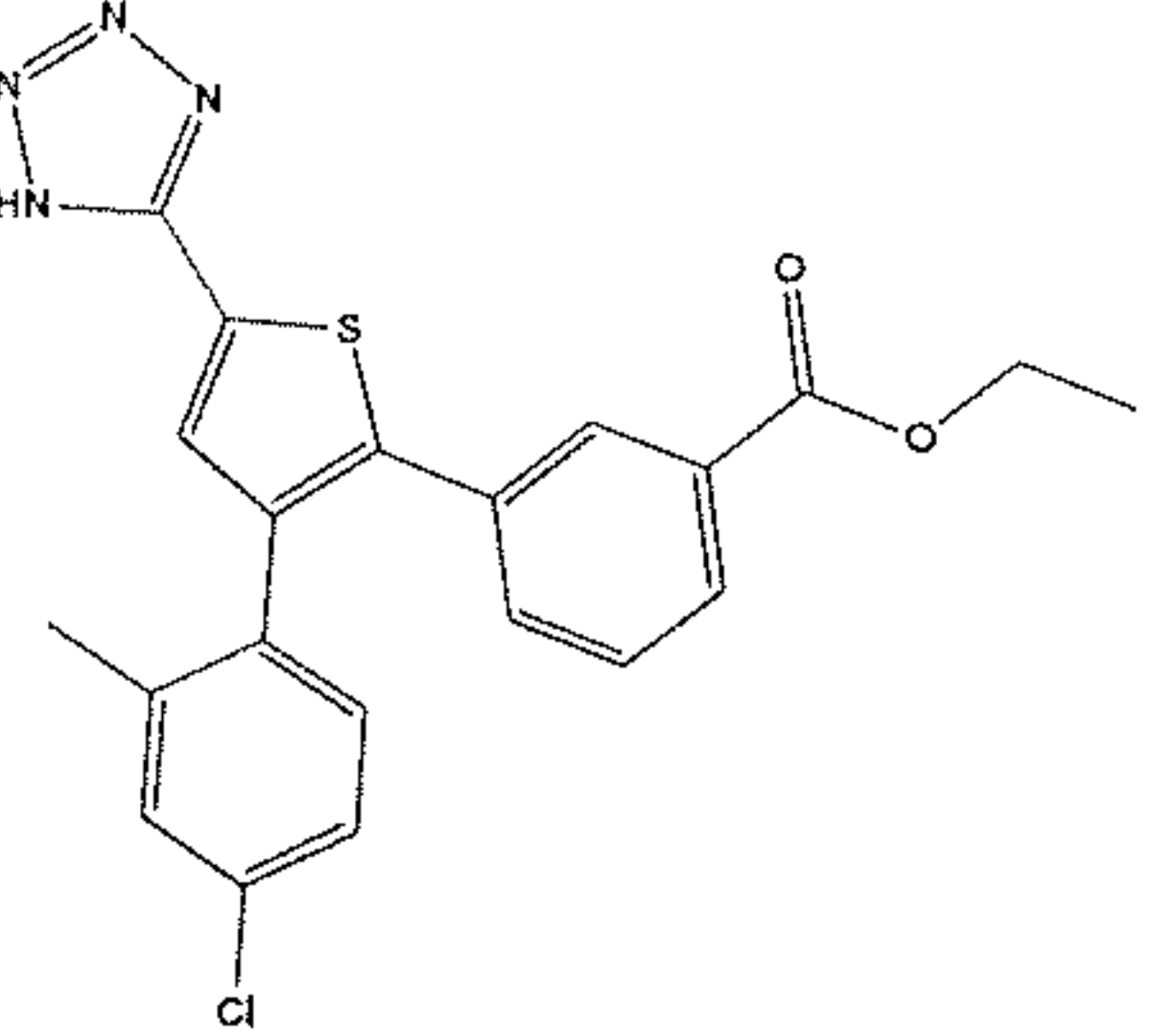
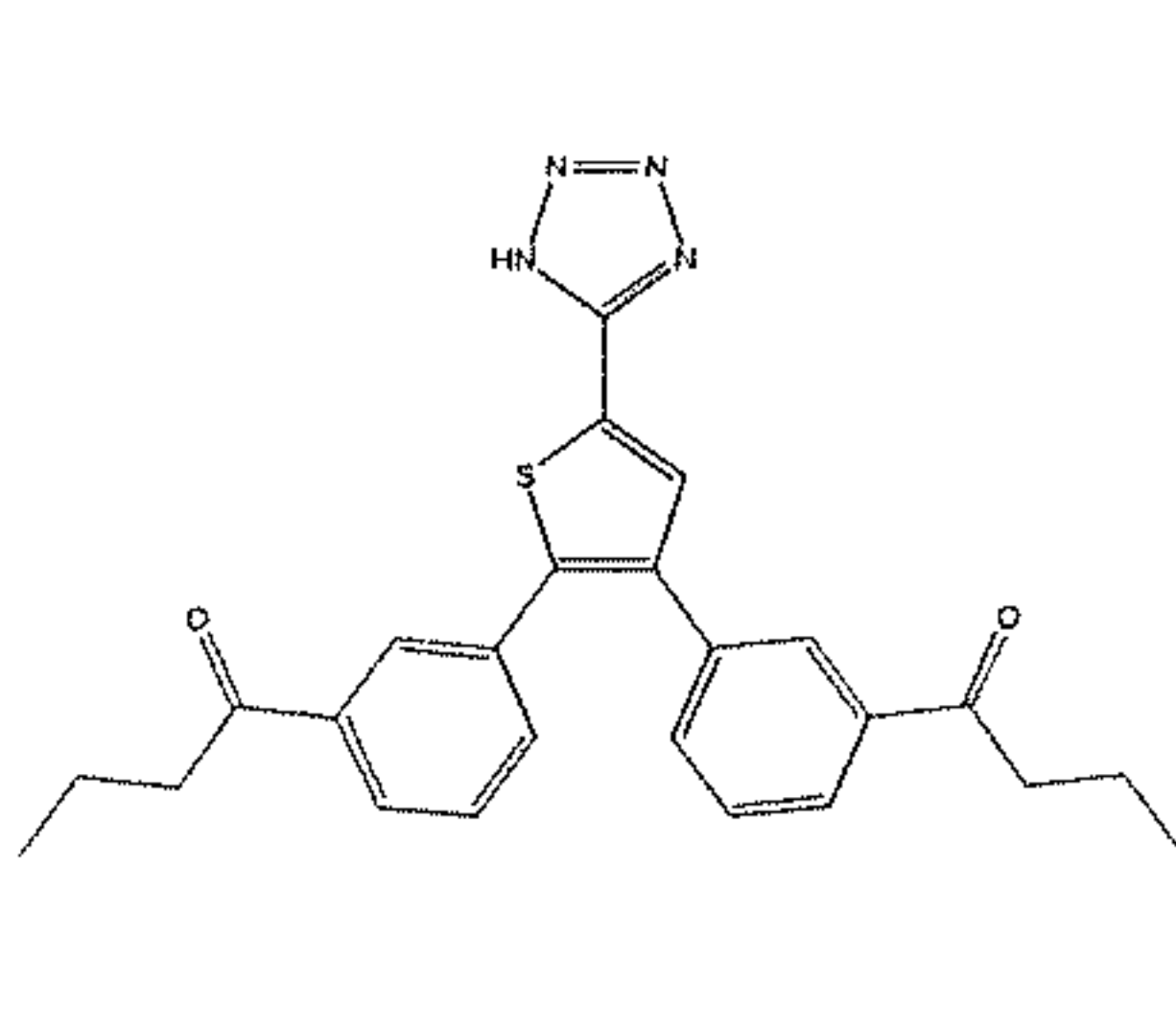
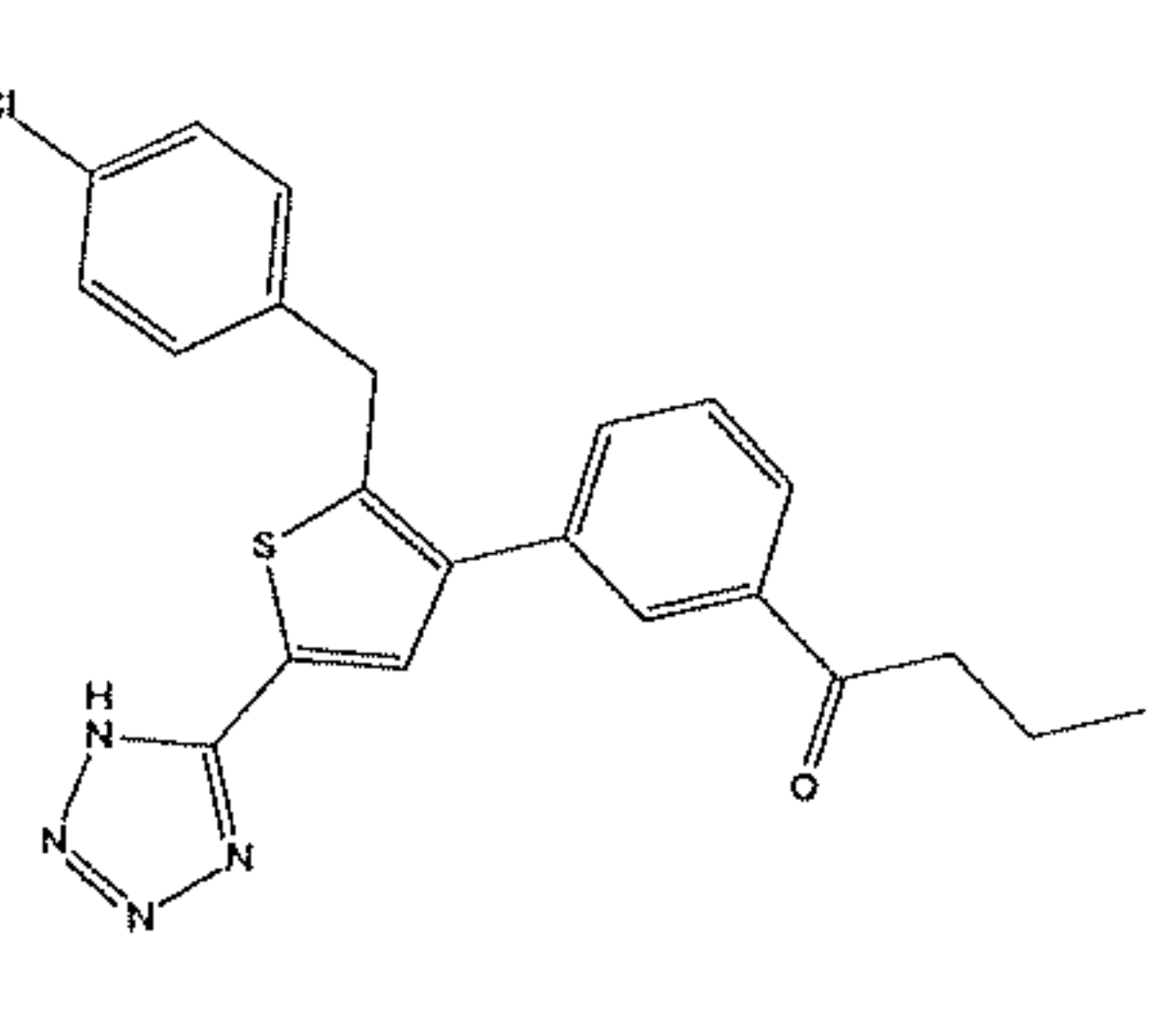
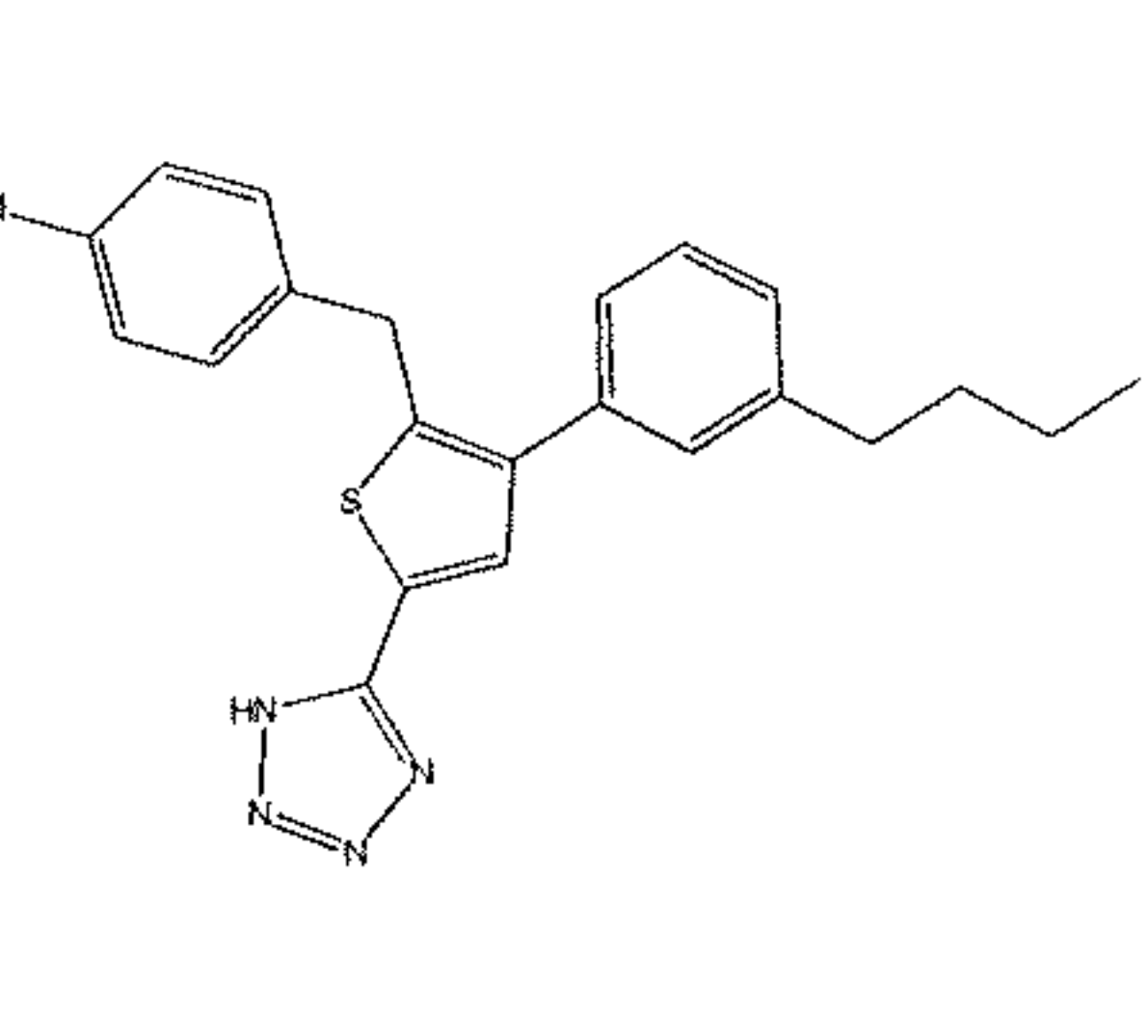
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MRSA_MIC: 8  DNM0577	MRSA_MIC: 60  DNM0578	MRSA_MIC: 2  DNM0579	MRSA_MIC: 2  DNM0580
MRSA_MIC: 2  DNM0581	MRSA_MIC: 8  DNM0582	MRSA_MIC: 8  DNM0587	MRSA_MIC: 8  DNM0588
MRSA_MIC: 4  DNM0589	MRSA_MIC: 60  DNM0593	MRSA_MIC: 15  DNM0595	MRSA_MIC: 8  DNM0596
MRSA_MIC: 30  DNM0597	MRSA_MIC: 30  DNM0599	MRSA_MIC: 15  DNM0600	MRSA_MIC: 4  DNM0606

FIG 1-3

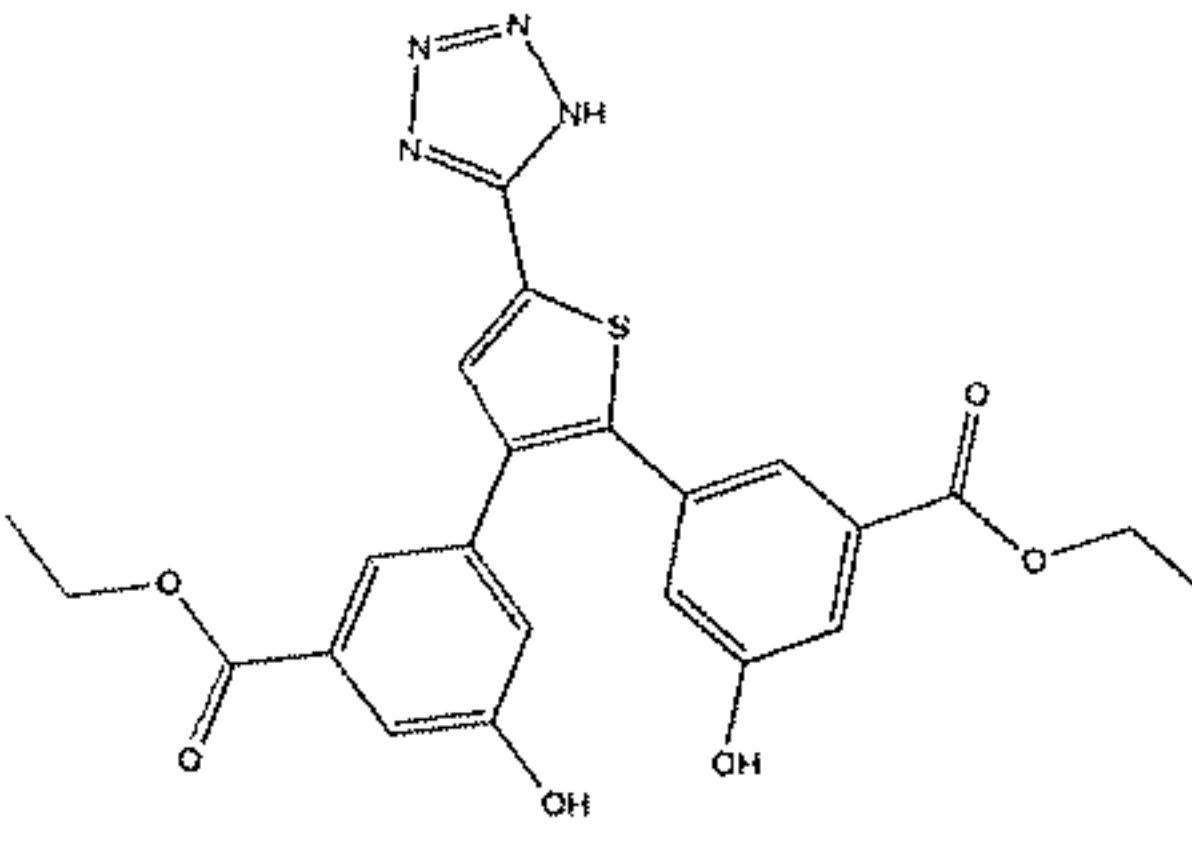
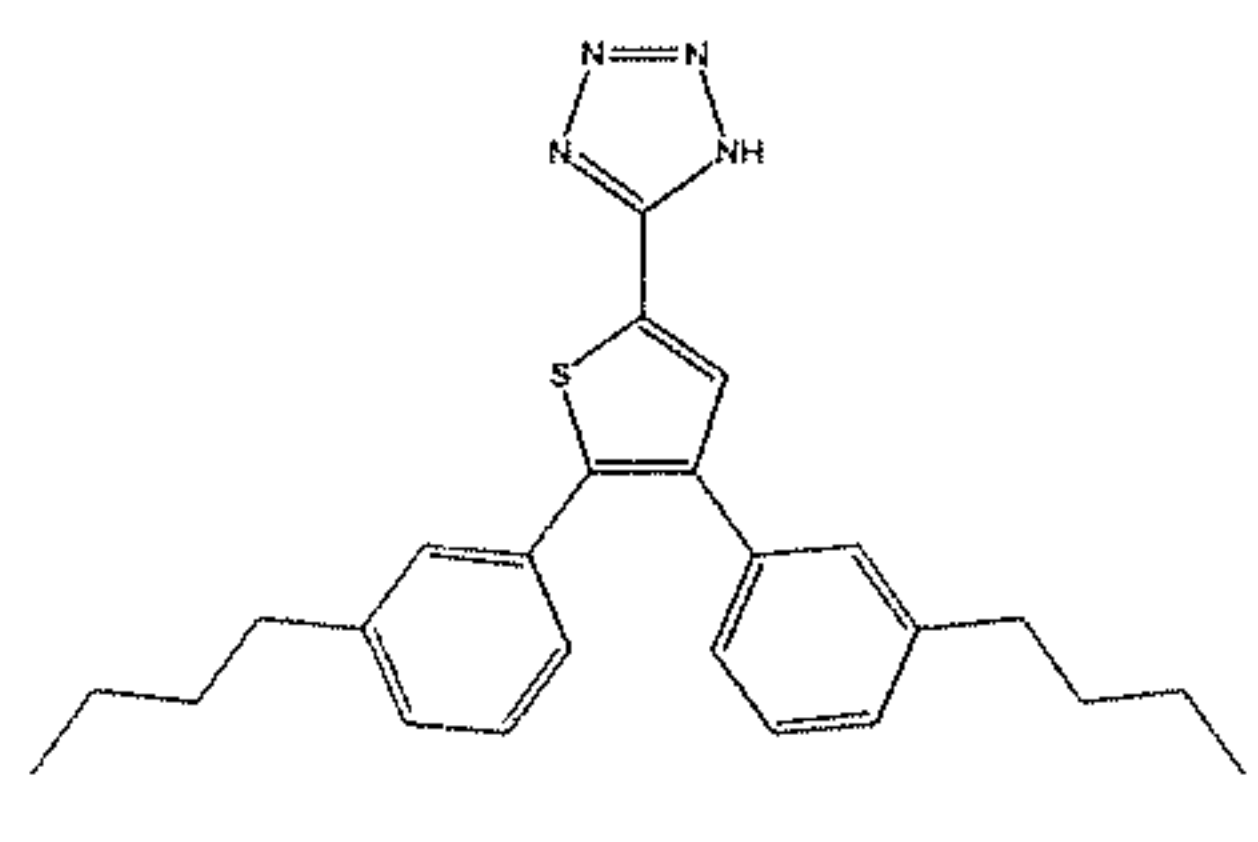
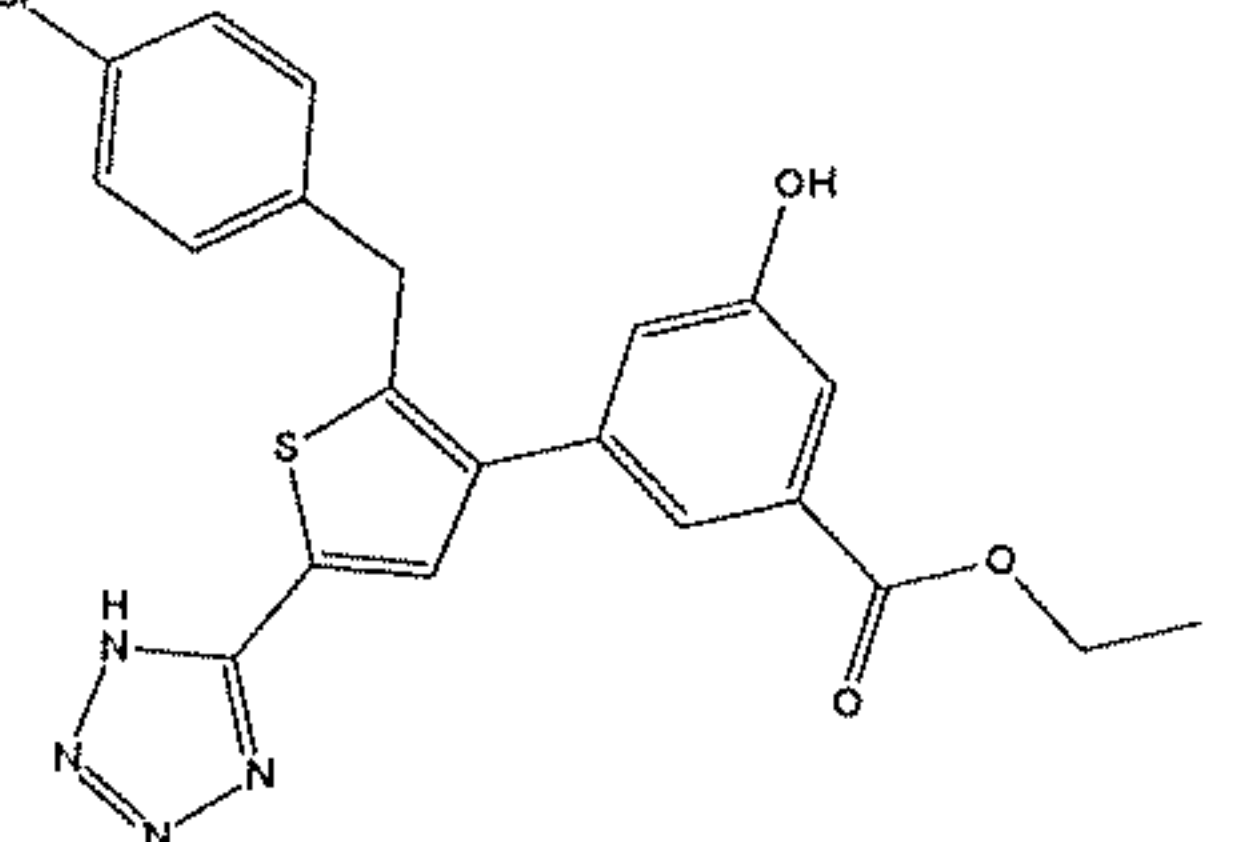
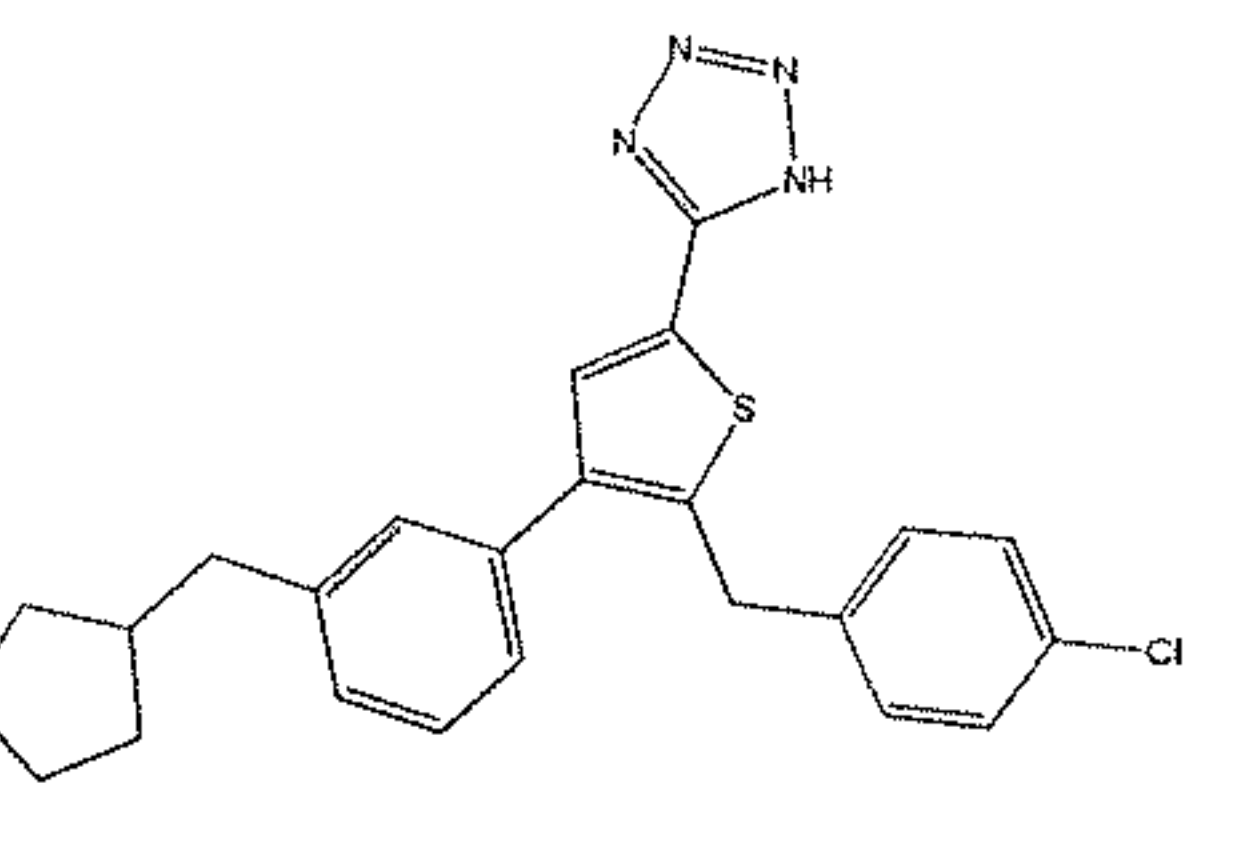
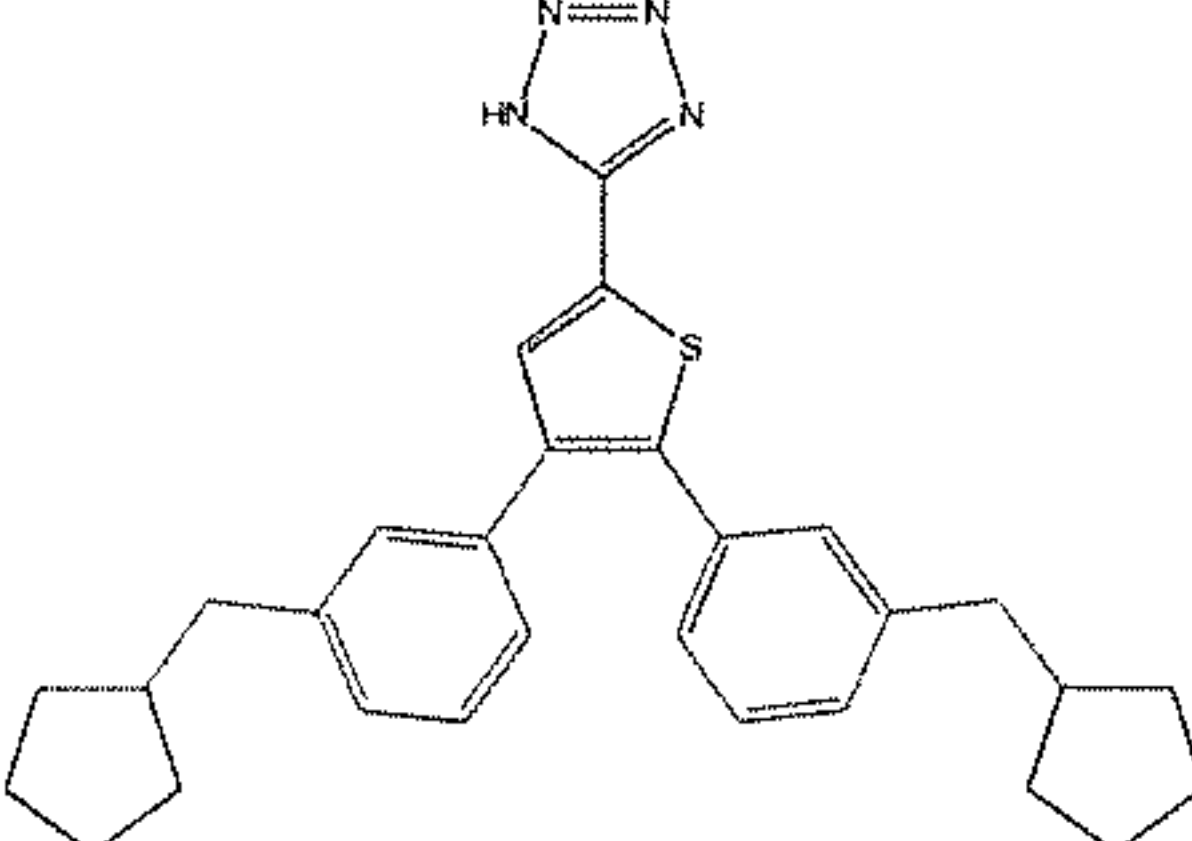
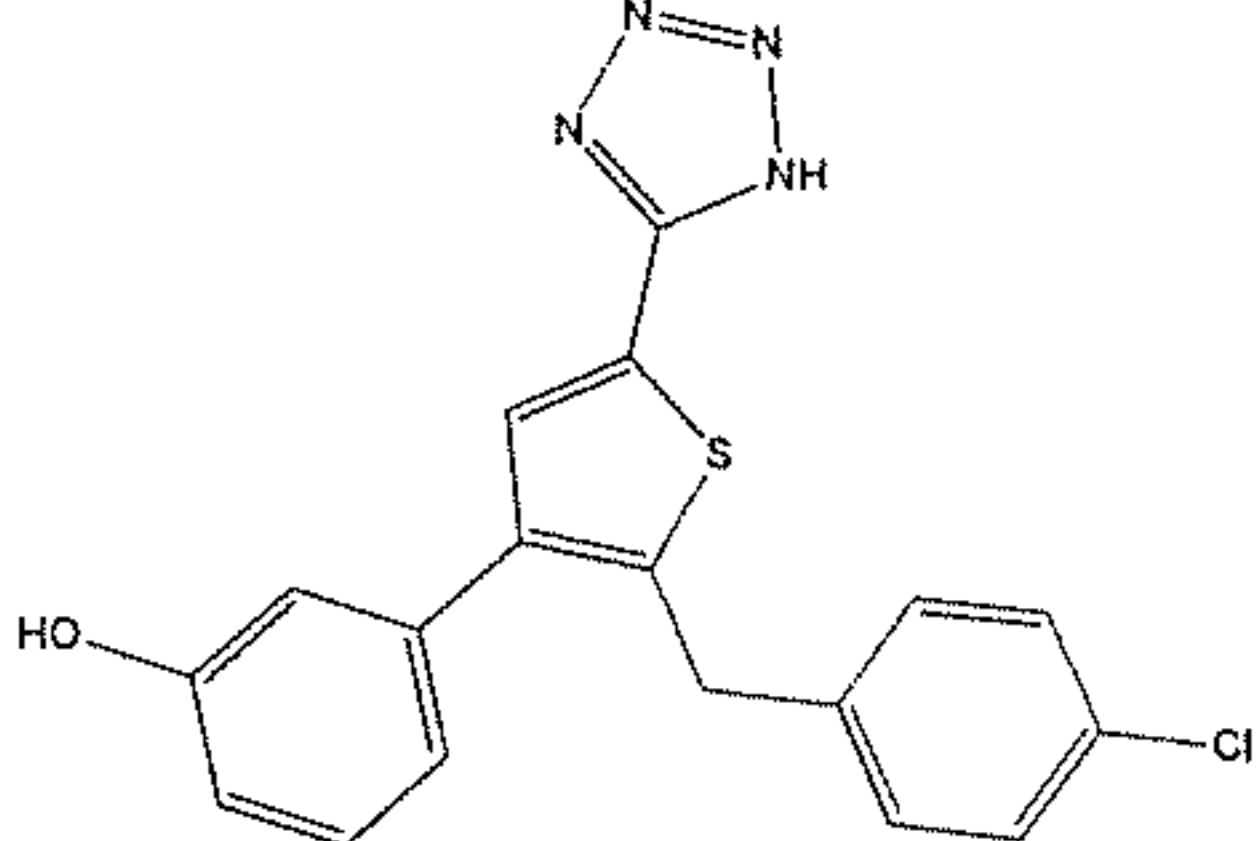
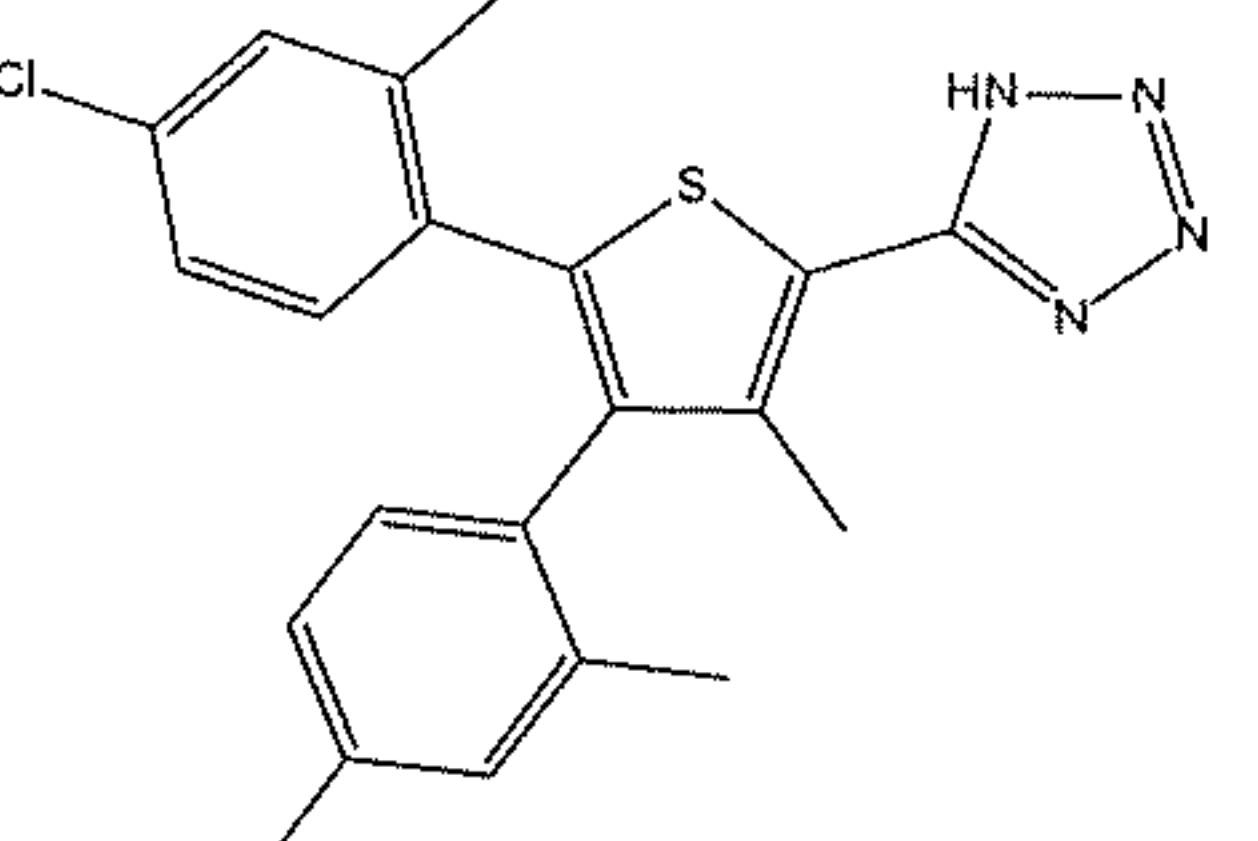
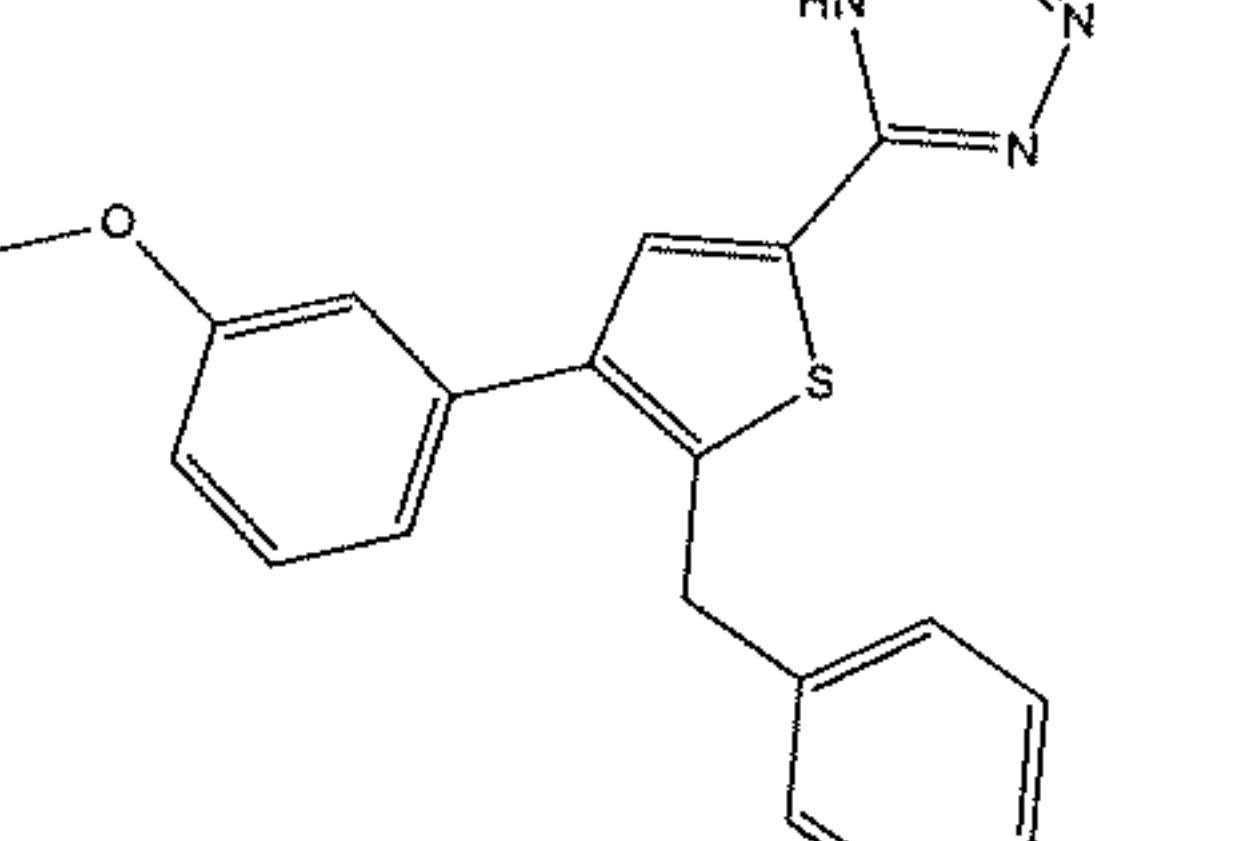
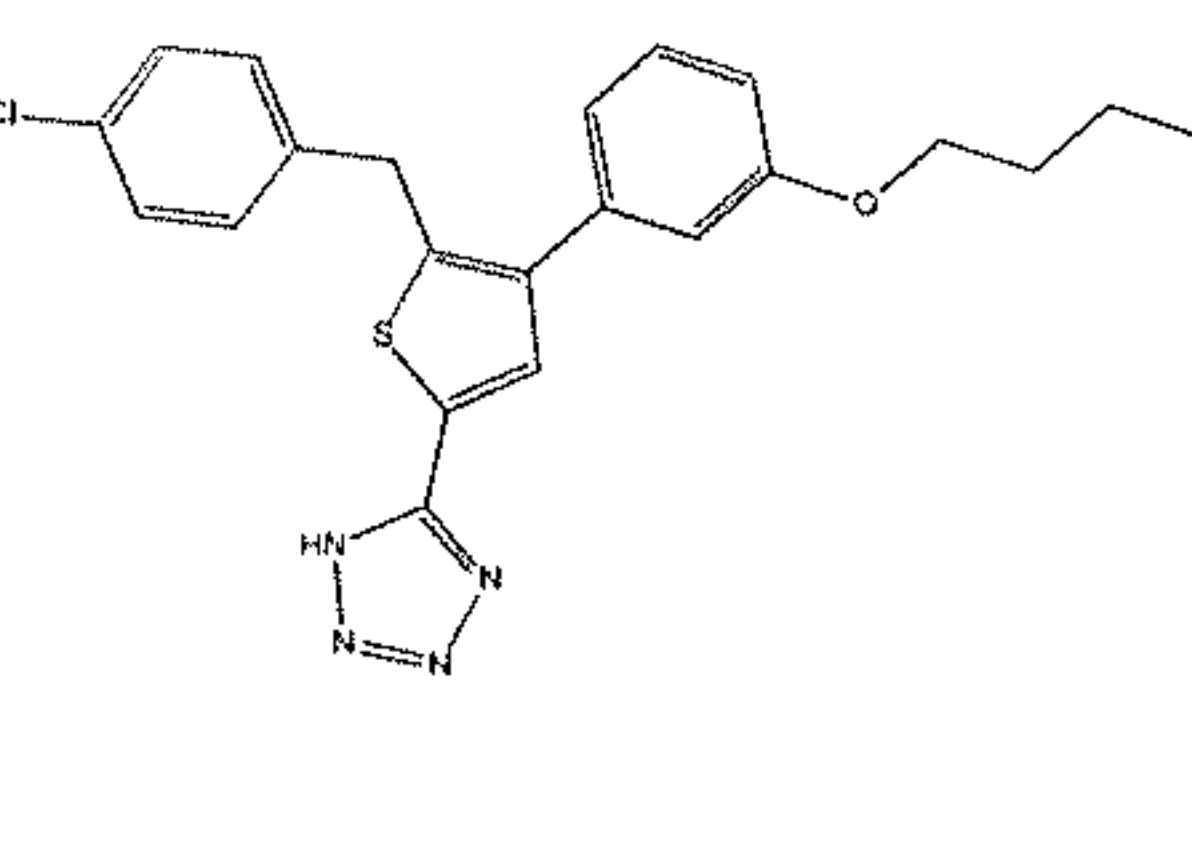
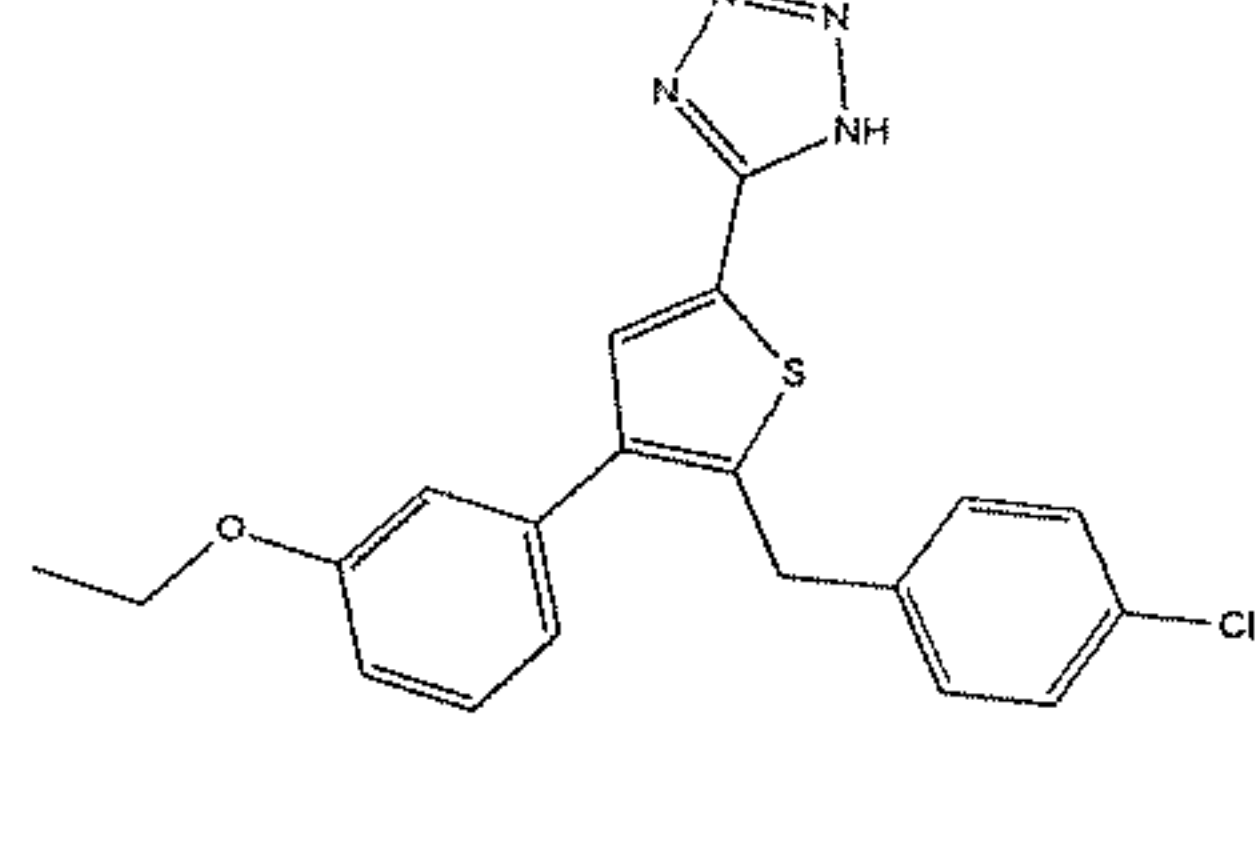
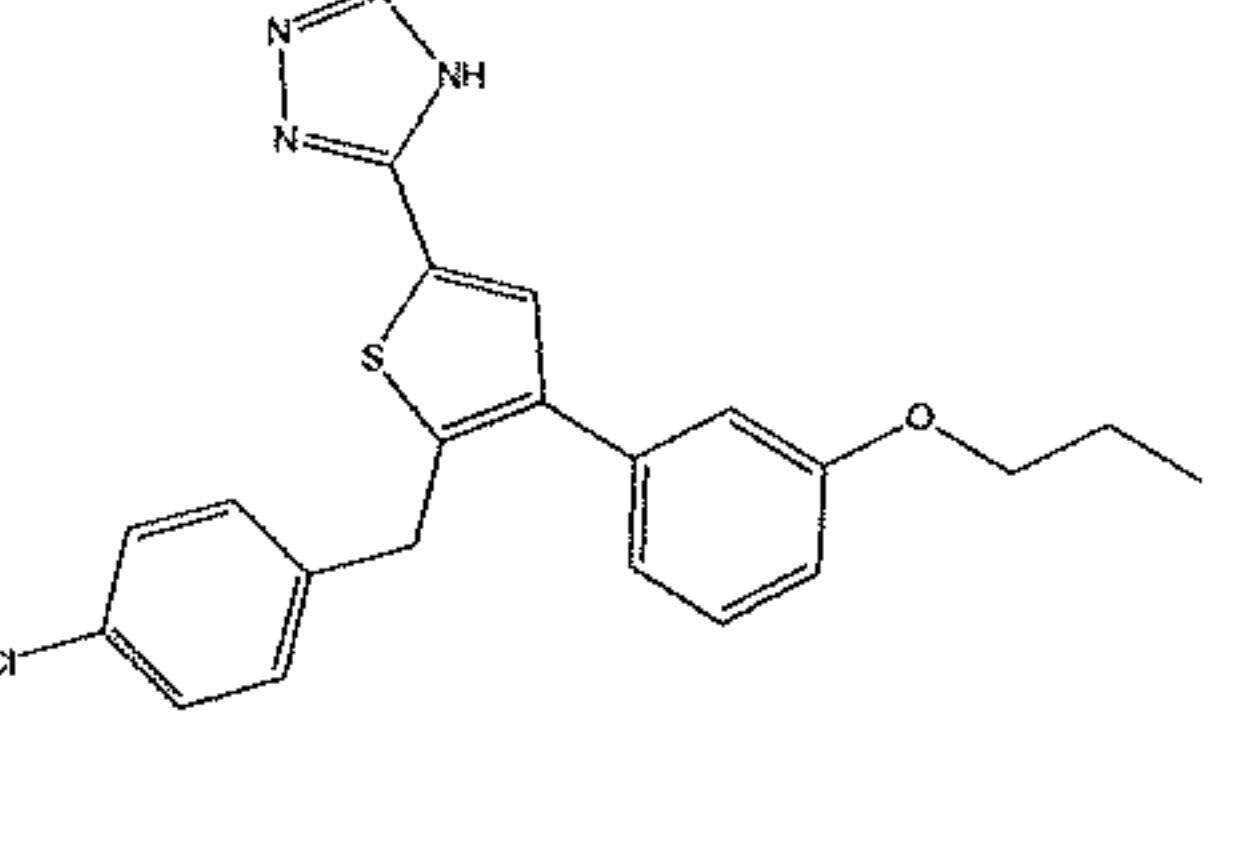
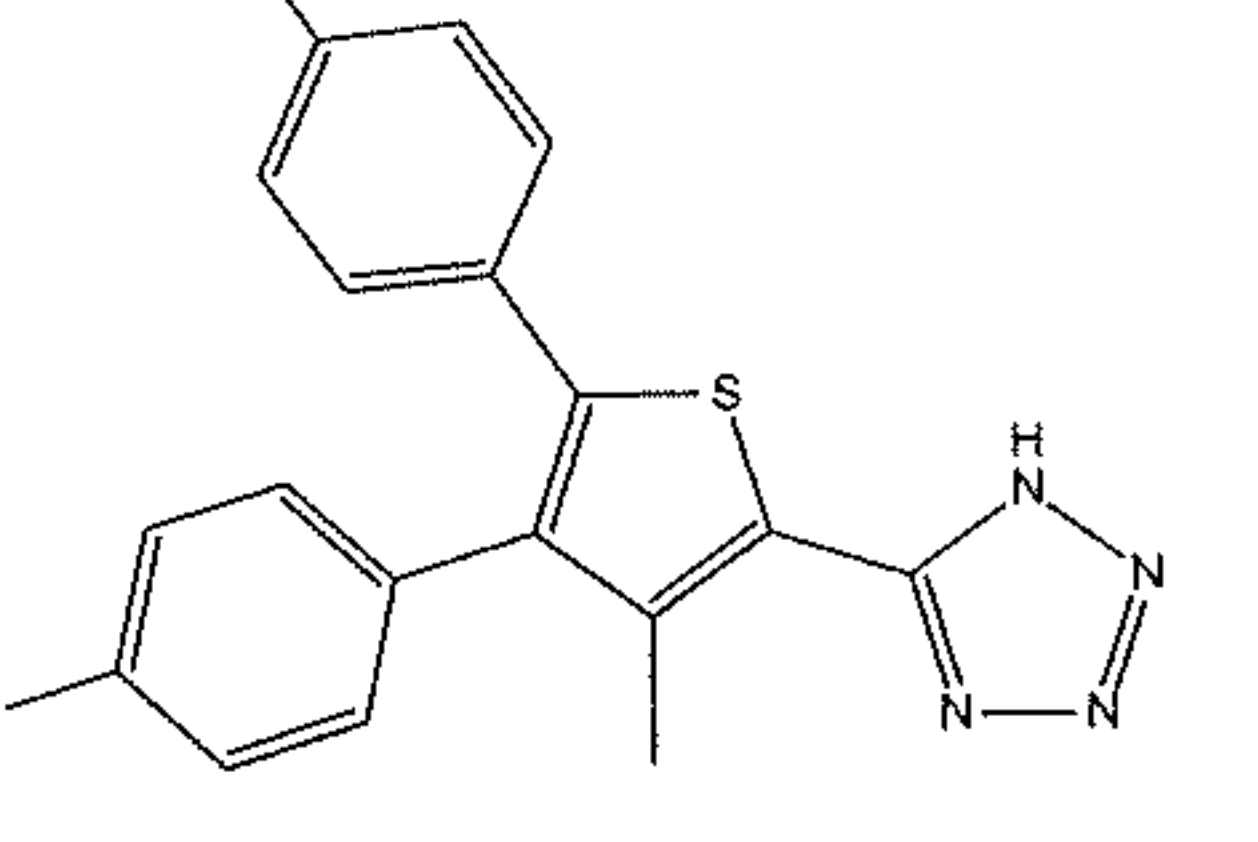
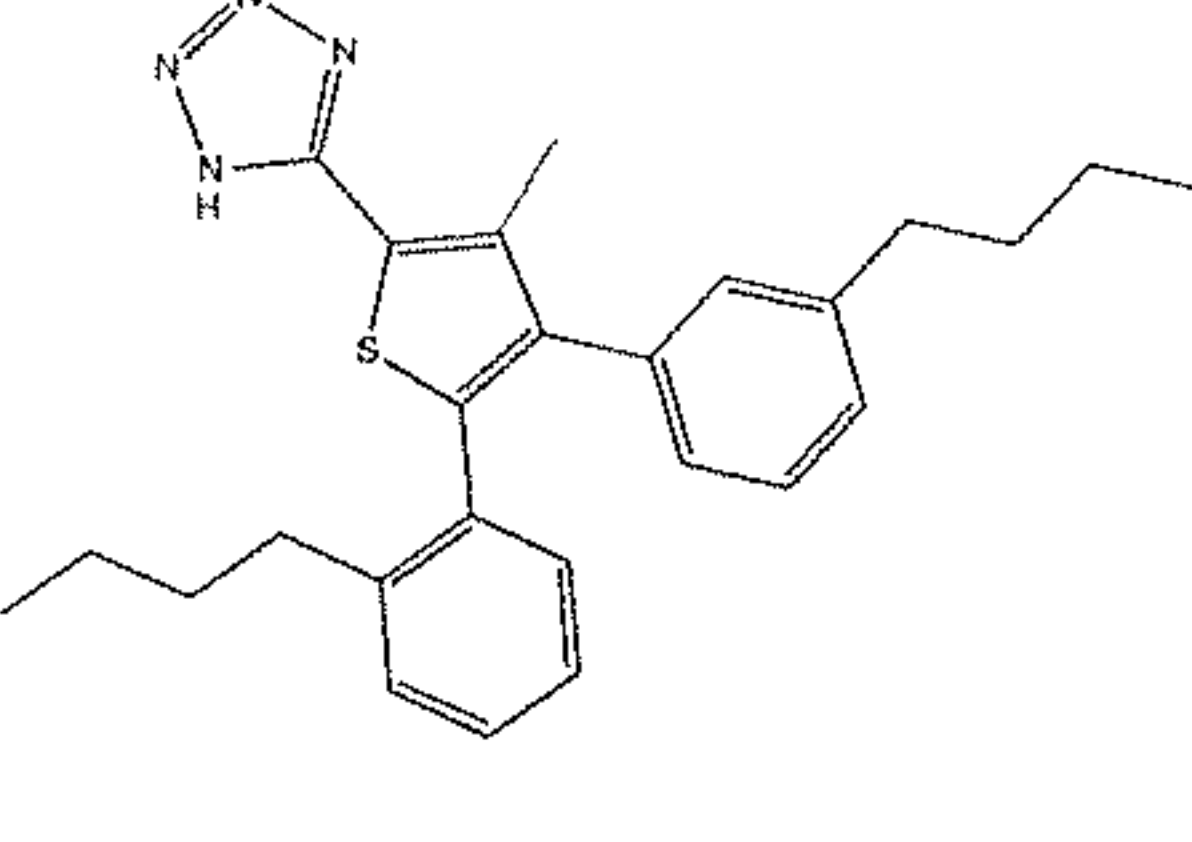
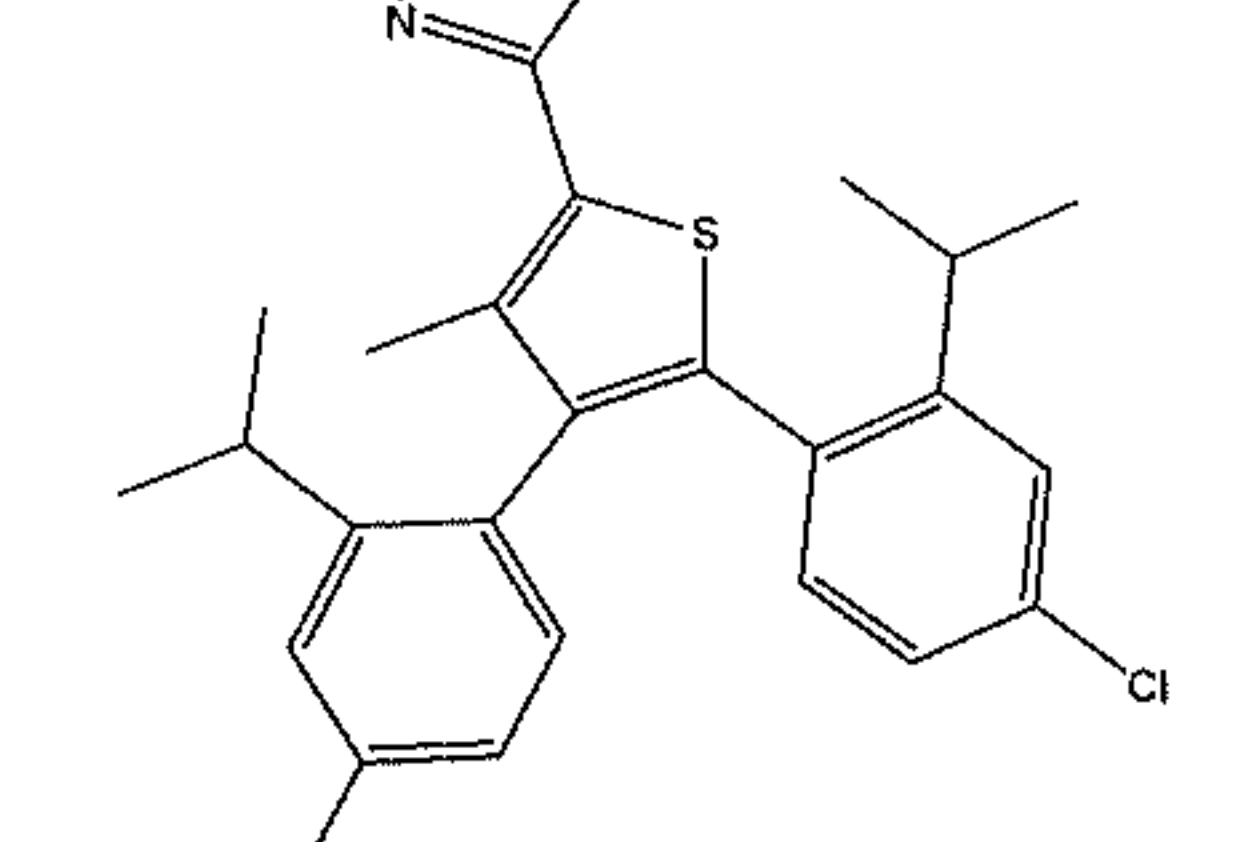
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MRSA_MIC: 125  DNM0612	MRSA_MIC: 125  DNM0613	MRSA_MIC: 2  DNM0614	MRSA_MIC: 30  DNM0615
MRSA_MIC: 8  DNM0616	MRSA_MIC: 15  DNM0617	MRSA_MIC: 8  DNM0618	MRSA_MIC: 2  DNM0619
MRSA_MIC: 1  DNM0627	MRSA_MIC: 2  DNM0631		

FIG. 1-4

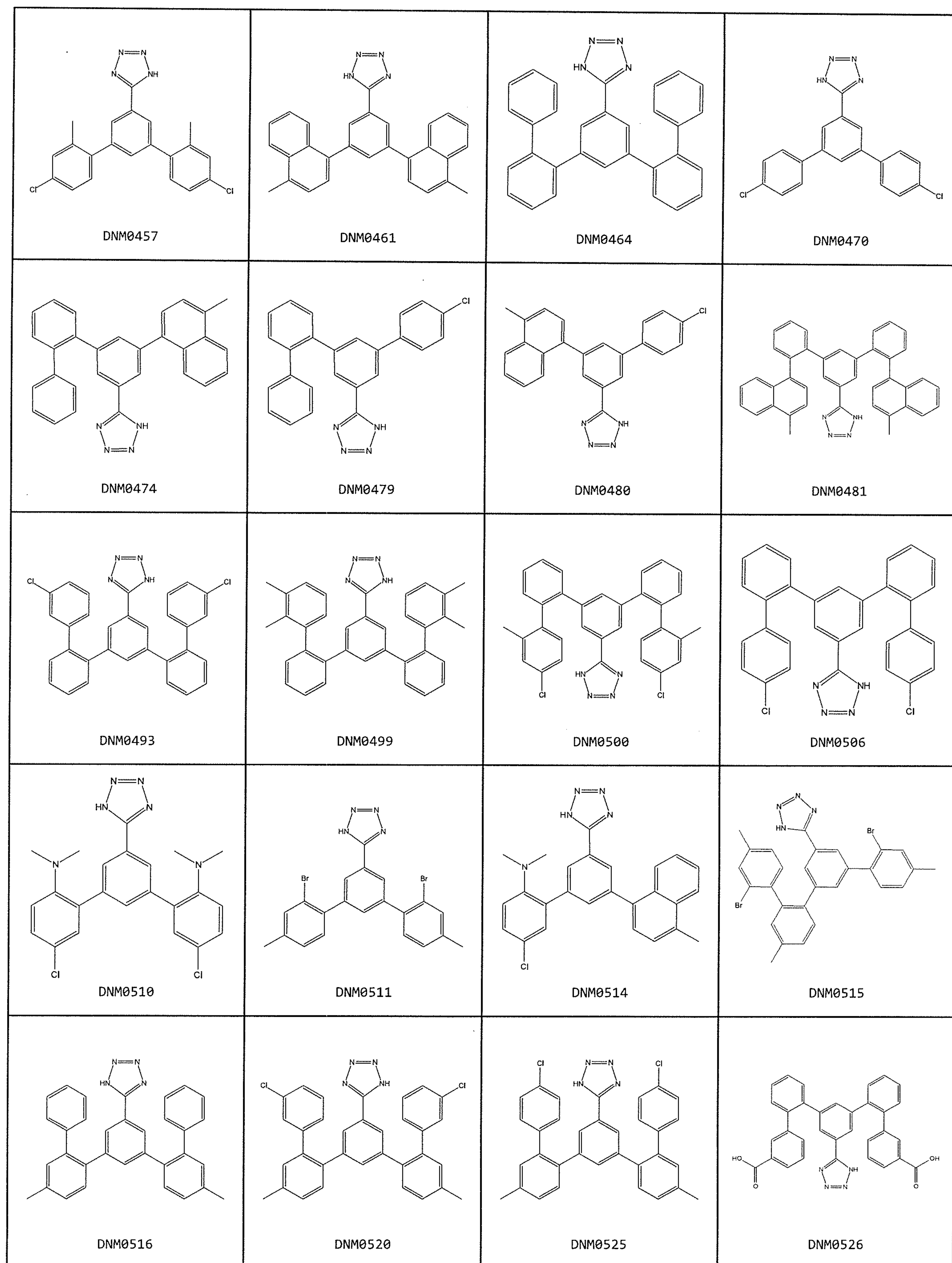


FIG. 2-1

