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Heterosubstituted N-thiolated beta-lactam compounds and methods of use

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Turos et al.

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(45) **Date of Patent:** Dec. 7, 2010

(54) **HETEROSUBSTITUTED N-THIOLATED BETA-LACTAM COMPOUNDS AND METHODS OF USE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 556 days.

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(51) **Int. Cl.**

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C07D 403/12 (2006.01)

C07D 227/00 (2006.01)

A61K 31/397 (2006.01)

A61K 31/4035 (2006.01)

(52) **U.S. Cl.** **514/210.15; 540/355**

(58) **Field of Classification Search** **540/355; 514/210.15**

See application file for complete search history.

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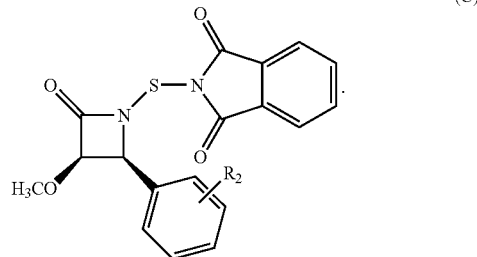
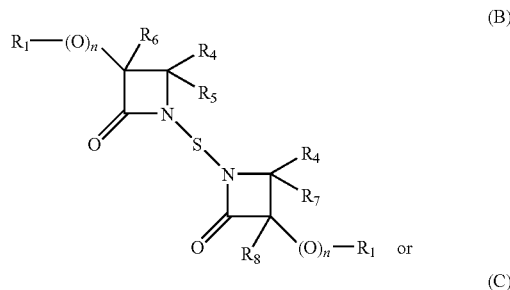
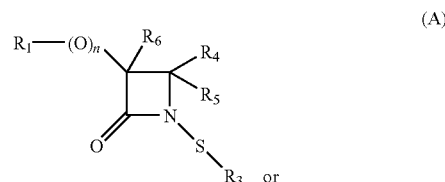
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(57) **ABSTRACT**

The invention relates to heterosubstituted N-thiolated beta-lactams, compositions comprising these compounds, methods for their production, and methods of use as antibiotics to inhibit the growth of bacteria. In one embodiment, the compounds have the structure shown in formula (A) or formula (B) or formula (C):



wherein the R groups are as defined in the specification. The antibacterial agents of the invention can be administered to a human or animal to treat or inhibit bacterial infection, such as that of *Staphylococcus* species, including methicillin-resistant *Staphylococcus aureus* (MRSA).

22 Claims, 6 Drawing Sheets

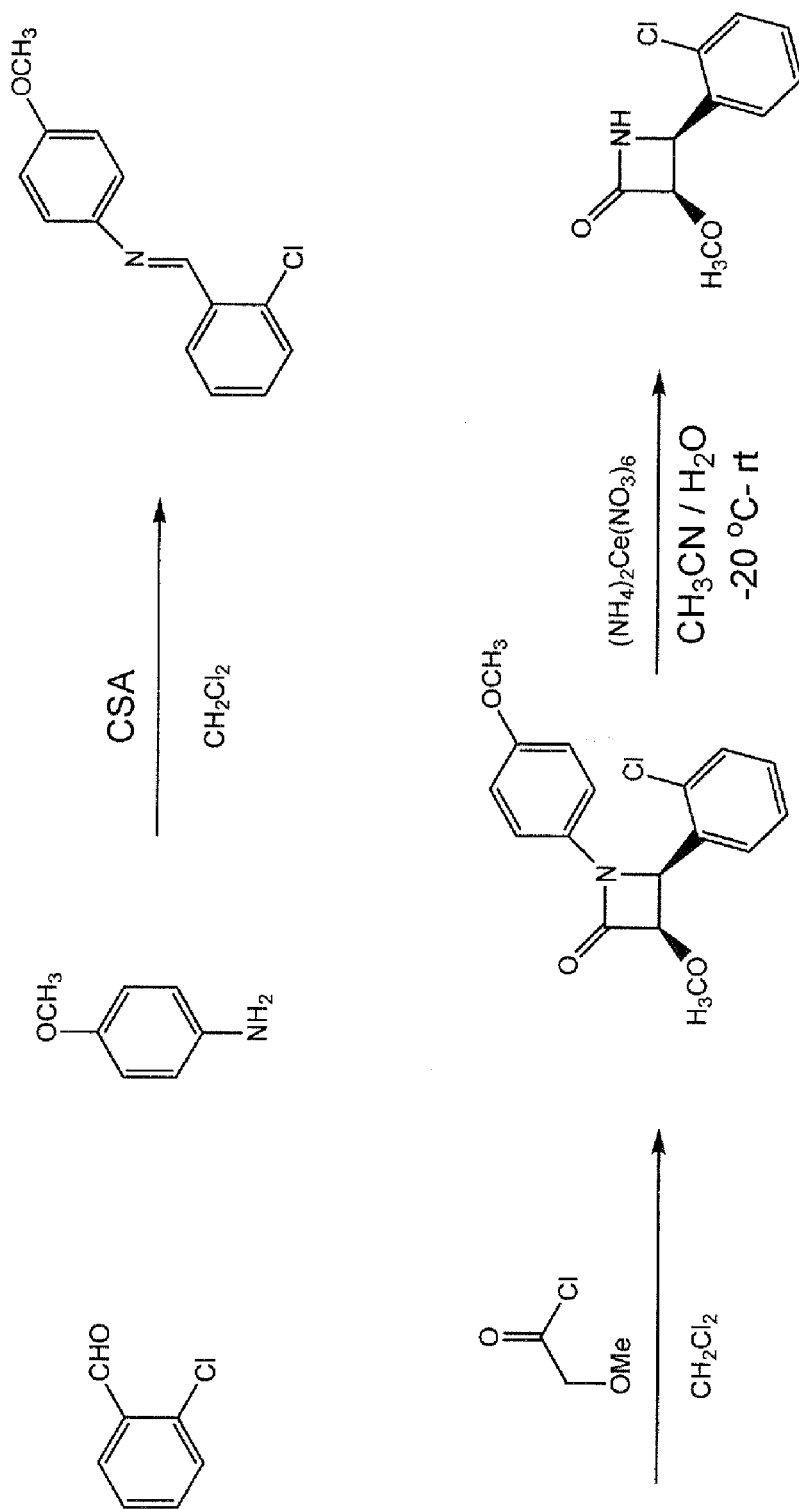


FIGURE 1

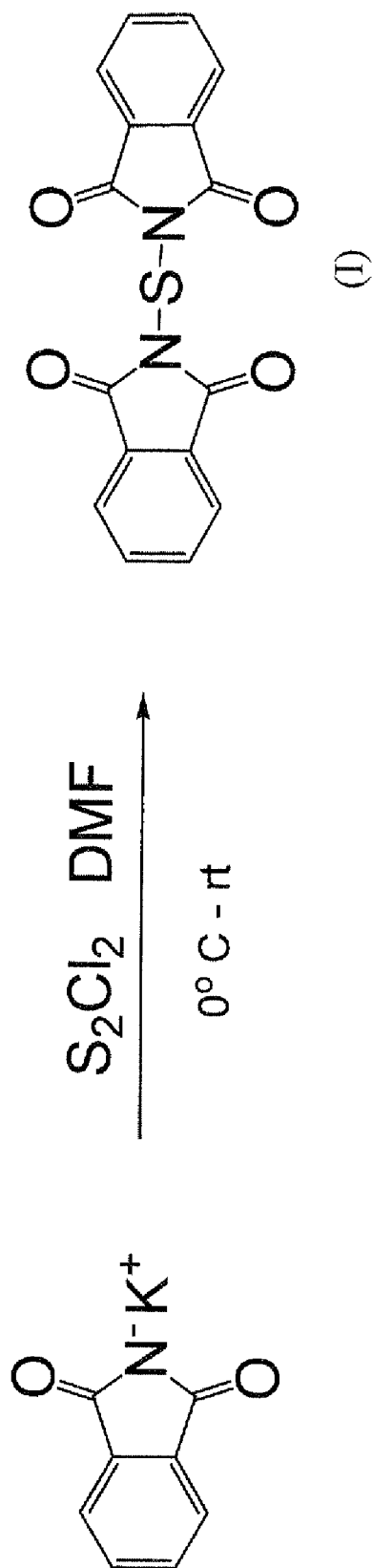


FIGURE 2

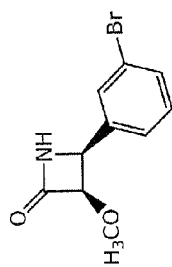
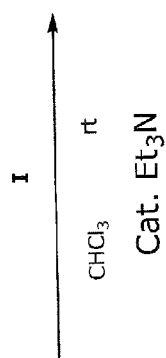
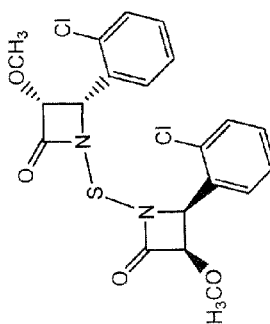
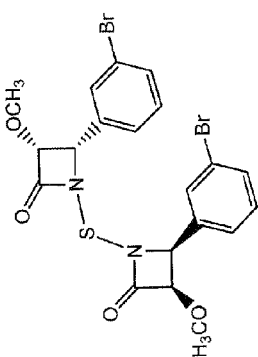
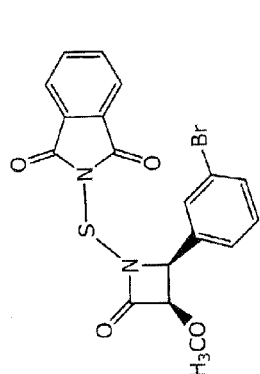


FIGURE 3A

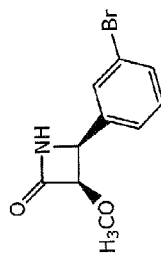
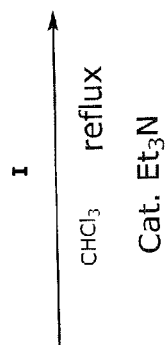


FIGURE 3B

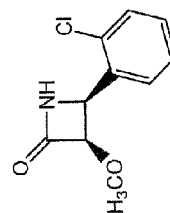
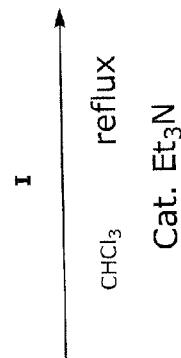


FIGURE 3C

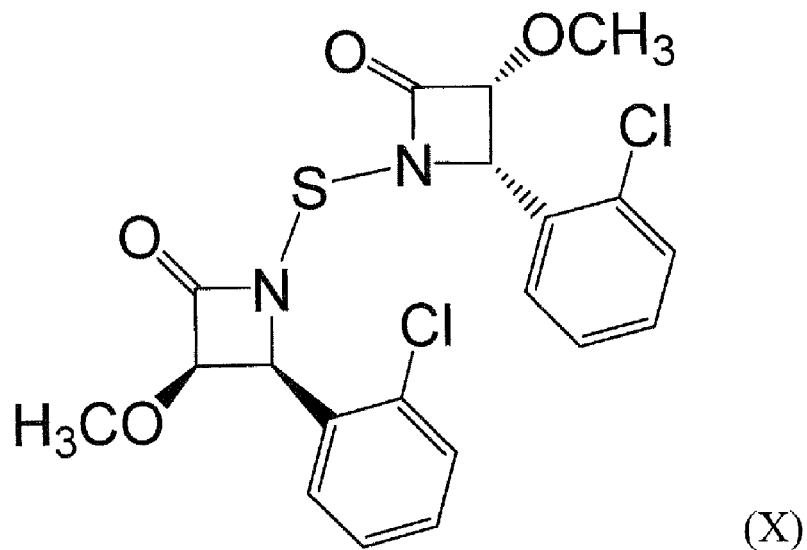


FIGURE 4A

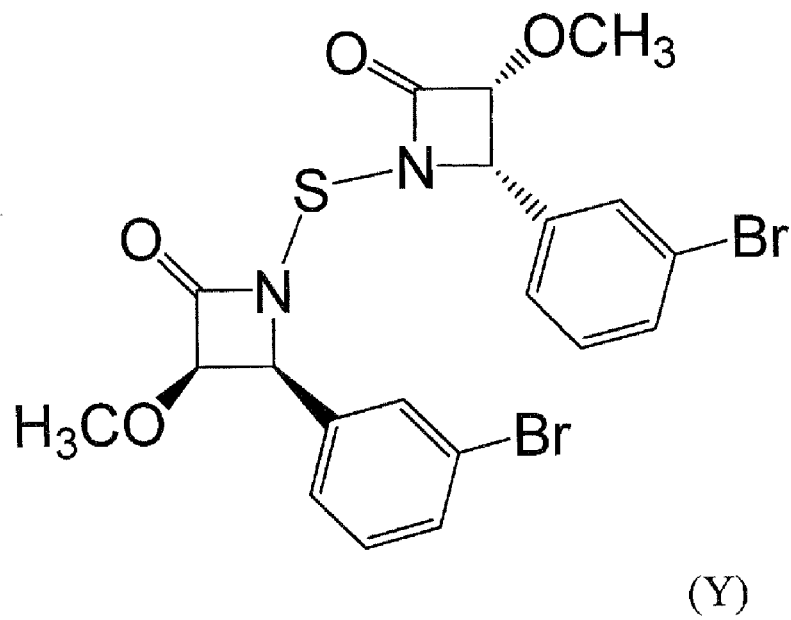
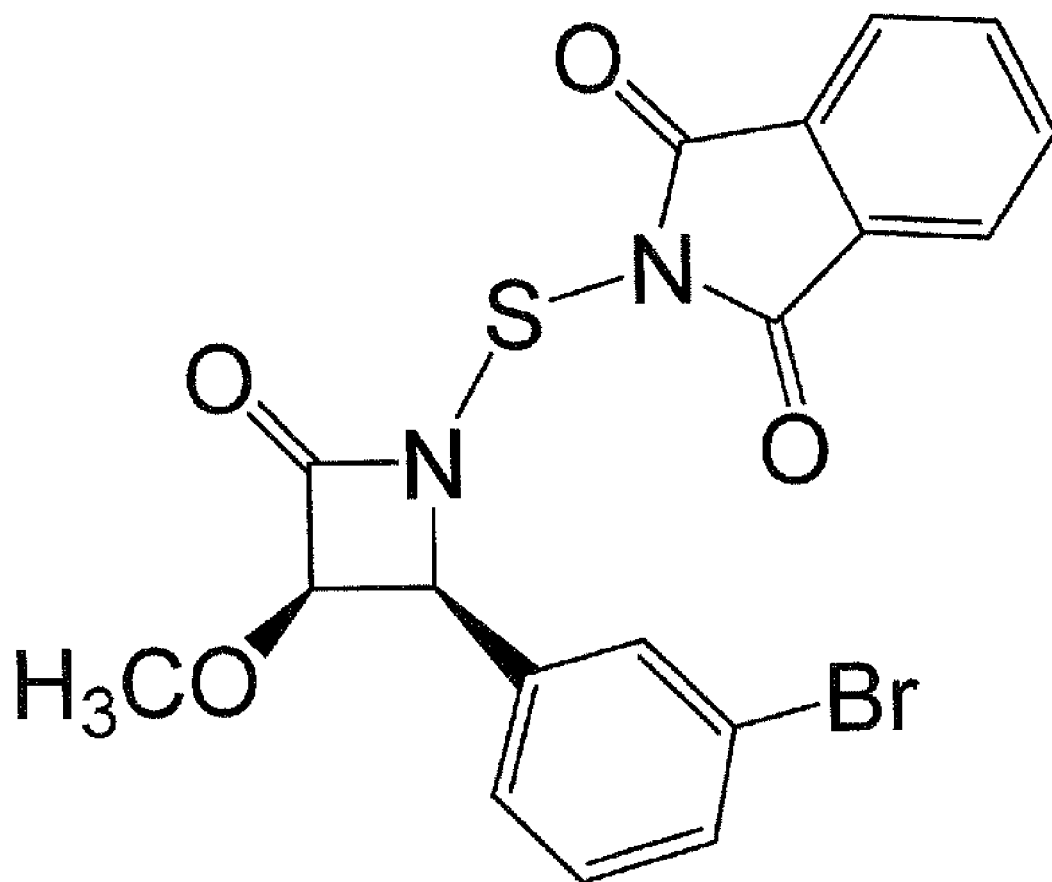


FIGURE 4B



(Z)

FIGURE 4C

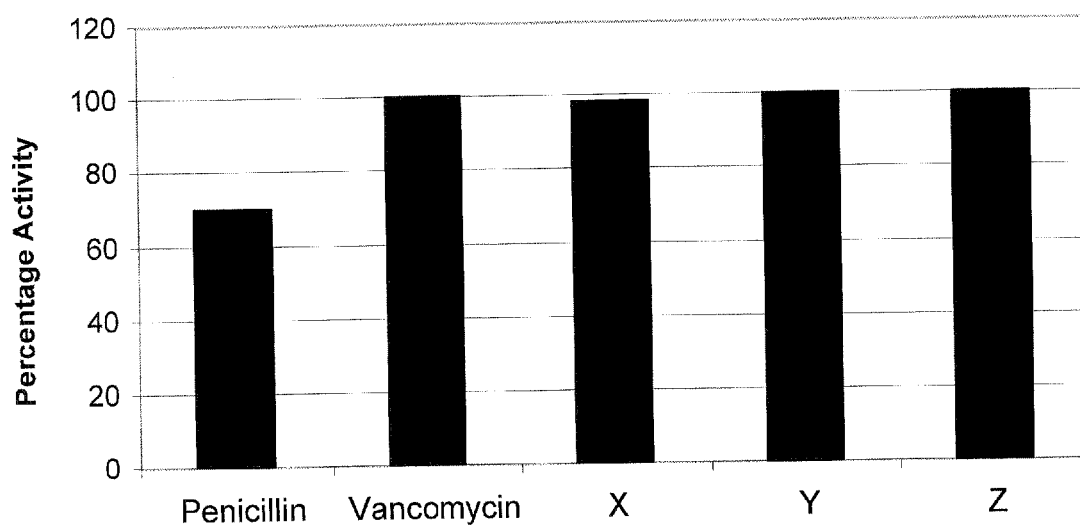


FIGURE 5

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HETEROSUBSTITUTED N-THIOLATED BETA-LACTAM COMPOUNDS AND METHODS OF USE

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims the benefit of U.S. Provisional Application Ser. No. 60/844,291, filed Sep. 13, 2006, which is hereby incorporated by reference herein in its entirety, including any figures, tables, nucleic acid sequences, amino acid sequences, and drawings.

GOVERNMENT SUPPORT

The subject matter of this application has been supported by a research grant from the National Institutes of Health under grant number R01 A151351. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

For more than 60 years, N-thiolated β -lactam antibiotics have played an essential role in treating bacterial infections (Morin et al., 1982 and Kukacs et al., 1990). The development of multi-drug resistant *Staphylococcus* infections is an increasing concern for the global health community. Infection caused by methicillin-resistant *Staphylococcus aureus* (MRSA) is becoming increasingly difficult to treat with conventional antibiotics, leading to a sharp rise in clinical complications. Recently a new class of N-thiolated β -lactam has been found to inhibit bacterial growth in *Staphylococcus aureus* (Turos et al., 2000) including methicillin-resistant *Staphylococcus aureus* (MRSA) strains.

BRIEF SUMMARY OF THE INVENTION

The present invention concerns heterosubstituted N-thiolated beta-lactam compounds, compositions comprising these compounds, methods for their production, and methods of use as antibiotics to inhibit the growth of bacteria. The antibacterial agents of the invention can be administered to a human or animal to treat or inhibit bacterial infection (therapeutically or prophylactically), such as that of *Staphylococcus* species, including methicillin-resistant *S. aureus*.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a reaction scheme for the synthesis of beta-lactams that can be used according to the present invention (see Turos et al. (2005)).

FIG. 2 shows a reaction scheme for the synthesis of a phthalimide dimer that can be used according to the present invention (see Kalnins (1966)).

FIGS. 3A-3C show reaction schemes for the synthesis of heterosubstituted N-thiolated beta-lactam compounds of the present invention.

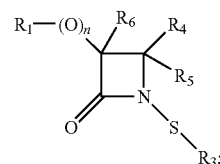
FIGS. 4A-4C show examples of heterosubstituted N-thiolated beta-lactam compounds of the present invention identified as compounds. FIG. 4A is structure X, FIG. 4B is structure Y, and FIG. 4C is structure Z.

FIG. 5 shows bioactivity of heterosubstituted N-thiolated beta-lactam compounds X, Y, and Z (shown in FIG. 4) of the present invention as tested in Kirby-Bauer diffusion assay against methicillin resistant *Staphylococcus aureus*.

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DETAILED DESCRIPTION OF THE INVENTION

The present invention concerns heterosubstituted N-thiolated beta-lactams. In one embodiment, a beta-lactam compound of the invention has the structure shown in formula (A):



(A)

wherein R_1 is a hydrocarbon group having 1 to 8 carbon atoms and can be, for example, an alkyl, alkenyl, or alkynyl group;

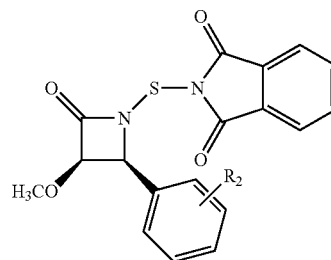
R_3 is a heteroalkyl, heterocycloalkyl or heteroaryl, any of which can be optionally substituted with R_2 , wherein R_2 is one or more halides, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, carboxylic ester group, —CHO, —COOH, or COX, wherein X is Cl, F, Br, or I;

R_4 , R_5 , and R_6 are, independently, hydrogen, alkyl, alkenyl, alkynyl, aryl, heteroalkyl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, halides, hydroxyl, nitro, cyano, alkoxy, amido, amino, carboxylic ester group, —CHO, —COOH, or COX, wherein X is Cl, F, Br, or I; any of which can be optionally substituted with R_2 , wherein R_2 is one or more halides, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, carboxylic ester group, —CHO, —COOH, or COX, wherein X is Cl, F, Br, or I; and

wherein $n=0$ or 1;

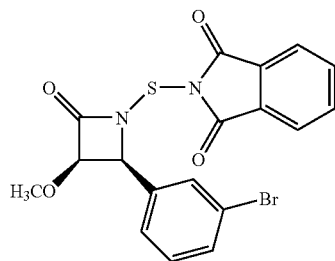
or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

In one embodiment, a compound of the invention has the structure shown in formula (A) wherein R_1 is an alkyl group. In another embodiment, R_4 is an aryl group. In a specific embodiment, R_1 is an alkyl group and R_4 is an aryl group. In an exemplified embodiment, R_1 is a methyl and R_4 is phenyl optionally substituted with one or more halogens. In a specific embodiment, the halogen is Cl or Br. In a specific embodiment, R_3 is attached to the sulfur atom through a heteroatom, such as an N atom. In one embodiment, R_3 is an optionally substituted phthalimido. In one embodiment, a compound has the structure:

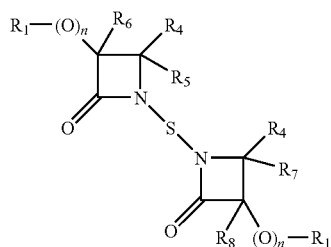


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In an exemplified embodiment, a compound of the invention has the structure shown below:



In another embodiment, a beta-lactam compound of the invention has the structure shown in formula (B):



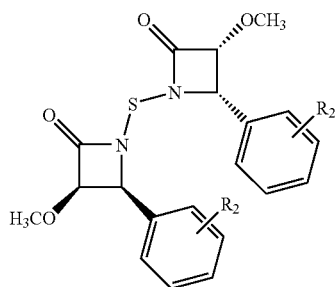
wherein R_1 is, independently, a hydrocarbon group having 1 to 8 carbon atoms and can be, for example, an alkyl, alkenyl, or alkynyl group; and

R_4 , R_5 , R_6 , R_7 , and R_8 are, independently, hydrogen, alkyl, alkenyl, alkynyl, aryl, heteroalkyl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, halides, hydroxyl, nitro, cyano, alkoxy, amido, amino, carboxylic ester group, $-\text{CHO}$, $-\text{COOH}$, or COX , wherein X is Cl, F, Br, or I, any of which can be optionally substituted with R_2 , wherein R_2 is one or more halides, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, carboxylic ester group, $-\text{CHO}$, $-\text{COOH}$, or COX , wherein X is Cl, F, Br, or I;

wherein $n=0$ or 1;

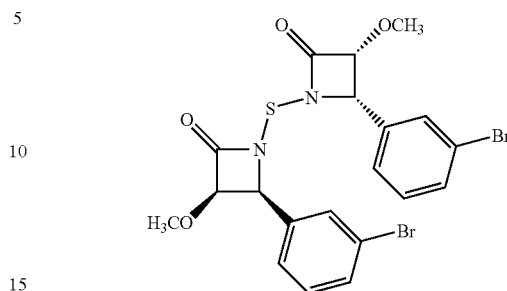
or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

In one embodiment, a compound of the invention has the structure shown in formula (B) wherein R_1 is an alkyl group. In another embodiment, R_4 is an aryl group. In a specific embodiment, R_1 is an alkyl group and R_4 is an aryl group. In an exemplified embodiment, R_1 is a methyl and R_4 is phenyl optionally substituted with one or more halogens. In a specific embodiment, the halogen is Cl or Br. In one embodiment, a compound has the structure:

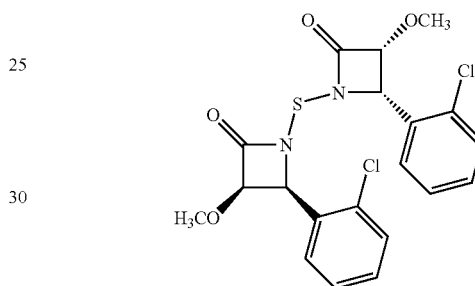


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In an exemplified embodiment, a compound of the invention has the structure shown below:

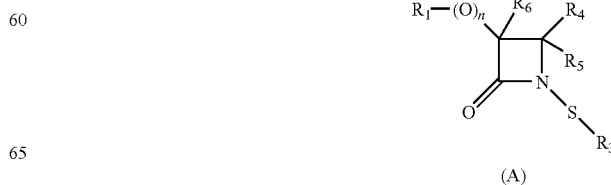
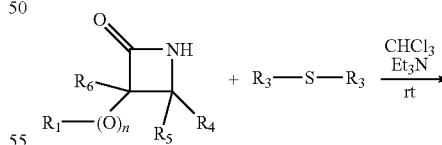


In another exemplified embodiment, a compound of the invention has the structure shown below:



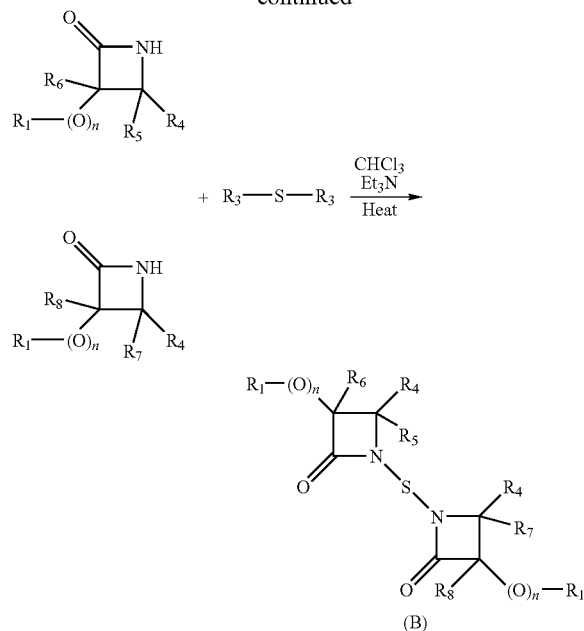
The subject invention also concerns prodrugs of the compounds described herein. Prodrugs of compounds refers to compounds that can undergo chemical changes when provided under physiological conditions, such as when the prodrug is administered to a person or animal, to thereby convert the prodrug into an N-thiolated beta-lactam compound of the present invention.

The subject invention also concerns methods for synthesizing compounds of the invention. General reaction schemes are shown below:



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-continued



wherein R_1 is a hydrocarbon group having 1 to 8 carbon atoms and can be, for example, an alkyl, alkenyl, or alkynyl group;

R_3 is a heteroalkyl, heterocycloalkyl or heteroaryl, any of which can be optionally substituted with R_2 , wherein R_2 is one or more halides, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, carboxylic ester group, $-\text{CHO}$, $-\text{COOH}$, or COX , wherein X is Cl, F, Br, or I; and

R_4 , R_5 , R_6 , R_7 , and R_8 are, independently, hydrogen, alkyl, alkenyl, alkynyl, aryl, heteroalkyl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, halides, hydroxyl, nitro, cyano, alkoxy, amido, amino, carboxylic ester group, $-\text{CHO}$, $-\text{COOH}$, or COX , wherein X is Cl, F, Br, or I, any of which can be optionally substituted with R_2 , wherein R_2 is one or more halides, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, carboxylic ester group, $-\text{CHO}$, $-\text{COOH}$, or COX , wherein X is Cl, F, Br, or I;

wherein $n=0$ or 1;

or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

Beta-lactam starting material can be synthesized as described in Turos et al. (2005). In one embodiment, a beta-lactam starting material is reacted with phthalimide dimer in a solvent, such as chloroform (CHCl_3), and triethylamine (Et_3N) under room temperature conditions or reflux (heat) conditions at elevated temperature. Phthalimide dimer can be synthesized as described in Kalnins (1966). Chemical reactions and products are shown in FIGS. 3A-3C. Methods of synthesis related to N-thiolated beta-lactam are also disclosed in U.S. Pat. Nos. 6,476,015 and 6,946,458.

The subject invention also concerns methods of using one or more compounds of the invention to treat or prevent a bacterial infection. In one embodiment, a method of the invention comprises administering an effective amount of one or more compounds of the invention to a person or animal in need of treatment. Optionally, the subject methods provide for screening of persons or animals to determine whether the person or animal has a bacterial infection amenable to treatment by a compound of the present invention. Patients that can be treated according to the present invention, include, but

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are not limited to, humans and other mammals (such as primates (monkey, chimpanzee, ape, etc.) dog, cat, cow, pig, horse, etc.), or bird, reptile, etc. Compounds and pharmaceutically acceptable compositions administered to the person or animal via any suitable route, including, for example, orally or parenterally, by intravenous, intramuscular, intraperitoneally, subcutaneous or topical routes, or via nasal or rectal administration. An ordinarily skilled clinician can readily assess the patient to determine optimal dosage, dosage form, and dosage schedule for the patient.

Bacterial infections that can be treated or prevented include, but are not limited to, infections caused by gram-positive bacteria, such as *Bacillus* spp., *Listeria* spp., *Staphylococcus* spp., *Streptococcus* spp., *Enterococcus* spp., and *Clostridium* spp., and gram-negative bacteria, such as *Escherichia* spp., *Salmonella* spp., *Pseudomonas* spp., *Helicobacter* spp., *Legionella* spp., *Moraxella* spp., *Neisseria* spp., *Hemophilus* spp., *Klebsiella* spp. and *Enterobacter* spp. Other bacteria that can be inhibited or killed by compounds of the invention include *Shigella* spp., *Acromonas* spp., *Vibrio* spp., *Bordetella* spp., *Brucella* spp., *Treponema* spp., *Lep-tospira* spp., *Corynebacter* spp., *Micrococcus* spp., *Streptomyces* spp., *Nocardia* spp., *Actinomyces* spp., *Yersinia* spp., *Chlamydia* spp., *Mycoplasma* spp., *Rickettsiae* spp., *Pasteurella* spp., *Spirillum* spp., and *Mycobacterium* spp. In one embodiment, a person or animal being treated according to the methods herein is infected with methicillin-resistant *Staphylococcus aureus*. In one embodiment, a compound of the invention is provided as a pharmaceutically acceptable composition that comprises, for example, a pharmaceutically acceptable carrier or excipient.

The bioactivity of these compounds has been tested by Kirby-Bauer diffusion assay against methicillin resistant *Staphylococcus aureus* (MRSA) and were found to have antibacterial activity against the MRSA equal to that of Vancomycin. For example, the compounds of the invention can be administered to humans or animals to inhibit the growth of bacteria, such as *Staphylococcus*, including MRSA. The mode of action of these compounds is believed to be similar to N-thiolated beta-lactams and they may be formulated and used in a similar fashion (see U.S. Pat. No. 6,946,458 (Turos) and U.S. Pat. No. 6,476,015 (Turos et al.), which are incorporated herein by reference in their entirety).

The subject invention also concerns methods for killing or inhibiting the growth of a bacterial organism. In one embodiment, a bacterial organism is contacted with one or more compounds of the present invention. Bacterial organisms contemplated within the scope of the invention include gram-positive bacteria, such as *Bacillus* spp., *Listeria* spp., *Staphylococcus* spp., *Streptococcus* spp., *Enterococcus* spp., and *Clostridium* spp., and gram-negative bacteria, such as *Escherichia* spp., *Salmonella* spp., *Pseudomonas* spp., *Helicobacter* spp., *Legionella* spp., *Moraxella* spp., *Neisseria* spp., *Hemophilus* spp., *Klebsiella* spp. and *Enterobacter* spp. Other bacteria that can be inhibited or killed by compounds of the invention include *Shigella* spp., *Acromonas* spp., *Vibrio* spp., *Bordetella* spp., *Brucella* spp., *Treponema* spp., *Lep-tospira* spp., *Corynebacter* spp., *Micrococcus* spp., *Streptomyces* spp., *Nocardia* spp., *Actinomyces* spp., *Yersinia* spp., *Chlamydia* spp., *Mycoplasma* spp., *Rickettsiae* spp., *Pasteurella* spp., *Spirillum* spp., and *Mycobacterium* spp. In an exemplified embodiment, the bacterial organism is a methicillin-resistant strain of *Staphylococcus aureus*.

The compounds and compositions of the invention can also be formulated for finding livestock and the use thereof is contemplated by the present invention.

The invention further encompasses methods for inhibiting the growth of bacteria by contacting the bacteria with an effective amount of the compounds of the invention in vitro or in vivo, or by applying the compound to a substrate (surface) likely to come in contact with the bacteria, such as a work surface, table, surgical instrument, implant or other device to

be placed in or on the body (i.e., foreign object to be inserted into a subject, such as a stent, catheter, access port, intravenous delivery tube (Hickman), heart valve, dental implant, electro-mechanical device, prosthetic device, glucose sensor, or stabilizing device such as orthopedic nails and pins), eating or cooking utensil, etc. The subject invention also concerns substrates which have a compound of the invention attached or applied thereto.

As used herein, alkyl means straight or branched chain, saturated or mono- or polyunsaturated hydrocarbon groups having from 1 to 20 carbon atoms and C_{1-X} alkyl means straight or branched chain alkyl groups containing from one up to X carbon atoms. For example, C_{1-6} alkyl means straight or branched chain alkyl groups containing from one up to 6 carbon atoms. Alkoxy means an alkyl-O— group in which the alkyl group is as previously described. Cycloalkyl includes a nonaromatic monocyclic or multicyclic ring system, including fused and spiro rings, of from about three to about 10 carbon atoms. A cyclic alkyl may optionally be partially unsaturated. Cycloalkoxy means a cycloalkyl-O— group in which cycloalkyl is as defined herein. Aryl means an aromatic monocyclic or multicyclic carbocyclic ring system, including fused and spiro rings, containing from about six to about 14 carbon atoms. Aryloxy means an aryl-O— group in which the aryl group is as described herein. Alkylcarbonyl means a $RC(O)$ — group where R is an alkyl group as previously described. Alkoxy carbonyl means an $ROC(O)$ — group where R is an alkyl group as previously described. Cycloalkylcarbonyl means an $RC(O)$ — group where R is a cycloalkyl group as previously described. Cycloalkoxy carbonyl means an $ROC(O)$ — group where R is a cycloalkyl group as previously described.

Heteroalkyl means a straight or branched-chain having from one to 20 carbon atoms and one or more heteroatoms selected from nitrogen, oxygen, sulfur, or silicon, wherein the nitrogen and sulfur atoms may optionally be oxidized, i.e., in the form of an N-oxide or an S-oxide. Heterocycloalkyl means a monocyclic or multicyclic ring system (which may be saturated or partially unsaturated), including fused and spiro rings, of about five to about 14 elements wherein one or more of the elements in the ring system is an element other than carbon and is selected from nitrogen, oxygen, silicon, or sulfur atoms. Heteroaryl means a five to about a 14-membered aromatic monocyclic or multicyclic hydrocarbon ring system, including fused and spiro rings, in which one or more of the elements in the ring system is an element other than carbon and is selected from nitrogen, oxygen, silicon, or sulfur and wherein an N atom may be in the form of an N-oxide. Arylcarbonyl means an $aryl-CO$ — group in which the aryl group is as described herein. Heteroarylcarbonyl means a heteroaryl- CO — group in which the heteroaryl group is as described herein and heterocycloalkylcarbonyl means a heterocycloalkyl- CO — group in which the heterocycloalkyl group is as described herein. Aryloxy carbonyl means an $ROC(O)$ — group where R is an aryl group as previously described. Heteroaryloxy carbonyl means an $ROC(O)$ — group where R is a heteroaryl group as previously described. Heterocycloalkoxy means a heterocycloalkyl-O— group in which the heterocycloalkyl group is as previously described. Heterocycloalkoxy carbonyl means an $ROC(O)$ — group where R is a heterocycloalkyl group as previously described.

Examples of saturated alkyl groups include, but are not limited to, methyl, ethyl, N-propyl, isopropyl, N-butyl, tert-butyl, isobutyl, sec-butyl, N-pentyl, N-hexyl, N-heptyl, and N-octyl. An unsaturated alkyl group is one having one or more double or triple bonds. Unsaturated alkyl groups include, for example, ethenyl, propenyl, butenyl, hexenyl, vinyl, 2-propynyl, 2-isopentenyl, 2-butenyl, ethynyl, 1-propynyl, 3-propynyl, 3-butenyl, 1-pentenyl, 2-pentenyl, 3-pentenyl, 4-pentenyl, 1-hexenyl, 2-hexenyl, 3-hexenyl, 4-hexenyl, 5-hexenyl, 1-heptenyl, 2-heptenyl, 3-heptenyl,

4-heptenyl, 5-heptenyl, 1-nonenyl, 2-nonenyl, 3-nonenyl, 4-nonenyl, 5-nonenyl, 6-nonenyl, 7-nonenyl, 8-nonenyl, 1-decenyl, 2-decenyl, 3-decenyl, 4-decenyl, 5-decenyl, 6-decenyl, 7-decenyl, 8-decenyl, 9-decenyl; 1-undecenyl, 2-undecenyl, 3-undecenyl, 4-undecenyl, 5-undecenyl, 6-undecenyl, 7-undecenyl, 8-undecenyl, 9-undecenyl, 10-undecenyl, 1-dodecenyl, 2-dodecenyl, 3-dodecenyl, 4-dodecenyl, 5-dodecenyl, 6-dodecenyl, 7-dodecenyl, 8-dodecenyl, 9-dodecenyl, 10-dodecenyl, 11-dodecenyl, 1-tridecenyl, 2-tridecenyl, 3-tridecenyl, 4-tridecenyl, 5-tridecenyl, 6-tridecenyl, 7-tridecenyl, 8-tridecenyl, 9-tridecenyl, 10-tridecenyl, 11-tridecenyl, 12-tridecenyl, 1-tetradecenyl, 2-tetradecenyl, 3-tetradecenyl, 4-tetradecenyl, 5-tetradecenyl, 6-tetradecenyl, 7-tetradecenyl, 8-tetradecenyl, 9-tetradecenyl, 10-tetradecenyl, 11-tetradecenyl, 12-tetradecenyl, 13-tetradecenyl, 1-pentadecenyl, 2-pentadecenyl, 3-pentadecenyl, 4-pentadecenyl, 5-pentadecenyl, 6-pentadecenyl, 7-pentadecenyl, 8-pentadecenyl, 9-pentadecenyl, 10-pentadecenyl, 11-pentadecenyl, 12-pentadecenyl, 13-pentadecenyl, and 14-pentadecenyl. Cycloalkyl groups include, for example, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, 1-cyclohexenyl, 3-cyclohexenyl, cycloheptyl, and cyclooctyl. Heterocycloalkyl groups include, for example, 1-piperidinyl, 2-piperidinyl, 3-piperidinyl, 3-morpholinyl, 4-morpholinyl, tetrahydrofuran-2-yl, tetrahydrofuran-3-yl, tetrahydrothien-2-yl, tetrahydrothien-3-yl, 1-piperazinyl, 2-piperazinyl, 1,4-diazabicyclooctane, and succinimido. Aryl groups include, for example, phenyl, indenyl, biphenyl, 1-naphthyl, 2-naphthyl, anthracenyl, and phenanthracenyl. Heteroaryl groups include, for example, 1-pyrrolyl, 2-pyrrolyl, 3-pyrrolyl, furyl, thienyl, imidazolyl, oxazolyl, thiazolyl, pyrazolyl, pyridyl, indolyl, quinolyl, isoquinolyl, benzoquinolyl, carbazolyl, phthalimido, pyrimidinyl, terazolyl, and diazaphenanthrenyl. "Alkoxy" can include methoxy, ethoxy, propoxy, isopropoxy, butoxy, iso-butoxy, sec-butoxy, pentoxy, 3-pentoxy, hexoxy, heptyloxy, octyloxy, nonyloxy, decyloxy, undecyloxy, dodecyloxy, tridecyloxy, tetradecyloxy, or pentadecyloxy.

As used herein, halogen means the elements fluorine (F), chlorine (Cl), Bromine (Br), and iodine (I).

Compounds of the subject invention also include hydrates and physiologically-acceptable salts of the subject compounds. Physiologically-acceptable salts includes salts of the compounds of the invention which are prepared with acids or bases, depending on the particular substituents found on the subject compounds described herein. Examples of physiologically-acceptable base addition salts include sodium, potassium, calcium, ammonium, or magnesium salt. Examples of physiologically-acceptable acid addition salts include hydrochloric, hydrobromic, nitric, phosphoric, carbonic, sulfuric, and organic acids like acetic, propionic, benzoic, succinic, fumaric, mandelic, oxalic, citric, tartaric, maleic, and the like. Physiologically-acceptable salts of compounds of the invention can be prepared using conventional techniques.

It will be appreciated by those skilled in the art that compounds of the invention may contain one or more asymmetrically substituted carbon atoms which can give rise to stereoisomers. It is understood that the invention extends to all such stereoisomers, including enantiomers, and diastereoisomers and mixtures, including racemic mixtures thereof.

Compounds of the subject invention can be formulated according to known methods for preparing physiologically acceptable compositions. Formulations are described in detail in a number of sources which are well known and readily available to those skilled in the art. For example, *Remington's Pharmaceutical Science* by E. W. Martin describes formulations which can be used in connection with the subject invention. In general, the compositions of the subject invention will be formulated such that an effective amount of the compound is combined with a suitable carrier in order to facilitate effective administration of the composi-

tion. The compositions used in the present methods can also be in a variety of forms. These include, for example, solid, semi-solid, and liquid dosage forms, such as tablets, pills, powders, liquid solutions or suspension, suppositories, injectable and infusible solutions, and sprays. The preferred form depends on the intended mode of administration and therapeutic application. The compositions also preferably include conventional physiologically-acceptable carriers and diluents which are known to those skilled in the art. Examples of carriers or diluents for use with the subject compounds include water, saline, ethanol, dimethyl sulfoxide, glycerol, alumina, starch, and equivalent carriers and diluents. To provide for the administration of such dosages for the desired therapeutic treatment, compositions of the invention will advantageously comprise between about 0.1% and 99%, and especially, 1 and 15% by weight of the total of one or more of the subject compounds based on the weight of the total composition including carrier or diluent.

In addition, the compounds of the present invention that exhibit antibacterial activity may also be used as medications, and also as substances for preserving inorganic and organic materials, especially organic materials of all kinds, for example, polymers, lubricants, paints, fibers, leather, paper, timber, foodstuffs, and water. For example, these compounds can be covalently bonded to the polymer.

The subject invention also concerns a kit comprising in one or more containers at least one compound of the subject invention. In one embodiment, a kit of the invention also comprises a pharmaceutically acceptable diluent and/or carrier. A kit of the invention can also comprise, in addition to at least one compound of the present invention, other antibiotics, such as penicillin, cephalosporins, carbapenems, and beta-lactamase inhibitors.

All patents, patent applications, provisional applications, and publications referred to or cited herein are incorporated by reference in their entirety, including all figures and tables, to the extent they are not inconsistent with the explicit teachings of this specification.

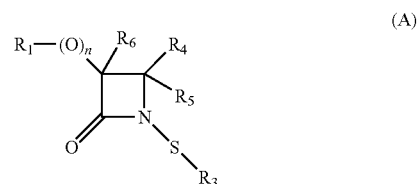
It should be understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application and the scope of the appended claims. In addition, any elements or limitations of any invention or embodiment thereof disclosed herein can be combined with any and/or all other elements or limitations (individually or in any combination) or any other invention or embodiment thereof disclosed herein, and all such combinations are contemplated with the scope of the invention without limitation thereto.

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 Kalnins, Malda (1966) "Reactions of Phthalimide and Potassium Phthalimide with Sulfur Monochloride," *Canadian Journal of Chemistry*, 44: 2111-2113.
 Morin et al. (1982) "Chemistry and Biology of beta-lactam Antibiotics," Vol. 1-3. New York: Academic Press.
 Kukacs et al. (1990) "Recent Progress in the Chemical Synthesis of Antibiotics" Berlin, Springer-Verlag.
 Turos, E. et al. (2005) "N-Methylthio β -lactam Antibacterials: Effects of the C₃/C₄ Ring Substituents on Anti-MRSA Activity," *Bioorganic & Medicinal Chemistry*, 13: 6289-6308.
 Turos et al. (2000) *Tetrahedron* 56:5571-5578.
 Ren et al. (1998) *J. Org. Chem.* 63: 8898-8917.

We claim:

1. A compound having the structure shown in formula (A):



wherein R₁ is a hydrocarbon group having 1 to 8 carbon atoms;

R₃ is a phthalimido which can be optionally substituted with R₂, wherein R₂ is one or more halogen, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, —CHO, —COOH, or COX, wherein X is Cl, F, Br, or I; and

R₄, R₅, and R₆ are, independently, hydrogen, alkyl, alkenyl, alkynyl, aryl, heteroalkyl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, halogen, hydroxyl, nitro, cyano, alkoxy, amido, amino, —CHO, —COOH, or COX, wherein X is Cl, F, Br, I; or any of which can be optionally substituted with R₂, wherein R₂ is one or more halogen, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, —CHO, —COOH, or COX, wherein X is Cl, F, Br, or I; and

wherein n=0 or 1;

or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

2. The compound according to claim 1, wherein R₁ is alkyl.

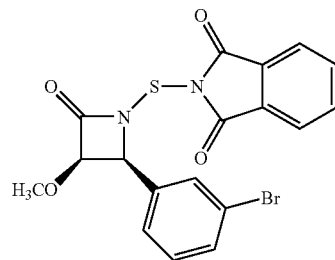
3. The compound according to claim 1, wherein R₄ is aryl.

4. The compound according to claim 1, wherein R₁ is alkyl and R₄ is aryl.

5. The compound according to claim 1, wherein R₁ is methyl and R₄ is phenyl optionally substituted with one or more halogen.

6. The compound according to claim 5, wherein said one or more are selected from the group consisting of Cl and Br.

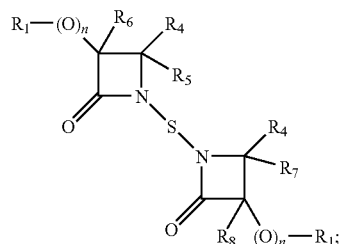
7. The compound according to claim 1, wherein the compound has the structure:



or a pharmaceutically acceptable salt, hydrate, ester, or amide thereof.

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8. A compound having the structure shown in formula (B):



wherein R_1 is a hydrocarbon group having 1 to 8 carbon atoms; and

wherein R_4 , R_5 , R_6 , R_7 , and R_8 are, independently, hydrogen, alkyl, alkenyl, alkynyl, aryl, heteroalkyl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, halogen, hydroxyl, nitro, cyano, alkoxy, amido, amino, $-\text{CHO}$, $-\text{COOH}$, or COX , wherein X is Cl, F, Br, or I; any of which can be optionally substituted with R_2 , wherein R_2 is one or more halogen, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, $-\text{CHO}$, $-\text{COOH}$, or COX , wherein X is Cl, F, Br, or I; and

wherein $n=0$ or 1;

or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

9. The compound according to claim 8, wherein R_1 is alkyl.

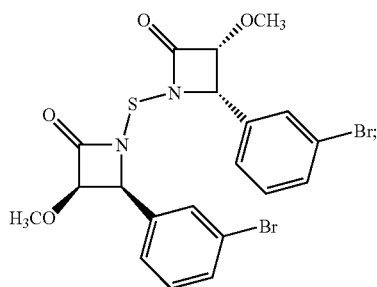
10. The compound according to claim 8, wherein R_4 is aryl.

11. The compound according to claim 8, wherein R_1 is alkyl and R_4 is aryl.

12. The compound according to claim 8, wherein R_1 is methyl and R_4 is phenyl optionally substituted with one or more halogen.

13. The compound according to claim 12, wherein said one or more halogens halogen are selected from the group consisting of Cl and Br.

14. The compound according to claim 8, wherein the compound has the structure:



or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

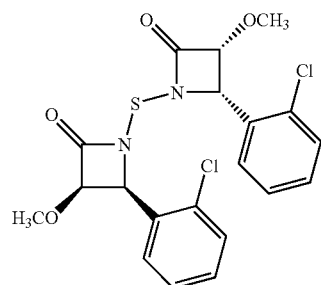
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15. The compound according to claim 8, wherein the compound has the structure:

(B) 5

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or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

16. A compound having the structure shown in formula (C):

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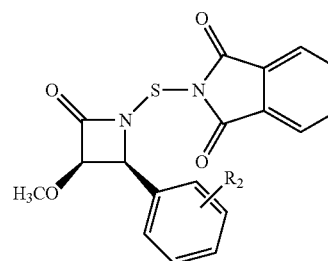
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(C)

wherein R_2 is one or more halogen, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, $-\text{CHO}$, $-\text{COOH}$, or COX , wherein X is Cl, F, Br, or I;

or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

17. The compound according to claim 16, wherein R_2 is one or more halogen.

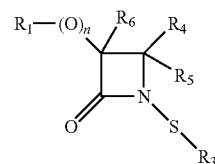
18. The compound according to claim 17, wherein said one or more halogen is selected from the group consisting of Cl and Br.

19. A composition comprising a compound having the structure shown in formula (A):

(A)

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wherein R_1 is a hydrocarbon group having 1 to 8 carbon atoms;

R_3 is a phthalimido which can be optionally substituted with R_2 , wherein R_2 is one or more halogen, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, $-\text{CHO}$, $-\text{COOH}$, or COX , wherein X is Cl, F, Br, or I; and

R_4 , R_5 , and R_6 are, independently, hydrogen, alkyl, alkenyl, alkynyl, aryl, heteroalkyl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl,

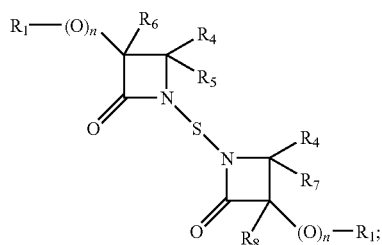
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halogen, hydroxyl, nitro, cyano, alkoxy, amido, amino, —CHO, —COOH, or COX, wherein X is Cl, F, Br, or I; any of which can be optionally substituted with R₂, wherein R₂ is one or more halogen, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, —CHO, —COOH, or COX, wherein X is Cl, F, Br, or I; and

wherein n=0 or 1;

or a pharmaceutically acceptable salt, hydrate, ester or amide thereof;

or a compound having the structure shown in formula (B):



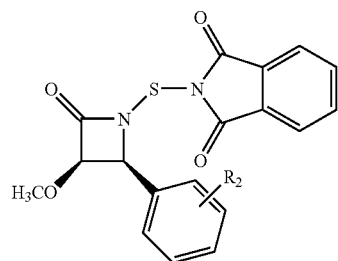
wherein R₁ is a hydrocarbon group having 1 to 8 carbon atoms; and

wherein R₄, R₅, R₆, R₇, and R₈ are, independently, hydrogen, alkyl, alkenyl, alkynyl, aryl, heteroalkyl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, halogen, hydroxyl, nitro, cyano, alkoxy, amido, amino, —CHO, —COOH, or COX, wherein X is Cl, F, Br, or I; any of which can be optionally substituted with R₂, wherein R₂ is one or more halogen, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, —CHO, —COOH, or COX, wherein X is Cl, F, Br, or I; and

wherein n=0 or 1;

or a pharmaceutically acceptable salt, hydrate, ester or amide thereof;

or a compound having the structure shown in formula (C):



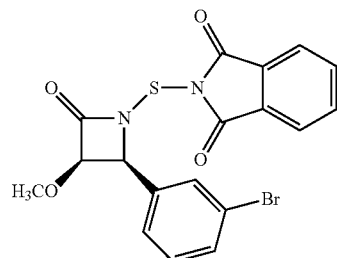
wherein R₂ is one or more halogen, hydroxyl, nitro, cyano, alkyl, alkenyl, alkynyl, aryl, heteroaryl, cycloalkyl, heterocycloalkyl, cycloalkenyl, heterocycloalkenyl, alkoxy, amido, amino, —CHO, —COOH, or COX, wherein X is Cl, F, Br, or I;

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or a pharmaceutically acceptable salt, hydrate, ester or amide thereof;

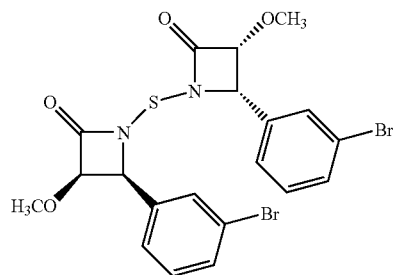
and a pharmaceutically acceptable carrier, diluent, or excipient.

20. The compound according to claim 19, wherein the compound has the structure:



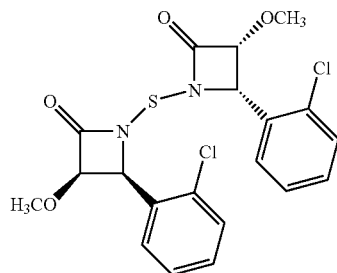
or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

21. The compound according to claim 19, wherein the compound has the structure:



or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

22. The compound according to claim 19, wherein the compound has the structure:



or a pharmaceutically acceptable salt, hydrate, ester or amide thereof.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,846,920 B2
APPLICATION NO. : 11/852100
DATED : December 7, 2010
INVENTOR(S) : Edward Turos et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 6,

Line 19, "Borclatella spp.," should read --Bordatella spp.,--.

Column 7,

Line 13, "Up to" should read --up to--.

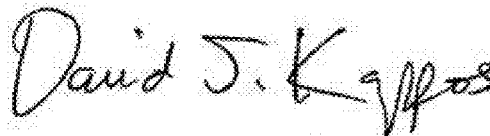
Column 10,

Lines 28-29, "Br, I; or any of" should read --Br, or I; any of--.

Column 11,

Line 45, "or more halogens halogen" should read --or more halogen--.

Signed and Sealed this
Fifteenth Day of February, 2011

A handwritten signature in black ink, reading "David J. Kappos". The signature is written in a cursive, flowing style with a large initial "D" and a stylized "K".

David J. Kappos
Director of the United States Patent and Trademark Office