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(54) **ALKOXY SUBSTITUTED BENZIMIDAZOLE COMPOUNDS, PHARMACEUTICAL PREPARATIONS CONTAINING THE SAME, AND METHODS OF USING THE SAME**

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(52) **U.S. Cl.** ..... **514/338**  
(58) **Field of Search** ..... 514/338

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#### (57) ABSTRACT

Compounds of the formula (Ia) are disclosed by the invention, along with compositions thereof optionally in combination with compounds of formulae (Ib). Methods of making and using the same are also disclosed.

**12 Claims, No Drawings**

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# ALKOXY SUBSTITUTED BENZIMIDAZOLE COMPOUNDS, PHARMACEUTICAL PREPARATIONS CONTAINING THE SAME, AND METHODS OF USING THE SAME

## CROSS-REFERENCE TO RELATED APPLICATIONS

The instant application claims priority to U.S. Provisional Application Serial No. 60/150,878 filed Aug. 26, 1999, the disclosure of which is incorporated herein by reference in its entirety.

## FIELD OF THE INVENTION

The invention generally relates to novel pharmaceutically active compounds, compositions comprising the same, pharmaceutical formulations of the same, methods of making the same, and methods of using the same.

## BACKGROUND OF THE INVENTION

Various compounds used in inhibiting gastric acid secretion are known in the art and include a class of benzimidazole-substituted compounds, one of which is omeprazole. Omeprazole is currently commercially available in the formulation PRILOSEC®. In particular, U.S. Pat. No. 4,255,431 proposes such benzimidazole-substituted compounds generally described by the formula (III) in the '431 patent that allegedly encompasses omeprazole. Various methods of making these compounds are also proposed in the '431 patent.

European Pat. No. 0 124 495 B1 proposes various salts of omeprazole, namely alkaline salts of the formula (I) in the '495 reference which includes lithium, sodium, potassium, magnesium, and calcium salts, along with methods of making the salts. The methods of forming these salts may involve employing a hydroxide, alkoxide, or amine base, or cation exchange using a metal salt.

Erlandsson, P., et al. *J. Chromatography*, 532 (1990) pp. 305-319 propose separating the (-) and (+) enantiomers of omeprazole utilizing chromatographic techniques. In this publication, the separation is proposed to take place on a preparative scale using a cellulose-based chiral phase, e.g., trisphenyl-carbamoyl cellulose coated on 3-aminopropyl silica. It is appreciated that other schemes and processes are available for this separation.

PCT Publication No. WO 94/27988 proposes salts of the single enantiomers of omeprazole and methods of making the same. The process involves separating the two stereoisomers of a diastereomer mixture of an acyloxymethyl-substituted benzimidazole compound described by the formula (IV) set forth in this published application, followed by solvolysis of each separated diastereomer in an alkaline solution. Salts of the single enantiomers are formed and isolated by neutralizing aqueous solutions of the salts of the single enantiomers of omeprazole with a neutralizing agent.

PCT Publication No. WO 96/02535 proposes a process for the enantioselective synthesis of single enantiomers of omeprazole or its alkaline salts. The process employs an oxidizing agent and a chiral titanium complex which may include a titanium(IV) compound.

PCT Publication No. WO 98/54171 proposes the magnesium salt of the (-) enantiomer of omeprazole. The '171 publication also proposes a method of synthesizing the above magnesium salt as well as the potassium salt of (-) omeprazole that may be used as a suitable intermediate for preparing the magnesium salt. The potassium salt is taught to be useful in treating gastrointestinal diseases.

U.S. Pat. No. 5,386,032 to Brändström proposes an improved method for synthesizing omeprazole which involves reacting 5-methoxy-2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methyl-thio]-1H benzimidazole with m-chloroperoxybenzoic acid in a methylene chloride solution.

The teachings regarding the methods of making omeprazole as referred to in these references, salts thereof, enantiomers thereof, and salts of the enantiomers, as well as formulations which may include these compounds, all rely on the chemical structure of omeprazole being accurately determined and the referenced compound or compounds being consistently prepared using the referenced techniques. More specifically, a methoxy group on the benzimidazole ring has been explicitly stated in the literature to be present at the 5-position, in omeprazole, a racemic mixture, and an optically pure isomer of omeprazole designated as esomeprazole or s-omeprazole. Applicants have now unexpectedly discovered that the complexity of omeprazole and the intricacies of the bioactivity of each of its previously undiscovered attributes has never been disclosed. More specifically, Applicants have confirmed that the methods of the prior art do not yield a single compound having the methoxy group in the 5-position on the benzimidazole ring as previously taught, nor do all of the methods of the prior art yield consistent results. In fact, omeprazole as conventionally referred to as a bulk drug substance (in its solid state) is confirmed to be present in the form of two pharmaceutically active compounds having the methoxy group on the benzimidazole ring at the 6- and 5-positions. Additionally, Applicants have discovered the presence of a second chiral location at the pyridine ring plane in each of the two compounds such that each compound has two positional isomers and four diastereomers. Therefore, the present invention provides these individual compounds, along with any salts, hydrates, solvates, combinations thereof, and polymorphs thereof, compositions of the above, and methods of making the same which are not taught or suggested by the prior art.

## SUMMARY OF THE INVENTION

The present invention generally provides compounds represented by formula (Ia), co-crystallized compositions of compounds represented by formulae (Ia) and (Ib), each described in detail herein, one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof, and complexes thereof. Diastereomers of the above are also provided. The invention also provides compositions and pharmaceutical formulations of the above. Methods of making the above are also provided by the invention.

More specifically, the present discovery pertains to novel compounds, particularly a compound having a methoxy moiety at the 6-position on the benzimidazole ring, and compositions comprising compounds having methoxy groups at the 5- and 6-positions respectively. It is unexpected and highly uncommon that these individual compounds are present in co-crystalline form which comprise a single composition. Ratios of the above isomers can be manipulated, and novel compounds encompassing a myriad of ratios of diastereomers of such compounds are also provided. Each of these is described in greater detail hereinafter.

The invention also provides methods of administering the above compounds represented by formula (Ia) and the compositions of compounds represented by formulae (Ia) and (Ib) described in detail herein, along with one or more

optional pharmaceutically acceptable salts, solvates, hydrates, complexes, or combinations of these compounds, diastereomers thereof, compositions thereof, and pharmaceutically acceptable formulations of the above, to a mammal in need of treatment.

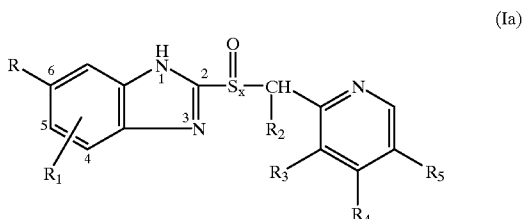
These and other aspects of the invention are set forth in greater detail herein.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention is described hereinbelow in greater detail with reference to its preferred embodiments. These embodiments, however, are set forth to illustrate the invention and are not to be construed as a limitation thereof, the invention being defined by the claims.

In one aspect, the invention relates to a compound represented by the formula (Ia) as set forth below. Applicants have unexpectedly discovered that this compound, in solid state, has not been taught or suggested by the prior art. Additionally, it has been unexpectedly discovered that this newly-discovered compound has two distinct chiral locations: (1) a chiral center at the sulfoxide group and (2) a chiral plane located at the pyridinal moiety of such compound. More specifically, it has been furthered discovered that when  $R_4$  is alkoxy, or other appropriate substituents, such group is locked into a fixed configuration generally perpendicular to the pyridine plane by the steric hindrance of the two substituents located in the  $R_3$  and  $R_5$  positions providing  $R_3$  and  $R_5$  are not hydrogen. The locked orientation of this substituent, preferably methoxy, gives rise to a chiral plane in which part or all of such substituent, preferably the methyl substituent of such preferred methoxy group, is located either above or below the unsymmetrical pyridine chiral plane.

The compound represented by formula (Ia) is as follows:



wherein:

$S_x$  represents a chiral sulfur atom comprising at least one of the diastereomers represented by  $S_{xa}$  and  $S_{xb}$ , wherein  $S_{xa}$  is the (-) enantiomer and  $S_{xb}$  is the (+) enantiomer;

R is alkoxy;

$R_1$  is selected from the group consisting of hydrogen, alkyl, halogen, carboalkoxy, alkoxy, and alkanoyl;

$R_2$  is hydrogen or alkyl; and

$R_3$ ,  $R_4$ , and  $R_5$  may be the same or different and are each selected from the group consisting of hydrogen, alkyl, alkoxy, and alkoxyalkoxy,

wherein when  $R_4$  is alkoxy and neither  $R_3$  nor  $R_5$  are not hydrogen, the alkyl substituent of such alkoxy group is selected from the group consisting of at least one of the enantiomers represented by  $R_{4q}$  and  $R_{4z}$ ; wherein  $R_{4q}$  is the (-) enantiomer and lies above the chiral plane; and  $R_{4z}$  is the (+) enantiomer and lies below the chiral plane;

or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of said compound represented by formula (Ia).

In one embodiment, all of  $R_3$ ,  $R_4$ , and  $R_5$  are not hydrogen. In another embodiment, when two of  $R_3$ ,  $R_4$ , and  $R_5$  are hydrogen, the third is not methyl. The compound represented by formula (Ia) is preferably present in solid state.

The term "alkoxy" preferably refers to alkoxy groups having up to 5 carbon atoms, preferably up to 3 carbon atoms such as, for example, methoxy, ethoxy, n-propoxy, or isopropoxy.

The term "carboalkoxy" preferably refers to groups having up to 5 carbon atoms such as, for example, carbomethoxy, carboethoxy, carbopropoxy, and carbobutoxy.

The term "alkoxyalkoxy" preferably refers to groups having up to 5 carbon atoms such as, for example, methoxymethoxy, ethoxyethoxy, and the like. Methoxyethoxy is also encompassed under this definition.

The term "alkyl" preferably refers to alkyl groups having up to 7 carbon atoms, more preferably up to 4 carbon atoms, and is thus preferably selected from methyl, ethyl, n-propyl, isopropyl, n-butyl, or isobutyl.

The term "halogen" refers to chloro, bromo, fluoro, or iodo.

The term "alkanoyl" preferably refers to groups having up to 4 carbon atoms. Examples include formyl, acetyl, and propionyl.

In a preferred embodiment, R is methoxy;  $R_1$  is hydrogen;  $R_2$  is hydrogen;  $R_3$  is methyl;  $R_4$  is methoxy; and  $R_5$  is methyl.

Applicants note that throughout the provisional application upon which priority is claimed, the  $R_1$  substituent was referred to as being in the 4-position in the compound represented by formula (Ia). For the purposes of the present application, the benzimidazole ring is numbered such that the  $R_1$  substituent of the compound of formula (Ia) is present in the 6-position.

In various embodiments of the present invention, the compound represented by formula (Ia) may be present in the form of various individual diastereomers including, for example:

(a)  $S_{xa}-R_{4q}$ ;

(b)  $S_{xa}-R_{4z}$ ;

(c)  $S_{xb}-R_{4q}$ ; and

(d)  $S_{xb}-R_{4z}$ ;

or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof. These descriptions are provided to permit differentiation of the various stereoisomers (diastereomers) throughout this document, and represent the following in standard chemical nomenclature:

(a)  $S_{xa}-R_{4q}$ , (S)-(S), or (-)-(-);

(b)  $S_{xa}-R_{4z}$ , (S)-(R), or (-)-(+);

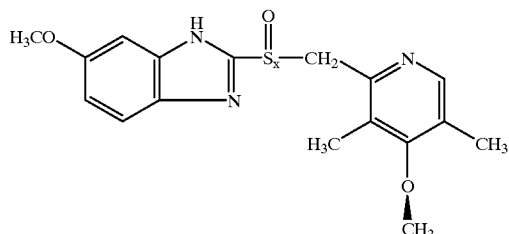
(c)  $S_{xb}-R_{4q}$ , (R)-(S), or (+)-(-); and

(d)  $S_{xb}-R_{4z}$ , (R)-(R), or (+)-(+).

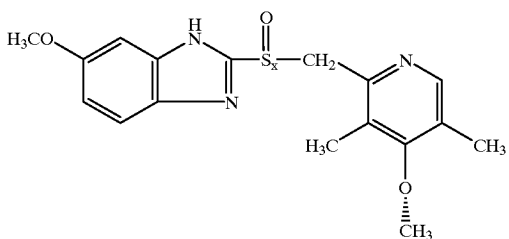
For the purposes of the invention, the term "enantiomer" as referred to herein, refers to diastereomer pairs that are non-superimposable mirror images of each other. The term "enantiomeric pair" as referenced herein refers to pairs of enantiomers that generate a racemic mixture. Examples of enantiomeric pairs include: (1) S-S and R-R and (2) S-R and R-S of the compounds of formulae (Ia) and/or (Ib). The term "(-) enantiomer" may encompass any of the diastereomers S-S or S-R and pair thereof. The term "(+) enantiomer" may encompass any of the diastereomers R-R and R-S and pair thereof.

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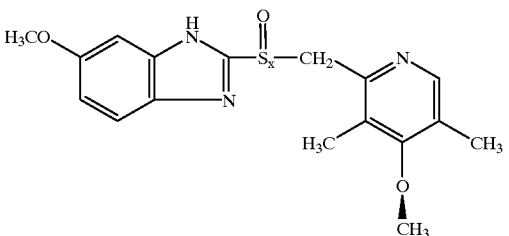
Preferred embodiments of various species of the compound represented by formula (Ia) are represented by the formulae (Iai), (Iaii), (Iaiii), and (Iaiv):



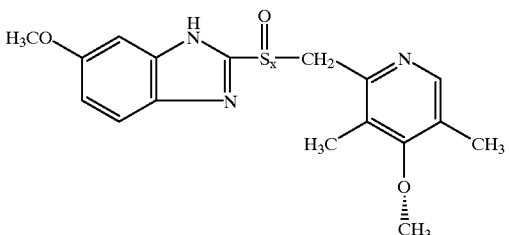
wherein  $S_x$  is  $S_{xa}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of said compound represented by formula (Iai);



wherein  $S_x$  is  $S_{xa}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of said compound represented by formula (Iaii);



wherein  $S_x$  is  $S_{xb}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of said compound represented by formula (Iaiii); and

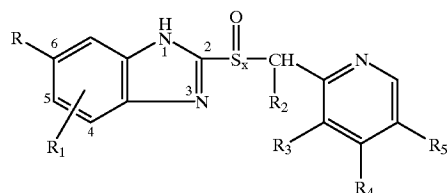


wherein  $S_x$  is  $S_{xb}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of said compound represented by formula (Iaiv).

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The above compounds may be made by various methods including those set forth in greater detail herein. Other methods may be also employed.

In another aspect, the invention relates to a composition comprising two or more compounds represented by the formula (Ia) set forth below. In particular, and as discussed in greater detail herein, Applicants provide any combination of any of the four diastereomers in varying ratio amounts.



wherein:

$S_x$  represents a chiral sulfur atom comprising at least one of the enantiomer represented by  $S_{xa}$  and  $S_{xb}$ , wherein  $S_{xa}$  is the (-) enantiomer and  $S_{xb}$  is the (+) enantiomer;

$R$  is alkoxy;

$R_1$  is selected from the group consisting of hydrogen, alkyl, halogen, carboalkoxy, alkoxy, and alkanoyl;

$R_2$  is hydrogen or alkyl; and

$R_3$ ,  $R_4$ , and  $R_5$  may be the same or different and are each selected from the group consisting of hydrogen, alkyl, alkoxy, and alkoxyalkoxy,

wherein when  $R_4$  is alkoxy and neither  $R_3$  nor  $R_5$  are not hydrogen, the alkyl substituent of such alkoxy group is selected from the group consisting of at least one of the enantiomers represented by  $R_{4q}$  and  $R_{4z}$ , wherein  $R_{4q}$  is the (-) enantiomer and lies above the chiral plane; and  $R_{4z}$  is the (+) enantiomer and lies below the chiral plane;

or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of said compounds represented by formula (Ia).

The composition of two or more compounds may contain various amounts of the enantiomers  $S_{xa}$ ,  $S_{xb}$ ,  $R_{4q}$ , and  $R_{4z}$ . Methods for making the various enantiomers and diastereomers are set forth herein. In one embodiment, for example, each of the diastereomers represented by  $S_{xa}$  and  $S_{xb}$  in the compounds represented by formula (Ia) is present in a range from about 0 percent (w/w) to about 100 percent (w/w) such that the total percentage of the sum of  $S_{xa}$  and  $S_{xb}$  equals about 100 percent (w/w). In another embodiment, each of the enantiomers represented by  $R_{4q}$  and  $R_{4z}$  is present in a range from about 0 percent (w/w) to about 100 percent (w/w) such that when the total percentage of the sum of  $R_{4q}$  and  $R_{4z}$  equals about 100 percent (w/w).

In the above composition, each of the at least two compounds, may be the same or different. Any number of combinations of individual diastereomers or combinations thereof of the compound represented by formula (Ia) may be present in the composition. Examples of such diastereomers are as follows:  $S_{xa}-R_{4q}$ ;  $S_{xa}-R_{4z}$ ;  $S_{xb}-R_{4q}$ ; and  $S_{xb}-R_{4z}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Ia).

In various embodiments, the above diastereomers or combinations thereof may be present in such a manner wherein the composition forms a racemic mixture. In other embodiments, the diastereomers may be present in such a manner wherein the composition does not form a racemic mixture.

In one embodiment, the diastereomers of each of the compounds represented by formula (Ia) in the composition are  $S_{xa}-R_{4q}$  and  $S_{xb}-R_{4z}$  or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Ia). These diastereomers may be present in amounts such that the composition forms a racemic mixture, or alternatively, these diastereomers may be present in amounts such that the composition does not form a racemic mixture. In one embodiment, the composition comprising  $S_{xa}-R_{4q}$  and  $S_{xb}-R_{4z}$  or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Ia) may be essentially free of compounds represented by formula (Ia) having diastereomers  $S_{xa}-R_{4z}$  and  $S_{xb}-R_{4q}$ . When used in reference to individual diastereomers throughout this document, the term "essentially free" means that a composition comprising compounds of the present invention having such specified diastereomers and diastereomer pairs containing no more than about 5 percent concentration of compounds having non-specified diastereomers and/or diastereomer pairs, as set forth herein. In one embodiment, for example, compounds having these diastereomers ( $S_{xa}-R_{4q}$  and  $S_{xb}-R_{4z}$ ) will form compositions in crystalline form which are free or, more typically, essentially free of compounds having the diastereomers of  $S_{xa}-R_{4z}$  and  $S_{xb}-R_{4q}$ .

In another embodiment, the diastereomers of each of the compounds represented by formula (Ia) in the composition are  $S_{xa}-R_{4q}$  and  $S_{xa}-R_{4z}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Ia). In one example of this embodiment, the above composition is essentially free of compounds represented by formula (Ia) having diastereomers represented by  $S_{xb}-R_{4q}$  and/or  $S_{xb}-R_{4z}$ . Typically, this composition is in the form of an oil which, using the technique taught hereinafter, may form a crystalline, generally a microcrystalline composition. Such a composition may be formed by various techniques such as, for example, a lyophilization technique. Otherwise, a "salt" of such composition may also be formed independently or, preferably, in situ, as described hereinafter.

In another embodiment, the diastereomers of each of the compounds represented by formula (Ia) in the composition are  $S_{xb}-R_{4z}$  and  $S_{xb}-R_{4q}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Ia). In one example of this embodiment, the above composition is essentially free of compounds represented by formula (Ia) having diastereomers represented by  $S_{xa}-R_{4z}$  and/or  $S_{xa}-R_{4q}$ . Otherwise, a "salt" of such composition may also be formed independently or, preferably, in situ, as described hereinafter.

In another embodiment, the diastereomers of each of the compounds represented by formula (Ia) in the composition is  $S_{xa}-R_{4q}$  or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Ia). In an example of this embodiment, the composition is optically pure. The term "optically pure" has the meaning generally accepted in the art, and also includes given or selected diastereomers and/or diastereomer pairs being essentially free of other compounds and/or impurities which would substantially affect the optical rotation of the composition. In another example of this embodiment, the composition is essentially free of compounds represented by the formula (Ia) having diastereomers  $S_{xa}-R_{4z}$ ,  $S_{xb}-R_{4q}$ , and  $S_{xb}-R_{4z}$ .

In another embodiment, the diastereomers of each of the compounds represented by formula (Ia) in the composition is  $S_{xa}-R_{4z}$  or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Ia). In one example of this embodiment, the composition is optically pure as defined herein. In another example of this embodiment, the composition is essentially free of compounds represented by the formula (Ia) having diastereomers  $S_{xa}-R_{4q}$ ,  $S_{xb}-R_{4q}$ , and  $S_{xb}-R_{4z}$ .

In another embodiment, the diastereomers of each of the compounds represented by formula (Ia) in the composition is  $S_{xb}-R_{4q}$  or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Ia). In an example of this embodiment, the composition is optically pure as preferably defined herein. In another example of this embodiment, the composition is essentially free of compounds represented by the formula (Ia) having diastereomers  $S_{xa}-R_{4q}$ ,  $S_{xa}-R_{4z}$ , and  $S_{xb}-R_{4z}$ .

In another embodiment, the diastereomers of each of the compounds represented by formula (Ia) in the composition is  $S_{xb}-R_{4z}$  or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Ia). In an example of this embodiment, the composition is optically pure. In another example of this embodiment, the composition is essentially free of compounds represented by the formula (Ia) having diastereomers  $S_{xa}-R_{4q}$ ,  $S_{xa}-R_{4z}$ , and  $S_{xb}-R_{4q}$ .

Compounds of the present invention comprising each of the individual diastereomers represented by  $S_{xa}-R_{4q}$ ;  $S_{xa}-R_{4z}$ ;  $S_{xb}-R_{4q}$ ; and  $S_{xb}-R_{4z}$  may provide significantly greater biological activity for the prevention and/or treatment of the disease states discussed hereinbelow than components of the present invention comprising such compound having the selected diastereomers in combination with such compounds having any of the other referenced diastereomers.

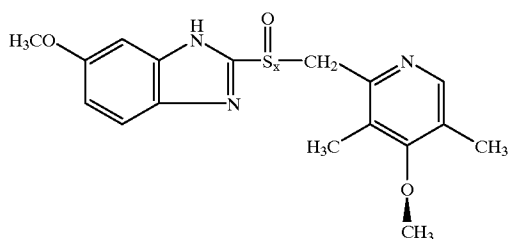
Accordingly, methods of the present invention provide for improved biological activity/efficacy (e.g. inhibition of gastric acid secretions and treatment of gastric acid disturbances in mammals, including humans) of pharmaceutically active compounds omeprazole and esomeprazole, as presently known in the art, comprising administering to such mammals in need of treatment any composition of the present invention comprising compounds or compositions of the present invention having an individual diastereomers comprising  $S_{xa}-R_{4q}$ ;  $S_{xa}-R_{4z}$ ;  $S_{xb}-R_{4q}$ ; or  $S_{xb}-R_{4z}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof. Also provided are such methods wherein said compounds or complexes of the present invention having said selected individual diastereomer pair essentially free of compounds of the present invention having diastereomer pairs other than said selected individual diastereomers. A preferred diastereomer is  $S_{xa}-R_{4q}$ , and an especially preferred diastereomer is  $S_{xa}-R_{4z}$ .

In addition, the present invention also provides for improved biological activity/efficacy of compositions of the present invention comprising compounds or compositions of the present invention having two or more diastereomers comprising  $S_{xa}-R_{4q}$ ;  $S_{xa}-R_{4z}$ ;  $S_{xb}-R_{4q}$ ; or  $S_{xb}-R_{4z}$ , comprising administering to mammals, including humans, in need of inhibition of gastric acid secretion or treatment of gastric acid disturbances any composition of the present invention comprising compounds or compositions of the present invention having an individual diastereomer selected from the group consisting of  $S_{xa}-R_{4q}$ ;  $S_{xa}-R_{4z}$ ;

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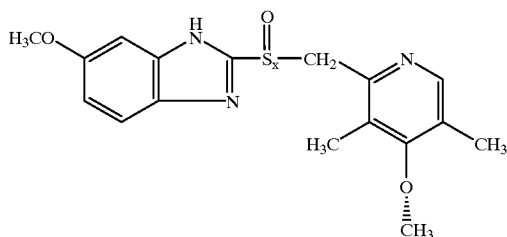
$S_{xb}$ — $R_{4q}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof. Also provided are such methods wherein said compounds or complexes of the present invention having said selected individual diastereomer essentially free of compounds of the present invention having diastereomers other than said selected individual diastereomer.

In any of the above embodiments, each of the two or more compounds represented by formula (Ia), which each of said compounds may be the same or different, except as otherwise designated, are preferably compounds of the formulae represented by (Iai), (Iaii), (Iaiii), or (Iaiv):



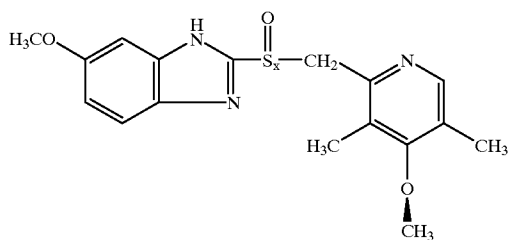
(Iai)

wherein  $S_x$  is  $S_{xa}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Iai);



(Iaii)

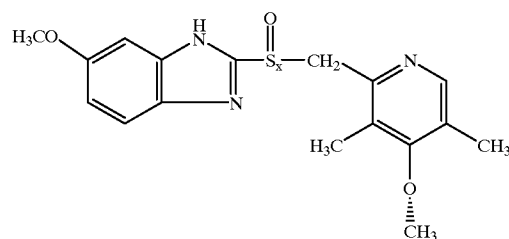
wherein  $S_x$  is  $S_{xa}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Iaii);



(Iaiii)

wherein  $S_x$  is  $S_{xb}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Iaiii); and

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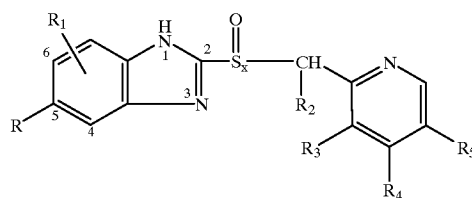
(Iaiv)

wherein  $S_x$  is  $S_{xb}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Iaiv). Other species of the compound represented by the formula (Ia) may be employed for the purposes of the invention.

Any of the above embodiments encompassing the compound represented by formula (Ia), or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound and compositions thereof may be present in crystalline form.

In another aspect, the invention also provides a composition of active pharmaceutical ingredient ("API") comprising any of the above composition embodiments, each of which may be present in crystalline form. Advantageously, any of the compositions comprising compounds represented by formula (Ia) may also comprise any of the specific compounds represented by formulae (Iai), (Iaii), (Iaiii), and (Iaiv), or one or more pharmaceutically acceptable salts, solvates, hydrates, polymorphs, or combinations thereof whether in crystalline form, amorphous form, or a combination thereof, can be used in any such API composition.

The invention also provides any of the compositions set forth herein comprising the two or more compounds of formula (Ia) being essentially free of compounds represented by formula (Ib):



(Ib)

wherein:

$S_x$  represents a chiral sulfur atom comprising at least one of the enantiomers represented by  $S_{xa}$  and  $S_{xb}$ , wherein  $S_{xa}$  is the (−) enantiomer and  $S_{xb}$  is the (+) enantiomer;  $R$  is alkoxy;

$R_1$  is selected from the group consisting of hydrogen, alkyl, halogen, carboalkoxy, alkoxy, and alkanoyl;

$R_2$  is hydrogen or alkyl; and

$R_3$ ,  $R_4$ , and  $R_5$  may be the same or different and are each selected from the group consisting of hydrogen, alkyl, alkoxy, and alkoxyalkoxy,

wherein when  $R_4$  is alkoxy and neither  $R_3$  nor  $R_5$  are hydrogen, the alkyl substituent of such alkoxy group is selected from the group consisting of at least one of the enantiomers represented by  $R_{4q}$  and  $R_{4z}$ ; wherein  $R_{4q}$  is the (−) enantiomer and lies above the chiral plane; and  $R_{4z}$  is the (+) enantiomer and lies below the chiral plane;

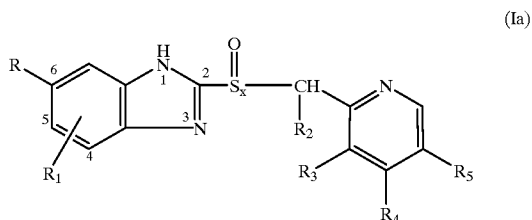
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or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of said compounds represented by formula (Ib).

For the purposes of the invention, the term "pure" refers to a compound of the formula (Ia) being present in an amount such that other components are present in amounts below limits detectable by conventional technology, preferably compound of formula (Ia) being present at least about 97 percent (w/w) or at least about 98 percent (w/w). The term "essentially pure" refers to a compound of the formula (Ia) having trace levels of other components (e.g., a compound of formula (Ib), impurities, etc.), preferably from about 1 percent to about 4 or about 5 percent of other components. As used herein, the term "essentially free of compounds of formula (Ib)" refers to the compound represented by formula (Ia) preferably being present in an amount which has no more than 5 percent (w/w) of such compounds represented by formula (Ib) in such composition. In another embodiment, the compound of formula (Ia) may be present in pure form, i.e., containing non-detectable or trace amounts of the compound of formula (Ib).

In another aspect, and as discussed in greater detail herein, Applicants have discovered that the compounds of formulae (Ia) and (Ib) are typically formed in a manner such that they are present in the same crystalline lattice, i.e., the compounds co-crystallize from solution. Thus, in this aspect, the invention further relates to a composition comprising one molecule each of:

(a) a compound represented by formula (Ia):



wherein:

S<sub>x</sub> represents a chiral sulfur atom comprising at least one of the enantiomers represented by S<sub>xa</sub> and S<sub>xb</sub>, wherein S<sub>xa</sub> is the (–) enantiomer and S<sub>xb</sub> is the (+) enantiomer;

R is alkoxy;

R<sub>1</sub> is selected from the group consisting of hydrogen, alkyl, halogen, carboalkoxy, alkoxy, and alkanoyl;

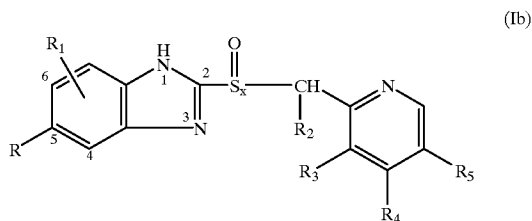
R<sub>2</sub> is hydrogen or alkyl; and

R<sub>3</sub>, R<sub>4</sub>, and R<sub>5</sub> may be the same or different and are each selected from the group consisting of hydrogen, alkyl, alkoxy, and alkoxyalkoxy,

wherein when R<sub>4</sub> is alkoxy and neither R<sub>3</sub> nor R<sub>5</sub> are hydrogen, the alkyl substituent of such alkoxy group is selected from the group consisting of at least one of the enantiomer represented by R<sub>4q</sub> and R<sub>4z</sub>, wherein R<sub>4q</sub> is the (–) enantiomer and lies above the chiral plane; and R<sub>4z</sub> is the (+) enantiomer and lies below the chiral plane; co-crystallized with:

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(b) a compound represented by formula (Ib):



wherein:

S<sub>x</sub> represents a chiral sulfur atom comprising at least one of the enantiomers represented by S<sub>xa</sub> and S<sub>xb</sub>, wherein S<sub>xa</sub> is the (–) enantiomer and S<sub>xb</sub> is the (+) enantiomer;

R is alkoxy;

R<sub>1</sub> is selected from the group consisting of hydrogen, alkyl, halogen, carboalkoxy, alkoxy, and alkanoyl;

R<sub>2</sub> is hydrogen or alkyl; and

R<sub>3</sub>, R<sub>4</sub>, and R<sub>5</sub> may be the same or different and are each selected from the group consisting of hydrogen, alkyl, alkoxy, and alkoxyalkoxy,

wherein when R<sub>4</sub> is alkoxy and neither R<sub>3</sub> nor R<sub>5</sub> are hydrogen, the alkyl substituent of such alkoxy group is selected from the group consisting of at least one of the enantiomers represented by R<sub>4q</sub> and R<sub>4z</sub>, wherein R<sub>4q</sub> is the (–) enantiomer and lies above the chiral plane; and R<sub>4z</sub> is the (+) enantiomer and lies below the chiral plane;

wherein R of a compound represented by formula (Ia) and R<sub>1</sub> of a compound represented by formula (Ib) each is the same alkoxy substituent; and

each substituent of S<sub>x</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, and R<sub>5</sub> of a compound represented by each of formulae (Ia) and (Ib) are the same;

or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the composition. The compounds represented by formulae (Ia) and (Ib) may be the same or different relative to the pyridine enantiomers, but the same for sulfoxide enantiomers.

Any of the above compositions may include various amounts of the compounds represented by formulae (Ia) and (Ib). In different embodiments, for example, the composition may comprise the above compounds, which may be the same or different, in the following ratios denoted by (a), (b), and (c):

(a) a compound represented by formula (Ia) being present in a range from about 1 percent (w/w) to about 99 percent (w/w) and a compound represented by formula (Ib) is present in a range from about 1 percent (w/w) to about 99 percent (w/w) such that the sum of the total percentage of such compounds represented by formulae (Ia) and (Ib) equals about 100 percent (w/w);

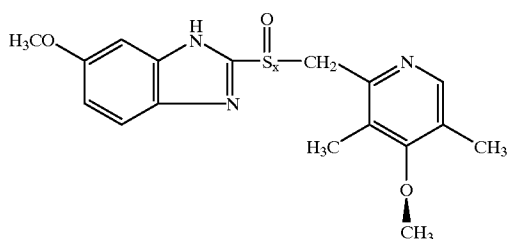
(b) a compound represented by formula (Ia) being present in a range from about 96 percent (w/w) to about 99 percent (w/w) and a compound represented by formula (Ib) is present in a range from about 1 percent (w/w) to about 4 percent (w/w) such that the sum of the total percentage of such compounds represented by formulae (Ia) and (Ib) equals about 100 percent (w/w); or

(c) a compound represented by formula (Ia) being present in a range from about 1 percent (w/w) to about 91 percent (w/w) and a compound represented by formula

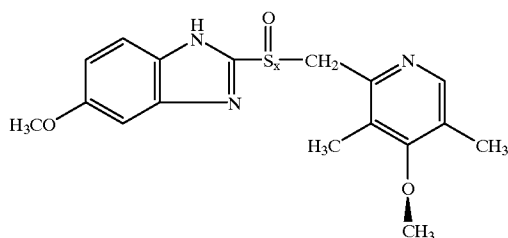
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(Ib) is present in a range from about 9 percent (w/w) to about 99 percent (w/w) such that the sum of the total percentage of such compounds represented by formulae (Ia) and (Ib) equals about 100 percent (w/w).

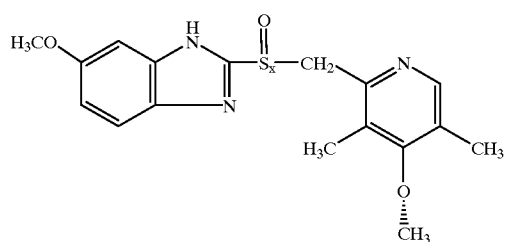
Each of the above embodiments discussed in (a), (b), or (c) above may include various combinations of diastereomers. Such diastereomers are as follows: (a)  $S_{xa}-R_{4q}$  (b)  $S_{xa}-R_{4z}$  (c)  $S_{xb}-R_{4q}$  or (d)  $S_{xb}-R_{4z}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compounds represented by formulae (Ia) and (Ib). Any of the above composition embodiments may include, for example, compounds of the pairs Iai-Ibi, Iaii-Ibii, Iaiii-Ibiii, and Iaiiv-Ibiv as follows:



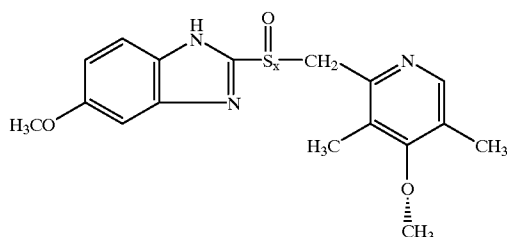
and



wherein each  $S_x$  is  $S_{xa}$ ;  
or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the composition;



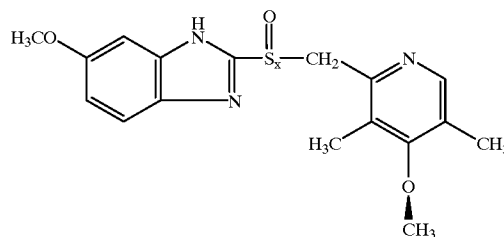
and



wherein each  $S_x$  is  $S_{xa}$ ;  
or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the composition;

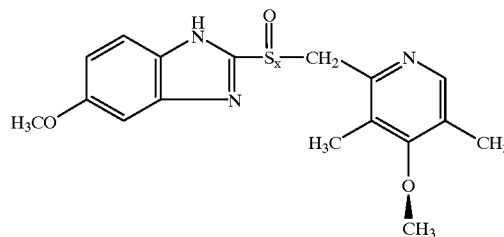
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(Iaiii)



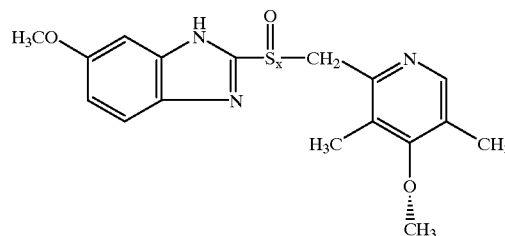
and

(Ibiii)



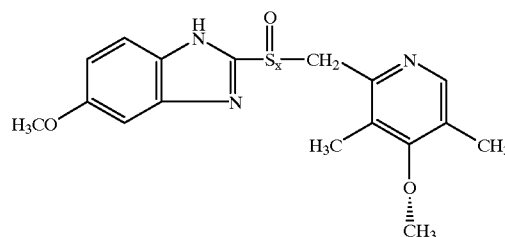
wherein each  $S_x$  is  $S_{xb}$ ;  
or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the composition;

(Iaiiv)



and

(Ibiv)



wherein each  $S_x$  is  $S_{xb}$ ;  
or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the composition.

Hereinafter, the compounds (Iai), (Iaii), (Iaiii), (Iaiiv), (Ibi), (Ibii), (Ibiii), and (Ibiv) are defined by the structures presented above.

In another aspect, the invention provides a composition comprising two or more compounds each of compounds represented by formulae (Ia) and (Ib) as described above or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formulae (Ia) and (Ib). Each of the co-crystals in the composition of compounds represented by formulae (Ia) and (Ib), and compounds represented by formula (Ia) which are free, or essentially free of compounds represented by formula (Ib), if any, may be the same or different.

The above compositions may include various amounts of the compounds represented by formulae (Ia) and (Ib). In different embodiments, for example, the composition may comprise the above compounds, which may be the same or different, in the following ratios denoted by (a), (b), and (c):

- (a) a compound represented by formula (Ia) being present in a range from about 1 percent (w/w) to about 99 percent (w/w) and a compound represented by formula (Ib) is present in a range from about 1 percent (w/w) to about 99 percent (w/w) such that the sum of the total percentage of such compounds represented by formulae (Ia) and (Ib) equals about 100 percent (w/w);
- (b) a compound represented by formula (Ia) being present in a range from about 96 percent (w/w) to about 99 percent (w/w) and a compound represented by formula (Ib) is present in a range from about 1 percent (w/w) to about 4 percent (w/w) such that the sum of the total percentage of such compounds represented by formulae (Ia) and (Ib) equals about 100 percent (w/w); or
- (c) a compound represented by formula (Ia) being present in a range from about 1 percent (w/w) to about 91 percent (w/w) and a compound represented by formula (Ib) is present in a range from about 9 percent (w/w) to about 99 percent (w/w) such that the sum of the total percentage of such compounds represented by formulae (Ia) and (Ib) equals about 100 percent (w/w).

The above compositions comprising compounds represented by formulae (Ia) and (Ib) may advantageously include various percentages of these compounds. In one embodiment for example, the percentage of compounds represented by formula (Ib) in the composition is less than about 40 percent (w/w) and the percentage of compounds of formula (Ia) is such that the sum of the total percentage of such compounds represented by formulae (Ia) and (Ib) is equal to about 100 percent (w/w). In another embodiment, the percentage of compounds represented by formula (Ib) in said composition is from about 9 percent (w/w) to about 40 percent (w/w) and the percentage of compounds of formula (Ia) is such that the sum of the total percentage of such compounds represented by formulae (Ia) and (Ib) is equal to about 100 percent (w/w).

The composition of two or more compounds may contain various amounts of the enantiomers  $S_{xa}$ ,  $S_{xb}$ ,  $R_{4q}$ , and  $R_{4z}$ . Methods for making the various enantiomers and diastereomers are set forth herein. In one embodiment, for example, each of the enantiomers represented by  $S_{xa}$  and  $S_{xb}$  in the compounds represented by formula (Ia) is present in a range from about 0 percent (w/w) to about 100 percent (w/w) such that the total percentage of the sum of  $S_{xa}$  and  $S_{xb}$  equals about 100 percent (w/w). In another embodiment, each of the enantiomers represented by  $R_{4q}$  and  $R_{4z}$  is present in a range from about 0 percent (w/w) to about 100 percent (w/w) such that when the total percentage of the sum of  $R_{4q}$  and  $R_{4z}$  equals about 100 percent (w/w).

In the above composition, each of the at least two compounds, may be the same or different. Any number of combinations of individual diastereomers or combinations thereof of the compound represented by formula (Ia) may be present in the composition. Examples of such diastereomers are as follows:  $S_{xa}-R_{4q}$ ;  $S_{xa}-R_{4z}$ ;  $S_{xb}-R_{4q}$ ; and  $S_{xb}-R_{4z}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented in formulae (Ia) and (Ib).

In various embodiments, the above diastereomers or combinations thereof may be present in such a manner wherein the composition forms a racemic mixture. In other embodiments, such diastereomers may be present in such a manner wherein the composition does not form a racemic mixture.

In another embodiment, the diastereomers of the compounds represented by formulae (Ia) and (Ib) which are present in the above compositions may include the following: (a)  $S_{xa}-R_{4q}$  and (b)  $S_{xb}-R_{4z}$  or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compounds represented by formulae (Ia) and (Ib). In one example of this embodiment, the composition forms a racemic mixture. In another example of this embodiment, the composition does not form a racemic mixture. In another example of this embodiment, the composition is essentially free from compounds having diastereomers represented by  $S_{xa}-R_{4z}$  and  $S_{xb}-R_{4q}$ .

In another embodiment, the diastereomers of each of the compounds represented by formulae (Ia) and (Ib) in the composition are  $S_{xa}-R_{4q}$  and  $S_{xa}-R_{4z}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compound represented by formula (Ia). In one example of this embodiment, the above composition is essentially free of compounds represented by formulae (Ia) and (Ib) having diastereomers represented by  $S_{xb}-R_{4q}$  and/or  $S_{xb}-R_{4z}$ . Typically, this composition is in the form of an oil which, using the technique taught hereinafter, may form a crystalline, preferably a microcrystalline composition. Otherwise, a "salt" of such composition may also be formed independently or, preferably, in situ, as described hereinafter.

In another embodiment, the diastereomers of the compounds represented by formulae (Ia) and (Ib) which are present in the above compositions may include the following: (a)  $S_{xb}-R_{4q}$  and (b)  $S_{xa}-R_{4z}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compounds represented by formulae (Ia) and (Ib). In one example of this embodiment, the enantiomer represented by  $S_{xa}$  in each compound in each composition is present in optically pure form as defined herein. In another example of this embodiment, the composition is essentially free from compounds having diastereomers represented by  $S_{xa}-R_{4q}$  and  $S_{xb}-R_{4z}$ . The above compositions comprising the various diastereomer components may be present in various amounts. In another example of the above embodiments, the percentage of enantiomers represented by  $R_{4z}$  for either or both of the compounds represented by formulae (Ia) and (Ib) comprises greater than about 5 percent (w/w) and less than about 49 percent (w/w) in the compounds represented by formulae (Ia) and (Ib) such that the sum of the total percentage of such enantiomers represented by  $R_{4q}$  and  $R_{4z}$  equals about 100 percent (w/w). In another example of the above embodiments, the percentage of enantiomers represented by  $R_{4z}$  for either or both of the compounds represented by formulae (Ia) and (Ib) comprises greater than about 51 percent (w/w) in the compounds represented by formulae (Ia) and (Ib) such that the sum of the total percentage of such enantiomers represented by  $R_{4q}$  and  $R_{4z}$  equals about 100 percent (w/w).

In another embodiment, the diastereomers of the compounds represented by formulae (Ia) and (Ib) which are present in the above compositions may include the following: (a)  $S_{xb}-R_{4q}$  and (b)  $S_{xb}-R_{4z}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compounds represented by formulae (Ia) and (Ib). In one example of this embodiment, the enantiomer represented by  $S_{xa}$  in each compound in each composition is present in optically pure form as defined herein. In another example of this embodiment, the composition is essentially free from compounds having diastereomers represented by  $S_{xa}-R_{4q}$  and  $S_{xa}-R_{4z}$ . The above

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compositions comprising the various diastereomer components may be present in various amounts. In another example of the above embodiments, the percentage of enantiomers represented by  $R_{4z}$  for either or both of the compounds represented by formulae (Ia) and (Ib) comprises greater than about 5 percent (w/w) and less than about 49 percent (w/w) in the compounds represented by formulae (Ia) and (Ib) such that the sum of the total percentage of such enantiomers represented by  $R_{4q}$  and  $R_{4z}$  equals about 100 percent (w/w). In another example of the above embodiments, the percentage of enantiomers represented by  $R_{4z}$  for either or both of the compounds represented by formulae (Ia) and (Ib) comprises greater than about 51 percent (w/w) in the compounds represented by formulae (Ia) and (Ib) such that the sum of the total percentage of such enantiomers represented by  $R_{4q}$  and  $R_{4z}$  equals about 100 percent (w/w).

In another embodiment of the above composition, the diastereomers of each of such compounds represented by formulae (Ia) and (Ib) each is  $S_{xa}-R_{4q}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compounds represented by formulae (Ia) and (Ib). In various embodiments of the compositions of the invention, the compounds represented by formulae (Ia) and (Ib) may be present in optically pure form, with the term optically pure being preferably defined hereinabove. In another example of this embodiment, the composition comprising compounds represented by formulae (Ia) and (Ib) are essentially free of such compounds comprising each of the diastereomers represented by: (a)  $S_{xa}-R_{4z}$ ; (b)  $S_{xb}-R_{4q}$ ; and (c)  $S_{xb}-R_{4z}$ .

In another embodiment of the above composition, the diastereomers of each of such compounds represented by formulae (Ia) and (Ib) each is  $S_{xa}-R_{4z}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compounds represented by formulae (Ia) and (Ib). In various embodiments of the compositions of the invention, the compounds represented by formulae (Ia) and (Ib) may be present in optically pure form, with the term optically pure being preferably defined herein. In another example of this embodiment, the composition comprising compounds represented by formulae (Ia) and (Ib) are essentially free of such compounds comprising each of the diastereomers represented by: (a)  $S_{xa}-R_{4q}$  (b)  $S_{xb}-R_{4q}$  and (c)  $S_{xb}-R_{4z}$ .

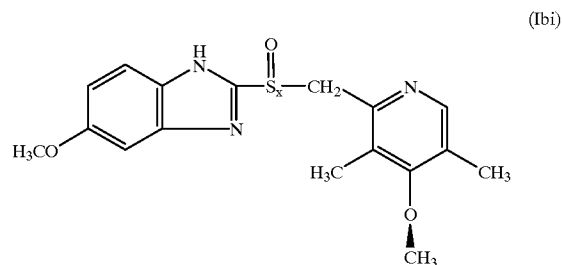
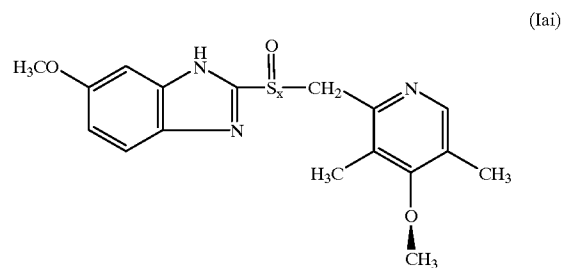
In another embodiment of the above composition, the diastereomers of each of such compounds represented by formulae (Ia) and (Ib) each is  $S_{xb}-R_{4q}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the compounds represented by formulae (Ia) and (Ib). In various embodiments of the compositions of the invention, the compounds represented by formulae (Ia) and (Ib) may be present in optically pure form, with the term optically pure being preferably defined herein. In another example of this embodiment, the composition comprising compounds represented by formulae (Ia) and (Ib) are essentially free of such compounds comprising each of the diastereomers represented by: (a)  $S_{xa}-R_{4q}$  (b)  $S_{xa}-R_{4z}$  and (c)  $S_{xb}-R_{4z}$ .

In another embodiment of the above composition, the diastereomers of each of such compounds represented by formulae (Ia) and (Ib) each is  $S_{xb}-R_{4z}$ , or one or more pharmaceutically acceptable salts, solvates, hydrates, or

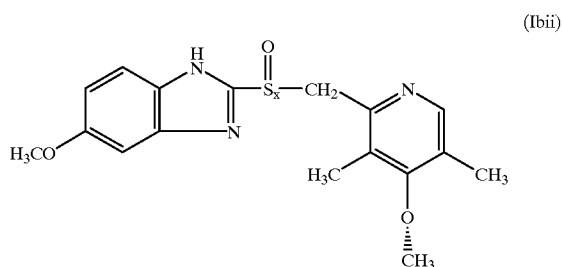
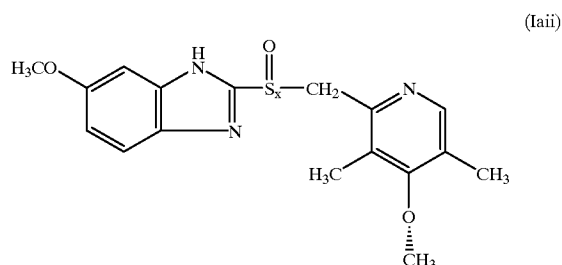
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combinations thereof of the compounds represented by formulae (Ia) and (Ib). In various embodiments of the compositions of the invention, the compounds represented by formulae (Ia) and (Ib) may be present in optically pure form, with the term optically pure being preferably defined herein. In another example of this embodiment, the composition comprising compounds represented by formulae (Ia) and (Ib) are essentially free of such compounds comprising each of the diastereomers represented by: (a)  $S_{xa}-R_{4q}$  (b)  $S_{xa}-R_{4z}$  and (c)  $S_{xb}-R_{4q}$ .

Any of the composition embodiments may include, for example, compounds of the pairs Iai-Ibi, Iaii-Ibii, Iaiii-Ibiii, and Iaiiv-Ibiv as follows:



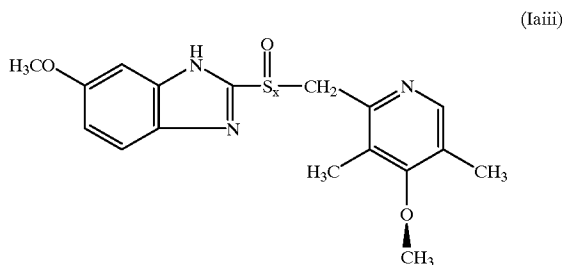
wherein each  $S_x$  is  $S_{xa}$ ; or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof of the composition;



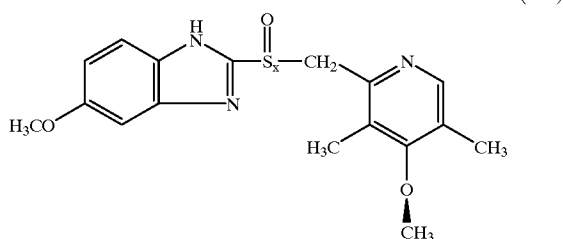
wherein each  $S_x$  is  $S_{xa}$ ;

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or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof the composition;

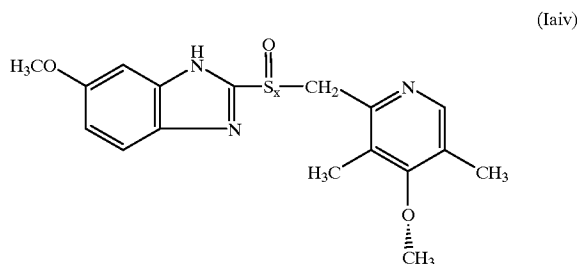


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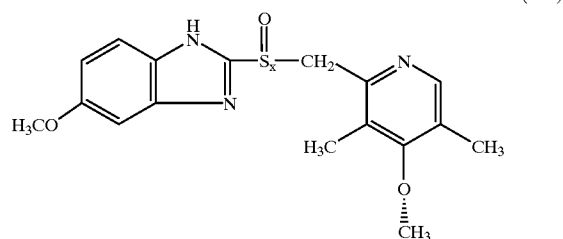


wherein each  $S_x$  is  $S_{xb}$ ;

or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof the composition;



and



wherein each  $S_x$  is  $S_{xb}$ ;

or one or more pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof the composition.

Any of the above composition embodiments comprising any of the compounds represented by formulae (Ia) and (Ib), individual species of compounds (Iai)-(Ibi), (Iaii)-(Ibii), (Iaiii)-(Ibiii), and (Iaiv)-(Ibiv), diastereomers thereof, or any pharmaceutically acceptable salts, solvates, hydrates, or combinations thereof, may be present in crystalline form.

The invention also provides compositions of active pharmaceutical ingredient ("API") comprising any of the above composition embodiments. Advantageously, any of the compositions comprising compounds represented by formulae

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(Ia) and (Ib) may also comprise any of the specific compositions represented by formulae (Iai)-(Ibi); (Iaii)-(Ibii); (Iaiii)-(Ibiii); and (Iaiv)-(Ibiv) or one or more pharmaceutically acceptable salts, solvates, hydrates, polymorphs, or combinations thereof, whether in crystalline form, amorphous form, or a combination thereof, can be used in any such API compositions.

The compounds represented by formulae (Ia) and (Ib) may be prepared as described in various embodiments. More specifically, the methods describe forming the compounds in solution. The presence of either the compound of formula (Ia) or (Ia)/(Ib) in solution causes formation of the corresponding tautomer. Thus, these methods essentially describe forming each series of compounds. However, the present invention provides novel compounds of the formulae (Ia) and (Ib) in their respective solid states.

Compounds of the present invention are prepared by using a variety of synthetic processes. For example, in the crystallization of "omeprazole" from solution, the amount of compound represented by formula (Ia) significantly varies by the rate of crystallization. Accordingly, slight variations within the same process as taught in the prior art, such process not being appropriately controlled or defined as to regulate the amount of previously unknown compound represented by formula (Ia), will result in various ratios of compounds represented by formula (Ia) to compounds represented by formula (Ib).

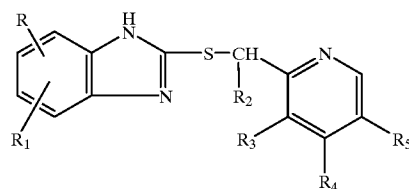
Additionally, when using such process represented in the prior art, negligible or trace amounts of previously unknown compounds are formed as described herein. For example, in the preparation of "omeprazole" as referenced in the immediately preceding paragraph, compounds having the previously unknown diastereomers  $S_{xa}-R_{4q}$  and  $S_{xb}-R_{4z}$  are formed with varying and inconsistent ratios of compounds represented by formulae (Ia) and (Ib). Also formed in trace quantities, and typically in amorphous form, are compounds represented by formulae (Ia) and (Ib) having the previously unknown diastereomers  $S_{xa}-R_{4z}$  and  $S_{xb}-R_{4q}$ .

Furthermore, when prior art processes are used with the intent of forming "salts" of "omeprazole", the rather broad teachings may result in salts, but may also result in the formation of novel complexes which are described herein.

Accordingly, the processes taught in the prior art for the preparation of "omeprazole" as well as "esomeprazole" (the intended S-isomer of "omeprazole") provide quantities of previously unknown and unrecognized compounds having pharmaceutical activity, or which are used as intermediates in the preparation of pharmaceutically active compounds of the present invention. Furthermore, many such processes do not invariably provide the same result when conducted as taught in the prior art.

Embodiments describing methods of preparing the compounds of the present invention follow. In various embodiments, neither  $R_3$  nor  $R_5$  are not hydrogen when  $R_4$  is alkoxy.

In one embodiment, the compounds may be formed by oxidizing a compound of formula (II):

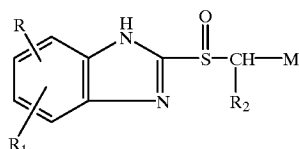


wherein R is alkoxy at the 5- or 6-position,  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ , and  $R_5$  have the meanings defined above, to form the compound of formulas (Ia) or (Ib). The oxidation of the

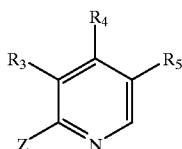
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sulfur atom to sulfinyl ( $S \rightarrow O$ ) typically takes place in the presence of an oxidizing agent selected from the group consisting of nitric acid, hydrogen peroxide, peracids, peresters, ozone, dinitrogen tetraoxide, iodosobenzene, N-halosuccinimide, 1-chlorobenzotriazole, t-butylhypochlorite, diazobicyclo-[2,2,2]-octane bromine complex, sodium metaperiodate, selenium dioxide, manganese dioxide, chromic acid, ceric ammonium nitrate, bromine, chlorine, and sulfonyl chloride. The oxidation usually takes place in a solvent wherein the oxidizing agent is present in some excess in relation to the product to be oxidized.

In another embodiment, a compound of the formula (III):

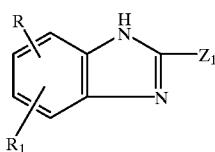


wherein R, R<sub>1</sub>, and R<sub>2</sub> are defined herein, and M is a metal selected from potassium, sodium, and lithium; may be reacted with a compound of the formula (IV):

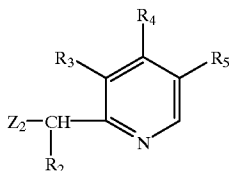


wherein R<sub>3</sub>, R<sub>4</sub>, and R<sub>5</sub> have the same meanings as given above, and Z is a reactive esterified hydroxy group to form compounds of formulas (Ia) and (Ib).

In another embodiment, a compound of formula (V):



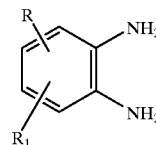
wherein R and R<sub>1</sub> are defined herein and Z<sub>1</sub> is SH or a reactive esterified hydroxy group, is reacted with a compound of the formula (VI):



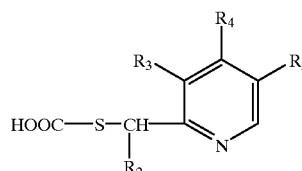
wherein R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, and R<sub>5</sub> have the same meanings as given above, and Z<sub>2</sub> is a reactive esterified hydroxy group or SH, to form an intermediate of formula (II) above, which then is oxidized to give compounds of formulas (Ia) and (Ib).

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In another embodiment, a compound of formula (VII):



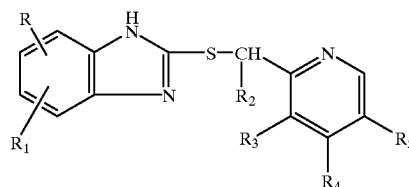
wherein R and R<sub>1</sub> are defined above is reacted with a compound of the formula (VIII):



wherein R<sub>1</sub>, R<sub>3</sub>, R<sub>4</sub>, and R<sub>5</sub> are defined above, to form an intermediate of formula (II) above, which then is oxidized to give compounds of formulas (Ia) and (Ib).

In the reactions above, Z, Z<sub>1</sub>, and Z<sub>2</sub> may be a reactive esterified hydroxy group which is a hydroxy group esterified with strong, inorganic or organic acid, preferably a hydrohalogen acid, such as hydrochloric acid, hydrobromic acid, or hydroiodic acid, as well as sulfuric acid or a strong organic sulfonic acid, such as, for example, a strong aromatic acid, e.g., benzenesulfonic acid, 4-bromobenzenesulfonic acid or 4-toluenesulfonic acid. The starting materials are known or may, if they should be new, be obtained according to processes known per se.

In another embodiment, compounds of formulas (Ia) and (Ib) may be formed by reacting a compound of the formula (II):



wherein R, R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, and R<sub>5</sub> have the meanings defined above, with m-chloroperoxybenzoic acid in a methylene chloride solution. The reaction should be carried out at a substantially constant pH. The reaction product is then extracted with a base (e.g., NaOH) and the aqueous phase is separated from the organic phase. An alkyl formate is added to the aqueous phase resulting in the crystallization of the compounds of formulas (Ia) and (Ib).

The invention also provides methods for producing compositions of compounds represented by formula (Ia) and (Ib). As discussed herein, Applicants have unexpectedly discovered that it is possible to obtain the compounds of formulae (Ia) and (Ib) in co-crystallized compositions in various amounts relative to one another according to techniques taught below.

Applicants have confirmed that solution NMR reveals the tautomerization of the compounds of formulas (Ia) and (Ib). Solution NMR suggests that the tautomerization reaches an

equilibrium at approximately a 2:1 ratio of compounds represented by formula (Ia) to compounds represented by formula (Ib). Upon crystallization and isolation, the compound of formula (Ia) appears to be the more energetically favorable isomer and crystallizes first. This equilibration/crystallization process allows for the predominant isolation of the solid (e.g., crystalline) isomer of compound of formula (Ia). Through solution NMR experiments, it is believed that the exchange rate of the amine proton during tautomerization may be pH dependent. For example, with the addition of a small amount of base, the proton exchange rate was shown to slow, and two distinct proton NMR peaks were observed for each of the benzimidazole aromatic protons.

Methods for forming compositions comprising compounds of formulae (Ia) and (Ib) are described herein with reference to certain embodiments. However, variations from these embodiments may be carried out without departing from these separation methods described by the present invention.

As alluded to above, Applicants have determined that compositions of compounds of formulae (Ia) and/or (Ib) may be formed in relative ratios of the compounds to one another not suggested by the prior art. In one embodiment, the method may provide this compound substantially free from its corresponding isomer (the compound of formula (Ib)). Preferably, the compound represented by formula (Ia) is present in an amount ranging from about 96 to about 99 percent (w/w). The method generally includes first providing a solution comprising the tautomers of formulas (Ia) and (Ib) and a solvent. Examples of solvents include, but are not limited to, an aqueous solvent (e.g., water) or an organic solvent. Examples of organic solvents include, but are not limited to, a ketone (e.g., acetone), a nitrile solvent (e.g., acetonitrile, acetonitrile/water), an amine solvent (e.g., dimethyl formamide (DMF) or pyridine), an aryl solvent (e.g., toluene), a halogenated solvent (e.g., methylene chloride, chloroform), an alcohol (e.g., methanol, ethanol), ammonium hydroxide, and a sulfur-containing solvent (e.g., dimethyl sulfoxide (DMSO)). Mixtures of the above may also be employed.

Preferably, the solution is saturated. The solution is evaporated slowly (preferably from about 3 days to about 7 days) until crystal formation is achieved, with the compounds represented by formulae (Ia) and/or (Ib) co-crystallizing in the same lattice.

Advantageously, the relative amounts of compounds of formulae (Ia) and (Ib) that may be obtained in co-crystalline form can be manipulated by judicious selection of a number of variables relating, but not necessarily limited to, solvent choice, temperature, and vapor diffusion control rate. The selection of solvent for use in the method may be governed by various considerations. For example, although not intending to be bound by theory, it is believed that the use of slower evaporation solvents (e.g., DMF) and their controlled evaporation at lower temperatures produces crystals with a higher percentage of the compound represented by formula (Ia) in the crystalline lattice, preferably compound of formula (Ia) being pure or essentially pure as defined herein. In other embodiments, solvents with lower vapor pressures (e.g., methylene chloride, ethanol, and chloroform) are capable of yielding crystals with higher percentages of compound represented by formula (Ib) in the crystalline lattice, typically up to about 20 percent (w/w) to about 30 percent (w/w) of the compound represented by formula (Ib).

With all other factors being consistent, temperature does not appear to significantly influence which of the compounds of the present invention (e.g. compounds represented

by formulae (Ia) and (Ib)) will be formed, but may influence the size and clarity of such crystals. Typically, temperatures below ambient temperature provides crystals having larger size and better clarity.

The crystallization (e.g., recrystallization) rate may also be influenced by the rate of solvent evaporation, and is influenced by using methods well known in the art. In one embodiment, by exposing a sample of compounds represented by formulae (Ia) and (Ib) to the surrounding environment, the rate of evaporation should increase and the formation of the compound represented by formula (Ib) in the crystal lattice should increase. Conversely, in another embodiment, by controlling (i.e., slowing) the rate of evaporation, the recrystallization process should be slowed, thus yielding purer amounts of the compound represented by formula (Ia).

Accordingly, one may manipulate various processing variables as set forth herein to yield the percentage of compound(s) represented by formulae (Ia) and/or (Ib) as desired. For example, in one preferred embodiment, using DMF, reduced evaporation, and lowered temperatures, higher percentages of the compound represented by formula (Ia) are obtained, preferably from about 96 to about 100 percent (w/w). Crystals containing the highest percentages of the compound represented by formula (Ib) (e.g., from about 10 percent to about 40 percent (w/w), and more preferably about 10 percent to about 20 percent) may be produced using a solvent comprising ethanol and ammonium hydroxide, reduced evaporation, and ambient temperature.

The structure of the compound of formula (Ia), and in particular, 6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole, has been confirmed by x-ray single crystal analyses on isolated crystals formed in accordance with the above method.

By employing the above method of obtaining the compound represented by formula (Ia) in solid state, one obtains the (–) and (+) enantiomers as a racemic mixture, with these enantiomers including various amounts of diastereomers as set forth herein. In one embodiment, Applicants have discovered that the (–) and (+) enantiomers may be predominantly present as the S—S and R—R diastereomers respectively. Although not intending to be bound by theory, in this embodiment, the two molecules (i.e., compounds of formulae (Ia) and (Ib)) co-crystallize in a centric space group in which the molecules are related to each other through a center of inversion and linked by hydrogen bonding from the amine hydrogens to the sulfoxide oxygens. The methoxy methyl is directed towards the center of the bridged complex. Examination of the contact distances in the region where the other methoxy methyl would presumably reside demonstrates that there is not adequate space within the lattice for the other diastereomers (S—R and R—S) to co-exist. In this embodiment, the compound represented by formula (Ia) may comprise about 99 percent (w/w) of the R—R and S—S diastereomers and the remaining percentage of other components which may include, for example, the diastereomers S—R and R—S, generally in amorphous form.

In the above embodiment, the crystallization of the compounds represented by formulae (Ia) and (Ib) is believed to be controlled thermodynamically by a bipyramidal inversion equilibrium at the sulfoxide chiral center which forces the R—S diastereomer to S—S and the S—R diastereomer to R—R diastereomer. Such behavior may be confirmed by examining the x-ray crystal structure and more specifically, the crystal packing. Not intending to be bound by theory, it

is believed that the molecular packing does not provide adequate area for the other diastereomers to be present within the current crystal lattice.

Upon obtaining a composition comprising the compound of formula (Ia) as described above, one may apply a suitable technique to resolve the individual (–) and (+) enantiomers. One may then apply a suitable technique (including, for example, those described subsequently) to resolve the diastereomer components in the (–) and (+) enantiomers. With respect to the (–) enantiomer of the compound represented by formula (Ia), in a number of embodiments, the above techniques are capable of yielding about 95 percent (w/w) of the S—S diastereomer and about 5 percent (w/w) of the S—R diastereomer of the compound of formula (Ia), particularly in the specific embodiment in which compound (Ia) is described by compounds of the formulae (Iai) and (Iaii). Although not intending to be bound by theory, it is believed that the bipyramidal inversion equilibrium at the sulfoxide chiral center forces the R—S diastereomer to the S—S diastereomer of the compound represented by formula (Ia). Moreover, the composition of the resolved (+) enantiomer by the resolution techniques set forth herein allow for the formation of predominantly the R—R diastereomer (e.g., about 95 percent (w/w)). Similar to the formation of the S—S diastereomer, a bipyramidal inversion equilibrium is believed to occur forcing the S—R diastereomer to the R—R diastereomer. Alternatively, in another embodiment, a biosynthesis resolution method allows for the (–) enantiomer to be resolved from the (+) enantiomer wherein the composition of the (–) enantiomer includes about 50 percent (w/w) of the S—S diastereomer and about 50 percent (w/w) of the S—R diastereomer. Likewise, the (+) diastereomer resolved by this biosynthesis method includes about 50 percent (w/w) of the R—S diastereomer and about 50 percent (w/w) of the R—R diastereomer.

The above techniques can also be used to co-crystallize a metal ion analogue of the compounds represented by formulae (Ia) and (Ib) in the amounts set forth above. Redissolving such compound(s) is believed to initiate the bipyramidal inversion which generates the diastereomer components S—S, S—R, R—S, and R—R in amounts which are believed to depend upon, but not potentially limited to, the bipyridinal inversion equilibrium rate, the time it takes to create the metal analog, and the time it takes to crystallize the analog. It should be appreciated that these variables may be manipulated by one skilled in the art. Preferably, the range of each of the four diastereomers can range from about a 60:40 ratio to about a 100:0 ratio of enantiomeric S—R and R—S analogs compound to S—S and R—R analogs.

The present invention also provides a method of forming a compound of formula (Ib) in the solid state. In a preferred specific embodiment, the method encompasses increasing the level of the compound represented by formula (Ib) in a composition comprising the compounds represented by formulae (Ia) and (Ib). The method comprises subjecting a compound of formula (Ia) to grinding conditions sufficient to permit a solid state phase transformation of the compound of formula (Ia) to a compound of formula (Ib). Preferably, the compound represented by the formula (Ia) is present in a composition and the above method increases the percentage of the compound represented by formula (Ib) present in the composition. In this embodiment, prior to the subjecting step, the composition may contain the compound represented by formula (Ia) essentially free from the compound represented by formula (Ib), although it should be appreciated that other examples are contemplated in which the

composition comprises the compounds of formulae (Ia) and (Ib) in amounts set forth herein.

Various conditions may be manipulated during the subjecting step to govern the amount of compound represented by formula (Ib), e.g., revolutions per minute (RPM) and length of subjecting step. The subjecting step is preferably carried out from about 350 rpm to about 500 rpm, more preferably from about 350 rpm to about 450 rpm, and most preferably about 450 rpm. A preferred time for carrying out the subjecting step is from about 5 to about 30 minutes, more preferably from about 10 min to about 30 min, and most preferably about 15 minutes. Advantageously, the compounds are not degraded during this operation. The subjecting step may be carried out by various machines that apply appropriate grinding energies to solid materials. Preferably, the machine is a mechanical grinder. One example of a suitable grinder is set forth in U.S. Pat. No. 5,773,173 to Whittle et al., the disclosure of which is incorporated herein by reference in its entirety. It should be appreciated that one may employ embodiments other than those described above and still be within the scope of the method of forming the compound of the formula (Ib) in solid state.

Although not intending to be bound by theory, the compound of formula (Ia) is believed to be crystalline with little amorphous content. However, when grinding is applied to a solid sample comprising the compound of formulae (Ia), and in a preferred embodiment the compounds of formulae (Ia) and (Ib), an increase in the amorphous character of the sample is believed to result along with an increase in the amount of compound of formula (Ib). Again not intending to be bound by theory, it is believed that the sample undergoes a solid state transformation and “recrystallizes” or transforms over a relatively short period of time from the more amorphous state to a more crystalline state subsequent to grinding. Nonetheless, it is believed that by performing multiple grinding steps in sequence, (i.e., grinding followed by relaxation followed by grinding) one may obtain a solid sample that becomes more amorphous in character and hence comprises a greater amount of the compound of the formula (Ib) as opposed to a sample that has experienced a lower amount of grinding.

The above method may provide various amounts of the compound of formula (Ib).

The structure of the compound of formula (Ib) can be confirmed by solid state techniques such as, for example, X-ray powder diffraction patterns, Raman, FTIR, solid state NMR, and thermal analysis, of the ground material and the unground material. For example, comparison of the two powder patterns showed distinct decreases in intensity, broadening of the peaks, and an increase in the amorphous nature for the ground material. The ground material showed a powder pattern that is more consistent with the proposed more amorphous nature of the compound of formula (Ib), e.g., 5-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole.

The present invention also provides the compounds of formulae (Ia) and (Ib) in the form of pharmaceutically acceptable salts as described hereinbelow. Similar to the making of the compounds of formulae (Ia) and/or (Ib) described above, the making of a salt of each of the compounds of formulae (Ia) and/or (Ib) in solution results in the making of salts of both compounds due to tautomerization occurring in solution. Thus, these methods describe making salts of both compounds.

Depending on the process conditions and the starting materials, the end product of the synthetic processes for preparing compounds represented by formulae (Ia) and/or

(Ib) is typically obtained as a free base. Basic, neutral or mixed salts may be obtained as well as solvates and hemi-, mono-, sesqui- or polyhydrates. Examples of suitable bases for salt formation include, but is not limited to, compounds containing alkali metals or alkali earth metals, although it is appreciated by the skilled artisan that bases containing other types of metals may be used. Examples of inorganic bases include, but are not limited to, sodium hydroxide, sodium carbonate, sodium bicarbonate, potassium hydroxide, calcium hydroxide, magnesium hydroxide, and the like. Organic bases in the form of, for example, nitrogen-containing components may be also used. Exemplary nitrogen-containing compounds include, but are not limited to, ammonium, organic amines, and the like. The free bases that are obtained may form salts with organic or inorganic acids.

As discussed in greater detail herein, metal hydrides, particularly sodium hydride, are preferably used in making the salts of the compounds of the present invention. Other methods that have been conventionally thought to be useful in making salts of such compounds have been found by Applicants to not invariably result in the formation of such salts, but instead have resulted in complex formation. Thus, the method of making such salts employing the metal hydrides of these compounds is not suggested by the prior art.

Acid addition salts may be difficult to form because of the acid labile nature of the compounds of the invention, but could be formed at a pH above 6.0 since the stability of the compounds increases. Acids suitable for making such salts may include, but are not limited to, hydrohalogen acids, sulfonic, phosphoric, nitric, and perchloric acids; aliphatic, alicyclic, aromatic, heterocyclic carboxy or sulfonic acids, such as formic, acetic, propionic, succinic, glycolic, lactic, malic, tartaric, citric, ascorbic, maleic, hydroxymaleic, pyruvic, phenylacetic, benzoic, p-aminobenzoic, antranilic, p-hydroxybenzoic, salicylic or p-aminosalicylic acid, embonic, methanesulfonic, ethanesulfonic, hydroxyethanesulfonic, ethylenesulfonic, halogenbenzenesulfonic, toluenesulfonic, naphthylsulfonic or sulfanilic acids; methionine, tryptophane, lysine or arginine.

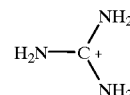
These or other salts of the new compounds, as e.g., picrates, may serve as purifying agents of the free bases obtained. Salts of the bases may be formed, separated from solution, and then the free base may be recovered from a new salt solution in a purer state. Because of the relationship between the new compounds in free base form and their salts, it will be understood that the corresponding salts are included within the scope of the invention.

The salts may be prepared by various techniques. For example, such salts can be prepared from organic compounds when that compound has an "acidic" proton. The proton may be removed, for example, by a type of base that allows for the formation of an anionic species of the compound countered by the cation. In embodiments encompassing polar, protic environments, such as an alkali or alkaline metal hydroxide or alkaline metal alkoxide present in an alcohol or mixed organic solvent such as a 2-butanone/toluene mixture it is believed that the conversion to the salt may be governed by pKa differences. In various embodiments, such techniques are capable of yielding salts of the compounds of the present invention having the diastereomers represented by  $S_{xa}-R_{4z}$  and  $S_{xb}-R_{4q}$  in a range from about 60 to about 70 percent (w/w).

Another example of a method for preparing salts of compounds represented by formulae (Ia) and/or (Ib) comprises subjecting such compounds to a polar, aprotic envi-

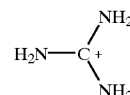
ronment to form such salts. Examples of polar, aprotic environments include, for example, an alkali or alkaline metal hydride in an organic solvent (e.g., tetrahydrofuran (THF) or dimethylformamide (DMF)). Although not intending to be bound by theory, in polar, aprotic environments, the salt conversion may be governed by factors such as solubility of both the organic compound and the base used and the steric hindrance interactions. Although both types of reactions (e.g., polar, protic environments and polar, aprotic environments) can be used in forming the salts, reactions taking place in polar, aprotic environments are preferred. For example, using a polar, aprotic environment may preferably provide from about 90 to about 95 percent (w/w) yield of salts of the compounds, and/or compositions of the present invention. Although various alkali and alkaline metal salts can be made using the above methods, it is preferred to form sodium or magnesium salts of compounds of the present invention.

The salts may be formed by various reactions. For example, in one embodiment, a complex may be formed by reacting the compounds represented by formulae (Ia) with a cation  $A^{z+}$  by a suitable technique, e.g., ion-pair extraction. In the above embodiment, A is lithium, sodium, potassium, magnesium, calcium, titanium(4+),  $N^+(R^1)_4$ , or:

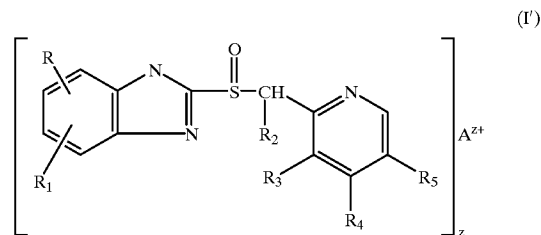


wherein  $R^1$  is an alkyl group containing 1 to 4 carbon atoms, and z is 1, 2, or 4. For example, tetrabutylammonium salts of the invention may be prepared by dissolving the  $A^{z+}$  salt in water containing one or more tetrabutylammonium compounds such as, for example, the chloride or hydroxide followed by extraction of the tetrabutylammonium salt into a methylene chloride phase, and subsequent isolation of the tetrabutylammonium salt. In this manner, other tetraalkylammonium salts may be prepared.

In one embodiment, the salt of the compound of formula (I') may be formed by reacting the compound of formulae (Ia) and/or (Ib) with a base capable of releasing the cation  $A^{z+}$  wherein z is 1, 2, or 4; and A is lithium, sodium, potassium, magnesium, calcium, titanium(4+),  $N^+(R^1)_4$ , or:



wherein  $R^1$  is an alkyl group containing 1 to 4 carbon atoms, to provide a salt of the formula (I'):



wherein R is alkoxy in the 5- or 6-position:  $R_1$  is selected from the group consisting of hydrogen, alkyl, halogen, carboalkoxy, alkoxy, and alkanoyl;  $R_2$  is hydrogen or alkyl;

and  $R_3$ ,  $R_4$ , and  $R_5$  may be the same or different and are each selected from the group consisting of hydrogen, alkyl, alkoxy, and alkoxyalkoxy, and wherein  $z$  and  $A^{z+}$  are defined above.

In one example, lithium, potassium, or sodium salts of the formula (I') may be prepared by treating the compounds of the formulae (Ia) and/or (Ib) with LiOH, NaOH, or KOH in an aqueous or nonaqueous medium, or with LiOR<sup>1</sup>, LiNH<sub>2</sub>, LiNR<sup>1</sup><sub>2</sub>, NaOR<sup>1</sup>, NaNH<sub>2</sub>, NaNR<sup>1</sup><sub>2</sub>, KOR<sup>1</sup>, KNH<sub>2</sub>, KNR<sup>1</sup><sub>2</sub> wherein R<sup>1</sup> is defined above, in an aqueous or a nonaqueous medium. Magnesium, calcium, or titanium salts may be prepared by treating a compound of the formulae (Ia) or (Ib) with Mg(OR<sup>1</sup>)<sub>2</sub>, Ca(OR<sup>1</sup>)<sub>2</sub>, CaH<sub>2</sub>, Ti(OR<sup>1</sup>)<sub>4</sub> or TiH<sub>4</sub>, wherein R<sup>1</sup> is defined herein, in a nonaqueous solvent such as an alcohol (for the alcoholates), e.g., ROH, or in an ether such as tetrahydrofuran.

In another example, a salt of the compound of formula (I') wherein A is:



may be prepared by treating compounds of the present invention with a strong base of the formula:



dissolved in a solvent such as, for example, an alcohol.

A salt represented by formula (I') may be converted to another salt of the same formula by exchanging the cation. When both the starting material and the salt obtained as final product are sufficiently soluble, such an exchange may be performed by using a cation-exchange resin saturated with the cation desired in the product. The exchange may also be performed by utilizing the low solubility of a desired salt.

The reaction between the compound of formulae (Ia) and/or (Ib) and  $A^{z+}$  may also be carried out by ion-pair extraction. For example, tetrabutylammonium salts of the invention may be prepared by dissolving the Na+salt in water containing one or more tetrabutylammonium compounds followed by extraction of the tetrabutylammonium salt into a methylene chloride phase, and subsequent isolation of the tetrabutylammonium salt. In this manner, other tetraalkylammonium salts may be prepared.

Illustrative examples of the radical R<sup>1</sup> are methyl, ethyl, n-propyl, n-butyl, isobutyl, sec-butyl, and tert-butyl.

A preferred method for forming magnesium salts of compounds of the present invention is characterized by the following consecutive steps: a) treating at least one compound of formulae (Ia) and/or (Ib) or salts thereof with magnesium alcoholate in a solution; b) separating inorganic salts from the reaction mixture; c) crystallizing the magnesium salts of such formulae (Ia) and/or (Ib); d) isolating the obtained crystalline magnesium salts and, optionally, e) purifying and drying the crystalline magnesium salts using conventional methods.

A process for manufacturing the magnesium salts is described as follows: a lower alcohol, such as methanol, ethanol, n-propanol or iso-propanol, preferably methanol, is treated in a solution of polar solvents with a weighed amount of magnesium at temperatures between about 0° C. and

between about 10° C. and about 40° C. After addition of the magnesium to the solution the temperature can, in a second step be raised further to between about 0° C. and reflux temperature, preferably about 20° C. to about 50° C. After termination of the reaction the temperature is reduced to about 0° C. to about 40° C., preferably about 10° C. to about 25° C. The compound of formula (Ia) or (Ib) or a salt thereof is then added to the solution and after termination of the reaction the mixture is cooled to about -10° C. to about +20° C, preferably about -5° C. to about +5° C. The solvent is then evaporated to about 40 to about 60 percent of the initial volume, which makes the inorganic salts precipitate. The precipitate is separated from the reaction solution for example by centrifugation or filtration and the solution is heated from about 5° C. to about 30° C. whereafter the solution is seeded with magnesium crystals of the compound of formula (Ia) or (Ib). An amount of water, which is approximately equal to the volume of the solution, is added to start the crystallization. The solution is cooled to about -10° C. to about +20° C., preferably about 0° C. to about 10° C. to complete the crystallization. The crystals are then separated from the mother liquid for example by centrifugation or filtration and washed with polar solvents preferably an aqueous lower alcohol such as aqueous methanol. Finally, the produced crystals are dried preferably under reduced pressure and heating.

The magnesium salts may include various amounts of the compounds of the formulae (Ia) and/or (Ib). For example, in one embodiment, a magnesium salt composition may preferably comprise up to about 30 percent (w/w) of the compound of formula (Ib), and more preferably about 27 percent (w/w) of the compound of formula (Ib).

In another aspect, the invention also provides complexes of the compound represented by the formulae (Ia) and/or (Ib). In particular, the invention provides a composition comprising a complex of: (a) two or more compounds encompassed by compositions set forth herein comprising compounds represented by formulae (Ia) and/or (Ib); at least one atom of a metal cation, preferably an alkali or alkaline metal cation. Exemplary metal cations are selected from the Groups IA, IIA, and IIIa of the periodic table although other cations may be employed. Preferably, the composition is present in crystalline form. Sodium and magnesium each are examples of preferred cations.

Such compositions of the present invention may employ solvent(s) that are typically employed in forming complexes. In a preferred embodiment, such compositions further include two solvents. The solvents are those which are capable of donating a pair of electrons, alcohols, THF, DMF, DMSO, and mixtures thereof. The complexes of the invention may be formed by using materials which are known to be used in forming complexes, e.g., alkoxides and hydroxides of metal cations such as, without limitation, those described above. The two or more compounds represented by formula (Ia) may be the same or different and may be present as compounds with any one of the four diastereomer configurations (e.g.,  $S_{xa}-R_{4q}$ ,  $S_{xa}-R_{4z}$ ,  $S_{xb}-R_{4q}$ , and  $S_{xb}-R_{4z}$ ).

In general, complexes of compounds of formulae (Ia) and/or (Ib) typically include two compounds having at least one metal cation positioned therebetween. The metal cation bonds with various appropriate lone pair or electron donating sites on the two compounds, namely oxygen and nitrogen atoms with respect to such compounds. In various preferred embodiments, such complexes also include at least one "solvent residue" which is obtained from one or more solvents set forth herein. In such complexes, the solvent

residue is bound to the metal cation and the nitrogen present on the benzimidazole portion of the compounds. Examples of suitable solvent residues include, without limitation, alkoxides (e.g., lower ( $C_1$  to  $C_4$ ) alkoxides) with ethoxide being preferred.

The ratio of metal cation to compound in a complex of the invention typically depends on the specific structure of the compound and the valence of the metal cation. In embodiments employing a solvent residue, the amount of such residue that is employed will typically depend on the above factors as well as the type of residue used. In preferred embodiments, the ratio of: (1) compounds of formulae (Ia) and/or (Ib) as defined by any of compounds (Iai), (Iaii), (Iaiii), (Iaiv), (Ibi), (Ibii), (Ibiii), and (Ibiv), respectively, or combinations thereof; to (2) one or more metal cation; to (3) solvent residue will typically be 2:1:1 or 2:2:2 respectively. Other ratios may be required depending on the change of the cation and the type of complex embodiment.

In various embodiments, the compositions comprising the complexes may be essentially free from compounds represented by formula (Ib), as defined herein.

In these embodiments, the term "essentially free from" preferably refers to such complexes formed with sodium as the metal cation comprising at least about 95 percent (w/w) of the compound represented by formula (Ia).

The compositions comprising the complexes described above preferably are in crystalline form.

In certain embodiments, the compositions comprising the complexes may employ the diastereomers of the compounds represented by formula (Ia), and if applicable, the compounds represented by formula (Ib) according to any of the embodiments set forth hereinabove. In one non-limiting embodiment, for example, the concentration of compounds having the combination of the diastereomers  $S_{xa}-R_{4z}$  and  $S_{xb}-R_{4q}$  is from about 50 percent (w/w) to about 100 percent (w/w) of the composition, and the concentration of the compounds having the diastereomers  $S_{xa}-R_{4q}$  and  $S_{xb}-R_{4z}$  is from about 0 percent (w/w) to about 50 percent (w/w) of the composition, such that the sum of the total concentration of all such compounds is about 100 percent (w/w). Preferably, the concentration of such compounds having the combination of diastereomer pairs  $S_{xa}-R_{4z}$  and  $S_{xa}-R_{4q}$  is greater than about 70 percent.

Hydrates and solvates of the compounds of formulas (Ia) and (Ib) along with polymorphs thereof are also provided by the invention and may be formed according to techniques known to one having ordinary skill in the pharmaceutical arts. As an example, solvates of any embodiments encompassing the compounds represented by formula (Ia) may be made according to known techniques. Suitable solvents for use in providing the solvates are known in the art and may vary according to the particular embodiment. Exemplary solvents include hydrates alcohols, such as, without limitation, methanol, ethanol, and the like.

The invention also pertains to methods for providing each of the diastereomers  $S-S$ ,  $S-R$ ,  $R-S$ , and  $R-R$  of the compounds of formulae (Ia) and/or (Ib), or pairs thereof, in resolved form. Preferably, in various embodiments, each diastereomer pair of compounds (Ia) and/or (Ib) are essentially free of the three other diastereomers, or combinations thereof, e.g., at least 95 percent (w/w).

As set forth herein, the compounds of (Ia) and (Ib) have been discovered to exhibit chirality at two distinct locations: (1) an atomic chiral center located at each sulfoxide group

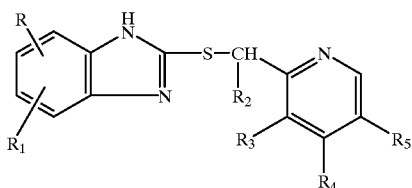
(as referenced by the first letter denoted in the diastereomer pair designation) and (2) a structural chiral center (i.e., a chiral plane) located at each pyridinal moiety on the compound (as referenced by the second letter denoted in the diastereomer pair designation). A preferred method for resolving each of the above diastereomer pairs involves first resolving the structural chiral center of the various materials used in making compounds (Ia) and/or (Ib) including those set forth herein. For example, the starting pyridine compound may be resolved at the  $R_4$  position referred to herein, or alternatively one of the pyridinal-moiety containing intermediates can be resolved at the  $R_4$  position such as, for example, a thiol compound represented by formulae (II) or (VIII). In this instance, the resolution of the thiol compound is carried out prior to oxidation which eventually forms compound (Ia) and/or (Ib). The actual techniques for resolving the structural chiral centers may be carried out by various suitable methods.

Subsequent to oxidation, the materials used in making the compounds (Ia) and/or (Ib) are then be resolved at the atomic chiral center eventually providing each of the resolved diastereomer pairs of compounds (Ia) and/or (Ib). Any number of techniques may be used to resolve the atomic chiral center of these compounds, e.g., recrystallization from an optically active solvent, use of microorganisms, reactions with optically active acids forming salts which can be separated based on different solubilities of the diastereomers. Suitable optically active acids are, for example, the L- and D-forms of tartaric acid, di-o-tolyl-tartaric acid, malic acid, mandelic acid, camphorsulfonic acid or quinic acid.

In one embodiment, atomic chiral center resolution of the compounds of formulae (Ia) and (Ib) may be obtained by chromatographic techniques. Materials that may be used in this method include a cellulose (e.g., triphenylcarbamoyl-cellulose) coated on a column that includes a silica-containing material (e.g., silica or 3-aminopropyl silica). The column may be prepared by suspension in an organic solvent (e.g., methanol or 2-propanol) using an appropriate technique such as, for example, a descending slurry-packing technique.

Mobile phases for use in this procedure can be prepared by various methods, such as, for example, using n-hexane and diethylamine in different ratios. Other materials, however, may be employed such as, without limitation, alcohols (e.g., methanol, ethanol). The compounds of formula (Ia) and (Ib) may be combined in the mobile phase along with other components known in the art such as, for example, a suitable buffer (e.g., a phosphate compound). The mobile phase is then passed through the column under processing (e.g., temperature, flow, and pressure) conditions that may be set by the operator. The diastereomer that first eluted from the column can be isolated by evaporation of the solvents. The diastereomer can be deemed isolated by known analytical techniques.

In another embodiment, the formation of compounds of formulae (Ia) and/or (Ib) having resolved atomic chiral centers may be formed by carrying out the asymmetric oxidation in an organic solvent of a pro-chiral sulphide according to the formula (X):



(X)

wherein R, R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, and R<sub>5</sub> are defined above with R being present in the 6- or 5-position, with an oxidizing agent and a chiral titanium complex, optionally in the presence of a base.

A number of oxidizing agents may be employed such as, for example, a hydroperoxide, more particularly tert-butylhydroperoxide or cumene hydroperoxide.

The titanium complex suitable for use in the reaction may be prepared using various methods. In one embodiment, the titanium complex is prepared from a chiral ligand and a titanium (IV) compound such as, for example, preferably titanium(IV) alkoxide, and optionally in the presence of water. An especially preferred titanium (IV) alkoxide is titanium (IV) isoperoxide or isopropoxide. Various amounts of chiral titanium complex may be used. Typically, an amount less than approximately about 0.50 equivalents is preferred and an especially preferred amount is about 0.05 to about 0.30 equivalents.

The titanium complex may also be prepared by reacting titanium tetrachloride with a chiral ligand in the presence of a base. The chiral ligand used in the preparation of the titanium complex is typically a branched or unbranched alkyl diol, or an aromatic diol. Preferred chiral diols are, for example, esters of tartaric acid, especially (+)-diethyl L-tartrate or (-)-diethyl D-tartrate. It should be noted that the titanium complex may be prepared in the presence of the compound of formula (X) or before the compound of formula (X) is added to the reaction vessel.

The oxidation is preferably carried out in the presence of a base. For example, the base may be an inorganic or organic base, such as, but not limited to, a hydrogen carbonate, an amide, or an amine such as guanidine or an amidine. Examples of other bases include triethylamine or N,N-diisopropylethylamine.

The oxidation is typically carried out in the presence of an organic solvent. The solvent can be selected with respect to suitable conditions. Suitable organic solvents include, but are not limited to, toluene, ethyl acetate, methyl ethyl ketone, methyl isobutyl ketone, diethyl carbonate, tert butyl methyl ether, tetra hydrofuran, methylene chloride, and the like, and blends and mixtures thereof.

The oxidation is preferably carried out in the organic solvent at room temperature or just above room temperature, e.g., between about 20° C. and about 40° C. It is believed that the reaction times may be longer if the reaction is carried out below 20° C. The temperature of the reaction may be varied according to the intentions of one skilled in the art.

The products formed during the oxidation reaction may be extracted with an aqueous solution of ammonia or another N-containing base to avoid precipitation and/or formation of insoluble titanium salts. The aqueous phase is separated from the organic phase of the obtained mixture and the isolated aqueous phase is neutralized by the addition of a neutralizing agent resulting in the protonation of the diastereomers. The diastereomers may be extracted by an organic solvent. They may also be crystallized in an organic

or aqueous solvent resulting in the desired resolved diastereomers of compounds (Ia) and/or (Ib). In addition to using the above techniques to provide individual diastereomers S<sub>xa</sub>-R<sub>4q</sub>, S<sub>xa</sub>-R<sub>4z</sub>, S<sub>xb</sub>-R<sub>4q</sub>, and S<sub>xb</sub>-R<sub>4z</sub>, these techniques may be used to provide various combinations of diastereomers as set forth herein, including, without limitation, those which are essentially free from other diastereomers.

The invention also provides for methods of making salts of diastereomers and pairs thereof. A preferred method for making the salts of the individual diastereomers and/or pairs thereof first involves forming these diastereomers of pairs thereof according to the teachings of the preceding section, in which the chiral plane is first resolved followed by resolution of the sulfoxide atomic chiral center. Salts of these resolved diastereomers or pairs thereof may then be formed according to various techniques.

Examples of salts of diastereomers or pairs thereof that may be obtained include, but are not limited to, alkali and alkaline metal salts. As an example, to obtain optically pure alkali salts of the compounds of formulae (Ia) and/or (Ib), the diastereomer obtained in a manner described herein, may be treated with: (1) a base, such as for example, M<sub>1</sub><sup>+</sup>OH wherein M<sub>1</sub> is sodium, ammonium, potassium, or lithium, in a aqueous or nonaqueous medium; (2) M<sub>1</sub><sup>+</sup>OR<sup>2</sup> wherein M<sub>1</sub><sup>+</sup> is defined above, and R<sup>2</sup> is an alkyl group containing 1 to 4 carbon atoms; or (3) M<sub>1</sub><sup>+</sup>NH<sub>2</sub> wherein M<sub>1</sub><sup>+</sup> is defined above. In order to obtain the crystalline form of the alkali salts, addition of the base M<sub>1</sub><sup>+</sup>OH in a non-aqueous medium such as a mixture of 2-butanone and toluene, is preferred.

To obtain an optically pure alkaline metal salt of a diastereomer or pair thereof of the compounds of formulae (Ia) and/or (Ib), the optically pure alkali salt is treated with an aqueous solution of an inorganic alkaline metal salt such as, for example, M<sub>2</sub><sup>2+</sup>Cl<sub>2</sub> wherein M<sub>2</sub><sup>2+</sup> is an alkaline metal such as calcium, magnesium, strontium, barium, and the like, whereupon the alkaline metal salt of the single enantiomer is precipitated. The optically pure alkaline metal salts may also be prepared by treating a single enantiomer of compounds of formula (Ia) and/or (Ib) with a base such as, for example, M<sub>2</sub><sup>2+</sup>(OR<sup>3</sup>)<sub>2</sub> wherein R<sup>3</sup> is an alkyl group containing 1 to 4 carbon atoms, in a non-aqueous solvent such as alcohol (for alcoholates), e.g., ROH, or in an ether such as tetrahydrofuran.

A preferred embodiment for the preparation of the magnesium salts of the S-S or S-R diastereomer or pairs thereof of the compounds of formulae (Ia) and/or (Ib) polyhydrates comprises: a) treating a magnesium salt of the above individual diastereomer or pairs thereof of such compounds with water at a suitable temperature for a suitable time. The phrase "a suitable temperature" means a temperature which induces the transformation of starting material to product without decomposing any of these compounds. Examples of such suitable temperatures include, but are not limited to, ambient temperature and above. By a suitable time is meant a time that results in high conversion of the starting material into product without causing any decomposition of either compound, i.e., results in a good yield. This suitable time will vary depending on the temperature used in a way well known to people in the art. By increasing the temperature, less time is required to give the desired conversion. The amount of water is generally not crucial and will depend on the process conditions used. The magnesium salts of the above diastereomers or pairs thereof of the compounds of formulae (Ia) and/or (Ib) polyhydrates is thereafter separated from the aqueous slurry, for example by filtration or centrifugation and thereafter dried to constant weight.

Optionally, the process may comprise: b) oxidizing compounds of formula (II) defined herein, with an oxidizing agent and a chiral titanium complex, optionally in the presence of a base. The oxidation is carried out in an organic solvent, for example toluene or dichloromethane. The crude product is then converted to the corresponding potassium salt by treatment with a potassium source, such as methanolic potassium hydroxide or methanolic potassium methylate, followed by isolation of the formed salt.

The resulting potassium salts of the S—S or S—R diastereomers, or combinations thereof, of the compounds of formulae (Ia) and/or (Ib) are thereafter converted to the corresponding magnesium salts by treatment with a magnesium source, such as, for example, magnesium sulfate in a lower alkyl alcohol, such as methanol. The solution is optionally filtered and the precipitation is initialized by addition of a non-solvent such as acetone. The product is filtered off and optionally washed with water and further processed as is described in a) above. Alternatively, the potassium salts may be treated with a magnesium source, such as, for example, magnesium sulfate in water, and isolation of the magnesium salts of the S—S or S—R diastereomers or pairs thereof of the compounds of formula (Ia) and (Ib) polyhydrates, or any other conventional technique for transforming a potassium salt to the corresponding magnesium salt can be used.

The potassium salts of the S—R or S—S diastereomers, or pairs thereof, of the compounds of formulas (Ia) and (Ib) are suitable intermediates in the preparation of the magnesium salts of these diastereomers or pairs thereof. The potassium salts of these diastereomers may also be used as active components in pharmaceutical formulations to be used in the treatment of various diseases described herein, particularly gastrointestinal diseases.

The present invention also encompasses pharmaceutical formulations comprising at least one active pharmaceutical ingredient of the present invention and at least one pharmaceutically acceptable carrier, diluent, or excipient, the selection of which are known to the skilled artisan. For the purposes of the invention, the term "active ingredient" refers to any of the embodiments set forth herein referring to the compound(s) of formula (Ia) and/or (Ib), diastereomers thereof, any combinations of diastereomers thereof, pharmaceutically acceptable salts thereof, along with complexes, hydrates, solvates, and polymorphs of any of the above, as well as any compositions thereof. Prodrugs of any of these active pharmaceutical ingredients may also be employed for the purposes of the invention, most preferably as part of a pharmaceutical formulation, although their use in other embodiments may be carried out. The term "active ingredient" also encompasses, in one embodiment, a solid pharmaceutical composition of the present invention which is blended with at least one pharmaceutically acceptable excipient, diluted by an excipient or enclosed within such a carrier which can be in the form of a capsule, sachet, tablet, buccal, lozenge, paper, or other container. When the excipient serves as a diluent, it may be a solid, semi-solid, or liquid material which acts as a vehicle, carrier, or medium for the active ingredient. Thus, the formulations can be in the form of tablets, pills, powders, elixirs, suspensions, emulsions, solutions, syrups, soft and hard gelatin capsules, suppositories, sterile injectable solutions, and sterile packaged powders.

Examples of suitable excipients include, but are not limited to, starches, gum arabic, calcium silicate, microcrystalline cellulose, polyvinylpyrrolidone, cellulose, water, syrup, and methyl cellulose. The formulations can addition-

ally include lubricating agents such as, for example, talc, magnesium stearate and mineral oil; wetting agents; emulsifying and suspending agents; preserving agents such as methyl- and propyl hydroxybenzoates; sweetening agents; or flavoring agents. Polyols, buffers, and inert fillers may also be used. Examples of polyols include, but are not limited to: mannitol, sorbitol, xylitol, sucrose, maltose, glucose, lactose, dextrose, and the like. Suitable buffers encompass, but are not limited to, phosphate, citrate, tartarate, succinate, and the like. Other inert fillers which may be used encompass those which are known in the art and are useful in the manufacture of various dosage forms. If desired, the solid pharmaceutical compositions may include other components such as bulking agents and/or granulating agents, and the like. The compositions of the invention can be formulated so as to provide quick, sustained, or delayed release of the active ingredient after administration to the patient by employing procedures well known in the art.

In the event that the above formulations are to be used for parenteral administration, such a formulation typically comprises sterile aqueous and non-aqueous injection solutions comprising the active ingredient, which preparations are preferably isotonic with the blood of the intended recipient. These preparations may contain anti-oxidants, buffers, bacteriostats, and solutes which render the formulation isotonic with the blood of the intended recipient. Aqueous and non-aqueous sterile suspensions may include suspending agents and thickening agents. The formulations may be presented in unit-dose or multi-dose containers, for example sealed ampules and vials. Extemporaneous injection solutions and suspensions may be prepared from sterile powders, granules and tablets of the kind previously described.

In certain embodiments of the invention, the active ingredient may be made into the form of dosage units for oral administration. The active ingredient may be mixed with a solid, pulverant carrier such as, for example, lactose, saccharose, sorbitol, mannitol, starch, amylopectin, cellulose derivatives or gelatin, as well as with an antifriction agent such as, for example, magnesium stearate, calcium stearate, and polyethylene glycol waxes. The mixture is then pressed into tablets. If coated tablets are desired, the above prepared core may be coated with a concentrated solution of sugar, which may contain gum arabic, gelatin, talc, titanium dioxide, or with a lacquer dissolved in volatile organic solvent or mixture of solvents. To this coating various dyes may be added in order to distinguish among tablets with different active compounds or with different amounts of the active compound present.

Soft gelatin capsules may be prepared in which capsules contain a mixture of the active ingredient and vegetable oil. Hard gelatin capsules may contain granules of the active ingredient in combination with a solid, pulverulent carrier, such as, for example, lactose, saccharose, sorbitol, mannitol, potato starch, corn starch, amylopectin, cellulose derivatives, or gelatin.

Dosage units for rectal administration may be prepared in the form of suppositories which may contain the active ingredient in a mixture with a neutral fat base, or they may be prepared in the form of gelatin-rectal capsules which contain the active substance in a mixture with a vegetable oil or paraffin oil.

Liquid preparations for oral administration may be prepared in the form of syrups or suspensions, e.g., solutions containing an active ingredient, sugar, and a mixture of ethanol, water, glycerol, and propylene glycol. If desired, such liquid preparations may contain coloring agents, fla-

voring agents, and saccharin. Thickening agents such as carboxymethylcellulose may also be used.

Solutions for parenteral administration by injection may be prepared as an aqueous solution of a water soluble pharmaceutically acceptable salt of the active ingredient. These solutions may also contain stabilizing agents and/or buffering agents and may be manufactured in different dosage unit ampules.

Tablets for oral use are typically prepared in the following manner, although other techniques may be employed. The solid substances are ground or sieved to a desired particle size, and the binding agent is homogenized and suspended in a suitable solvent. The active ingredient and auxiliary agents are mixed with the binding agent solution. The resulting mixture is moistened to form a uniform suspension. The moistening typically causes the particles to aggregate slightly, and the resulting mass is pressed through a stainless steel sieve having a desired size. The layers of the mixture are then dried in controlled drying units for determined length of time to achieve a desired particle size and consistency. The granules of the dried mixture are sieved to remove any powder. To this mixture, disintegrating, aniffriction, and anti-adhesive agents are added. Finally, the mixture is pressed into tablets using a machine with the appropriate punches and dies to obtain the desired tablet size. The operating parameters of the machine may be selected by the skilled artisan.

Typically, preparation of lozenge and buccal dosage forms are prepared by methods known to one of ordinary skill in the art.

In a particular embodiment, the active ingredient may be present in a core surrounded by one or more layers including an enteric coating layer. With respect to formation of the core, the active ingredient is typically mixed with inert, preferably water soluble, conventional pharmaceutically acceptable constituents to obtain the preferred concentration of the active ingredient in the final mixture with an alkaline reacting, otherwise inert, pharmaceutically acceptable substance (or substances), which creates a "micro-pH" around each particle of active compound of not less than a pH of 7, preferably not less than a pH of 8, when water is adsorbed to the particles of the mixture or when water is added in small amounts to the mixture. Such substances can be chosen among, but are not limited to, sodium, potassium, calcium, magnesium, and aluminum salts of phosphoric acid, carbonic acid, citric acid, or other suitable weak inorganic or organic acids; substances typically used in antacid preparations such as aluminum, calcium, and magnesium hydroxides; magnesium oxide or composite substances such as, for example,  $\text{Al}_2\text{O}_3 \cdot 6\text{MgO} \cdot 12\text{H}_2\text{O}$  ( $\text{Mg}_6\text{Al}_2(\text{OH})_{16}\text{CO}_3 \cdot 4\text{H}_2\text{O}$ ),  $\text{MgO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot n\text{H}_2\text{O}$ , wherein n is not necessarily an integer and may be less than 2, or similar compounds; organic pH-buffering substances such as trihydroxymethylamino-methane or other similar, pharmaceutically acceptable pH-buffering substances. The stabilizing high pH-value in the powder mixture can also be achieved by using an alkaline reacting salt of the active compound such as, but not limited to, sodium, potassium, magnesium, and calcium salts of active ingredient, either alone or in combination with a conventional buffering substance as previously described.

The powder mixture may then be formulated into small beads, i.e., pellets or tablets, by conventional pharmaceutical procedures. The pellets, tablets, or gelatin capsules may then be used as cores for further processing.

The reacting cores containing the active ingredient may be separated from the enteric coating polymer(s) containing

free carboxyl groups, which otherwise is capable of causing degradation/discoloration of the active compound during the coating process or during storage. The subcoating layer (i.e., the separating layer), also serves as a pH-buffering zone in which hydrogen ions diffusing from the outside in towards the core can react with hydroxyl ions diffusing from the core towards the surface of the coated article. The pH-buffering properties of the separating layer can be further strengthened by introducing in the layer substances chosen from a group of compounds usually used in antacid formulations described above. The separating layer usually consists of one or more water soluble inert layers, optionally containing pH-buffering substances.

The separating layer(s) can be applied to the cores, typically in the form of pellets or tablets, by conventional coating procedures in a suitable coating pan or in a fluidized bed apparatus using water and/or conventional organic solvents for the coating solution. The material for the separating layer may be chosen among the pharmaceutically acceptable water soluble, inert compounds or polymers used for film-coating applications such as, for example, sugar, polyethylene glycol, polyvinylpyrrolidone, polyvinyl alcohol, hydroxypropyl cellulose, hydroxymethyl cellulose, hydroxypropyl methylcellulose, or the like. The thickness of the separating layer may be determined according to the skilled artisan.

In the case of tablets, another method to apply the coating can be performed by the dry coating technique. First, a tablet containing the active ingredient is compressed as described herein. Around this tablet, another layer is compressed using a suitable tableting technique machine. The outer, separating layer, contains pharmaceutically acceptable, in water soluble or in water, rapidly disintegrating tablet excipients. Conventional plasticizers, pigments, titanium dioxide talc, and other additives may be included in the separating layer. In embodiments encompassing gelatin capsules, the gelatin capsule itself serves as a separating layer.

The enteric coating layer is typically applied on to the sub-coated cores by conventional coating techniques such as, for example, pan coating or fluidized bed coating using solutions of polymers in water and/or suitable organic solvents or by using latex suspensions of the polymers. Enteric coating polymers that can be used include, for example, cellulose acetate phthalate, hydroxypropyl methylcellulose phthalate, polyvinyl acetate phthalate, carboxymethylethylcellulose, co-polymerized methacrylic acid/methacrylic acid methyl esters such as, for example, compounds known under the trade name Eudragit® L 12,5 or Eudragit® L 100 (Röhm Pharma of Darmstadt, Germany), or other similar compounds. The enteric coating can also be applied using water-based polymer dispersions, e.g. Aquateric® (FMC Corporation of Chicago, Ill.), Eudragit® L100-55 (Röhm Pharma of Darmstadt, Germany), Coating CE 5142 (BASF of Mount Olive, N.J.). The enteric coating layer can optionally contain a pharmaceutically acceptable plasticizer such as, for instance, cetanol, triacetin, citric acid esters such as, for example, those known under the trade name Citrofex® (Pfizer of New York, N.Y.), phthalic acid esters, dibutyl succinate or similar plasticizers. The amount of plasticizer is usually optimized for each enteric coating polymer(s). Dispersants such as talc, colorants and pigments may also be included into the enteric coating layer.

Thus, the formulations described by the above embodiments comprise cores containing at least one active ingredient described herein, optionally mixed with an alkaline reacting compound, or cores comprising a salt of at least one

active ingredient or one or more enantiomers thereof as taught herein, or at least one pharmaceutically acceptable salt, hydrate, solvate, or polymorph thereof, optionally mixed with an alkaline reacting compound. The alkaline reacting core material and/or alkaline salt of the active ingredient is believed to potentially enhance the stability of the active ingredient. The cores suspended in water form a solution or a suspension which has a pH which is higher than that of a solution in which the polymer used for enteric coating is just soluble. The cores may be coated with an inert reacting water soluble or in water rapidly disintegrating coating, optionally containing a pH-buffering substance, which separates the cores from the enteric coating. Without this separating layer, the resistance towards gastric juice may be too short and/or the storage stability of the dosage form would be unacceptably short. The sub-coated dosage form is finally coated with an enteric coating rendering the dosage form insoluble in acid media, but rapidly disintegrating/dissolving in neutral to alkaline media such as, for instance, the liquids present in the proximal part of the small intestine.

The final dosage form encompassing the above embodiments may be either an enteric coated tablet or capsule or in the case of enteric coated pellets, pellets dispensed in hard gelatin capsules or sachets or pellets formulated into tablets. It is desirable for the long term stability during storage that the water content of the final dosage form containing the active ingredient (enteric coated tablets, capsules or pellets) be kept low. As a consequence, the final package containing hard gelatin capsules filled with enteric coated pellets preferably also contain a desiccant, which reduces the water content of the gelatin shell to a level where the water content of the enteric coated pellets filled in the capsules does not exceed a certain level.

The invention also provides methods of treating a subject (e.g., mammal, particularly humans) comprising administering to a subject in need of such treatment a therapeutically effective amount of at least one active ingredient described above. The active ingredient(s) may be used to treat a number of disorders. Generally, the compound is useful for preventing and treating gastric acid related diseases in mammals and particularly humans. These diseases include, but may not be limited to, duodenal ulcer, *H. pylori* infection, gastric ulcer, gastro-esophageal reflux disease and symptoms associated therewith (e.g., heartburn), erosive esophagitis, pathological hypersecretory conditions (e.g., Zollinger-Ellison syndrome, endocrine adenomas and systematic mastocytosis), gastritis, duodenitis. The active ingredient(s) may also be used for the treatment of other gastrointestinal disorders where gastric acid inhibitory effect is desirable (e.g., in patients on NSAID therapy, in patients with Non Ulcer Dyspepsia). The active ingredient(s) may also be used in patients in intensive care situations, in patients with acute upper gastrointestinal bleeding, pre- and post-operatively to prevent acid aspiration of gastric acid and to prevent and treat stress ulceration. Moreover, the active ingredient(s) may be useful in the treatment of psoriasis as well as in the treatment of *Helicobacter* infections and diseases related to those. The active ingredient(s) may also be used for the treatment or "prophylaxis" of inflammatory conditions in mammals and particularly humans, particularly those involving lysozymal enzymes. As used herein, the term "treatment", or a derivative thereof, contemplates partial or complete inhibition of the stated disease state such as, for example, pain, when a composition of the present invention is administered prophylactically or following the onset of the disease state for which such

composition of the present invention is administered. For the purposes of the invention, "prophylaxis" refers to administration of the active ingredient(s) to a mammal to protect the mammal from any of the disorders set forth herein, as well as others. Other examples of such conditions that may be treated include rheumatoid arthritis and gout.

Other disorders that may be prevented or treated in accordance with the invention including schizophrenia, symptoms of bradyphremia in Parkinson's Disease, elevated intraocular pressure in the eye of a patient, and microbial infections associated with gram-negative bacteria (especially microaerophilic bacteria), bacteria of the genus *Campylobacter* represented by *C. pylori*. The treatment of infectious diseases due to such bacteria in mammalian animals including without limitation humans, cattle, horse, dog, mouse, rat, the control and inhibition of environmental pollution, and disinfectant use may be achieved by virtue of the invention.

The active ingredient(s) disclosed herein possess worthwhile therapeutic properties as gastric acid secretion inhibitors as demonstrated by the following tests. To determine the gastric acid secretion inhibitory properties, experiments are performed on conscious dogs provided with gastric fistulas of conventional type and duodenal fistulas, the latter ones used for direct intraduodenal administration of the active ingredient(s). After 18 hours starvation and deprivation of water the dogs are given a subcutaneous infusion of pentagastrin (1–4 nmol/kg, h) lasting for 6 to 7 hours. Gastric juice is collected in consecutive 30 minute samples. An aliquot of each sample is titrated with 0.1 N NaOH to pH 7 for titratable acid concentration using an automatic titrator and pH-meter. Acid output is calculated as mmol H<sup>+</sup>/60 minutes. The active ingredient(s), suspended in 0.5 percent methyl cellulose, is given intraduodenally in doses from 4 to 20  $\mu$ mol/kg when the secretory response to pentagastrin reaches a steady level. This embodiment may also be used for prophylaxis by administration of the active ingredient prior to pentagastrin.

The typical active daily dose of the active ingredient(s) will depend on various factors such as, for example, the individual requirement of each patient, the route of administration, and the disease. An attending physician may adjust the dosage rate based on these and other criteria if he or she so desires. As an example, a suitable oral dosage form may encompass from about 5 to about 360 mg total daily dose, typically administered in one single dose or equally divided doses. A more preferred range is from about 10 to about 60 mg total daily dose, and a most preferred range is from about 10 to about 40 mg total daily dose. Additionally, the active ingredient(s) may be administered in a solution, and, as an example, the daily doses set forth above may be employed. In one embodiment, the active ingredient(s) may be added in appropriate amounts to a solution such that the solution comprises, for example, from about 0.1 mg/ml to about 10 mg/ml of the active ingredient(s). It should be appreciated that daily doses other than those described above may be administered to a subject, as appreciated by an attending physician.

The following examples are intended to illustrate the invention, and are not to be construed as limiting the scope of the invention. For the purposes of the examples, the phrase "(5)6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole" refers to a co-crystallized mixture of 5-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole and 6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole.

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## EXAMPLE 1

## Preparation of Pure 6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole

Approximately 850 mL of methanol was placed in a 1 liter glass bottle with a screw cap. The solution was saturated by dissolving approximately 10.5 grams of (5)6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole, and the resulting solution was stirred. Once the solution was saturated, an additional 17 grams of (5)6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole was added to the saturated solution to create a suspension. The cap was sealed and the saturated suspension was allowed to stir and equilibrate for about four days.

After four days, the suspension was filtered through a paper filter and then washed with a small amount of methanol. The supernatant was returned to the 1 liter glass bottle and an additional 10 grams of (5)6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole was added to the saturated solution. The procedure was repeated to create an additional sample. All samples were shown to be pure 6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole by X-ray powder diffraction.

## EXAMPLE 2

## Preparation of Essentially Pure (5)6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole

To a 50 mL beaker was added about 1 g of (5)6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole to 30 mL of dimethylformamide (DMF). Additional (5)6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole was added to the resulting solution until a suspension of the material was formed. The solution was stirred for approximately 10 minutes, and then filtered through a 0.45  $\mu$ m Poly (tetrafluoroethylene) (PTFE) or Nylon filter. The resulting saturated solution was placed in a shallow petrie dish, covered and stored under refrigerated conditions (approximately 5° C.) until crystals formed (between 4–6 days). The identity of the title compound was confirmed by single crystal x-ray diffraction, and shown to contain about 97 percent (w/w) of the 6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole and about 3 percent (w/w) of 5-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole.

## EXAMPLE 3

## Preparation of (5)6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole

The procedure set forth in Example 2 is repeated except that ethanol is employed as a solvent in place of DMF and the resulting structure was shown by various X-ray crystal diffraction to contain 83 percent (w/w) of 6-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole and 17 percent (w/w) of 5-methoxy 2-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole.

## EXAMPLE 4

## Preparation of 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole Isomers

To a 50 mL beaker was added about 1 g of 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-

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1H-benzimidazole to 30 mL of DMF. Additional 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole was added to the resulting solution until a suspension of the material was formed. The solution was stirred for approximately 10 minutes, and then filtered through a 0.45  $\mu$ m PTFE or Nylon filter. The resulting saturated solution was placed in a shallow petrie dish, covered, and stored at ambient temperature until crystals formed (between 1–2 days). The identity of the title compound was confirmed by single crystal x-ray diffraction. The resulting structure was determined to contain about 93 percent (w/w) of the 6-methoxy isomer and about 7 percent (w/w) of the 5-methoxy isomer.

## EXAMPLE 5

## Preparation of 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole Isomers

To a 50 mL beaker was added about 1 g of 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole to 30 mL of methylene chloride. Additional 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole was added to the resulting solution until a suspension of the material was formed. The solution was stirred for approximately 10 minutes, and then filtered through a 0.45  $\mu$ m PTFE or Nylon filter. The resulting saturated solution was placed in a beaker, covered, and stored under refrigerated conditions (approximately 5° C.) until crystals formed (between 1–2 days). The identity of the title compound was confirmed by single crystal x-ray diffraction. The resulting structure was determined to contain about 88 percent (w/w) of the 6-methoxy isomer and about 12 percent (w/w) of the 5-methoxy isomer.

## EXAMPLE 6

## Preparation of 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole Isomers

To a 50 mL beaker was added about 1 g of 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole to 25 mL of acetone. Additional 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole was added to the resulting solution until a suspension of the material was formed. The solution was stirred for approximately 5 minutes, and then filtered through a 0.45  $\mu$ m PTFE or Nylon filter. The resulting saturated solution was placed in a 50 mL beaker, covered, and stored at ambient temperature until crystals formed (between 1–2 days). The identity of the title compound was confirmed by single crystal x-ray diffraction. The resulting structure was determined to contain about 86 percent (w/w) of the 6-methoxy isomer and about 14 percent (w/w) of the 5-methoxy isomer.

## EXAMPLE 7

## Preparation of 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole Isomers

The procedure set forth in Example 6 is repeated except that an ACN/water mixture was used as a solvent in place of acetone. A similar composition of 5- and 6-methoxy isomers resulted.

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## EXAMPLE 8

Preparation of 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole Isomers

The procedure set forth in Example 6 is repeated except that ACN was used as a solvent in place of acetone. A similar composition of 5- and 6-methoxy isomers resulted.

## EXAMPLE 9

Preparation of (5)6-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole Isomers

To a 400 mL beaker was added about 5 g of (5)6-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole to 200 mL of ethanol. 1.0 mL of ammonium hydroxide was added to this solution and additional 5(6)-methoxy-[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole was added to the resulting solution until a suspension of the material was formed. The solution was stirred for about 10 minutes, then filtered through a 0.45  $\mu$ m PTFE or Nylon filter. The resulting saturated solution was placed in two separate drying vessels, and stored in a fume hood at ambient temperature until crystals formed (between 1–12 hours). The identity of the title compound was confirmed by single crystal x-ray diffraction. The resulting structure was determined to contain about 82 percent (w/w) of the 6-methoxy isomer and about 18 percent (w/w) of the 5-methoxy isomer.

## EXAMPLE 10

Preparation of (5)6-methoxy-2[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole

(5)6-methoxy-2[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole (16.2 g; 0.0492 mol)] is reacted with m-chlorobenzoic acid (13.6 g; 0.0537 mol) with  $\text{CH}_2\text{Cl}_2$  acting as a solvent at a pH of 8.6. The pH is maintained by the presence of  $\text{KHCO}_3$  (5.6 g; 0.056 mol) acting as a buffer. The temperature is maintained at about 0° C. during the addition. Diluted NaOH is added to a pH above 12 and the  $\text{CH}_2\text{Cl}_2$  phase is separated off. Dimethylformamide (4.7 g) is charged to the water phase and the pH is kept above 9, whereupon a mixture of (5)6-methoxy-2[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole is formed. The crystals are filtered off and are washed with water and methanol at a temperature of about 0° C. The washed crystals are then dried under vacuum and are found to predominantly contain 6-methoxy-2[(4-methoxy-3,5-dimethyl-2-pyridinyl)-methylsulfinyl]-1H-benzimidazole.

## EXAMPLE 11

Preparation of the Sodium Salt of 6-methoxy-2-[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole

To a stirring suspension of 10 g (29 mmol) of (5)6-methoxy-2-[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole in 200 mL of methyl ethyl ketone (MEK) in a 1 L flask was added at ambient temperature 6 mL of a 5 M aqueous sodium hydroxide solution. To that mixture was added 200 mL of toluene. After approximately 7 minutes, the mixture became a clear solution.

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Approximately 2 minutes after that, the mixture became turbid again. This mixture was allowed to stir at ambient temperature overnight. The following morning, several crystals of 6-methoxy-2-[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole sodium salt were added to act as seed crystals. Within a few minutes the product began to precipitate. After approximately 1 hour, the product was isolated by vacuum filtration through filter paper on a ceramic Buchner funnel and rinsed with 25 mL of diethyl ether. The resulting solids were allowed to air-dry for 24 hours.

## EXAMPLE 12

Preparation of the Sodium Salt of 6-methoxy-2-[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole

To a flask containing 20 mL of methanol was slowly added with stirring 580 mg (14.48 mmol) of 60% sodium hydride dispersed in mineral oil. The resulting cloudy mixture was vacuum filtered through a glass-fiber filter paper to yield a clear solution. To this clear solution was added with stirring 5 g (14.48 mmol) of 6-methoxy-2-[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole. After approximately 5 minutes of stirring, the solution became clear. The stirring was stopped, the flask was covered and set aside. After approximately 5 minutes, crystals began to form. The mixture was placed in a 5° C. refrigerator overnight. The next day, the solids were isolated by vacuum filtration to give approximately 5 g of the desired product as a white, crystalline powder.

## EXAMPLE 13

Preparation of the Sodium Salt of 6-methoxy-2-[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole

To a stirring solution of 5 g (14.48 mmol) of (5)6-methoxy-2-[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole in 50 mL of dimethyl formamide (DMF) in a 100 mL beaker was slowly added at ambient temperature 580 mg (14.48 mmol) of 60% sodium hydride dispersed in mineral oil. Once all the sodium hydride was added, the mixture was allowed to stir for an additional 10 minutes. The solution was vacuum filtered through filter paper on a ceramic Buchner funnel. A 20 mL portion of the resulting solution was placed in a 250 mL round-bottom flask, diluted with 50 mL of toluene and concentrated under reduced pressure at 20° C. (2 times), followed by 50 mL of tetrahydrofuran (1 time). The resulting solids were dried 18 hours at ambient temperature in vacuo to yield the desired product as an off-white, crystalline powder. The powder was recrystallized from methanol by placing a filtered, saturated solution into the 5° C. refrigerator for several days, until crystals were present.

## EXAMPLE 14

Preparation of the Sodium Salt of 6-methoxy-2-[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole

To a stirring suspension of 5 g (14.48 mmol) of (5)6-methoxy-2-[[[(4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole in 50 mL of tetrahydrofuran (THF) in a 100 mL beaker was slowly added at ambient temperature 580 mg (14.48 mmol) of 60% sodium hydride

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dispersed in mineral oil. Once all the sodium hydride was added, the mixture was allowed to stir for an additional 20 minutes. The solids were isolated by vacuum filtration through filter paper on a ceramic Buchner funnel and rinsed with a small amount of THF. The solids were dried 18 hours at ambient temperature in vacuo to yield 4.8 g (90%) of the desired product as an off-white, crystalline powder. The powder was recrystallized from 1:1 methanol:ethyl acetate by placing a filtered, saturated solution into the 5° C. refrigerator for several days, until crystals were present.

## EXAMPLE 15

Preparation of the Sodium Salt of (–)(5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole

To a stirring solution of 1.5 g (4.33 mmol) of (–)(5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole in 15 mL of tetrahydrofuran (THF) in a 50 mL beaker was slowly added at ambient temperature 173 mg of 60% sodium hydride dispersed in mineral oil. Once all the sodium hydride was added, the mixture was allowed to stir for 45 minutes at ambient temperature. An additional 15 mL of THF was added to the mixture and was allowed to stir for an additional 20 minutes. The precipitated solids were isolated by vacuum filtration through filter paper on a ceramic Buchner funnel, rinsed with 40 mL of the THF and dried 18 hours at ambient temperature in vacuo to yield 1.3 g (81 percent) of the desired product of an off-white powder.

## EXAMPLE 16

Preparation of (+)(5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole Sodium Salt

To a stirring suspension of 650 mg (1.89 mmol) of (+)(5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole in 6.5 mL of methyl ethyl ketone (MEK) in a 50 mL flask was added at ambient temperature 0.39 mL of a 5 M aqueous sodium hydroxide solution. To that mixture was added 13 mL of water. The resulting mixture was turbid, so an additional 6.5 mL of MEK was added and the mixture became a clear, yellow solution. This mixture was allowed to stir at ambient temperature overnight. The following morning, several crystals of 6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole sodium salt were added to act as seed crystals, but no product crystals formed. A stream of dry nitrogen gas was blown over the mixture to begin removing the solvent. After approximately 10 minutes, the product precipitated. The solids were isolated by vacuum filtration and washed with a small amount of diethyl ether. The solids were then placed into a vacuum desiccator to remove the last traces of ether, to yield approximately 500 mg of the desired product as an off-white powder.

## EXAMPLE 17

Preparation of (5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole Magnesium Salt Tetrahydrate

1.65 g of 6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole sodium salt was dissolved in 30 mL of water. To the stirring solution was

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added 0.47 g of magnesium chloride dissolved in 20 mL of water. Immediately upon the addition of the magnesium chloride solution a white powder precipitated. The suspension was allowed to stir for 5 minutes, and then the product was isolated by vacuum filtration. The solids were then placed into a vacuum desiccator overnight to give the desired product as a white powder. A small portion of the powder was dissolved in methanol at about 75 mg/mL, filtered and diluted with an equal volume of water. This solution was partially covered and set aside to slowly evaporate. After approximately 5 days, crystals were isolated, analyzed by single crystal x-ray diffraction and shown to be the desired product.

## EXAMPLE 18

Preparation of a Mixture of the (–) Enantiomers of (5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole

(5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]thio]-1H-benzimidazole (4.0 g, 12.1 mmol) is suspended in toluene (12 mL). (–) Diethyl D-tartrate (0.17 mL, 1.0 mmol) and titanium(IV) isopropoxide (0.15 mL, 0.50 mmol) are added with stirring at 50° C. The mixture is stirred at 50° C. for 50 minutes and then N,N-diisopropylethylamine (0.085 mL, 0.50 mmol) is added at ca. 30° C. Then, cumene hydroperoxide (83%, 2.1 mL, 11.9 mmol) is added and the mixture is stirred for 15 minutes at 30° C. The resulting mixture contains the (–) enantiomers of (5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole.

## EXAMPLE 19

Preparation of a Mixture of the (+) Enantiomers of (5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole

(+) Diethyl L-tartrate (1.71 mL, 10 mmol) and titanium(IV) isopropoxide (1.5 mL, 5 mmol) are dissolved in methylene chloride (50 mL). Water (90  $\mu$ L, 5 mmol) is added with stirring and the resultant mixture is heated to reflux for one hour. The mixture is cooled to room temperature. Thereafter, (5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]thiol]-1H-benzimidazole (1.65 g, 5 mmol) and cumene hydroperoxide (80%, 1.5 g, 5.5 mmol) are added at room temperature. The solution is stirred at room temperature for 90 minutes. The final product provides (5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazoles.

## EXAMPLE 20

Preparation of (–)(5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole Magnesium Salt

To a nitrogen-purged flask containing 50 mL of methanol was added with stirring 0.11 g (4.5 mmol) of magnesium metal, followed by a catalytic amount (~0.5 mL) of methylene chloride. This mixture was heated to 40° C. for 5 hours, then removed from the heat and allowed to cool to ambient temperature. To the cloudy, stirring solution was added approximately 2 g of (–)(5)6-methoxy-2-[[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole. The flask was purged well with nitrogen, sealed and allowed to stir at ambient temperature overnight. Approximately 0.1 mL of water was then added to the

reaction mixture and allowed to stir for 30 minutes to precipitate inorganic magnesium salts. The mixture was then vacuum filtered, and the filtrate reduced to approximately 20% of the original volume under reduced pressure. To that resulting solution was added with stirring 100 mL of acetone. After approximately 5 minutes of stirring, a precipitate began to form. The mixture was allowed to stir for an additional 30 minutes. The solids were isolated by vacuum filtration and washed with some fresh acetone. The solids were allowed to air dry to yield 640 mg of the desired product.

EXAMPLE 21-29

Preparation of 6-methoxy-2-[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole from Mixtures of 5- and 6-methoxy Benzimidazoles

Compositions which are formed in Examples 3-10 are subjected to the procedure set forth in Example 1. Pure 6-methoxy compounds were thereafter obtained from this procedure.

EXAMPLE 30-33

Preparation of 6-methoxy-2-[[4-methoxy-3,5-dimethyl-2-pyridinyl)methyl]sulfinyl]-1H-benzimidazole from Mixtures of 5- and 6-methoxy Benzimidazoles

Compositions which are formed in Examples 15-17 and 20 are subjected to the procedure set forth in Example 1. Pure salts of the 6-methoxy compounds were thereafter obtained from this procedure.

EXAMPLE 34

Determination of Percentage of Co-Crystallized 5- and 6-methoxy-2-[[4-methoxy-3,5-dimethyl-2-pyridinyl)-methyl-sulfinyl]-1H Benzimidazole Isomers

Typically, a single Crystal X-Ray Diffraction was used to determine the percentage of 5- and 6-methoxy-2-[[4-methoxy-3,5-dimethyl-2-pyridinyl)-methyl-sulfinyl]-1H-benzimidazole isomers in an API. Without being bound to theory, it is believed that a crystalline material diffracts X-rays due to the constructive and destructive interference of the scatter of X-rays from the atoms of the molecule within the crystal lattice. The intensity and positions of the diffraction spots produced by the crystal is capable of generating structural information about the locations of the atoms in the molecule of a crystal.

In this instance, a single crystal of the material to be examined is mounted at the end of a glass fiber. The crystal is aligned in the diffractometer in a specific orientation. The diffraction spots are measured, then the crystal is rotated to the next position. The above sequence is then repeated until thousands of individual diffraction spots are measured and recorded. The diffraction spots are then analyzed and the data phased to generate an electron density map from which a molecular structure of the molecule is uniquely determined. The X-ray diffraction data is generated using either a Nonius CAD4 diffractometer or a Nonius Kappa CCD diffractometer made commercially available by Nonius Corporation of Delft, Netherlands. The diffraction data generated for the various batches of omeprazole API tested shows the molecular structure of the drug present. It was deter-

mined from the data that the crystal lattice contained various degrees of disorder of the 6 and 5-methoxy isomers within the API. The two isomers were found to co-crystallize within a single crystal lattice. This co-crystallization within the single lattice is believed to cause a distortion of the six independent unit cell parameters in relation to the amount of each isomer present. The exact amount of 5-methoxy isomer present was determined by a least-squares minimization of the data. A linear regression analysis of the cell constants to the percentage of the 5-methoxy isomer present demonstrated good correlation coefficients.

In this example, the compounds were found to contain predominantly two diastereomers, namely the S-S and R-R derivatives. Such proposed behavior was not expected, since the manner in which the compounds were synthesized is believed to be non-discriminatory towards selection of the S or R chiral plane with the corresponding S or R chiral center. Although not intending to be bound by theory, structural analysis reveals that the 5- and 6-methoxy isomers crystallize through a center of inversion and are linked by hydrogen bonding from the amine hydrogens to the sulfoxide oxygens. The methoxy methyls are believed to be directed towards the center of the bridged complex. Again not being bound by theory, examination of the contact distances in the region where the other methoxy methyl may reside reveals that there may not be adequate space within the lattice for the other diastereomer (S-R and R-S) to co-exist. The oxygen atom of the methoxy is observed to sit only about 3.6 Å from 4 other non-hydrogen atoms and 3.2 Å from 2 hydrogen atoms of an adjoining molecule of omeprazole. Normal Van DerWaals contact distances are typically about 3.7 Å for non-hydrogen atoms.

Enteric Coated Tablet  
A formulation employing an active ingredient is made according to the following recipe:

	g
<u>Core Material</u>	
Active Ingredient	225
Mannitol	1425
Hydroxypropyl cellulose	60
Microcrystalline cellulose	40
Anhydrous lactose	80
Sodium lauryl sulfate	5
Dibasic sodium phosphate dihydrate	8
Purified water	350
<u>Separating Layer</u>	
Core material	300
Hydroxypropyl cellulose	30
Talc	51
Magnesium stearate	4
Water	600
<u>Enteric Coating Layer</u>	
Pellets covered with separating layer	279
Methacrylic acid copolymer	140
Triethyl citrate	42
Mono- and diglycerides	7
Polysorbate 80	0.7
Water	300
<u>Tablets</u>	
Enteric coating layered pellets	352
Microcrystalline cellulose	1,052
Sodium Stearyl fumarate	3

Sodium lauryl sulfate is dissolved in purified water to form a granulation liquid. The active ingredient along with

the other dry ingredients used in making the core are dry mixed. The granulation liquid is added to the powder mixture and the resulting mass is kneaded and granulated to a proper consistency.

The wet mass is forced through an extruder equipped with screens. The extrudate is spheronized in a spheronizing apparatus. The core material is dried in a fluid bed dryer and classified into a suitable particle range. The prepared core material is covered with a separating layer in a fluid bed apparatus with a hydroxypropyl methylcellulose solution containing talc and magnesium stearate.

The enteric coating layer is sprayed onto the pellets covered with the separating layer from an aqueous dispersion of methacrylic acid copolymer, mono- and diglycerides, triethyl citrate, and polysorbate in a fluid bed apparatus.

Enteric coating layered pellets, microcrystalline cellulose and sodium stearyl fumarate are mixed and compressed into tablets using a rotary tableting machine.

Tablet	
A tablet is formed from the following ingredients:	
Ingredient	g
active ingredient	400-430
lactose, anhydrous	1,400-1,420
polyvinylpyrrolidone	100
sodium carbonate, anhydrous	15
methyl cellulose	12
distilled water	200
magnesium stearate	30

The active ingredient, lactose, polyvinylpyrrolidone, and sodium carbonate are homogenized and granulated by the addition of the methyl cellulose and distilled water. The wet mass is dried in a fluidized bed drier using an inlet air temperature of +50° C. for 30 minutes. The dried mixture is then forced through a sieve with an aperture of 0.5 mm. After mixing with magnesium stearate, the granulate is tableted on a tableting machine using 6 mm punches. The tablet weight is 100 mg. The tablet may optionally be coated with the separating layer and/or enteric coating as described in Example 35.

EXAMPLE37

Capsule

Capsule	
A capsule containing 30 mg of the active ingredient is prepared from the following ingredients:	
Ingredient	g
active ingredient	300
lactose	700
microcrystalline cellulose	40
hydroxypropyl cellulose, low-substituted	62
disodium hydrogen phosphate	2
purified water	q.s.

The active compound is mixed with the dry ingredients and granulated with a solution of disodium hydrogen phosphate. The wet mass is forced through an extruder and spheronized and dried in a fluidized bed drier. The resulting pellets are filled into capsules. Prior to being filled into capsules, the pellets may optionally be coated with the separating layer and/or enteric coating as described in Example 36.

The examples and embodiments as set forth in the detailed description are for illustrative purposes only and do not limit the scope of the invention.

That which is claimed:

1. 6-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole in pure form in a solid state, or pharmaceutically acceptable salts, hydrates, or combinations thereof.
2. A pharmaceutical formulation comprising a non-toxic amount of a compound according to claim 1 and at least one pharmaceutically acceptable carrier, diluent, excipient, or combination thereof.
3. A method of treating gastric acid related diseases in mammals comprising administering to a mammal in need of treatment a therapeutically effective amount of the pharmaceutical formulation according to claim 2.
4. 6-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole essentially free of 5-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole, or pharmaceutically acceptable salts, hydrates, or combinations thereof, wherein the 6-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole and the 5-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole co-crystallize in the same crystalline lattice.
5. A pharmaceutical formulation comprising a non-toxic amount of a compound according to claim 4 and at least one pharmaceutically acceptable carrier, diluent, excipient, or combination thereof.
6. A method of treating gastric acid related diseases in mammals comprising administering to a mammal in need of treatment a therapeutically effective amount of the pharmaceutical formulation according to claim 5.
7. A composition comprising 6-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole and 5-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole or pharmaceutically acceptable salts, hydrates, or combinations thereof, wherein the 6-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole is present in said composition in an amount from about 96% to about 100% (w/w) and wherein the 6-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole and the 5-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole co-crystallize in the same crystalline lattice.
8. A pharmaceutical formulation comprising a non-toxic amount of a compound according to claim 7 and at least one pharmaceutically acceptable carrier, diluent, excipient, or combination thereof.
9. A method of treating gastric acid related diseases in mammals comprising administering to a mammal in need of treatment a therapeutically effective amount of the pharmaceutical formulation according to claim 8.
10. A composition comprising 6-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole and 5-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole or pharmaceutically acceptable salts, hydrates, or combinations thereof, wherein the 5-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole is present in said composition in an amount greater than 18% (w/w) and wherein the 6-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole and the 5-methoxy-2-{{(4-methoxy-3,5-dimethyl(2-pyridyl))methyl}sulfinyl} benzimidazole co-crystallize in the same crystalline lattice.
11. A pharmaceutical formulation comprising a non-toxic amount of a compound according to claim 10 and at least

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one pharmaceutically acceptable carrier, diluent, excipient, or combination thereof.

12. A method of treating gastric acid related diseases in mammals comprising administering to a mammal in need of

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treatment a therapeutically effective amount of the pharmaceutical formulation according to claim 11.

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