

DESCRIPTION**CYCLIC AMINE COMPOUNDS****Technical Field**

The present invention relates to a cyclic amine compound
5 useful as an androgen receptor modulator and the like.

Background of the Invention

Androgen is synthesized in the testis and adrenal cortex,
bound to an androgen receptor in a target organ, and shows
various physiological activities. Chemically, any natural
10 androgen belongs to C19 steroid. The major androgen among them
is testosterone mainly synthesized in the testis, uptaken in a
target cell and shows strong physiological activity. In female,
adrenal cortex is a major androgen supply source.

Androgen is involved in the growth and function
15 maintenance of genital organ (prostate, vesicular gland,
epididymis, vas deferens etc.), sex differentiation in the
embryonic stage, spermatozoon formation, expression of secondary
sexual characteristics (induction of masculinization, for
example, muscle-skeleton, voice, fat distribution etc., and the
20 like), promotion of protein elaboration in muscle and the like,
bone metabolism and the like. Therefore, shortage of androgen
due to testis dysfunction, castration and the like results in
insufficient actions mentioned above, thus leading to various
diseases and degraded QOL (quality of life). To deal with the
25 situation, an androgen replacement therapy is generally employed.
Besides testosterone, synthetic androgen showing different
balance of androgenic action has been studied and put to
practical use in clinical situations.

On the other hand, when androgen is involved in the
30 progression of pathology, an androgen deprivation therapy is
employed. For example, in androgen dependent prostate cancer,
castration and administration of GnRH agonist decrease
testosterone and increase a treatment effect.

For androgen replacement therapy, testosterone and
35 synthetic androgen are generally used. However, they have a

steroid skeleton, which places much burden on the liver or shows other steroid hormone action. Therefore, an androgen receptor modulator (particularly agonist) having a non-steroidal skeleton is considered to be useful for the improvement of pathology
5 caused by insufficient androgen action (hypogonadism, male climacteric disorder and the like) and pathology expected to show improvement by the action of androgen (osteoporosis and the like).

It is known that a naphthalene derivative having a
10 pyrrolidine ring has a superior androgen receptor modulator action (WO 2004/16576). However, this reference does not disclose a pyrrolidinobenzene derivative having a substituent at the 3-position of pyrrolidine ring.

While a benzene derivative having a pyrrolidine ring,
15 which shows an anti-androgen action (JP 2002-88073 A and WO 2005/090282), and a benzene derivative having a pyrrolidine ring, which is used for osteoporosis and the like (WO 2005/108351) are known, a compound having a substituent at the 3-position of a pyrrolidine ring is not disclosed.

20 **Disclosure of the Invention**

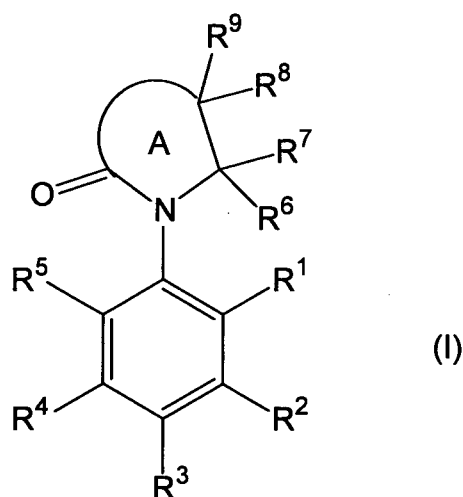
Problems to be Solved by the Invention

The present invention aims to provide a compound having a more superior androgen receptor modulating action.

Means of Solving the Problems

25 The present inventors have conducted intensive studies in view of the aforementioned problems and found that a cyclic aminobenzene compound represented by the formula (I) unexpectedly has a superior androgen receptor modulating action, which resulted in the completion of the present invention.

30 Accordingly, the present invention relates to [1] a compound represented by the formula (I)



wherein

R^1 is a hydrogen atom, a halogen atom, a group via a carbon atom, a group via a nitrogen atom, a group via an oxygen atom or a group via a sulfur atom;

R^2 is a hydrogen atom, a halogen atom, a group via a carbon atom, a group via a nitrogen atom, a group via an oxygen atom or a group via a sulfur atom;

R^3 is an electron-withdrawing group;

R^4 is a hydrogen atom, a halogen atom, a group via a carbon atom, a group via a nitrogen atom, a group via an oxygen atom or a group via a sulfur atom;

R^5 is a hydrogen atom, a halogen atom, a group via a carbon atom, a group via a nitrogen atom, a group via an oxygen atom or a group via a sulfur atom;

R^6 is a hydrogen atom, a halogen atom, a group via a carbon atom, a group via a nitrogen atom, a group via an oxygen atom or a group via a sulfur atom;

R^7 is an alkyl group optionally having substituent(s) or an aralkyl group optionally having substituent(s);

R^8 is a hydrogen atom, an alkyl group optionally having substituent(s), an alkenyl group optionally having substituent(s) or a cycloalkyl group optionally having substituent(s);

R^9 is a group via an oxygen atom; and

Ring A is a 5- or 6-membered ring optionally further having substituent(s) (in this case, Ring A may be a 5- or 6-membered ring forming a spiro bond with C₃₋₆ cycloalkane), or a salt thereof;

5 [2] the compound of the above-mentioned [1], wherein Ring A is a pyrrolidine ring optionally further having substituent(s) or a piperidine ring optionally further having substituent(s) (the pyrrolidine ring and piperidine ring optionally form a spiro bond with C₃₋₆ cycloalkane);

10 [3] the compound of the above-mentioned [1], wherein R¹ is a hydrogen atom, a halogen atom or a lower alkyl group optionally having substituent(s);

R² is a halogen atom, a lower alkyl group optionally having substituent(s) or a lower alkoxy group optionally having

15 substituent(s);

R³ is a cyano group;

R⁴ is a hydrogen atom or a halogen atom;

R⁵ is a hydrogen atom;

R⁶ is a hydrogen atom;

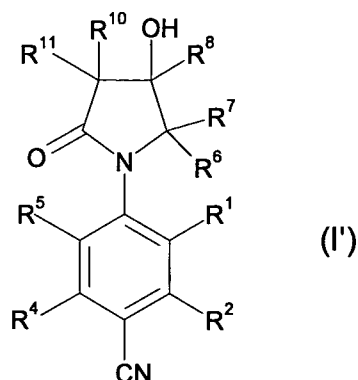
20 R⁷ is a lower alkyl group optionally having substituent(s) or an aralkyl group optionally having substituent(s);

R⁸ is a hydrogen atom, a lower alkyl group optionally having substituent(s) or a C₃₋₆ cycloalkyl group optionally having substituent(s);

25 R⁹ is a hydroxy group; and

Ring A is a 5-membered ring (pyrrolidine ring) which optionally has 1 or 2 substituents selected from a halogen atom, a lower alkyl group optionally having a hydroxy group, a lower alkenyl group and an aralkyl group, or a 5-membered ring (pyrrolidine
30 ring) forming a spiro bond with C₃₋₆ cycloalkane;

[4] the compound of the above-mentioned [1], wherein the formula (I) is the formula (I')



wherein

R¹ is a hydrogen atom, a halogen atom or a lower alkyl group optionally having substituent(s);

5 R² is a halogen atom, a lower alkyl group optionally having halogen atom(s) or a lower alkoxy group optionally having halogen atom(s);

R⁴ is a hydrogen atom or a halogen atom;

R⁵ and R⁶ are each a hydrogen atom;

10 R⁷ is a lower alkyl group optionally having substituent(s) or an aralkyl group optionally having substituent(s);

R⁸ is a hydrogen atom, a lower alkyl group optionally having substituent(s) or a C₃₋₆ cycloalkyl group optionally having substituent(s); and

15 R¹⁰ and R¹¹ are the same or different and each is a hydrogen atom, a halogen atom, a lower alkyl group optionally having a hydroxy group, a lower alkenyl group or an aralkyl group;

in this case, R¹⁰ and R¹¹ may form C₃₋₆ cycloalkane together with the adjacent carbon atom;

20 [5] the compound of the above-mentioned [4], wherein R¹ is a hydrogen atom, a halogen atom or a lower alkyl group;

R² is a halogen atom, a lower alkyl group optionally having halogen atom(s) or a lower alkoxy group optionally having halogen atom(s);

25 R⁷ is a lower alkyl group optionally having substituent(s) selected from a hydroxy group, a lower alkoxy group and a C₃₋₆ cycloalkyl group, or an aralkyl group optionally having substituent(s) selected from a halogen atom and a cyano group;

R⁸ is a hydrogen atom, a lower alkyl group or a C₃₋₆ cycloalkyl group; and

R¹⁰ and R¹¹ are the same or different and each is a hydrogen atom, a halogen atom, a lower alkyl group, a lower alkenyl group, an aralkyl group, or a lower alkyl group substituted by a hydroxyl group (in this case, R¹⁰ and R¹¹ optionally form cyclopropane together with the adjacent carbon atom);

[6] 4-[(2S,3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile, or a salt thereof;

10 [7] 2-chloro-4-[(4S,5S)-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile, or a salt thereof;

[8] 4-[(4R,5S)-5-ethyl-3,3-difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]-2-methoxybenzonitrile, or a salt thereof;

[9] 2-chloro-4-[(2S,3S,4S)-2-ethyl-3-hydroxy-4-methyl-5-oxopyrrolidin-1-yl]benzonitrile, or a salt thereof;

[10] 2-chloro-4-[(4R,5S)-5-ethyl-3,3-difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]benzonitrile, or a salt thereof;

[11] 4-[(2S,3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile;

20 [12] 2-chloro-4-[(4S,5S)-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile;

[13] 4-[(4R,5S)-5-ethyl-3,3-difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]-2-methoxybenzonitrile;

[14] 2-chloro-4-[(2S,3S,4S)-2-ethyl-3-hydroxy-4-methyl-5-oxopyrrolidin-1-yl]benzonitrile;

25 [15] 2-chloro-4-[(4R,5S)-5-ethyl-3,3-difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]benzonitrile;

[16] a prodrug of the compound of the above-mentioned [1];

[17] a pharmaceutical agent comprising the compound of the above-mentioned [1] or a prodrug thereof;

[18] the pharmaceutical agent of the above-mentioned [17], which is an androgen receptor modulator;

[19] the pharmaceutical agent of the above-mentioned [17], which is an androgen receptor agonist;

[20] the pharmaceutical agent of the above-mentioned [17], which is a tissue-selective androgen receptor modulator;

[21] the pharmaceutical agent of the above-mentioned [17], which is an agent for the prophylaxis or treatment of hypogonadism, male climacteric disorder, frailty, cachexia or osteoporosis;

[22] the pharmaceutical agent of the above-mentioned [17], which is a frailty suppressant, a muscle strength enhancer, a muscle increasing agent, a cachexia suppressant, a body weight decrease suppressant, an agent for the prophylaxis or treatment of prostate hypertrophy, amyotrophy or muscle loss caused by a disease or an agent for reducing the prostate weight;

[23] a method for the prophylaxis or treatment of hypogonadism, male climacteric disorder, frailty, cachexia or osteoporosis in a mammal, which comprises administering an effective amount of the compound of the above-mentioned [1] or a prodrug thereof;

[24] use of the compound of the above-mentioned [1] or a prodrug thereof for the production of an agent for the prophylaxis or treatment of hypogonadism, male climacteric disorder, frailty, cachexia or osteoporosis;

and the like.

The definitions of the substituents of compound (I) are explained below.

Examples of the "halogen atom" for R^1 , R^2 , R^4 , R^5 or R^6 include a fluorine atom, a chlorine atom, a bromine atom and an iodine atom.

Examples of the "group via a carbon atom" for R^1 , R^2 , R^4 , R^5 or R^6 include cyano, a hydrocarbon group optionally having substituent(s), acyl, optionally esterified carboxyl, imidoyl optionally having substituent(s), amidino optionally having substituent(s), carbamoyl optionally having substituent(s), thiocarbamoyl optionally having substituent(s), a heterocyclic group via a carbon atom, which optionally has substituent(s) and the like.

Examples of the above-mentioned "hydrocarbon group optionally having substituent(s)" include alkyl optionally

having substituent(s), alkenyl optionally having substituent(s), alkynyl optionally having substituent(s), cycloalkyl optionally having substituent(s), aryl optionally having substituent(s), aralkyl optionally having substituent(s) and the like.

5 Examples of the "alkyl" of the above-mentioned "alkyl optionally having substituent(s)" include lower alkyl (e.g., methyl, ethyl, propyl, isopropyl, butyl, isobutyl, sec-butyl, tert-butyl, pentyl, hexyl etc.) and the like. The lower alkyl is alkyl having a carbon number of 1 to 6.

10 Examples of the substituent that the above-mentioned "alkyl optionally having substituent(s)" may have include

- (i) a halogen atom (e.g., fluorine atom, chlorine atom, bromine atom and iodine atom),
- (ii) C₁₋₆ alkoxy (e.g., methoxy, ethoxy, propoxy, isopropoxy,
- 15 butoxy, isobutoxy, sec-butoxy, tert-butoxy etc.),
- (iii) C₂₋₆ alkenyl (e.g., vinyl, allyl etc.),
- (iv) C₂₋₆ alkynyl (e.g., ethynyl, propargyl etc.),
- (v) amino,
- (vi) mono-C₁₋₆ alkylamino (e.g., methylamino, ethylamino,
- 20 propylamino etc.),
- (vii) di-C₁₋₆ alkylamino (e.g., dimethylamino, diethylamino, dipropylamino etc.),
- (viii) mono-C₁₋₆ alkyl-carbonylamino (e.g., acetylamino, ethylcarbonylamino etc.),
- 25 (ix) di(C₁₋₆ alkyl-carbonyl)amino (e.g., di(acetyl)amino, di(ethylcarbonyl)amino, di(propylcarbonyl)amino etc.),
- (x) hydroxy,
- (xi) cyano,
- (xii) amidino,
- 30 (xiii) carboxyl,
- (xiv) C₁₋₆ alkoxy-carbonyl (e.g., methoxycarbonyl, ethoxycarbonyl, propoxycarbonyl etc.),
- (xv) carbamoyl,
- (xvi) mono-C₁₋₆ alkyl-carbamoyl (e.g., methylcarbamoyl,
- 35 ethylcarbamoyl etc.)

(xvii) di-C₁₋₆ alkyl-carbamoyl (e.g., dimethylcarbamoyl, diethylcarbamoyl etc.),

(xviii) cyclic aminocarbonyl (e.g., 1-azetinyldicarbonyl, piperidinocarbonyl, morpholinocarbonyl etc.),

5 (xix) ureido,

(xx) C₁₋₆ alkyl-ureido (e.g., methylureido, ethylureido etc.),

(xxi) C₃₋₆ cycloalkyl (e.g., cyclopropyl etc.) and the like, and 1 to 3 substituents may be present at substitutable position(s).

Examples of the "alkenyl" of the above-mentioned "alkenyl
10 optionally having substituent(s)" include lower alkenyl (e.g., vinyl, allyl, 2-methylprop-2-en-1-yl etc.) and the like. The lower alkenyl is alkenyl having a carbon number of 2 to 6.

Examples of the substituent that the above-mentioned "alkenyl optionally having substituent(s)" may have include
15 those similar to the substituents that the above-mentioned "alkyl optionally having substituent(s)" may have, lower alkyl (e.g., methyl, ethyl, propyl, isopropyl, butyl, isobutyl, sec-butyl, tert-butyl, pentyl, hexyl etc.) and the like, and 1 to 3 substituents may be present at substitutable position(s).

20 Examples of the "alkynyl" of the above-mentioned "alkynyl optionally having substituent(s)" include lower alkynyl (e.g., ethynyl, propargyl etc.) and the like. The lower alkynyl is alkynyl having a carbon number of 2 to 6.

Examples of the substituent that the above-mentioned
25 "alkynyl optionally having substituent(s)" may have include those similar to the substituents that the above-mentioned "alkenyl optionally having substituent(s)" may have and the like, and 1 to 3 substituents may be present at substitutable position(s).

30 Examples of the "cycloalkyl" of the above-mentioned "cycloalkyl optionally having substituent(s)" include C₃₋₈ cycloalkyl (e.g., cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, cyclooctyl etc.) and the like.

Examples of the substituent which the above-mentioned
35 "cycloalkyl optionally having substituent(s)" may have include

those similar to the substituent which the above-mentioned "alkenyl optionally having substituent(s)" may have and the like, and 1 to 3 substituents may be present at substitutable position(s).

5 Examples of the "aryl" of the above-mentioned "optionally having substituent(s) aryl" include C₆₋₁₄ aryl (e.g., phenyl, naphthyl, anthryl etc.) and the like.

 Examples of the substituent that the above-mentioned "aryl optionally having substituent(s)" may have include those similar
10 to the substituents that the above-mentioned "alkenyl optionally having substituent(s)" may have and the like, and 1 to 3 substituents may be present at substitutable position(s).

 Examples of the "aralkyl" of the above-mentioned "aralkyl optionally having substituent(s)" include C₇₋₁₄ aralkyl (e.g.,
15 benzyl, phenylethyl, naphthylmethyl etc.) and the like.

 Examples of the substituent that the above-mentioned "aralkyl optionally having substituent(s)" may have include those similar to the substituents that the above-mentioned "alkenyl optionally having substituent(s)" may have and the like,
20 and 1 to 3 substituents may be present at substitutable position(s).

 Examples of the above-mentioned "acyl" include a group formed by binding the above-mentioned "hydrocarbon group optionally having substituent(s)" with carbonyl.

25 Examples of the above-mentioned "optionally esterified carboxyl" include carboxyl optionally esterified by the above-mentioned "hydrocarbon group optionally having substituent(s)".

 Examples of the above-mentioned "imidoyl optionally having substituent(s)" include imidoyl optionally having 1 or 2 from
30 the above-mentioned "hydrocarbon group optionally having substituent(s)".

 Examples of the above-mentioned "amidino optionally having substituent(s)" include amidino optionally having 1 to 3 from the above-mentioned "hydrocarbon group optionally having
35 substituent(s)".

Examples of the above-mentioned "carbamoyl optionally having substituent(s)" include carbamoyl optionally having 1 or 2 from the above-mentioned "hydrocarbon group optionally having substituent(s)".

5 Examples of the above-mentioned "thiocarbamoyl optionally having substituent(s)" include thiocarbamoyl optionally having 1 or 2 from the above-mentioned "hydrocarbon group optionally having substituent(s)".

As the "heterocyclic group via a carbon atom" of the
10 above-mentioned "heterocyclic group via a carbon atom, which optionally has substituent(s)", an aromatic heterocyclic group or a saturated or unsaturated non-aromatic heterocyclic group (aliphatic heterocyclic group), each containing, as a ring-constituting atom (ring atom) besides carbon atoms, at least one,
15 preferably 1 to 4, more preferably 1 or 2, hetero atoms of 1 to 3 kinds (preferably 1 or 2 kinds) selected from an oxygen atom, a sulfur atom, a nitrogen atom and the like, and having a bond at a carbon atom, and the like are used.

As the "aromatic heterocyclic group", for example, a 5- or
20 6-membered monocyclic aromatic heterocyclic group such as furyl, thienyl, pyrrolyl, oxazolyl, isoxazolyl, thiazolyl, isothiazolyl, imidazolyl, pyrazolyl, 1,2,3-oxadiazolyl, 1,2,4-oxadiazolyl, 1,3,4-oxadiazolyl, furazanyl, 1,2,3-thiadiazolyl, 1,2,4-thiadiazolyl, 1,3,4-thiadiazolyl, 1,2,3-triazolyl, 1,2,4-triazolyl,
25 triazolyl, tetrazolyl, pyridyl, pyridazinyl, pyrimidinyl, pyrazinyl, triazinyl and the like and, for example, a 8- to 12-membered condensed polycyclic aromatic heterocyclic group such as benzofuranyl, isobenzofuranyl, benzo[b]thienyl, indolyl, isoindolyl, 1H-indazolyl, benzimidazolyl, benzoxazolyl, 1,2-benzoisoxazolyl, benzothiazolyl, benzopyranyl, 1,2-benzoisothiazolyl, 1H-benzotriazolyl, quinolyl, isoquinolyl, cinnolinyl, quinazolinyl, quinoxalinyl, phthalazinyl, naphthyridinyl, purinyl, pteridinyl, carbazolyl, α -carbolinyl, β -carbolinyl, γ -carbolinyl, acridinyl, phenoxazinyl,
35 phenothiazinyl, phenazinyl, phenoxathiinyl, thianthrenyl,

phenanthridinyl, phenanthrolinyl, indolizinyl, pyrrolo[1,2-b]pyridazinyl, pyrazolo[1,5-a]pyridyl, imidazo[1,2-a]pyridyl, imidazo[1,5-a]pyridyl, imidazo[1,2-b]pyridazinyl, imidazo[1,2-a]pyrimidinyl, 1,2,4-triazolo[4,3-a]pyridyl, 1,2,4-triazolo[4,3-b]pyridazinyl and the like, and the like are used.

As the "non-aromatic heterocyclic group", for example, a 3- to 8-membered (preferably 5- or 6-membered) saturated or unsaturated (preferably saturated) non-aromatic heterocyclic group (aliphatic heterocyclic group) such as oxiranyl, azetidiny, oxetanyl, thietanyl, pyrrolidinyl, tetrahydrofuryl, thiolanyl, piperidyl, tetrahydropyranyl, morpholinyl, thiomorpholinyl, piperazinyl and the like, and the like, or a non-aromatic heterocyclic group wherein the double bond of the aforementioned monocyclic aromatic heterocyclic group or condensed polycyclic aromatic heterocyclic group is partly or entirely saturated such as 1,2,3,4-tetrahydroquinolyl, 1,2,3,4-tetrahydroisoquinolyl and the like, and the like are used.

Examples of the substituent that the above-mentioned "heterocyclic group via a carbon atom, which optionally has substituent(s)" may have include those similar to the substituents that the above-mentioned "alkenyl group optionally having substituent(s)" may have and the like, and 1 to 3 substituents may be present at substitutable position(s).

Examples of the "group via a nitrogen atom" for R^1 , R^2 , R^4 , R^5 or R^6 include (i) amino, (ii) amino mono-substituted by the above-mentioned "group via a carbon atom" and (iii) amino di-substituted by the above-mentioned "group via a carbon atom" and C_{1-6} alkyl (e.g., methyl, ethyl, propyl etc.) and the like.

Examples of the "group via an oxygen atom" for R^1 , R^2 , R^4 , R^5 , R^6 or R^9 include hydroxyl optionally substituted by the above-mentioned "group via a carbon atom" and the like.

Examples of the "group via a sulfur atom" for R^1 , R^2 , R^4 , R^5 or R^6 include thiol optionally substituted by the above-mentioned "group via a carbon atom" and the like. The thiol may be oxidized.

The "electron-withdrawing group" for R^3 generally means a group having a tendency to attract an electron from others based on hydrogen in a molecule, and is not particularly limited as long as it is used in organic chemistry. For example, cyano, 5 nitro, halogen atom (e.g., fluorine atom, chlorine atom, bromine atom, iodine atom), acyl (similar to the above-mentioned "acyl"), optionally esterified carboxyl (similar to the above-mentioned "optionally esterified carboxyl"), optionally substituted carbamoyl (similar to the above-mentioned "optionally substituted carbamoyl") or C_{1-6} alkyl substituted by 1 to 5 10 halogen atoms (e.g., fluoromethyl, chloromethyl, difluoromethyl, dichloromethyl, trifluoromethyl, trichloromethyl etc.) and the like can be mentioned.

Examples of the "alkyl group optionally having 15 substituent(s)" for R^7 or R^8 include those similar to the above-mentioned "alkyl optionally having substituent(s)".

Examples of the "aralkyl group optionally having substituent(s)" for R^7 include those similar to the above-mentioned "aralkyl optionally having substituent(s)".

20 Examples of the "alkenyl group optionally having substituent(s)" for R^8 include those similar to the above-mentioned "alkenyl optionally having substituent(s)".

Examples of the "cycloalkyl group optionally having substituent(s)" for R^8 include those similar to the above- 25 mentioned "cycloalkyl optionally having substituent(s)".

Ring A is a 5- or 6-membered ring optionally having substituent(s) besides R^6 to R^9 . Examples of Ring A include a pyrrolidine ring and a piperidine ring.

Examples of the substituent that Ring A may further have 30 include those similar to the substituents that the above-mentioned "alkenyl optionally having substituent(s)" may have, lower alkyl having hydroxy (e.g., hydroxymethyl, 1-hydroxy-1-methylethyl etc.), lower alkenyl (e.g., vinyl, allyl, 2-methylprop-2-en-1-yl etc.), C_{6-14} aryl (e.g., phenyl, naphthyl, 35 anthryl etc.), C_{7-14} aralkyl (e.g., benzyl, phenylethyl,

naphthylmethyl etc.) and the like, and 1 to 3 substituents may be present at substitutable position(s). In addition, Ring A optionally forms a spiro bond with C₃₋₆ cycloalkane (e.g., cyclopropane, cyclobutane, cyclohexane).

5 Preferred as R¹ is a hydrogen atom, a halogen atom or a lower alkyl group optionally having substituent(s). Of these, (i) a hydrogen atom, (ii) a halogen atom or (iii) a lower alkyl group is preferable. Particularly, (i) a hydrogen atom, (ii) a fluorine atom or (iii) methyl is preferable.

10 Preferred as R² is a halogen atom, a lower alkyl group optionally having substituent(s) or a lower alkoxy group optionally having substituent(s). Of these, a halogen atom, a lower alkyl group optionally having halogen atom(s) or a lower alkoxy group optionally having halogen atom(s) is preferable.
15 Particularly, a fluorine atom, a chlorine atom, methyl optionally having fluorine atom(s) (e.g., trifluoromethyl etc.) or methoxy is preferable.

Preferred as R³ is a cyano group.

Preferred as R⁴ is a hydrogen atom or a halogen atom. Of
20 these, a hydrogen atom or a fluorine atom is preferable.

Preferred as R⁵ is a hydrogen atom.

Preferred as R⁶ is a hydrogen atom.

Preferred as R⁷ is a lower alkyl group optionally having substituent(s) or an aralkyl group optionally having
25 substituent(s). Of these, a lower alkyl group optionally having substituent(s) selected from a lower alkoxy group, a hydroxy group and a C₃₋₆ cycloalkyl group, or an aralkyl group optionally having substituent(s) selected from a halogen atom and a cyano group is preferable. Particularly, (1) methyl optionally having
30 substituent(s) selected from methoxy, hydroxy and cyclopropyl, (2) ethyl, (3) n-propyl, (4) isopropyl, (5) isobutyl, or (6) benzyl optionally having substituent(s) selected from a fluorine atom and cyano is preferable.

Preferred as R⁸ is a hydrogen atom, a lower alkyl group
35 optionally having substituent(s) or a C₃₋₆ cycloalkyl group

optionally having substituent(s). Of these, a hydrogen atom, a lower alkyl group or a C₃₋₆ cycloalkyl group is preferable. Particularly, a hydrogen atom, methyl or cyclopropyl is preferable.

5 Preferred as R⁹ is a hydroxy group.

Preferred as Ring A is a 5-membered ring (pyrrolidine ring) which optionally further has, besides R⁶ to R⁹, 1 or 2 substituents selected from a halogen atom, a lower alkyl group optionally has a hydroxy group, a lower alkenyl group and an
10 aralkyl group, or a 5-membered ring (pyrrolidine ring) forming a spiro bond with C₃₋₆ cycloalkane. Of these, a 5-membered ring (pyrrolidine ring) which optionally has, besides R⁶ to R⁹, 1 or 2 substituents selected from a fluorine atom, methyl, ethyl, 1-hydroxy-1-methylethyl, isobutyl, 2-methylprop-2-en-1-yl and
15 benzyl or a 5-membered ring (pyrrolidine ring) forming a spiro bond with cyclopropane is preferable.

Preferred as compound (I) is a compound wherein

R¹ is a hydrogen atom, a halogen atom or a lower alkyl group optionally having substituent(s);

20 R² is a halogen atom, a lower alkyl group optionally having substituent(s) or a lower alkoxy group optionally having substituent(s);

R³ is a cyano group;

R⁴ is a hydrogen atom or a halogen atom;

25 R⁵ is a hydrogen atom;

R⁶ is a hydrogen atom;

R⁷ is a lower alkyl group optionally having substituent(s) or an aralkyl group optionally having substituent(s);

R⁸ is a hydrogen atom, a lower alkyl group optionally
30 having substituent(s) or a C₃₋₆ cycloalkyl group optionally having substituent(s);

R⁹ is a hydroxy group; and

Ring A is a 5-membered ring (pyrrolidine ring) which optionally has 1 or 2 substituents selected from a halogen atom,
35 a lower alkyl group optionally having a hydroxy group, a lower

alkenyl group and an aralkyl group, or a 5-membered ring (pyrrolidine ring) forming a spiro bond with C₃₋₆ cycloalkane.

Particularly, preferred is a compound wherein

R¹ is (i) a hydrogen atom, (ii) a halogen atom or (iii) a lower alkyl group;

R² is a halogen atom, a lower alkyl group optionally having halogen atom(s) or a lower alkoxy group optionally having halogen atom(s);

R³ is a cyano group;

R⁴ is a hydrogen atom or a halogen atom;

R⁵ is a hydrogen atom;

R⁶ is a hydrogen atom;

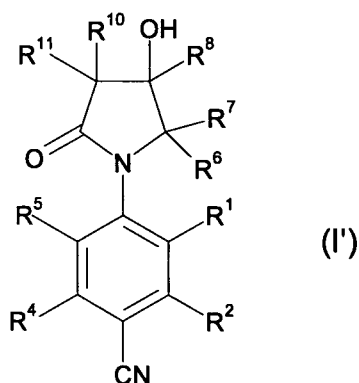
R⁷ is a lower alkyl group optionally having substituent(s) or an aralkyl group optionally having substituent(s);

R⁸ is a hydrogen atom, a lower alkyl group or a C₃₋₆ cycloalkyl group;

R⁹ is a hydroxy group; and

Ring A is preferably a 5-membered ring (pyrrolidine ring) which further optionally has, besides R⁶ to R⁹, 1 or 2 substituents selected from a halogen atom, a lower alkyl group optionally having a hydroxy group, a lower alkenyl group and an aralkyl group, or a 5-membered ring (pyrrolidine ring) forming a spiro bond with cyclopropane.

Furthermore, preferred is a compound of the formula (I')



wherein

R¹ is a hydrogen atom, a halogen atom or a lower alkyl group optionally having substituent(s);

R² is a halogen atom, a lower alkyl group optionally having halogen atom(s) or a lower alkoxy group optionally having halogen atom(s);

R⁴ is a hydrogen atom or a halogen atom;

5 R⁵ and R⁶ are each a hydrogen atom;

R⁷ is a lower alkyl group optionally having substituent(s) or an aralkyl group optionally having substituent(s);

R⁸ is a hydrogen atom, a lower alkyl group optionally having substituent(s) or a C₃₋₆ cycloalkyl group optionally having

10 substituent(s); and

R¹⁰ and R¹¹ are the same or different and each is a hydrogen atom, a halogen atom, a lower alkyl group optionally having a hydroxy group, a lower alkenyl group or an aralkyl group;

wherein R¹⁰ and R¹¹ may form C₃₋₆ cycloalkane together with the

15 adjacent carbon atom.

Preferred as compound (I') is a compound wherein

R¹ is a hydrogen atom, a halogen atom (e.g., fluorine atom) or a lower alkyl group (e.g., methyl);

R² is a halogen atom (e.g., fluorine atom, chlorine atom), a
20 lower alkyl group optionally having halogen atom(s) (e.g., trifluoromethyl) or a lower alkoxy group optionally having halogen atom(s) (e.g., methoxy);

R⁷ is a lower alkyl group (e.g., methyl, ethyl, n-propyl, isopropyl, isobutyl) optionally having substituent(s) selected
25 from a hydroxy group, a lower alkoxy group (e.g., methoxy) and a C₃₋₆ cycloalkyl group (e.g., cyclopropyl), or an aralkyl group (e.g., benzyl) optionally having substituent(s) selected from a halogen atom (e.g., fluorine atom) and a cyano group;

R⁸ is a hydrogen atom, a lower alkyl group (e.g., methyl) or a
30 C₃₋₆ cycloalkyl group (e.g., cyclopropyl); and

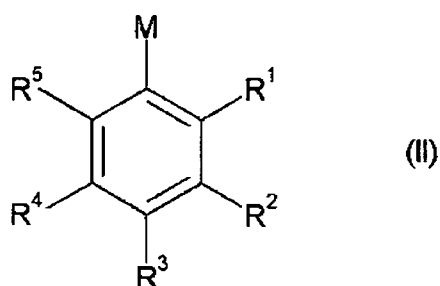
R¹⁰ and R¹¹ are the same or different and each is a hydrogen atom, a halogen atom (e.g., fluorine atom), a lower alkyl group (e.g., methyl, ethyl, isobutyl), a lower alkenyl group (e.g., 2-methylprop-2-en-1-yl etc.), an aralkyl group (e.g., benzyl), a
35 lower alkyl group substituted by a hydroxy group (e.g., 1-

hydroxy-1-methylethyl) (in this case, R¹⁰ and R¹¹ may form cyclopropane together with the adjacent carbon atom).

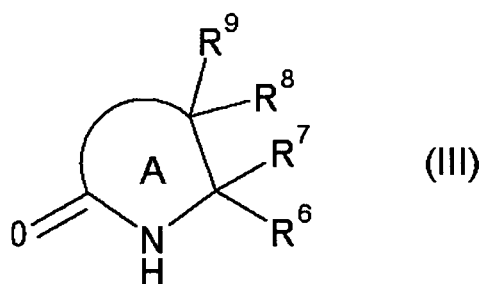
Preferred as compound (I) are more specifically the compounds described in the below-mentioned Examples 1 to 84 and
5 salts thereof.

The production methods of the compound (I) are described in the following. Compound (I) can be produced by a general organic synthesis method, or according to a known synthetic method (e.g., WO 2004-016576).

10 Compound (I) can be produced, for example, by reacting a compound represented by the formula (II)



wherein M is a leaving group, and the other symbols are as
15 defined above, with a compound represented by the formula (III)



wherein each symbol is as defined above, in the presence of a palladium catalyst and a suitable ligand, and removing a
20 protecting group when it is present.

Compounds (II) and (III) to be used as starting materials can be synthesized according to a known method or a method analogous thereto, for example, according to the methods shown in the Reference Examples below.

The above-mentioned compounds (II) and (III) also include salts thereof, and as such salts, those similar to the salts of compound (I) and the like are used. In addition, the groups in compounds (II) and (III) may be protected by protecting groups
5 used in general organic syntheses and, when desired, the protecting groups can be removed after reaction, according to known methods.

As the "leaving group" for M, for example, a halogen such as chlorine, bromine, iodine and the like,
10 trifluoromethanesulfonyloxy and the like can be used.

The compound (III) is generally used in an amount of 1 to 3 mol per 1 mol of compound (II). The reaction also proceeds smoothly by, where necessary, adding a base such as lithium carbonate, potassium carbonate, sodium carbonate, cesium
15 carbonate, sodium hydrogen carbonate, sodium hydroxide, sodium tert-butoxide, potassium tert-butoxide, triethylamine and the like.

As the palladium catalyst, palladium (II) acetate, tris(dibenzylideneacetone)dipalladium(0) and the like can be
20 used. Of these, tris(dibenzylideneacetone)dipalladium(0) is preferable.

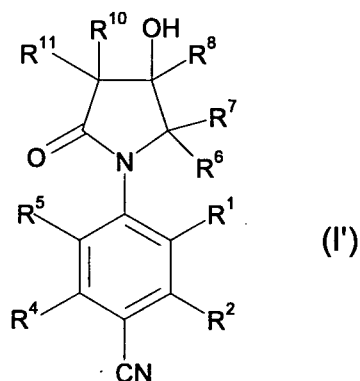
As the ligand to be used for the reaction, tris(ortho-tolyl)phosphine, BINAP, 1,1'-bis(diphenylphosphino)ferrocene, 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene and the like can
25 be used. Of these, 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene is preferable.

The reaction can be performed in an inert solvent, for example, tetrahydrofuran, diethyl ether, 1,2-dimethoxyethane, 1,4-dioxane, toluene, benzene, xylene, N,N-dimethylformamide
30 (DMF) etc., or a mixed solvent thereof. The reaction can be performed in a temperature range of about 0°C to 180°C. The reaction time is not particularly limited but it is generally 0.1 hr to 100 hr, preferably 0.5 hr to 72 hr.

Moreover, one or more substituents on Ring A in compound
35 (I) can be converted to other substituents. For example, it is

possible to reduce a carbonyl group to alcohol, lead alcohol to olefin by dehydration, or alkylate alcohol to ether according to a method known per se.

When compound (I) is a compound represented by the formula
5 (I')

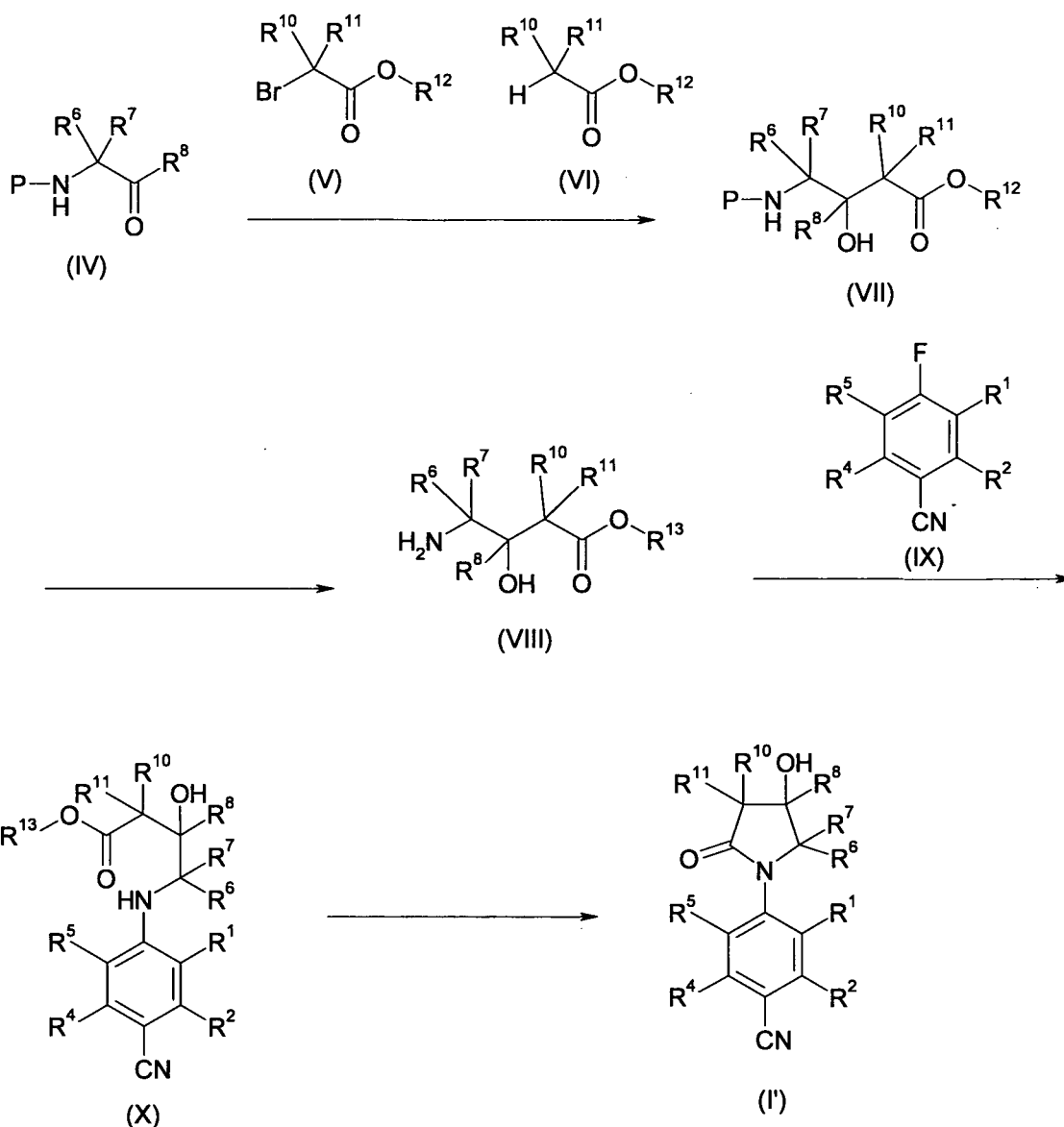


wherein each symbol is as defined above, compound (I') can be produced, for example, according to any of the following
10 synthetic methods 1 to 3, or a synthetic method analogous thereto.

Compounds (IV) to (XVI) in synthetic methods 1 to 3 also include salts thereof, and as such salts, those similar to the salts of compound (I) and the like are used. In addition, the
15 groups in compounds (IV) to (XVI) may be protected by protecting groups generally used for organic syntheses and, when desired, the protecting groups can be removed after reaction, according to known methods.

A simplified representation of reaction method 1 is shown
20 below.

(reaction method 1)



Compound (VII) wherein each symbol is as defined above can be synthesized according to a known synthetic method (e.g., J.R. Luly, et al., J. Org. Chem., 52, 1487-1492 (1987), A. Wyslouch, et al., Tetrahedron Asymmetry, 3, 1401-1410 (1992), S. Steurer, et al., Eur. J. Org. Chem., 1551-1560 (1999), D. Schirlin, et al., Tetrahedron, 52, 305-318 (1996)) or a method analogous thereto.

Compound (VII) can be produced by reacting compound (IV), wherein R⁶ to R⁸ are as defined above, and P is an amino-protecting group, with compound (V) or compound (VI) wherein R¹⁰ and R¹¹ are as defined above, and R¹² is lower alkyl such as tert-butyl and the like.

As the amino-protecting group for P, the protecting groups described in Theodora W. Greene, Peter G. M. Wuts, Protective Groups in Organic Synthesis third edition, pages 494 - 653.

Among those described, a benzyloxycarbonyl group (Z group) or a
5 tert-butoxycarbonyl group (Boc group) is preferable.

When compound (V) is used, a reaction can be carried out according to the conditions of a known Reformatsky reaction (e.g., Org. React., 22, 423 (1975); Synthesis, 571 (1989)).

Compound (V) is generally used in 1 to 3 mol per 1 mol of
10 compound (IV).

Compound (VII) can be produced by reacting compound (IV) with a Reformatsky reagent prepared from compound (V) and generally 1 to 3 mol of zinc per 1 mol of compound (V).

For preparation of a Reformatsky reagent, the copresence
15 of generally 0.1 to 1 mol of trimethylsilyl chloride or copper(I) chloride per 1 mol of compound (V) is effective.

The reaction can be carried out in an inert solvent, such as tetrahydrofuran, diethyl ether, 1,2-dimethoxyethane, 1,4-dioxane, toluene, benzene, xylene and the like, and a mixed
20 solvent thereof. The reaction is carried out within a temperature range of from about -40°C to 100°C. While the reaction time is not particularly limited, it is generally 0.1 hr to 100 hr, preferably 0.5 hr to 72 hr.

When compound (VI) is used, compound (VII) can be produced
25 by reacting compound (VI) with a base such as lithium diisopropylamide and the like and then reacting the resulting compound with compound (IV).

As the base, lithium hexamethyldisilazide, sodium hexamethyldisilazide, potassium hexamethyldisilazide and the
30 like can be used in addition to lithium diisopropylamide. The amount thereof to be used is generally 1 to 5 mol per 1 mol of compound (VI).

The reaction can be carried out in an inert solvent, such as tetrahydrofuran, diethyl ether, 1,2-dimethoxyethane, 1,4-
35 dioxane, toluene, benzene, xylene and the like, and a mixed

solvent thereof. The reaction is carried out within a temperature range of about -40°C to 100°C , preferably -40°C to 25°C . While the reaction time is not particularly limited, it is generally 0.1 hr to 100 hr, preferably 0.5 hr to 72 hr.

5 Compound (VIII) wherein R^6 to R^{11} are as defined above, and R^{13} is a hydrogen atom, lower alkyl such as tert-butyl and the like can be produced by removing an amino-protecting group P from compound (VII) according to the method described in, for example, Theodora W. Greene, Peter G. M. Wuts, Protective Groups
10 in Organic Synthesis third edition, pages 494 to 653 or a method analogous thereto.

The purity can be improved by recrystallizing a salt of compound (VIII) with an inorganic or organic acid. As the salt with an inorganic acid, a salt with hydrochloric acid,
15 hydrobromic acid, nitric acid, sulfuric acid, phosphoric acid and the like is used. As the salt with an organic acid, a salt with formic acid, acetic acid, trifluoroacetic acid, phthalic acid, fumaric acid, oxalic acid, tartaric acid, maleic acid, citric acid, succinic acid, malic acid, methanesulfonic acid,
20 benzenesulfonic acid, p-toluenesulfonic acid and the like is used.

Compound (X) wherein each symbol is as defined above can be produced by reacting compound (VIII) with compound (IX).

Compound (IX) is generally used in 1 to 3 mol per 1 mol of
25 compound (VIII). The reaction can also be carried out smoothly by adding, where necessary, a base such as lithium carbonate, potassium carbonate, sodium carbonate, cesium carbonate, sodium hydrogen carbonate, sodium hydroxide, sodium tert-butoxide, potassium tert-butoxide, triethylamine, diisopropylamine and the
30 like in 1 to 3 mol per 1 mol of compound (IX).

The reaction can be carried out in an inert solvent, such as tetrahydrofuran, diethyl ether, 1,2-dimethoxyethane, 1,4-dioxane, toluene, benzene, xylene, dimethylformamide, dimethyl sulfoxide and the like, and a mixed solvent thereof. The
35 reaction is carried out within a temperature range of about -40°C

to 120°C, preferably 25°C to 100°C. While the reaction time is not particularly limited, it is generally 0.1 hr to 100 hr, preferably 0.5 hr to 72 hr.

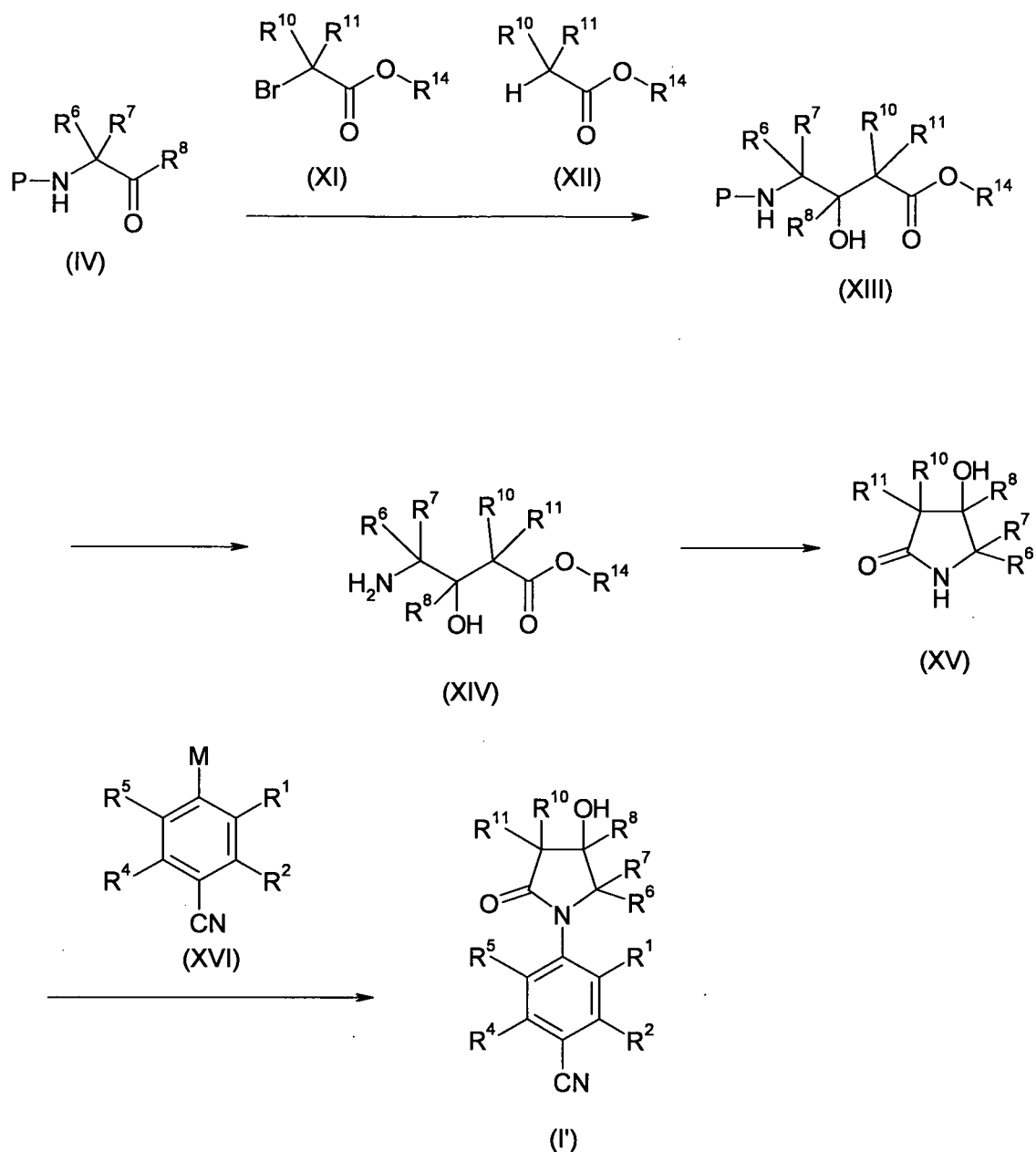
Compound (I') wherein each symbol is as defined above can
5 be produced by a cyclization reaction of compound (X).

The reaction can be carried out in an inert solvent, such as tetrahydrofuran, diethyl ether, 1,2-dimethoxyethane, 1,4-dioxane, toluene, benzene, xylene, dimethylformamide, dimethyl sulfoxide, acetic acid, trifluoroacetic acid and the like, and a
10 mixed solvent thereof. The reaction is carried out within a temperature range of about 0°C to 120°C, preferably 25°C to 80°C. While the reaction time is not particularly limited, it is generally 0.1 hr to 100 hr, preferably 0.5 hr to 72 hr.

The reaction can be carried out smoothly by adding, where
15 necessary, a base such as lithium carbonate, potassium carbonate, sodium carbonate, cesium carbonate, sodium hydrogen carbonate, sodium hydroxide, sodium tert-butoxide, potassium tert-butoxide, triethylamine, diisopropylamine and the like, acetic acid, trifluoroacetic acid, sulfuric acid and the like in generally 1
20 to 3 mol per 1 mol of compound (X).

A simplified representation of reaction method 2 is shown below.

(reaction method 2)



Compound (XIII) wherein R⁸ to R¹¹ are as defined above, and R¹⁴ is lower alkyl such as methyl, ethyl, propyl and the like, or aralkyl such as benzyl and the like can be produced by reacting
 5 compound (IV) wherein each symbol is as defined above with compound (XI) or compound (XII) wherein each symbol is as defined above under the same conditions as for the production method of compound (VII).

Compound (XIV) wherein each symbol is as defined above can
 10 be produced from compound (XIII) in the same manner as in the production method of compound (VIII).

Compound (XV) wherein each symbol is as defined above can be produced by a cyclization reaction of compound (XIV).

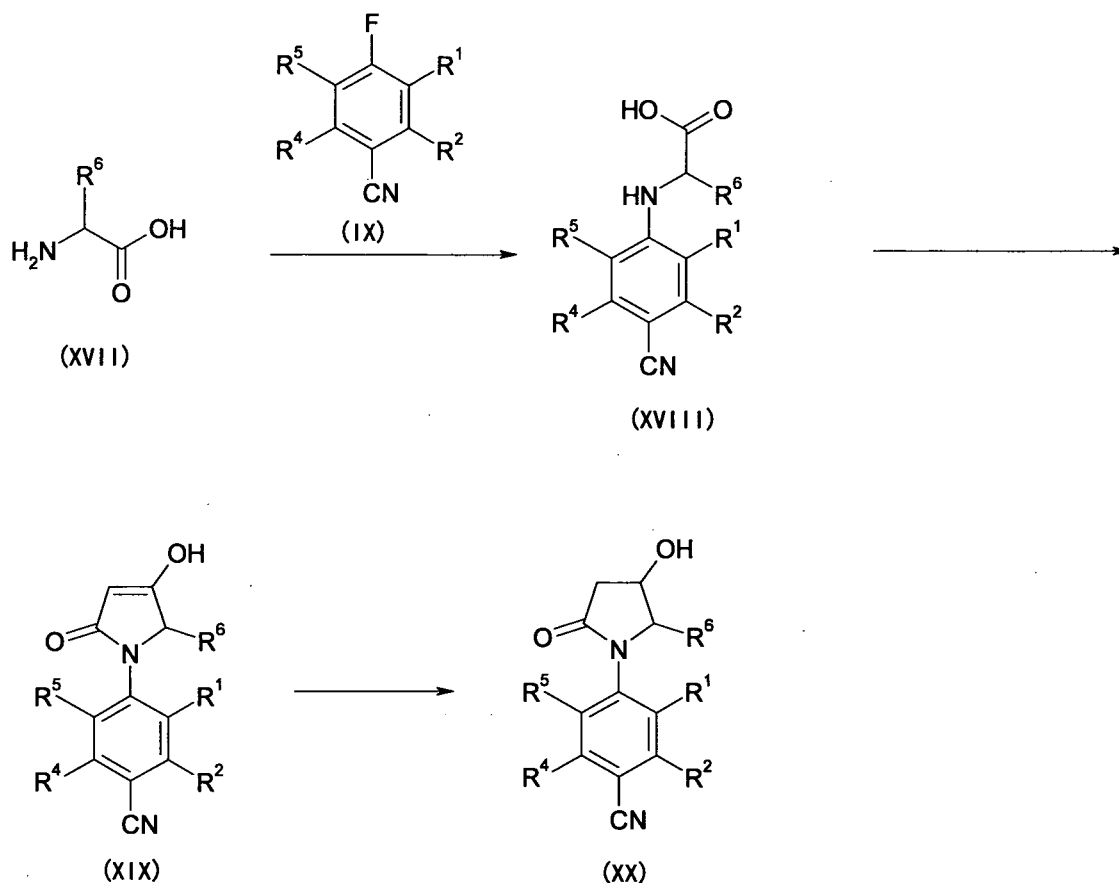
The reaction can be carried out in an inert solvent, such as tetrahydrofuran, diethyl ether, 1,2-dimethoxyethane, 1,4-dioxane, toluene, benzene, xylene, dimethylformamide, dimethyl sulfoxide and the like, and a mixed solvent thereof. The reaction is carried out within a temperature range of about 0°C to 120°C, preferably 25°C to 80°C. While the reaction time is not particularly limited, it is generally 0.1 hr to 100 hr, preferably 0.5 hr to 72 hr.

The reaction can also be carried out smoothly by adding, where necessary, a base such as lithium carbonate, potassium carbonate, sodium carbonate, cesium carbonate, sodium hydrogen carbonate, sodium hydroxide, sodium tert-butoxide, potassium tert-butoxide, triethylamine, diisopropylamine and the like in 1 to 3 mol per 1 mol of compound (XIV).

Compound (I') can be produced by reacting compound (XV) with compound (XVI) wherein each symbol is as defined above under the same conditions as for the production method of compound (I) from compound (II) and compound (III).

A simplified representation of reaction method 3 is shown below.

(reaction method 3)



Compound (XX) wherein each symbol is as defined above, which is compound (I') wherein R^7 to R^{11} are hydrogen atoms can be produced from amino acid (XVII) wherein each symbol is as defined above by the following method.

Compound (XVIII) can be produced by a condensation reaction of amino acid (XVII) and compound (IX) wherein each symbol is as defined above.

The reaction can be carried out using compound (IX) generally in 1 - 3 mol per 1 mol of compound (XVII) in an inert solvent, such as tetrahydrofuran, diethyl ether, 1,2-dimethoxyethane, 1,4-dioxane, toluene, benzene, xylene, dimethylformamide, dimethyl sulfoxide and the like, and a mixed solvent thereof. The reaction is carried out within a temperature range of about 0°C to 120°C , preferably 25°C to 100°C . While the reaction time is not particularly limited, it is generally 0.1 hr to 100 hr, preferably 0.5 hr to 72 hr.

The reaction can also be carried out smoothly by adding, where necessary, a base such as lithium carbonate, potassium carbonate, sodium carbonate, cesium carbonate, sodium hydrogen carbonate, sodium hydroxide, sodium tert-butoxide, potassium
5 tert-butoxide, triethylamine, diisopropylamine and the like in 1 to 3 mol per 1 mol of compound (XVII).

Compound (XIX) can be produced by reacting compound (XVIII) with N,N'-carbonyldiimidazole and the like to give an active ester, and reacting the ester with Meldrum's acid.

10 In addition to N,N'-carbonyldiimidazole, dicyclohexylcarbodiimide, diisopropylcarbodiimide, aqueous carbodiimide (e.g., 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride) and isopropyl chloroformate can be used. Particularly, N,N'-
15 carbonyldiimidazole is preferable.

Where necessary, the reaction can be carried out smoothly by adding, where necessary, 1-hydroxybenzotriazole, 4-(N,N-dimethylamino)pyridine and the like.

The reaction can be carried out using a condensation agent
20 and Meldrum's acid each generally in 1 - 3 mol per 1 mol of compound (XVIII) in an inert solvent, such as tetrahydrofuran, diethyl ether, 1,2-dimethoxyethane, ethyl acetate, 1,4-dioxane, toluene, benzene, xylene, dimethylformamide, dimethyl sulfoxide and a mixed solvent thereof. The reaction is carried out within
25 a temperature range of about 0°C to 120°C, preferably 25°C to 80°C. While the reaction time is not particularly limited, it is generally 0.1 hr to 100 hr, preferably 0.5 hr to 72 hr.

Compound (XX) can be produced by reducing compound (XIX).

As the reducing agent, sodium borohydride, lithium
30 borohydride, diisobutylaluminum hydride and the like can be used, with preference given to sodium borohydride. Using the reducing agent in 1 to 5 mol per 1 mol of compound (XIX), the reaction can be carried out in an inert solvent, such as tetrahydrofuran, diethyl ether, 1,2-dimethoxyethane, 1,4-dioxane, toluene,
35 benzene, xylene and a mixed solvent thereof. The reaction is

carried out within a temperature range of about 0°C to 100°C, preferably 0°C to 50°C. While the reaction time is not particularly limited, it is generally 0.1 hr to 100 hr, preferably 0.5 hr to 72 hr.

5 Thus-obtained compound (I) can be isolated and purified by a separation means known *per se*, such as concentration, concentration under reduced pressure, solvent extraction, liquid conversion, salting out, crystallization, recrystallization, phase transfer, chromatography and the like.

10 When compound (I) is obtained as a free form, it can be converted to a desired salt by a method known *per se* or a modification thereof; conversely, when compound (I) is obtained as a salt, it can be converted to a free form or other desired salt by a method known *per se* or a modification thereof.

15 The compound (I) may be a hydrate or a non-hydrate.

When compound (I) is obtained as a mixture of optically active forms, they can be separated to the object optically active forms by an optical resolution means known *per se*.

Compound (I) may be labeled with an isotope (e.g., ^2H , ^3H ,
20 ^{14}C etc.) and the like.

A prodrug of the compound (I) means a compound which is converted to the compound (I) with a reaction due to an enzyme, an gastric acid, etc. under the physiological condition in the living body, that is, a compound which is converted to the
25 compound (I) with oxidation, reduction, hydrolysis, etc. according to an enzyme; a compound which is converted to the compound (I) by hydrolysis etc. due to gastric acid, etc. A prodrug of compound (I) may be a compound obtained by subjecting amino in compound (I) to an acylation, alkylation or
30 phosphorylation (e.g., a compound obtained by subjecting amino in compound (I) to an eicosanoylation, alanylation, pentylaminocarbonylation, (5-methyl-2-oxo-1,3-dioxolen-4-yl)methoxycarbonylation, tetrahydrofuranylation, pyrrolidylmethylation, pivaloyloxymethylation and tert-butylation, etc.); a compound obtained by subjecting hydroxy in
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compound (I) to an acylation, alkylation, phosphorylation or
boration (e.g., a compound obtained by subjecting hydroxy in
compound (I) to an acetylation, palmitoylation, propanoylation,
pivaloylation, succinylation, fumarylation, alanylation,
5 dimethylaminomethylcarbonylation, etc.); a compound obtained by
subjecting a carboxyl group in compound (I) to an esterification
or amidation (e.g., a compound obtained by subjecting a carboxyl
group in compound (I) to an ethyl esterification, phenyl
esterification, carboxymethyl esterification,
10 dimethylaminomethyl esterification, pivaloyloxymethyl
esterification, ethoxycarbonyloxyethyl esterification,
phthalidyl esterification, (5-methyl-2-oxo-1,3-dioxolen-4-
yl)methyl esterification, cyclohexyloxycarbonylethyl
esterification and methylamidation, etc.) and the like. Any of
15 these compounds can be produced from compound (I) by a method
known *per se*.

A prodrug for compound (I) may also be one which is
converted into compound (I) under a physiological condition,
such as those described in IYAKUHIN no KAIHATSU (Development of
20 Pharmaceuticals), Vol.7, Design of Molecules, p.163-198, 1990,
Published by HIROKAWA SHOTEN.

The compound (including prodrug) of the present invention
may form a salt. A salt of the compound is not particularly
limited as long as it does not inhibit the reaction. For
25 example, a salt with inorganic base, an ammonium salt, a salt
with organic base, a salt with inorganic acid, a salt with
organic acid, a salt with amino acid and the like can be
mentioned. Preferable examples of salts with inorganic base
include alkali metal salt such as sodium salt, potassium salt
30 and the like, alkaline earth metal salt such as calcium salt,
magnesium salt and the like, and aluminum salt, ammonium salt
and the like. Preferable examples of salts with organic base
include salts with trimethylamine, triethylamine, pyridine,
picoline, 2,6-lutidine, ethanolamine, diethanolamine,
35 triethanolamine, cyclohexylamine, dicyclohexylamine, N,N'-

dibenzylethylenediamine and the like. Preferable examples of salts with inorganic acid include salts with hydrochloric acid, hydrobromic acid, nitric acid, sulfuric acid, phosphoric acid and the like. Preferable examples of salts with organic acid
5 include salts with formic acid, acetic acid, trifluoroacetic acid, phthalic acid, fumaric acid, oxalic acid, tartaric acid, maleic acid, citric acid, succinic acid, malic acid, methanesulfonic acid, benzenesulfonic acid, p-toluenesulfonic acid and the like. Preferable examples of salts with basic
10 amino acid include salts with arginine, lysine, ornithine and the like, and preferable examples of salts with acidic amino acid include salts with aspartic acid, glutamic acid and the like.

The compound (I) of the present invention or a salt
15 thereof or a prodrug thereof (hereinafter sometimes to be abbreviated as the compound of the present invention) has an androgen receptor modulating action, particularly an androgen receptor agonistic action, and can be used for the prophylaxis or treatment of diseases in mammals, for which administration of
20 an androgen receptor agonist is effective. The diseases for which administration of an androgen receptor agonist is effective include hypogonadism, osteoporosis, hormone resistant cancer (particularly LHRH agonist resistant cancer), climacteric disorder (particularly male climacteric disorder), frailty,
25 cachexia, anemia, arteriosclerosis, Alzheimer's disease, erectile dysfunction, depression, wasting disease, hypertriglyceridemia (hyperlipidemia) and the like. Particularly, it is used for the prophylaxis or treatment of hypogonadism, male climacteric disorder, frailty, cachexia or
30 osteoporosis.

The compound of the present invention has a tissue-selective androgen receptor modulating action and shows, for example, an antagonistic action on the prostate and an agonistic action on the muscle. Specifically, the compound of the present
35 invention shows an action to not increase the weight of the

prostate at a dose that increases the weight of the muscle (e.g., levator ani muscle and the like). More specifically, it increases the prostate weight by about 10% or less (preferably 0% or less) at a dose that increases the levator ani muscle weight by about 20% or more (preferably about 20% to about 50%). Here, referring to the "increase in the prostate weight of 0% or less", an increase of 0% means that the prostate weight does not increase or decrease, and an increase of less than 0% means that the prostate weight decreases by the absolute value thereof. Accordingly, the compound of the present invention can be used as a pharmaceutical agent shown below.

- (1) A frailty suppressant.
- (2) A muscle strength enhancer or muscle increasing agent (providing effects of no bedridden aged patients, shortened rehabilitation period and the like).
- (3) A suppressant of cachexia caused by, for example, AIDS, cancer and the like.
- (4) A body weight decrease suppressant.
- (5) An agent for the prophylaxis or treatment of prostate hypertrophy (that decreases the prostate weight).
- (6) An agent for the prophylaxis or treatment of amyotrophy.
- (7) An agent for reducing prostate weight.
- (8) An agent for the prophylaxis or treatment of muscle loss caused by diseases (e.g., muscular dystrophy, muscular atrophy, X-linkage spinal cord medulla oblongata muscular atrophy (SBMA), cachexia, malnutrition, Hansen's disease, diabetes, renal disease, COPD (chronic obstructive pulmonary diseases), cancer, terminal renal failure, sarcopenia (loss of muscle due to advancing age), emphysema, osteomalacia, HIV infection, AIDS, cardiomyopathy and the like).
- (9) A suppressant of loss of muscle strength in postmenopausal female.
- (10) A suppressant of bone mineral density of postmenopausal female.

(11) A suppressant of hot flash (e.g., glow, sweating and the like) in postmenopausal female.

(12) An agent for reducing the side effects of LHRH modulators such as LHRH agonists (leuprorelin, goserelin, buserelin, nafarelin, triptorelin, gonadorelin and the like), LHRH
5 antagonists (ganirelix, cetrorelix, antarelix, abarelix, sufugolix and the like) and the like.

(13) A suppressant of loss of muscle strength after administration of a pharmaceutical agent such as an LHRH
10 modulator and the like.

(14) A suppressant of decreased bone mineral density after administration of a pharmaceutical agent such as an LHRH modulator and the like.

(15) A suppressant of hot flash (e.g., glow, sweating and the
15 like) after administration of a pharmaceutical agent such as an LHRH modulator and the like.

In addition, the compound of the present invention shows effect as a frailty suppressant, a muscle strength enhancer or a muscle increasing agent while using as an agent for the
20 prophylaxis or treatment of prostate hypertrophy or an agent for reducing the weight of the prostate. Accordingly, it is expected to shorten the period of rehabilitation without leaving aged inpatients bedridden. Without the side effect of increasing the weight of the prostate, it is expected to provide
25 an agent for the prophylaxis or treatment of prostate cancer in patients with high possibility of prostate cancer. Without the side effect of virilization, moreover, it can be applied to female, and is expected to provide a suppressant of loss of muscle strength or bone mineral density loss in postmenopausal
30 female, or a suppressant of hot flash (glow, sweating etc.) in postmenopausal female. Furthermore, it also is expected as an agent for reducing the side effects of LHRH agonists (leuprorelin, goserelin, buserelin, nafarelin, triptorelin, gonadorelin and the like), and LHRH antagonists (ganirelix, cetrorelix, antarelix, abarelix, sufugolix and the like), a
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suppressant of loss of muscle strength or bone mineral density loss after administration of these pharmaceutical agents, or a suppressant of hot flash (glow, sweating and the like) after administration of these pharmaceutical agents.

5 The compound of the present invention achieves growth inhibition and cell death by conversely placing an excessive stimulation on cancer that has acquired resistance to a hormone treatment by being hypersensitive to androgen. Thus, it can be used as an agent for the prophylaxis or treatment of, from
10 various cancers, breast cancer, prostate cancer, endometrial cancer, cancer of the uterine cervix, ovarian cancer, urinary bladder cancer, thyroid cancer, bone tumor and penile cancer, that acquired hormone resistance, and is particularly useful as an agent for the prophylaxis or treatment of prostate cancer.

15 As hormone resistant cancer, for example, LHRH derivative resistant cancer, preferably LHRH agonist resistant cancer can be mentioned.

 The compound of the present invention shows low toxicity and can be used as a pharmaceutical agent as it is, or as a
20 pharmaceutical composition in admixture with a commonly known pharmaceutically acceptable carrier etc. in mammals (e.g., humans, horses, bovines, dogs, cats, rats, mice, rabbits, pigs, monkeys, and the like).

 In addition to the compound of the present invention, said
25 pharmaceutical composition may contain other active ingredients, e.g., the following hormonal therapeutic agents, anticancer agent (e.g., chemotherapeutic agents, immunotherapeutic agents, or pharmaceutical agents inhibiting the action of cell growth factors or cell growth factor receptors), antiemetic and the
30 like.

 As a pharmaceutical agent for mammals such as humans, the compound of the present invention can be administered orally in the form of, for example, tablets, capsules (including soft capsules and microcapsules), powders, granules and the like, or
35 parenterally in the form of injections, suppositories, pellets

and the like. Examples of the "parenteral administration route" include intravenous, intramuscular, subcutaneous, intra-tissue, intranasal, intradermal, instillation, intracerebral, intrarectal, intravaginal, intraperitoneal, intratumoral, 5 juxtaposition of tumor and administration directly to the lesion.

The dose of the compound of the present invention varies depending on the route of administration, symptoms, etc. For example, when it is administered orally as an anticancer agent to a patient (body weight 40 to 80 kg) with breast cancer or 10 prostate cancer, its dose is, for example, 0.1 to 200 mg/kg body weight per day, preferably 1 to 100 mg/kg body weight per day, and more preferably 1 to 50 mg/kg body weight per day. This amount may be administered once or in 2 to 3 divided portions daily.

15 The compound of the present invention can be orally or parenterally administered in the form of a solid dosage form such as tablet, capsule, granule, powder and the like; or a liquid preparation such as syrup, injection and the like, by admixing with a pharmaceutically acceptable carrier.

20 As a pharmaceutically acceptable carrier, various organic or inorganic carrier substances conventionally used as preparation materials can be used. For example, excipient, lubricant, binder and disintegrant for solid preparations, solvent, solubilizing agents, suspending agent, isotonicity 25 agent, buffer and soothing agent for liquid preparations and the like can be mentioned. Where necessary, preparation additives such as preservatives, antioxidants, colorants, sweetening agents and the like can be used.

Preferable examples of the excipient include lactose, 30 sucrose, D-mannitol, starch, crystalline cellulose, light anhydrous silicic acid and the like.

Preferable examples of the lubricant include magnesium stearate, calcium stearate, talc, colloidal silica and the like.

Preferable examples of the binder include crystalline cellulose, sucrose, D-mannitol, dextrin, hydroxypropylcellulose, hydroxypropylmethylcellulose, polyvinylpyrrolidone and the like.

Preferable examples of the disintegrant include starch,
5 carboxymethylcellulose, calcium carboxymethylcellulose, croscarmellose sodium, sodium carboxymethyl starch and the like.

Preferable examples of the solvent include water for injection, alcohol, propylene glycol, macrogol, sesame oil, corn oil and the like.

10 Preferable examples of the solubilizing agent s include polyethylene glycol, propylene glycol, D-mannitol, benzyl benzoate, ethanol, trisaminomethane, cholesterol, triethanolamine, sodium carbonate, sodium citrate and the like.

Preferable examples of the suspending agent include
15 surfactants such as stearyltriethanolamine, sodium lauryl sulfate, lauryl aminopropionate, lecithin, benzalkonium chloride, benzethonium chloride, glyceryl monostearate and the like; hydrophilic polymers such as polyvinyl alcohol, polyvinylpyrrolidone, sodium carboxymethylcellulose,
20 methylcellulose, hydroxymethylcellulose, hydroxyethylcellulose, hydroxypropylcellulose and the like; and the like.

Preferable examples of the isotonicity agent include sodium chloride, glycerol, D-mannitol and the like.

Preferable examples of the buffer include buffers such as
25 phosphate, acetate, carbonate, citrate and the like; and the like.

Preferable examples of the soothing agent include benzyl alcohol and the like.

Preferable examples of the preservative include
30 paraoxybenzoates, chlorobutanol, benzyl alcohol, phenethyl alcohol, dehydroacetic acid, sorbic acid and the like.

Preferable examples of the antioxidant include sulfite, ascorbic acid and the like.

A pharmaceutical composition can be produced according to
35 a conventional method by adding the compound of the present

invention generally in a proportion of 0.1 to 95% (w/w) relative to the total amount of the preparation, though subject to change depending on the dosage form, administration method, carrier and the like.

5 In addition, a combination of (1) administration of an effective amount of a compound of the present invention and (2) 1 to 3 selected from the group consisting of (i) administration of an effective amount of other anticancer agents, (ii) administration of an effective amount of other hormonal
10 therapeutic agents and (iii) non-drug therapy can prevent and/or treat cancer more effectively. As the non-drug therapy, for example, surgery, hypertensive chemical therapy using angiotensin II and the like, radiotherapy, gene therapy, thermotherapy, cryotherapy, laser cauterization, and the like
15 are used, and two or more of these may be combined.

For example, the compound of the present invention can be used in combination with other hormonal therapeutic agents, other anti-cancer agents (e.g., chemotherapeutic agent, immunotherapeutic agent (including vaccine), antibody, gene
20 therapy drugs, pharmaceutical agents inhibiting the action of cell growth factors and receptors thereof, pharmaceutical agents inhibiting angiogenesis), antiemetics and the like (hereinafter to be abbreviated as concomitant drug).

While the compound of the present invention exhibits
25 excellent anticancer action even when used as a simple agent, its effect can be still more enhanced or QOL of patients can be improved by using it in combination with one or more of the concomitant drug(s) mentioned above (multi-agent co-administration).

30 Examples of the "hormonal therapeutic agents" include fosfestrol, diethylstilbestrol, chlorotrianisene, medroxyprogesterone acetate, megestrol acetate, chlormadinone acetate, cyproterone acetate, danazol, dienogest, asoprisnil, allylestrenol, gestrinone, nomegestrol, tadenan, mepartricin,
35 raloxifene, ormeloxifene, levormeloxifene, anti-estrogen (e.g.,

tamoxifen citrate, toremifene citrate etc.), ER down-regulator(for example, fulvestrant etc.), human postmenopausal gonadotropin, follitropin, pill preparation, mepitiostane, testrolactone, aminoglutethimide, LH-RH derivative (e.g., LH-RH agonist (e.g., goserelin acetate, buserelin, leuprorelin etc.), LH-RH antagonist), droloxifene, epitiostanol, ethinylestradiol sulfonate, aromatase inhibitor (e.g., fadrozole hydrochloride, anastrozole, letrozole, exemestane, vorozole, formestane etc.), anti-androgens (e.g., flutamide, bicalutamide, nilutamide etc.), 5 α -reductase inhibitor (e.g., finasteride, dutasteride, epristeride etc.), corticosteroid (e.g., dexamethasone, prednisolone, betamethasone, triamcinolone etc.), androgen synthesis inhibitor (e.g., abiraterone etc.), retinoid and drugs that retard retinoid metabolism (e.g., liarozole etc.) and the like. Preferred is LH-RH derivative.

Examples of the "chemotherapeutic agents" include alkylating agent, metabolic antagonist, antitumor antibiotics, plant-derived antitumor agent, other chemotherapeutic agents and the like.

Examples of the "alkylating agent" include nitrogen mustard, nitrogen mustard-N-oxide hydrochloride, chlorambutyl, cyclophosphamide, ifosfamide, thiotepa, carboquone, improsulfan tosylate, busulfan, nimustine hydrochloride, mitobronitol, melphalan, dacarbazine, ranimustine, sodium estramustine phosphate, triethylenemelamine, carmustine, lomustine, streptozocin, pipobroman, etoglucid, carboplatin, cisplatin, miboplatin, nedaplatin, oxaliplatin, altretamine, ambamustine, dibrospidium hydrochloride, fotemustine, prednimustine, pumitepa, ribomustin, temozolomide, treosulphan, trophosphamide, zinostatin stimalamer, carboquone, adozelesin, cystemustine, bizelesin, and the like.

Examples of the "antimetabolites" include mercaptopurine, 6-mercaptopurine riboside, thioinosine, methotrexate, enocitabine, cytarabine, cytarabine ocfosfate, ancitabine hydrochloride, 5-FU drugs (e.g., fluorouracil, tegafur, UFT,

doxifluridine, carmofur, galloctabine, emitefur etc.),
aminopterin, leucovorin calcium, tabloid, butocin, folinate
calcium, levofolinate calcium, cladribine, emitefur, fludarabine,
gemcitabine, hydroxycarbamide, pentostatin, piritrexim,
5 idoxuridine, mitoguazone, thiazophrine, ambamustine and the like.

Examples of the "antitumor antibiotics" include
actinomycin D, actinomycin C, mitomycin C, chromomycin A3,
bleomycin hydrochloride, bleomycin sulfate, peplomycin sulfate,
daunorubicin hydrochloride, doxorubicin hydrochloride,
10 aclarubicin hydrochloride, pirarubicin hydrochloride, epirubicin
hydrochloride, neocarzinostatin, mithramycin, sarcomycin,
carzinophilin, mitotane, zorubicin hydrochloride, mitoxantrone
hydrochloride, idarubicin hydrochloride and the like.

Examples of the "plant-derived antitumor agent" include
15 etoposide, etoposide phosphate, vinblastine sulfate, vincristine
sulfate, vindesine sulfate, teniposide, paclitaxel, docetaxel,
DJ-927, vinorelbine, irinotecan, topotecan and the like.

Examples of the "other chemotherapeutic agents" include
sobuzoxane and the like.

20 Examples of the "immunotherapeutic agent (BRM)" include
picibanil, krestin, schizophyllan, lentinan, ubenimex,
interferon, interleukin, macrophage colony stimulating factor,
granulocyte colony stimulating factor, erythropoietin,
lymphotoxin, Corynebacterium parvum, levamisole, polysaccharide
25 K, procodazole and the like. As the vaccine, BCG vaccine,
PROVENGE, Onyvax-P, PROSTVAC-VF, GVAX, DCVax-Prostate,
SAPOIMMUNE, VPM-4-001 and the like are used.

Examples of the "antibody" include an antibody to EpiCAM,
an antibody to PSCA, and an antibody to PSMA.

30 The "growth factor" in said "pharmaceutical agents
inhibiting the action of cell growth factors or cell growth
factor receptors" may be any as long as it promotes cell
proliferation, which is normally peptide having a molecular
weight of not more than 20,000 that is capable of exhibiting its
35 activity at low concentrations by binding to a receptor.

Examples thereof include (1) EGF (epidermal growth factor) or substances possessing substantially the same activity as it [e.g., EGF, heregulin TGF- α , HB-EGF etc.], (2) insulin or substances possessing substantially the same activity as it [e.g., insulin, IGF (insulin-like growth factor)-1, IGF-2, and the like], (3) FGF (fibroblast growth factor) or substances possessing substantially the same activity as it [e.g., acidic FGF, basic FGF, KGF (keratinocyte growth factor), FGF-10, and the like], (4) other cell growth factors [e.g., CSF (colony stimulating factor), EPO (erythropoietin), IL-2 (interleukin-2), NGF (nerve growth factor), PDGF (platelet-derived growth factor), TGF β (transforming growth factor β), HGF (hepatocyte growth factor), VEGF (vascular endothelial cell growth factor), and the like], and the like.

Examples of the "growth factor receptors" include any receptors capable of binding to the aforementioned cell growth factors, such as EGF receptor, HER2, HER3 and HER4 belonging to the same family as that of EGF receptor, insulin receptor, IGF receptor, FGF receptor-1, FGF receptor-2, and the like.

Examples of the "pharmaceutical agents inhibiting the action of cell growth factors and receptors thereof" include trastuzumab (Herceptin (trademark); HER2 antibody), imatinib mesylate, ZD1839, cetuximab, gefitinib, erlotinib and the like.

Examples of the "pharmaceutical agents inhibiting angiogenesis" include antibodies to VEGF (e.g., bevacizumab), antibodies to VEGF receptors, VEGF receptor kinase inhibitors (e.g., SU11248 etc.), PDGF receptor kinase inhibitors, Tie2 kinase inhibitors, thalidomide and the like.

In addition to the aforementioned drugs, L-asparaginase, aceglatone, procarbazine hydrochloride, protoporphyrin-cobalt complex salt, mercuric hematoporphyrin-sodium, differentiation inducer (e.g., retinoid, vitamin D etc.), α -blocker (e.g., tamsulosin hydrochloride, naftopidil, urapidil, alfuzosin, terazosin, prazosin, silodosin etc.) serine/threonine kinase inhibitor, endothelin receptor antagonist (e.g., atrasentan

etc.), proteasome inhibitor (e.g., bortezomib etc.), Hsp90 inhibitor (e.g., 17-AAG etc.), spironolactone, minoxidil, 11 α -hydroxyprogesterone, and bone resorption inhibitory. metastasis suppressing agent (e.g., zoledronic acid, alendronic acid, pamidronic acid, etidronic acid, ibandronic acid, clodronic acid) can also be used.

As the "antiemetic", gastric motility enhancers such as 5-HT₃ antagonist such as ondansetron, tropisetron hydrochloride, azasetron, ramosetron, granisetron, dolasetron mesylate, palonosetron and the like, 5-HT₄ antagonists such as domperidone, mosapride, metoclopramide and the like, and the like; gastrointestinal tract motility regulators such as trimebutine and the like; phenothiazine pharmaceutical agents such as prochlorperazine maleate, promethazine, thiethylperazine and the like; tranquilizers such as haloperidol, chlorpromazine phenolphthalinate, diazepam, droperidol and the like; steroids such as dexamethasone, prednisolone, betamethasone, triamcinolone and the like; as well as dimethylhydrin acid, diphenhydramine, hyoscine, hyoscine hydrobromide, tetrabenazine and the like can be used.

As the aforementioned LH-RH derivative, an LH-RH derivative or a salt thereof effective for hormone dependent disease, particularly sex hormone dependent disease such as sex hormone dependent cancer (e.g., prostate cancer, uterine cancer, breast cancer, pituitary gland tumor, liver cancer and the like), prostate hypertrophy, endometriosis, hystero myoma, precocious puberty, dysmenorrhea, amenorrhea, premenstrual syndrome, polycystic ovary syndrome and the like and contraception (or infertility when rebound effect after cessation of the drug is used) are used. In addition, an LH-RH derivative or a salt thereof effective for benignant or malignant tumor, which is sex hormone independent but LH-RH sensitive, and the like is also used.

Specific examples of the LH-RH derivative or a salt thereof include peptides described in Treatment with GnRH

analogs: Controversies and perspectives (The Parthenon Publishing Group Ltd., published in 1996), JP-A-3-503165, JP-A-3-101695, JP-A-7-97334, JP-A-8-259460 and the like.

Examples of the LH-RH derivative include an LH-RH agonist and an LH-RH antagonist. As the LH-RH antagonist, for example, physiologically active peptide represented by the formula
X-D2Nal-D4ClPhe-D3Pal-Ser-A-B-Leu-C-Pro-DAlaNH₂
wherein X is N(4H₂-furoyl)Gly or NAc, A is a residue selected from NMeTyr, Tyr, Aph(Atz) and NMeAph(Atz), B is a residue
selected from DLys(Nic), DCit, DLys(AzaglyNic), DLys(AzaglyFur), DhArg(Et₂), DAph(Atz) and DhCi, and C is Lys(Nisp), Arg or hArg(Et₂), or a salt thereof and the like are used, particularly preferably abarelix, ganirelix, cetorelix, 5-(N-benzyl-N-methylaminomethyl)-1-(2,6-difluorobenzyl)-6-[4-(3-methoxyureido)phenyl]-3-phenylthieno[2,3-d]pyrimidin-2,4(1H,3H)-dione, 5-(N-benzyl-N-methylaminomethyl)-1-(2,6-difluorobenzyl)-6-[4-(3-ethylureido)phenyl]-3-phenylthieno[2,3-d]pyrimidin-2,4(1H,3H)-dione, 5-(N-benzyl-N-methylaminomethyl)-1-(2,6-difluorobenzyl)-6-[4-(3-ethylureido)phenyl]-3-phenylthieno[2,3-d]pyrimidin-2,4(1H,3H)-dione hydrochloride and the like are used.

As the LH-RH agonist, for example, physiologically active peptides represented by the formula
5-oxo-Pro-His-Trp-Ser-Tyr-Y-Leu-Arg-Pro-Z
wherein Y is a residue selected from DLeu, DAla, DTrp, DSer(tBu), D2Nal and DHis(ImBzl), and Z is NH-C₂H₅ or Gly-NH₂, or a salt thereof and the like are used. For example, they are goserelin acetate, buserelin and the like. Particularly, peptide wherein Y is DLeu and Z is NH-C₂H₅ (i.e., peptide A represented by 5-oxo-Pro-His-Trp-Ser-Tyr-DLeu-Leu-Arg-Pro-NH-C₂H₅; leuprorelin) or a salt thereof (e.g., acetate) is preferable.

When the amino acid, peptide, protecting group and the like of the polypeptide described in the present specification are indicated using abbreviations, they are based on the abbreviations according to the IUPAC-IUB Commission on Biochemical Nomenclature or conventional abbreviations in the

field. When an optical isomer due to amino acid is present, it means an L form unless otherwise specified.

Examples of the abbreviations are as follows.

- Abu : aminobutyric acid
- 5 Aibu : 2-aminobutyric acid
- Ala : alanine
- Arg : arginine
- Gly : glycine
- His : histidine
- 10 Ile : isoleucine
- Leu : leucine
- Met : methionine
- Nle : norleucine
- Nval : norvaline
- 15 Phe : phenylalanine
- Phg : phenylglycine
- Pro : proline
- (Pyr)Glu : pyroglutamic acid
- Ser : serine
- 20 Thr : threonine
- Trp : tryptophan
- Tyr : tyrosine
- Val : valine
- D2Nal: D-3-(2-naphthyl)alanine residue
- 25 DSer(tBu): O-tert-butyl-D-serine
- DHis(ImBzl): N^{im}-benzyl-D-histidine
- PAM : phenylacetamidomethyl
- Boc : t-butyloxycarbonyl
- Fmoc : 9-fluorenylmethyloxycarbonyl
- 30 Cl-Z : 2-chloro-benzyloxycarbonyl
- Br-Z : 2-bromo-benzyloxycarbonyl
- Bzl : benzyl
- Cl₂-Bzl: 2,6-dichlorobenzyl
- Tos : p-toluenesulfonyl
- 35 HONb : N-hydroxy-5-norbornane-2,3-dicarboxyimide

HOBt : 1-hydroxybenzotriazole

HOObt: 3-hydroxy-3,4-dihydro-4-oxo-1,2,3-benzotriazine

MeBzl: 4-methylbenzyl

Bom : benzyloxymethyl

5 Bum : t-butoxy methyl

Trt : trityl

DNP : dinitrophenyl

DCC : N,N'-dicyclohexylcarbodiimide

Of the aforementioned drugs, preferable concomitant drugs
10 are an LH-RH agonist (e.g., goserelin acetate, buserelin,
leuprorelin etc.) and the like.

When using the compound of the present invention and a
concomitant drug in combination, the administration time of the
compound of the present invention and the concomitant drug is
15 not restricted, and the compound of the present invention or the
concomitant drug can be administered to an administration
subject simultaneously, or may be administered at different
times. The dosage of the concomitant drug may be determined
according to the dose clinically used, and can be appropriately
20 selected depending on an administration subject, administration
route, disease, combination and the like.

The administration mode of the compound of the present
invention and the concomitant drug is not particularly limited,
and the compound of the present invention and the concomitant
25 drug only need to be combined on administration. Examples of
such administration mode include the following:

(1) administration of a single preparation obtained by
simultaneously processing the compound of the present invention
and the concomitant drug, (2) simultaneous administration of two
30 kinds of preparations of the compound of the present invention
and the concomitant drug, which have been separately produced,
by the same administration route, (3) administration of two
kinds of preparations of the compound of the present invention
and the concomitant drug, which have been separately produced,
35 by the same administration route in a staggered manner, (4)

simultaneous administration of two kinds of preparations of the compound of the present invention and the concomitant drug, which have been separately produced, by different administration routes, (5) administration of two kinds of preparations of the compound of the present invention and the concomitant drug, which have been separately produced, by different administration routes in a staggered manner (e.g., administration in the order of the compound of the present invention and the concomitant drug, or in the reverse order) and the like. In the following, these administration modes are collectively abbreviated as the concomitant drug of the present invention.

The concomitant drug of the present invention has low toxicity, and for example, the compound of the present invention and/or the above-mentioned concomitant drug can be mixed, according to a method known *per se*, with a pharmacologically acceptable carrier to give pharmaceutical compositions, such as tablets (including sugar-coated tablet, film-coated tablet), powders, granules, capsules (including soft capsule), solutions, injections, suppositories, sustained release agents and the like, which can be safely administered orally or parenterally (e.g., local, rectum, vein, and the like). An injection can be administered intravenously, intramuscularly, subcutaneously, into the organ, intranasally, intradermally, by instillation, intracerebrally, intrarectally, vaginally and intraperitoneally, intratumorally, proximally to the tumor and the like, or directly to the lesion.

As a pharmacologically acceptable carrier which may be used for producing the concomitant drug of the present invention, those similar to the aforementioned pharmacologically acceptable carriers that can be used for the pharmaceutical composition of the present invention can be used.

The compounding ratio of the compound of the present invention to the concomitant drug in the combination agent of the present invention can be appropriately selected depending on an administration subject, administration route, diseases and

the like.

For example, the content of the compound of the present invention in the combination agent of the present invention differs depending on the form of a preparation, and usually is
5 from about 0.01 to 100% by weight, preferably from about 0.1 to 50% by weight, further preferably from about 0.5 to 20% by weight, based on the entire preparation.

The content of the concomitant drug in the combination agent of the present invention differs depending on the form of
10 a preparation, and usually is from about 0.01 to 100% by weight, preferably from about 0.1 to 50% by weight, further preferably from about 0.5 to 20% by weight, based on the entire preparation.

The content of additives such as carrier and the like in the combination agent of the present invention differs depending
15 on the form of a preparation, and usually from about 1 to 99.99% by weight, preferably from about 10 to 90% by weight, based on the entire preparation.

In the case when the compound of the present invention and the concomitant drug are separately prepared respectively, the
20 same contents may be adopted.

These preparations can be produced by a method known *per se* usually used in a preparation process.

For example, the compound of the present invention and the concomitant drug can be made into an aqueous injection together
25 with a dispersing agent (e.g., Tween 80 (manufactured by Atlas Powder, US), HCO 60 (manufactured by Nikko Chemicals), polyethylene glycol, carboxymethylcellulose, sodium alginate, hydroxypropylmethylcellulose, dextrin and the like), a stabilizer (e.g., ascorbic acid, sodium pyrosulfite, and the
30 like), a surfactant (e.g., Polysorbate 80, macrogol and the like), a solubilizer (e.g., glycerin, ethanol and the like), a buffer (e.g., phosphoric acid and alkali metal salt thereof, citric acid and alkali metal salt thereof, and the like), an isotonizing agent (e.g., sodium chloride, potassium chloride,
35 mannitol, sorbitol, glucose and the like), a pH regulator (e.g.,

hydrochloric acid, sodium hydroxide and the like), a preservative (e.g., ethyl parahydroxybenzoate, benzoic acid, methylparaben, propylparaben, benzyl alcohol and the like), a dissolving agent (e.g., conc. glycerin, meglumine and the like),
5 a solubilizing agent (e.g., propylene glycol, sucrose and the like), a soothing agent (e.g., glucose, benzyl alcohol and the like), and the like, or can be dissolved, suspended or emulsified in a vegetable oil such as olive oil, sesame oil, cotton seed oil, corn oil and the like or a solubilizing agent
10 such as propylene glycol and prepared into an oily injection, whereby an injection is afforded.

To produce a preparation for oral administration, an excipient (e.g., lactose, sucrose, starch and the like), a disintegrating agent (e.g., starch, calcium carbonate and the
15 like), a binder (e.g., starch, gum Arabic, carboxymethylcellulose, polyvinylpyrrolidone, hydroxypropylcellulose and the like), a lubricant (e.g., talc, magnesium stearate, polyethylene glycol 6000 and the like) and the like, for example, can be added to the compound of the
20 present invention or the concomitant drug, according to a method known *per se*, and the mixture can be compression-molded, then if desirable, the molder product can be coated by a method known *per se* for the purpose of masking of taste, enteric property or durability, to obtain a preparation for oral administration. As
25 the coating agent, for example, hydroxypropylmethylcellulose, ethylcellulose, hydroxymethylcellulose, hydroxypropylcellulose, polyoxyethylene glycol, Tween 80, Pluronic F68, cellulose acetate phthalate, hydroxypropylmethylcellulose phthalate, hydroxymethylcellulose acetate succinate, Eudoragit (methacrylic
30 acid-acrylic acid copolymer, manufactured by Rohm, DE), pigment (e.g., iron oxide red, titanium dioxide, etc.) and the like can be used. The preparation for oral administration may be any of a immediate-release preparation and a sustained release preparation.

For example, to give a suppository, the compound of the present invention and the concomitant drug can be made into an oily or aqueous solid, semisolid or liquid suppository according to a method known *per se*. As the oily substrate to be used for
5 the aforementioned composition, for example, glycerides of higher fatty acids [e.g., cacao butter, Witepsols (manufactured by Dynamit Nobel, Germany), etc.], medium chain fatty acid [e.g., Miglyols (manufactured by Dynamit Nobel, Germany), etc.], or vegetable oils (e.g., sesame oil, soybean oil, cotton seed oil
10 and the like), and the like are listed. Further, as the aqueous substrate, for example, polyethylene glycols, propylene glycol are listed, and as the aqueous gel substrate, for example, natural gums, cellulose derivatives, vinyl polymers, acrylic acid polymers and the like are listed.

15 As the above-mentioned sustained release preparation, sustained release microcapsules and the like are used.

The sustained release microcapsule can be produced by a method known *per se* and, for example, a sustained-release preparation such as the one shown in the following [2] is
20 preferably formed and administered.

The compound of the present invention is preferably molded into an oral administration preparation such as a solid preparation (e.g., powder, granule, tablet, capsule) and the like, or molded into a rectal administration preparation such as
25 a suppository. Particularly, an oral administration preparation is preferable.

The concomitant drug can be made into the above-mentioned drug form depending on the kind of the drug.

[1] An injection of the compound of the present invention
30 or the concomitant drug, and preparation thereof, [2] a sustained release preparation or immediate-release preparation of the compound of the present invention or the concomitant drug, and preparation thereof, [3] a sublingual, buccal or intraoral quick integrating agent of the compound of the present invention

or the concomitant drug, and preparation thereof, will be specifically described in the following.

[1] Injection and preparation thereof

An injection prepared by dissolving the compound of the present invention or the concomitant drug into water is preferable. This injection may be allowed to contain a benzoate and/or salicylate.

The injection is obtained by dissolving the compound of the present invention or the concomitant drug, and if desirable, a benzoate and/or salicylate, into water.

As the above-mentioned salts of benzoic acid and salicylic acid, for example, salts of alkali metals such as sodium, potassium and the like, salts of alkaline earth metals such as calcium, magnesium and the like, ammonium salts, meglumine salts, salts with organic acid salts such as tromethamol and the like, etc. are used.

The concentration of the compound of the present invention or the concomitant drug in an injection is from 0.5 to 50 w/v%, preferably from about 3 to 20 w/v%. The concentration of a benzoate or/and salicylate is from 0.5 to 50 w/v%, preferably from about 3 to 20 w/v%.

Into this injection, additives usually used in an injection, for example, a stabilizer (e.g., ascorbic acid, sodium pyrosulfite and the like), a surfactant (e.g., Polysorbate 80, macrogol and the like), a solubilizer (e.g., glycerin, ethanol and the like), a buffer (e.g., phosphoric acid and alkali metal salt thereof, citric acid and alkali metal salt thereof, and the like), an isotonizing agent (e.g., sodium chloride, potassium chloride and the like), a dispersing agent (e.g., hydroxypropylmethylcellulose, dextrin), a pH regulator (e.g., hydrochloric acid, sodium hydroxide and the like), a preservative (e.g., ethyl parahydroxybenzoate, benzoic acid and the like), a dissolving agent (e.g., conc. glycerin, meglumine and the like), a solubilizing agent (e.g., propylene glycol, sucrose and the like), a soothing agent (e.g., glucose, benzyl

alcohol and the like), and the like, can be appropriately blended. These additives are generally blended in a proportion usually used in an injection.

It is advantageous that pH of an injection is controlled
5 from pH 2 to 12, preferably from pH 2.5 to 8.0 by addition of a pH regulator.

An injection is obtained by dissolving the compound of the present invention or the concomitant drug and if desirable, a benzoate and/or a salicylate, and if necessary, the above-
10 mentioned additives into water. These may be dissolved in any order, and can be appropriately dissolved in the same manner as in a conventional method of producing an injection.

An aqueous solution for injection is advantageously heated, alternatively, for example, filter sterilization, high pressure
15 heat sterilization and the like can be conducted in the same manner as for a usual injection, to provide an injection.

It is advantageous that an aqueous solution for injection be subjected to high pressure heat sterilization at 100 to 121°C for 5 to 30 min.

20 Further, a preparation endowed with an antibacterial property of a solution may also be produced so that it can be used as a preparation which is divided and administered multiple-times.

[2] Sustained release preparation or immediate-release
25 preparation, and preparation thereof

A sustained release preparation is preferable, which is obtained, if desirable, by coating a nucleus containing the compound of the present invention or the concomitant drug with a film agent such as a water-insoluble substance, swellable
30 polymer and the like. For example, a sustained release preparation for oral administration of once administration per day is preferable.

As the water-insoluble substance used in a film agent, there are listed, for example, cellulose ethers such as
35 ethylcellulose, butylcellulose and the like, cellulose esters

such as cellulose acetate, cellulose propionate and the like, polyvinyl esters such as polyvinyl acetate, polyvinyl butyrate and the like, acrylic acid/methacrylic acid copolymers, methyl methacrylate copolymers, ethoxyethyl methacrylate/cinnamoethyl methacrylate/aminoalkyl methacrylate copolymers, polyacrylic acid, polymethacrylic acid, methacrylic acid alkylamide copolymers, poly(methyl methacrylate), polymethacrylates, polymethacrylamides, aminoalkyl methacrylate copolymers, poly(methacrylic anhydride), glycidyl methacrylate copolymers, particularly, acrylic acid-based polymers such as Eudoragit (Rohm Pharma) such as Eudoragit RS-100, RL-100, RS-30D, RL-30D, RL-PO, RS-PO (ethyl acrylate/methyl methacrylate/trimethylammoniummethyl methacrylate chloride copolymer), Eudoragit NE-30D (methyl methacrylate/ethyl acrylate copolymer), and the like, hydrogenated oils such as hydrogenated castor oil (e.g., Lubri wax (Freund Corporation) and the like) and the like, waxes such as carnauba wax, glycerin fatty acid ester, paraffin and the like, polyglycerin fatty esters, and the like.

As the swellable polymer, polymers having an acidic dissociating group and showing pH dependent swell are preferable, and polymers having an acidic dissociating group, which manifest small swelling in acidic regions such as in stomach and large swelling in neutral regions such as in small intestine and large intestine, are preferable.

As such a polymer having an acidic dissociating group and showing pH dependent swell, cross-linkable polyacrylic acid polymers such as, for example, Carbomer 934P, 940, 941, 974P, 980, 1342 and the like, polycarbophil, calcium polycarbophil (last two are manufactured by BF Goodrich), Hiviswako 103, 104, 105, 304 (all are manufactured by Wako Pure Chemical Industries, Ltd.), and the like, are listed.

The film agent used in a sustained release preparation may further contain a hydrophilic substance.

As the hydrophilic substance, for example, polysaccharides which may contain a sulfate group such as pullulan, dextrin, alkali metal alginate and the like, polysaccharides having hydroxyalkyl or carboxyalkyl such as hydroxypropylcellulose, 5 hydroxypropylmethylcellulose, carboxymethylcellulose sodium and the like, methylcellulose, polyvinylpyrrolidone, polyvinyl alcohol, polyethylene glycol and the like can be mentioned.

The content of a water-insoluble substance in the film agent of a sustained release preparation is from about 30 to 10 about 90% (w/w), preferably from about 35 to about 80% (w/w), further preferably from about 40 to about 75% (w/w), the content of a swellable polymer is from about 3 to about 30% (w/w), preferably from about 3 to about 15% (w/w). The film agent may further contain a hydrophilic substance, and in which case, the 15 content of a hydrophilic substance in the film agent is about 50% (w/w) or less, preferably about 5 to 40% (w/w), further preferably from about 5 to 35% (w/w). This % (w/w) indicates % by weight based on a film agent composition which is obtained by removing a solvent (e.g., water, lower alcohols such as methanol, 20 ethanol and the like) from a film agent solution.

The sustained release preparation is produced by preparing a nucleus containing a drugs as exemplified below, then, coating the resulted nucleus with a film agent solution prepared by heat-solving a water-insoluble substance, swellable polymer and 25 the like or by dissolving or dispersing it in a solvent.

I. Preparation of nucleus containing drug

The form of nucleus containing a drug to be coated with a film agent (hereinafter, sometimes simply referred to as nucleus) is not particularly restricted, and preferably, the 30 nucleus is formed into particles such as a granule or fine particle.

When the nucleus is composed of granules or fine particles, the average particle size thereof is preferably from about 150 to about 2000 μm , further preferably, from about 500 to about 35 1400 μm .

Preparation of the nucleus can be effected by a usual production method. For example, a suitable excipient, binding agent, disintegrating agent, lubricant, stabilizer and the like are mixed with a drug, and the mixture is subjected to a wet
5 extrusion granulating method, fluidized bed granulating method or the like, to prepare a nucleus.

The content of drugs in a nucleus is from about 0.5 to about 95% (w/w), preferably from about 5.0 to about 80% (w/w), further preferably from about 30 to about 70% (w/w).

10 As the excipient contained in the nucleus, for example, saccharides such as sucrose, lactose, mannitol, glucose and the like, starch, crystalline cellulose, calcium phosphate, corn starch and the like are used. Among them, crystalline cellulose, corn starch are preferable.

15 As the binding agent, for example, polyvinyl alcohol, hydroxypropylcellulose, polyethylene glycol, polyvinyl pyrrolidone, Pluronic F68, gum Arabic, gelatin, starch and the like are used. As the disintegrating agent, for example, carboxymethylcellulose calcium (ECG505), croscarmellose sodium
20 (Ac-Di-Sol), crosslinked polyvinylpyrrolidone (Crospovidone), low substituted hydroxypropylcellulose (L-HPC) and the like are used. Among them, hydroxypropylcellulose, polyvinylpyrrolidone, lower substituted hydroxypropylcellulose are preferable. As the lubricant and coagulation inhibitor, for example, talc,
25 magnesium stearate and inorganic salts thereof are used, and as the lubricant, polyethylene glycol and the like are used. As the stabilizer, acids such as tartaric acid, citric acid, succinic acid, fumaric acid, maleic acid and the like, are used.

A nucleus can also be prepared by, in addition to the
30 above-mentioned, for example, a rolling granulation method in which a drug or a mixture of a drug with an excipient, lubricant and the like are added portionwise onto an inert carrier particle which is the core of the nucleus while spraying a binder dissolved in a suitable solvent such as water, lower
35 alcohol (e.g., methanol, ethanol and the like) and the like, a

pan coating method, a fluidized bed coating method or a melt granulating method. As the inert carrier particle, for example, those made of sucrose, lactose, starch, crystalline cellulose or waxes can be used, and the average particle size thereof is preferably from about 100 μm to about 1500 μm .

For separating a drug contained in a nucleus and a film agent, the surface of the nucleus may be coated with a protective agent. As the protective agent, for example, the above-mentioned hydrophilic substances, water-insoluble substances and the like are used. As the protective agent, preferably polyethylene glycol, and polysaccharides having hydroxyalkyl or carboxyalkyl are used, more preferably, hydroxypropylmethylcellulose and hydroxypropylcellulose are used. The protective agent may contain, as stabilizer, acids such as tartaric acid, citric acid, succinic acid, fumaric acid, maleic acid and the like, and lubricants such as talc and the like. When the protective agent is used, the coating amount is from about 1 to about 15% (w/w), preferably from about 1 to about 10% (w/w), further preferably from about 2 to about 8% (w/w), based on the nucleus.

The protective agent can be coated by a usual coating method, and specifically, the protective agent can be coated by spray-coating the nucleus, for example, by a fluidized bed coating method, pan coating method and the like.

II. Coating of nucleus with film agent

A nucleus obtained in the above-mentioned step I is coated with a film agent solution obtained by heat-solving the above-mentioned water-insoluble substance and pH-dependent swellable polymer, and a hydrophilic substance, or by dissolving or dispersing them in a solvent, to give a sustained release preparation.

As the method for coating a nucleus with a film agent solution, for example, a spray coating method and the like are listed.

The composition ratio of a water-insoluble substance, swellable polymer or hydrophilic substance in a film agent solution is appropriately selected so that the contents of these components in a coated film are the above-mentioned contents, respectively.

The coating amount of a film agent is from about 1 to about 90% (w/w), preferably from about 5 to about 50% (w/w), further preferably from about 5 to about 35% (w/w), based on a nucleus (not including coating amount of protective agent).

As the solvent in a film agent solution, water or an organic solvent can be used alone or in admixture thereof. In the case of use in admixture, the mixing ratio of water to an organic solvent (water/organic solvent: by weight) can be varied in the range from 1 to 100%, and is preferably from 1 to about 30%. The organic solvent is not particularly restricted providing it dissolves a water-insoluble substance, and for example, lower alcohols such as methyl alcohol, ethyl alcohol, isopropyl alcohol, n-butyl alcohol and the like, lower alkanone such as acetone and the like, acetonitrile, chloroform, methylene chloride and the like are used. Among them, lower alcohols are preferable, and ethyl alcohol and isopropyl alcohol are particularly preferable. Water, and a mixture of water with an organic solvent are preferably used as a solvent for a film agent. In this case, if necessary, an acid such as tartaric acid, citric acid, succinic acid, fumaric acid, maleic acid and the like may also be added into a film agent solution for stabilizing the film agent solution.

An operation of coating by spray coating can be effected by a usual coating method, and specifically, it can be performed by spray-coating a film agent solution onto a nucleus by a fluidized bed coating method, pan coating method and the like. In this case, if necessary, talc, titanium oxide, magnesium stearate, calcium stearate, light anhydrous silicic acid and the like may also be added as a lubricant, and glycerin fatty acid

ester, hydrogenated castor oil, triethyl citrate, cetyl alcohol, stearyl alcohol and the like may also be added as a plasticizer.

After coating with a film agent, if necessary, an antistatic agent such as talc and the like may be mixed.

5 The immediate-release preparation may be liquid (solution, suspension, emulsion and the like) or solid (particle, pill, tablet and the like). Oral agents and parenteral agents such as an injection and the like are used, and oral agents are preferable.

10 The immediate-release preparation, usually, may contain, in addition to an active component drug, also carriers, additives and excipients conventionally used in the production field (hereinafter, sometimes abbreviated as excipient). The preparation excipient to be used is not particularly restricted
15 providing it is an excipient ordinarily used as a preparation excipient. For example, as the excipient for an oral solid preparation, lactose, starch, corn starch, crystalline cellulose (Avicel PH101, manufactured by Asahi Kasei Corporation, and the like), powder sugar, granulated sugar, mannitol, light anhydrous
20 silicic acid, magnesium carbonate, calcium carbonate, L-cysteine and the like are listed, and preferably, corn starch and mannitol and the like are listed. These excipients can be used alone or in combination of two or more. The content of the excipient is, for example, from about 4.5 to about 99.4 w/w%,
25 preferably from about 20 to about 98.5 w/w%, further preferably from about 30 to about 97 w/w%, based on the total amount of the immediate-release preparation.

The content of a drug in the immediate-release preparation can be appropriately selected in the range from about 0.5 to
30 about 95%, preferably from about 1 to about 60% based on the total amount of the immediate-release preparation.

When the immediate-release preparation is an oral solid preparation, it usually contains, in addition to the above-mentioned components, also an integrating agent. As this
35 integrating agent, for example, carboxymethylcellulose calcium

(ECG-505, manufactured by Gotoku Yakuhin), croscarmellose sodium (e.g., Actisol, manufactured by Asahi Kasei Corporation), crospovidone (e.g., Kollidon CL, manufactured by BASF), low substituted hydroxypropylcellulose (manufactured by Shin-Etsu Chemical Co., Ltd.), carboxymethylstarch (manufactured by Matsutani Kagaku K.K.), carboxymethylstarch sodium (Exprotab, manufactured by Kimura Sangyo), partially pregelatinized starch (PCS, manufactured by Asahi Kasei Corporation), and the like are used, and for example, those which disintegrate a granule by adsorbing water in contact with water, causing swelling, or making a channel between an effective ingredient constituting the nucleus and an excipient, can be used. These disintegrating agents can be used alone or in combination of two or more. The amount of the disintegrating agent to be used is appropriately selected depending on the kind and blending amount of a drug to be used, design of releasing property, and the like, and for example, from about 0.05 to about 30 w/w%, preferably from about 0.5 to about 15 w/w%, based on the total amount of the quick releasing agent.

When the immediate-release preparation is an oral solid preparation, it may further contain, in addition to the above-mentioned composition, if desired, additives conventional in solid preparations. As such an additive, there are used, for example, a binder (e.g., sucrose, gelatin, gum Arabic powder, methylcellulose, hydroxypropylcellulose, hydroxypropylmethylcellulose, carboxymethylcellulose, polyvinylpyrrolidone, pullulan, dextrin and the like), a lubricant (e.g., polyethylene glycol, magnesium stearate, talc, light anhydrous silicic acid (e.g., Aerosil (Nippon Aerosil))), a surfactant (e.g., anionic surfactants such as sodium alkylsulfate and the like, nonionic surfactants such as polyoxyethylene fatty acid ester and polyoxyethylene sorbitan fatty acid ester, polyoxyethylene castor oil derivatives and the like), a colorant (e.g., tar coloring matter, caramel, iron oxide red, titanium oxide, riboflavins), if necessary, an

appetizing agent (e.g., sweetening agent, flavoring agent and the like), an adsorbent, preservative, wetting agent, antistatic agent, and the like. Further, as the stabilizer, an organic acid such as tartaric acid, citric acid, succinic acid, fumaric
5 acid and the like may also be added.

As the above-mentioned binder, hydroxypropylcellulose, polyethylene glycol and polyvinylpyrrolidone and the like are preferably used.

The immediate-release preparation can be prepared by,
10 based on a usual technology of producing preparations, mixing the above-mentioned components, and if necessary, further kneading the mixture, and molding it. The above-mentioned mixing is conducted by generally used methods, for example, mixing, kneading and the like. Specifically, when a immediate-
15 release preparation is formed, for example, into a particle, it can be prepared, according to the same means as in the above-mentioned method for preparing a nucleus of a sustained release preparation, by mixing the components using a vertical granulator, universal kneader (manufactured by Hata Tekkosho),
20 fluidized bed granulator FD-5S (manufactured by Powrex Corporation), and the like, and then, granulating the mixture by a wet extrusion granulation method, fluidized bed granulation method and the like.

Thus obtained immediate-release preparation and sustained
25 release preparation may be themselves made into preparations or made into preparations appropriately together with preparation excipients and the like, separately, by an ordinary method, then, may be administered simultaneously or may be administered in combination at any administration interval, or they may be
30 themselves made into one oral preparation (e.g., granule, fine particle, tablet, capsule and the like) or made into one oral preparation appropriately together with preparation excipients and the like. It may also be permissible that they are made into granules or fine particles, and filled in the same capsule
35 to be used as a preparation for oral administration.

[3] Sublingual, buccal or intraoral quick disintegrating agent and preparation thereof

Sublingual, buccal or intraoral quick disintegrating agents may be a solid preparation such as tablet and the like, 5 or may be an oral mucosa membrane patch (film).

As the sublingual, buccal or intraoral quick disintegrating agent, a preparation containing the compound of the present invention or the concomitant drug and an excipient is preferable. It may contain also auxiliary agents such as a 10 lubricant, isotonizing agent, hydrophilic carrier, water-dispersible polymer, stabilizer and the like. Further, for easy absorption and increased bioavailability, β -cyclodextrin or β -cyclodextrin derivatives (e.g., hydroxypropyl- β -cyclodextrin and the like) and the like may also be contained.

15 As the above-mentioned excipient, lactose, sucrose, D-mannitol, starch, crystalline cellulose, light anhydrous silicic acid and the like are listed. As the lubricant, magnesium stearate, calcium stearate, talc, colloidal silica and the like are listed, and particularly, magnesium stearate and colloidal 20 silica are preferable. As the isotonizing agent, sodium chloride, glucose, fructose, mannitol, sorbitol, lactose, saccharose, glycerin, urea and the like are listed, and particularly, mannitol is preferable. As the hydrophilic carrier, swellable hydrophilic carriers such as crystalline 25 cellulose, ethylcellulose, crosslinkable polyvinylpyrrolidone, light anhydrous silicic acid, silicic acid, dicalcium phosphate, calcium carbonate and the like are listed, and particularly, crystalline cellulose (e.g., microcrystalline cellulose and the like) is preferable. As the water-dispersible polymer, gums 30 (e.g., gum tragacanth, acacia gum, guar gum), alginates (e.g., sodium alginate), cellulose derivatives (e.g., methylcellulose, carboxymethylcellulose, hydroxymethylcellulose, hydroxypropylcellulose, hydroxypropylmethylcellulose), gelatin, aqueous starch, polyacrylic acids (e.g., Carbomer), 35 polymethacrylic acid, polyvinyl alcohol, polyethylene glycol,

polyvinylpyrrolidone, polycarbophil, ascorbate palmitates and the like are listed, and hydroxypropylmethylcellulose, polyacrylic acid, alginate, gelatin, carboxymethylcellulose, polyvinylpyrrolidone, polyethylene glycol and the like are
5 preferable. Particularly, hydroxypropylmethylcellulose is preferable. As the stabilizer, cysteine, thiosorbitol, tartaric acid, citric acid, sodium carbonate, ascorbic acid, glycine, sodium sulfite and the like are listed, and particularly, citric acid and ascorbic acid are preferable.

10 The sublingual, buccal or intraoral quick disintegrating agent can be produced by mixing the compound of the present invention or the concomitant drug and an excipient by a method known *per se*. Further, if desired, the above-mentioned auxiliary agents such as a lubricant, isotonizing agent,
15 hydrophilic carrier, water-dispersible polymer, stabilizer, colorant, sweetening agent, preservative and the like may be mixed. The sublingual, buccal or intraoral quick disintegrating agent is obtained by mixing the above-mentioned components simultaneously or at a time interval, then subjecting the
20 mixture to tablet-making molding under pressure. For obtaining suitable hardness, it may also be permissible that the materials are moistened by using a solvent such as water, alcohol and the like if desired before and after the tablet making process, and after the molding, the materials are dried, to obtain a product.

25 In the case of molding into a mucosa membrane patch (film), the compound of the present invention or the concomitant drug and the above-mentioned water-dispersible polymer (preferably, hydroxypropylcellulose, hydroxypropylmethylcellulose), excipient and the like are dissolved in a solvent such as water and the
30 like, and the resulted solution is cast to give a film. Further, additives such as a plasticizer, stabilizer, antioxidant, preservative, colorant, buffer, sweetening agent and the like may also be added. For imparting suitable elasticity to the film, glycols such as polyethylene glycol, propylene glycol and
35 the like may be contained, or for enhancing adhesion of the film

to an intraoral mucosa membrane lining, a bio-adhesive polymer (e.g., polycarbophil, carbopol) may also be contained. In the casting, a solution is poured on the non-adhesive surface, spread to uniform thickness (preferably, about 10 to 1000
5 micron) by an application tool such as a doctor blade and the like, then, the solution is dried to form a film. It may be advantageous that thus formed film is dried at room temperature or under heat, and cut into a desired area.

As the preferable intraoral quick disintegrating agent,
10 there are used solid quick scattering dosage form composed of a network body comprising the compound of the present invention or the concomitant drug, and an aqueous or water-diffusible carrier which is inert to the compound of the present invention or concomitant drug. This network body is obtained by sublimating
15 a solvent from the solid composition constituted of a solution prepared by dissolving the compound of the present invention or the concomitant drug in a suitable solvent.

It is preferable that the composition of an intraoral quick disintegrating agent contains a matrix forming agent and a
20 secondary component, in addition to the compound of the present invention or the concomitant drug.

Examples of the matrix forming agent include animal proteins or vegetable proteins such as gelatins, dextrans, soybean, wheat and psyllium seed protein and the like; rubber
25 substances such as gum Arabic, guar gum, agar, xanthane gum and the like; polysaccharides; alginic acids; carboxymethylcelluloses; carageenans; dextrans; pectines; synthetic polymers such as polyvinylpyrrolidone and the like; substances derived from a gelatin-gum Arabic complex, and the
30 like. Further, saccharides such as mannitol, dextrose, lactose, galactose, trehalose and the like; cyclic saccharides such as cyclodextrin and the like; inorganic salts such as sodium phosphate, sodium chloride and aluminum silicate and the like; amino acids having 2 to 12 carbon atoms such as glycine, L-
35 alanine, L-aspartic acid, L-glutamic acid, L-hydroxyproline, L-

isoleucine, L-leucine, L-phenylalanine and the like, are contained.

One or more of the matrix forming agents can be introduced in a solution or suspension before solidification. Such as
5 matrix forming agent may be present in addition to a surfactant, or may be present while a surfactant being excluded. The matrix forming agents aid to maintain the compound of the present invention or the concomitant drug in the solution or suspension in diffused condition, in addition to formation of the matrix.

10 The composition may contain secondary components such as a preservative, antioxidant, surfactant, thickening agent, colorant, pH controlling agent, flavoring agent, sweetening agent, food taste masking agent and the like. As the suitable colorant, there are listed red, black and yellow iron oxides,
15 and FD & C dyes such as FD & C Blue 2, FD & C Red 40 and the like manufactured by Ellis and Everard. Examples of the suitable flavoring agent include mint, raspberry, licorice, orange, lemon, grapefruit, caramel, vanilla, cherry, grape flavor and combinations thereof. Examples of the suitable pH
20 controlling agent include citric acid, tartaric acid, phosphoric acid, hydrochloric acid and maleic acid. Examples of the suitable sweetening agent include aspartame, acesulfame K and thaumatin and the like. Examples of the suitable food taste masking agent include sodium bicarbonate, ion exchange resin,
25 cyclodextrin-inclusion compounds, adsorbent substances and microcapsulated apomorphine.

The preparation contains the compound of the present invention or the concomitant drug in an amount usually from about 0.1 to about 50% by weight, preferably from about 0.1 to
30 about 30% by weight, and preferable are preparations (such as the above-mentioned sublingual agent, buccal and the like) which can dissolve 90% or more of the compound of the present invention or the concomitant drug (into water) within the time range of about 1 to about 60 min, preferably of about 1 to about
35 15 min, more preferably of about 2 to about 5 min, and intraoral

quick disintegrating preparations which are disintegrated within the range of 1 to 60 sec, preferably of 1 to 30 sec, further preferably of 1 to 10 sec, after placed in an oral cavity.

The content of the above-mentioned excipient in the whole preparation is from about 10 to about 99% by weight, preferably from about 30 to about 90% by weight. The content of β -cyclodextrin or β -cyclodextrin derivative in the whole preparation is from 0 to about 30% by weight. The content of the lubricant in the whole preparation is from about 0.01 to about 10% by weight, preferably from about 1 to about 5% by weight. The content of the isotonizing agent in the whole preparation is from about 0.1 to about 90% by weight, preferably, from about 10 to about 70% by weight. The content of the hydrophilic carrier in the whole preparation is from about 0.1 to about 50% by weight, preferably, from about 10 to about 30% by weight. The content of the water-dispersible polymer in the whole preparation is from about 0.1 to about 30% by weight, preferably, from about 10 to about 25% by weight. The content of the stabilizer in the whole preparation is from about 0.1 to about 10% by weight, preferably, from about 1 to 5% by weight. The above-mentioned preparation may further contain additives such as a colorant, sweetening agent, preservative and the like, if necessary.

The dosage of a combination agent of the present invention differs depending on the kind of a compound of the present invention, age, body weight, condition, drug form, administration method, administration period and the like, and for example, for one prostate cancer patient (adult, body weight: about 60 kg), the combination agent is administered intravenously, at a dose of about 0.01 to about 1000 mg/kg/day, preferably about 0.01 to about 100 mg/kg/day, more preferably about 0.1 to about 100 mg/kg/day, particularly about 0.1 to about 50 mg/kg/day, especially about 1.5 to about 30 mg/kg/day, in terms of the compound of the present invention or the concomitant drug, respectively, once or several times in

division a day. Of course, since the dosage as described above varies depending on various conditions, amounts smaller than the above-mentioned dosage may sometimes be sufficient, further, amounts over that range sometimes have to be administered.

5 The amount of the concomitant drug can be set at any value unless side effects are problematical. The daily dosage in terms of the concomitant drug differs depending on the severity of the symptom, age, sex, body weight, sensitivity difference of the subject, administration period, interval, and nature,
10 pharmacy, kind of the pharmaceutical preparation, kind of effective ingredient, and the like, and not particularly restricted, and the amount of a drug is, in the case of oral administration for example, usually from about 0.001 to 2000 mg, preferably from about 0.01 to 500 mg, further preferably from
15 about 0.1 to 100 mg, per 1 kg of a mammal and this is usually administered once to 4-times in division a day.

In administration of a combination agent of the present invention, it may be permissible that the compound of the present invention is administered after the first administration
20 of the concomitant drugs or vice versa, though they may be administered simultaneously. When administered at a time interval, the interval differs depending on the effective ingredient to be administered, drug form and administration method, and for example, when the concomitant drug is
25 administered first, a method in which the compound of the present invention is administered within time range of from 1 min to 3 days, preferably from 10 min to 1 day, more preferably from 15 min to 1 hr after administration of the concomitant drug is exemplified. When the compound of the present invention is
30 administered first, a method in which the concomitant drug is administered within time range of from 1 min to 1 day, preferably from 10 min to 6 hrs, more preferably from 15 min to 1 hr after administration of the compound of the present invention is exemplified.

In a preferable administration method, for example, the concomitant drug which has been molded into an oral administration preparation is administered orally at a daily dose of about 0.001 to 200 mg/kg, and about 15 min later, the
5 compound of the present invention which has been molded into an oral administration preparation is administered orally at a daily dose of about 0.005 to 100 mg/kg.

Furthermore, the pharmaceutical composition or the concomitant drug of the present invention can be combined with a
10 non-drug therapy such as (1) surgery, (2) hypertensive chemotherapy using angiotensin II etc., (3) gene therapy, (4) thermotherapy, (5) cryotherapy, (6) laser cauterization, (7) radiotherapy, and the like.

For example, by using the pharmaceutical composition of the present invention or the concomitant drug of the present
15 invention before and after an operation and the like, or before and after a treatment combining two or three kinds thereof, effects of prevention of resistance expression, elongation of Disease-Free Survival, suppression of cancer metastasis or
20 recurrence, apothanasia and the like can be obtained.

In addition, a treatment with the pharmaceutical composition of the present invention or the concomitant drug of the present invention can be combined with a supporting therapy [(i) administration of antibiotic (e.g., β -lactam such as
25 pansporin and the like, macrolides such as clarithromycin and the like etc.) for complication with various infectious diseases, (ii) administration of high-calory infusion, amino acid preparation or general vitamin preparation for malnutrition improvement, (iii) administration of morphine for pain
30 mitigation, (iv) administration of pharmaceutical agent for reducing side effects such as nausea, vomiting, anorexia, diarrhea, leucopenia, thrombocytopenia, hemoglobin concentration decrease, hair loss, hepatopathy, renopathy, DIC, fever and the like, and (v) administration of pharmaceutical agent for
35 suppressing multiple drug resistance of cancer etc.].

Specific examples of a pharmaceutical agent for such object, e.g., "antiemetic", include gastric motility enhancers such as 5-HT₃ antagonists (e.g., ondansetron, tropisetron hydrochloride, azasetron, ramosetron, granisetron, dolasetron mesylate, palonosetron and the like); NK1 receptor antagonists (e.g., sendide, CP-99994, CP-100263, CP-122721-1, CP-96345, FK224, RPR100893, NKP608, aprepitant (EMEND (trademark)) and the like; 5-HT₄ antagonists (e.g., domperidone, mosapride, metoclopramide and the like), and the like; gastrointestinal tract motility regulators such as trimebutine and the like; phenothiazine pharmaceutical agents such as prochlorperazine maleate, promethazine, thiethylperazine and the like; tranquilizers such as haloperidol, chlorpromazine phenolphthalinate, diazepam, droperidol and the like; steroids such as dexamethasone, prednisolone, betamethasone, triamcinolone and the like; as well as dimethylhydrin acid, diphenhydramine, hyoscine, hyoscine hydrobromide, tetrabenazine and the like.

Preferably, the pharmaceutical composition of the present invention or the combination agent of the present invention is administered orally (including sustained-release preparations), intravenously (including boluses, infusions and clathrates), subcutaneously and intramuscularly (including boluses, infusions and sustained-release preparations), transdermally, intratumorally or proximally before or after the above-described treatment is conducted.

As a period for administration of the pharmaceutical composition of the present invention or the combination agent of the present invention before the surgery, etc., for example, it can be administrated once about 30 min to 24 hr before the surgery, etc., or in 1 to 3 cycles about 3 to 6 months before the surgery, etc. In this way, the surgery, etc. can be conducted easily because, for example, a cancer tissue can be reduced by administering the pharmaceutical composition of the

present invention or the combination agent of the present invention before the surgery, and the like.

As a period for administration of the pharmaceutical composition of the present invention or the combination agent of the present invention after the surgery and the like, for example, it can be administrated repeatedly about 30 min to 24 hr after the surgery, and the like in a unit of several weeks to 3 months. In this way, the effect of the surgery and the like can be enhanced by administering the pharmaceutical composition of the present invention or the combination agent of the present invention after the surgery and the like.

Examples

The present invention is explained in detail in the following by referring to Reference Examples, Examples, Preparation Examples and Experimental Examples, which are not to be construed as limitative.

The elution in column chromatography in Reference Examples and Examples was performed under observation by TLC (thin-layer chromatography). In the TLC observation, Kieselgel 60F₂₅₄ plate (Merck) was used as a TLC plate, the solvent used as an elution solvent in the column chromatography was used as a developing solvent, and the means of detection used was an UV detector. As silica gel for column, Kieselgel 60F₂₅₄ (70-230 mesh) manufactured by Merck again or Purif-Pack (SI 60 μ m), Purif-Pack (NH 60 μ m) manufactured by MORITEX was used. NMR spectra are shown by proton NMR with tetramethylsilane as the internal standard, using VARIAN Gemini-200 (200 MHz type spectrometer), VARIAN Mercury-300 (300 MHz) or JMTCO400/54 (400 MHz type) (JEOL Ltd.); δ values are expressed in ppm. The reaction using a microwave reaction apparatus was performed using Emrys Optimizer manufactured by Biotage. The infrared absorption spectrum (IR) was measured using Paragon 1000 manufactured by PerkinElmer. The melting point was measured using MPA100 type melting point measurement apparatus, Optimelt, manufactured by Stanford Research System.

The abbreviations used in Reference Examples and Examples mean the following.

- s : singlet
br : broad
5 brs: broad singlet
d : doublet
t : triplet
q : quartet
dd : double doublet
10 ddd: double double doublet
dt : double triplet
dq : double quartet
m : multiplet
J : coupling constant
15 Hz : hertz

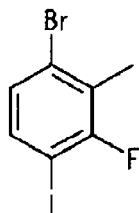
THF : tetrahydrofuran

DMSO: dimethyl sulfoxide

DMF : N,N-dimethylformamide

Reference Example 1

- 20 1-bromo-3-fluoro-4-iodo-2-methylbenzene



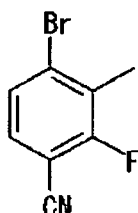
- A solution of diisopropylamine (6.06 mL) in THF (100 mL) was cooled to -78°C , n-butyllithium-hexane (24.9 mL, 1.6 mol/L) was added dropwise and, after the completion of the dropwise
25 addition, the mixture was stirred at -78°C for 1 hr. Subsequently, a solution of 4-bromo-2-fluoro-1-iodobenzene (10.0 g) in THF (50 mL) was added dropwise, and the mixture was further stirred at -78°C for 1 hr. Methyl iodide (2.90 mL) was added dropwise at -78°C and the mixture was further stirred at -
30 78°C for 2 hr, and the mixture was warmed to room temperature. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with

saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure to give the title compound as a brown oil (yield: 10.5 g, yield: 100%).

¹H-NMR(CDCl₃)δ:2.37(3H,d,J=2.6Hz), 7.10(1H,dd,J=8.5,1.1Hz), 7.39-7.46(1H,m).

Reference Example 2

4-bromo-2-fluoro-3-methylbenzonitrile

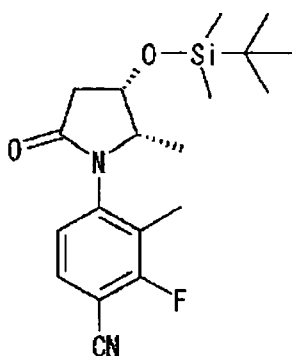


To a solution of 1-bromo-3-fluoro-4-iodo-2-methylbenzene (2.00 g) in DMF (15 mL) were added zinc cyanide (336 mg) and tetrakis(triphenylphosphine)palladium(0) (367 mg), and the mixture was stirred under an argon atmosphere at 100°C for 5.5 hr. The reaction mixture was added to water, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography to give the title compound as a colorless solid (yield: 1.21 g, 89%).

¹H-NMR(CDCl₃)δ:2.39(3H,d,J=2.6Hz), 7.29-7.36(1H,m), 7.44-7.50(1H,m).

Reference Example 3

4-[(2S,3S)-3-(tert-butyldimethylsilyloxy)-2-methyl-5-oxopyrrolidin-1-yl]-2-fluoro-3-methylbenzonitrile



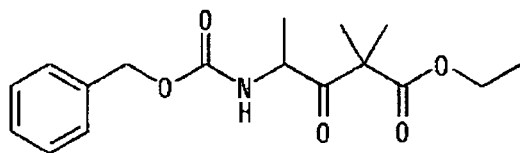
To a solution of 4-bromo-2-fluoro-3-methylbenzonitrile (1.10 g), (4S,5S)-4-(tert-butyldimethylsilyloxy)-5-

methylpyrrolidin-2-one (1.18 g), cesium carbonate (2.51 g),
tris(dibenzylideneacetone)dipalladium(0) (235 mg) and 4,5-
bis(diphenylphosphino)-9,9-dimethylxanthene (297 mg) in dioxane
(30 mL) was stirred under an argon atmosphere at 80°C for 8 hr.
5 The reaction mixture was added to water, and the mixture was
extracted with ethyl acetate. The extract was washed with
saturated brine, dried over anhydrous magnesium sulfate, and
concentrated under reduced pressure. The residue was purified
by silica gel column chromatography to give the title compound
10 as a colorless solid (yield: 347 mg, 19%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.11 (6H, d, $J=7.2\text{Hz}$), 0.91 (9H, s), 1.04 (3H, d, $J=6.4\text{Hz}$),
2.19 (3H, d, $J=2.3\text{Hz}$), 2.50 (1H, dd, $J=16.8, 2.4\text{Hz}$),
2.78 (1H, dd, $J=16.8, 5.4\text{Hz}$), 4.09–4.22 (1H, m), 4.44–4.50 (1H, m),
6.96 (1H, d, $J=8.7\text{Hz}$), 7.45–7.53 (1H, m).

15 Reference Example 4

Ethyl 4-{[(benzyloxy)carbonyl]amino}-2,2-dimethyl-3-
oxopentanoate

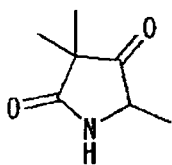


20 A solution of ethyl (4S)-4-{[(benzyloxy)carbonyl]amino}-3-
oxopentanoate (13.8 g) synthesized according to the method
described in Tetrahedron Letters, vol. 41, pages 3979–3982, 2000,
methyl iodide (8.79 mL) and potassium carbonate (13.01 g) in
acetone (200 mL) was stirred under reflux overnight. The
25 reaction mixture was added to water, and the mixture was
extracted with ethyl acetate. The extract was washed with
saturated brine, dried over anhydrous magnesium sulfate, and
concentrated under reduced pressure. The residue was purified
by silica gel column chromatography to give the title compound
30 as a colorless oil (yield: 11.82 g, 78%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.22 (3H, t, $J=7.2\text{Hz}$), 1.31 (3H, d, $J=6.8\text{Hz}$), 1.41 (3H, s),
1.43 (3H, s), 4.06–4.22 (2H, m), 4.74 (1H, dd, $J=8.5, 7.2\text{Hz}$), 5.02–
5.17 (2H, m), 5.23–5.37 (1H, m), 7.28–7.46 (5H, m).

Reference Example 5

3,3,5-trimethylpyrrolidine-2,4-dione

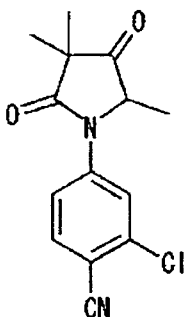


To a solution of ethyl 4-[[(benzyloxy) carbonyl] amino]-2,2-dimethyl-3-oxopentanoate (10.5 g) in methanol (150 mL) was added 10% palladium carbon (containing 50% water, 5.0 g), and the mixture was stirred under a hydrogen atmosphere overnight. The reaction mixture was filtered, and the filtrate was concentrated under reduced pressure. The obtained solid was washed with hexane to give the title compound as a colorless solid (yield: 4.00g, 87%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.26 (3H, s), 1.27 (3H, s), 1.40 (3H, d, $J=6.8\text{Hz}$), 4.08 (1H, q, $J=6.9\text{Hz}$), 6.07 (1H, brs).

Reference Example 6

2-chloro-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile

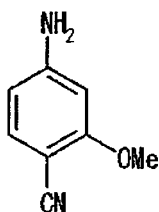


Using 4-bromo-2-chlorobenzonitrile (199 mg), 3,3,5-trimethylpyrrolidine-2,4-dione (100 mg), cesium carbonate (346 mg), tris(dibenzylideneacetone)dipalladium(0) (65 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (82 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 135 mg, 69%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.35 (3H, s), 1.40 (3H, s), 1.46 (3H, d, $J=6.8\text{Hz}$), 4.61 (1H, q, $J=6.9\text{Hz}$), 7.55 (1H, dd, $J=8.6, 2.1\text{Hz}$), 7.72 (1H, d, $J=8.5\text{Hz}$), 7.87 (1H, d, $J=2.1\text{Hz}$).

Reference Example 7

4-amino-2-methoxybenzonitrile



2-Methoxy-4-nitrobenzonitrile (5.0 g) and iron powder (7.84 g) were suspended in ethanol (150 mL), and concentrated hydrochloric acid (35 mL) was added dropwise at room temperature.

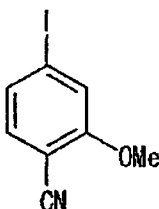
5 The reaction mixture was stirred at room temperature for 3 hr, neutralized with sodium hydrogen carbonate, and extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column

10 chromatography, and the obtained solid was washed with hexane to give the title compound as a red-brown solid (yield: 3.05 g, 73%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 3.86 (3H, s), 4.15 (2H, brs), 6.16 (1H, d, $J=2.1\text{Hz}$), 6.22 (1H, dd, $J=8.3, 2.1\text{Hz}$), 7.30 (1H, d, $J=8.3\text{Hz}$).

15 Reference Example 8

4-iodo-2-methoxybenzonitrile



To a suspension of copper iodide (4.63 g) in acetonitrile (50 mL) was added tert-butyl nitrite (3.61 mL) at room

20 temperature, a solution of 4-amino-2-methoxybenzonitrile (3.00 g) in acetonitrile (30 mL) was added dropwise thereto at 65°C and, after the completion of the dropwise addition, the mixture was further stirred at 65°C for 2 hr. The reaction mixture was added to aqueous sodium thiosulfate solution, and the mixture was

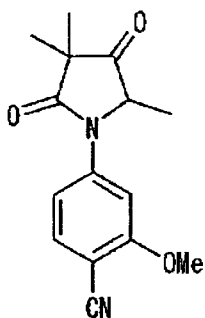
25 extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography, and the obtained solid was

washed with diisopropyl ether to give the title compound as a yellow solid (yield: 2.56 g, 49%).

$^1\text{H-NMR}$ (CDCl_3) δ : 3.93 (3H, s), 7.24 (1H, d, $J=8.1\text{Hz}$), 7.33 (1H, d, $J=1.1\text{Hz}$), 7.39 (1H, dd, $J=8.1, 1.1\text{Hz}$).

5 Reference Example 9

2-methoxy-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile

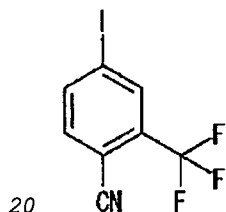


Using 4-iodo-2-methoxybenzonitrile (835 mg), 3,3,5-trimethylpyrrolidine-2,4-dione (350 mg), cesium carbonate (1.21 g), tris(dibenzylideneacetone)dipalladium(0) (227 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (287 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 330 mg, 49%).

15 $^1\text{H-NMR}$ (CDCl_3) δ : 1.35 (3H, s), 1.40 (3H, s), 1.46 (3H, d, $J=6.8\text{Hz}$), 3.97 (3H, s), 4.62 (1H, q, $J=6.9\text{Hz}$), 6.88 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.60 (1H, d, $J=8.5\text{Hz}$), 7.66 (1H, d, $J=2.1\text{Hz}$).

Reference Example 10

4-iodo-2-(trifluoromethyl)benzonitrile

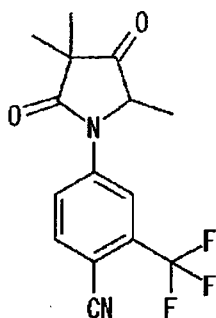


Using copper iodide (6.14 g), tert-butyl nitrite (4.79 mL) and 4-amino-2-(trifluoromethyl)benzonitrile (5.00 g), and in the same manner as in Reference Example 8, the title compound was obtained as a pale-yellow solid (yield: 4.40 g, 55%).

25 $^1\text{H-NMR}$ (CDCl_3) δ : 7.54 (1H, d, $J=8.1\text{Hz}$), 8.06 (1H, dd, $J=8.1, 1.1\text{Hz}$), 8.14 (1H, s).

Reference Example 11

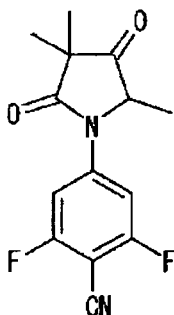
2-(trifluoromethyl)-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile



Using 4-iodo-2-(trifluoromethyl)benzonitrile (957 mg),
 5 3,3,5-trimethylpyrrolidine-2,4-dione (350 mg), cesium carbonate (1.21 g), tris(dibenzylideneacetone)dipalladium(0) (227 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (287 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 452 mg, 59%).
 10 ¹H-NMR(CDCl₃)δ:1.36(3H,s), 1.42(3H,s), 1.48(3H,d,J=7.0Hz), 4.68(1H,q,J=6.8Hz), 7.86(1H,dd,J=8.7,1.5Hz), 7.91(1H,d,J=8.7Hz), 8.12(1H,d,J=1.5Hz).

Reference Example 12

2,6-difluoro-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile
 15

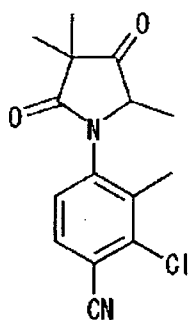


Using 4-bromo-2,6-difluorobenzonitrile (502 mg), 3,3,5-trimethylpyrrolidine-2,4-dione (250 mg), cesium carbonate (866 mg), tris(dibenzylideneacetone)dipalladium(0) (162 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (205 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 305 mg, 62%).

¹H-NMR(CDCl₃)δ:1.35(3H,s), 1.40(3H,s), 1.50(3H,d,J=7.0Hz), 4.54(1H,q,J=7.0Hz), 7.38-7.45(2H,m).

25 Reference Example 13

2-chloro-3-methyl-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile



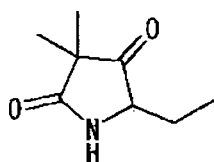
Using 2-chloro-4-iodo-3-methylbenzonitrile (894 mg)

5 synthesized from 4-amino-2-chloro-3-methylbenzonitrile in the same method as in Reference Example 8, 3,3,5-trimethylpyrrolidine-2,4-dione (350 mg), cesium carbonate (1.21 g), tris(dibenzylideneacetone)dipalladium(0) (227 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (287 mg), and in the
10 same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 46 mg, 6%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.30 (3H, d, $J=6.8\text{Hz}$), 1.38 (3H, brs), 1.40 (3H, s), 2.31 (3H, s), 4.15-4.58 (1H, m), 7.21 (1H, d, $J=8.3\text{Hz}$), 7.63 (1H, d, $J=8.3\text{Hz}$).

15 Reference Example 14

5-ethyl-3,3-dimethylpyrrolidine-2,4-dione

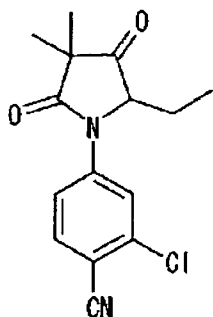


Using ethyl 4-[[(benzyloxy) carbonyl] amino]-3-oxohexanoate, and in the same manner as in Reference Example 4 and Reference
20 Example 5, the title compound was obtained as a colorless solid.

$^1\text{H-NMR}$ (CDCl_3) δ : 0.97 (3H, t, $J=7.5\text{Hz}$), 1.23 (3H, s), 1.26 (3H, s), 1.63-1.94 (2H, m), 3.98 (1H, dd, $J=6.6, 5.1\text{Hz}$), 6.28 (1H, brs).

Reference Example 15

2-chloro-4-(5-ethyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile
25

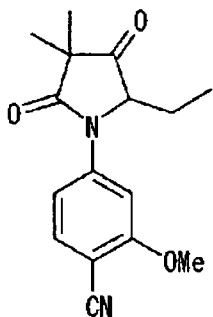


Using 4-bromo-2-chlorobenzonitrile (219 mg), 5-ethyl-3,3-dimethylpyrrolidine-2,4-dione (120 mg), cesium carbonate (378 mg), tris(dibenzylideneacetone)dipalladium(0) (71 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (89 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 147 mg, 65%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.76 (3H, t, $J=7.5\text{Hz}$), 1.34 (3H, s), 1.36 (3H, s), 1.77-1.91 (1H, m), 1.99-2.14 (1H, m), 4.62-4.66 (1H, m), 7.55 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.73 (1H, d, $J=8.5\text{Hz}$), 7.84 (1H, d, $J=2.1\text{Hz}$).

Reference Example 16

4-(5-ethyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)-2-methoxybenzonitrile

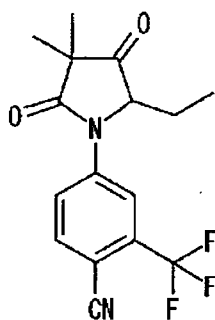


Using 4-iodo-2-methoxybenzonitrile (459 mg), 5-ethyl-3,3-dimethylpyrrolidine-2,4-dione (250 mg), cesium carbonate (787 mg), tris(dibenzylideneacetone)dipalladium(0) (148 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (186 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 300 mg, 65%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.78 (3H, t, $J=7.5\text{Hz}$), 1.34 (3H, s), 1.36 (3H, s), 1.79-1.95 (1H, m), 1.97-2.13 (1H, m), 3.97 (3H, s), 4.63-4.68 (1H, m), 6.90 (1H, dd, $J=8.5, 1.9\text{Hz}$), 7.57-7.62 (2H, m).

Reference Example 17

4-(5-ethyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)-2-(trifluoromethyl)benzonitrile

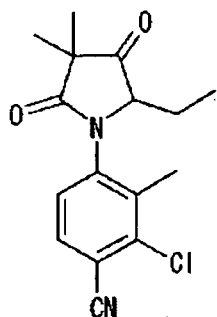


Using 4-iodo-2-(trifluoromethyl)benzonitrile (526 mg), 5-ethyl-3,3-dimethylpyrrolidine-2,4-dione (250 mg), cesium carbonate (787 mg), tris(dibenzylideneacetone)dipalladium(0) (148 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (186 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a pale-yellow oil (yield: 298 mg, 57%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.77 (3H, t, $J=7.4\text{Hz}$), 1.36 (3H, s), 1.38 (3H, s), 1.77-1.93 (1H, m), 2.02-2.17 (1H, m), 4.71 (1H, dd, $J=6.1, 2.7\text{Hz}$), 7.86 (1H, dd, $J=8.4, 1.9\text{Hz}$), 7.91 (1H, d, $J=8.4\text{Hz}$), 8.08 (1H, d, $J=1.9\text{Hz}$).

Reference Example 18

2-chloro-4-(5-ethyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)-3-methylbenzonitrile



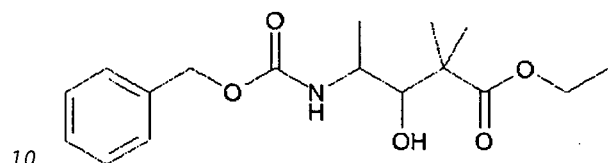
A solution of 2-chloro-4-iodo-3-methylbenzonitrile (983 mg), 5-ethyl-3,3-dimethylpyrrolidine-2,4-dione (550 mg), cesium carbonate (1.73 g), tris(dibenzylideneacetone)dipalladium(0) (325 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (615 mg) in dioxane was reacted in a microwave reactor at 120°C for 5 hr. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium

sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography and recrystallized from THF/hexane to give the title compound as a colorless solid (yield: 294 mg, 27%).

¹H-NMR(CDCl₃)δ:0.78-0.95(3H,m), 1.31-1.42(6H,m), 1.49-1.95(2H,m), 2.32(3H,s), 4.18-4.57(1H,m), 7.15-7.39(1H,m), 7.62(1H,d,J=8.1Hz).

Reference Example 19

ethyl 4-{[(benzyloxy)carbonyl]amino}-2,2-dimethyl-3-hydroxypentanoate

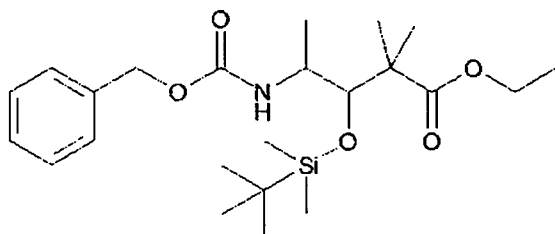


To a solution of ethyl 4-{[(benzyloxy)carbonyl]amino}-2,2-dimethyl-3-oxopentanoate (5.76 g) in methanol (100 mL) was added sodium borohydride (940 mg) at 0°C, and the mixture was stirred at room temperature for 17 hr. Saturated aqueous ammonium chloride solution was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=50/1→1/3) to give the title compound as a colorless solid (yield: 4.26 g, 74%).

¹H-NMR(CDCl₃)δ:1.01(3H,d,J=6.8Hz), 1.12-1.40(10H,m), 3.39-3.64(1H,m), 3.76-4.24(3H,m), 4.85-5.33(3H,m), 7.22-7.42(5H,m).

Reference Example 20

ethyl 4-{[(benzyloxy)carbonyl]amino}-2,2-dimethyl-3-(tert-butyldimethylsilyloxy)pentanoate



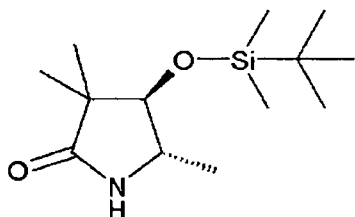
To a solution of ethyl 4-{[(benzyloxy)carbonyl]amino}-2,2-dimethyl-3-hydroxypentanoate (5.7 g) and 2,6-lutidine(2.27 mL)

in THF (80 mL) was added under ice-cooling tert-butyltrimethylsilyl trifluoromethanesulfonate (3.44 mL) and, after warming to room temperature, the mixture was stirred for 17 hr. The reaction mixture was added to water, and the mixture
5 was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=50/1→2/1) to give the title compound as a colorless oil
10 (yield: 5.42 g, 70%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.03-0.20 (6H, m), 0.88-0.95 (9H, m), 1.06-1.33 (12H, m), 3.73-4.19 (4H, m), 4.55-5.22 (3H, m), 7.26-7.41 (5H, m).

Reference Example 21

(4RS,5SR)-4-(tert-butyltrimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one
15



To a solution of ethyl 4-[[[(benzyloxy)carbonyl]amino]-2,2-dimethyl-3-(tert-butyltrimethylsilyloxy)pentanoate (2.73 g) in methanol (13 mL) was added 10% palladium carbon (containing 50%
20 water, 170 mg), and the mixture was stirred at room temperature for 3 hr under a hydrogen atmosphere and filtered. The filtrate was concentrated under reduced pressure, and the residue was dissolved in ethanol (20 mL). A 20% solution (4 mL) of sodium ethoxide-ethanol was added thereto, and the mixture was refluxed
25 for 2 hr. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent:
30 hexane/ethyl acetate=10/1→1/2) to give the title compound (yield: 700 mg, 44%) and (4RS,5RS)-4-(tert-

butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one (yield: 380 mg, 24%), each as an oil.

(4RS,5SR)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one

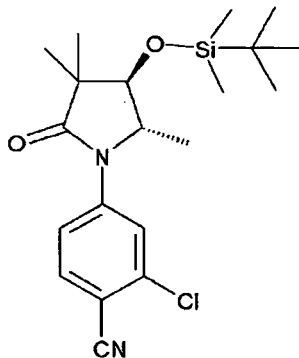
¹H-NMR(CDCl₃)δ:0.09(6H,s), 0.90(9H,s), 1.06(3H,s), 1.15(3H,s), 1.25(3H,d,J=6.2Hz), 3.31-3.44(1H,m), 3.55(1H,d,J=6.8Hz), 5.17-5.42(1H,m).

(4RS,5RS)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one

¹H-NMR(CDCl₃)δ:0.07(3H,s), 0.08(3H,s), 0.92(9H,s), 1.12(3H,s), 1.15(3H,s), 1.18(3H,d,J=6.8Hz), 3.69-3.82(1H,m), 4.00(1H,d,J=6.4Hz), 6.04-6.48(1H,m).

Reference Example 22

rac-2-chloro-4-[(4R,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]benzonitrile

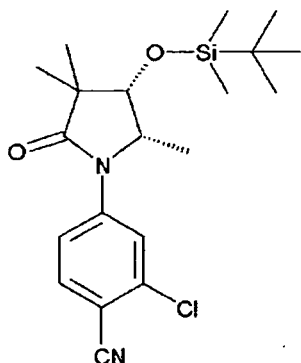


Using (4RS,5SR)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one (105.9 mg), 4-bromo-2-chlorobenzonitrile (89 mg), cesium carbonate (200 mg), tris(dibenzylideneacetone)dipalladium(0) (20 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (25 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 121 mg, 75%).

¹H-NMR(CDCl₃)δ:0.13-0.16(6H,m), 1.12(9H,s), 1.12(3H,s), 1.28(3H,s), 1.31(3H,d,J=6.1Hz), 3.72(1H,d,J=6.1Hz), 3.90(1H,t,J=6.1Hz), 7.39(1H,dd,J=8.7,2.1Hz), 7.59-7.71(2H,m).

Reference Example 23

rac-2-chloro-4-[(4R,5R)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]benzonitrile



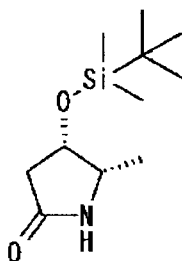
Using (4R,5R)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one (380 mg), 4-bromo-2-chlorobenzonitrile (320 mg), cesium carbonate (722 mg),

5 tris(dibenzylideneacetone)dipalladium(0) (68 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (85 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 400 mg, 69%).

¹H-NMR(CDCl₃)δ: 0.13(3H,s), 0.14(3H,s), 0.95(9H,s), 1.21-
10 1.22(6H,m), 1.28(3H,d,J=6.6Hz), 4.18(1H,d,J=7.4Hz), 4.25-
4.37(1H,m), 7.55-7.68(2H,m), 7.89(1H,d,J=1.9Hz).

Reference Example 24

(4S,5S)-4-(tert-butyldimethylsilyloxy)-5-methylpyrrolidin-2-one

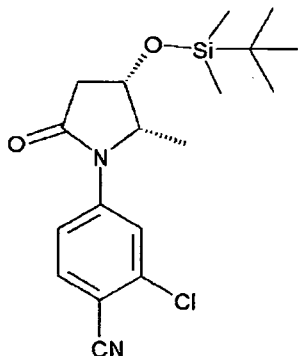


15 A solution of (4S,5S)-4-hydroxy-5-methylpyrrolidin-2-one (3.0 g) in THF (50 mL) was cooled to 0°C, 2,6-lutidine (4.55 mL) and tert-butyldimethylsilyl trifluoromethanesulfonate (6.6 mL) were added thereto and, after warming to room temperature, the mixture was stirred at room temperature for 18 hr. Water was
20 added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous sodium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=9/1→1/2) to give
25 the title compound as a colorless solid (yield: 4.54 g, 76%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.07 (6H, s), 0.90 (9H, s), 1.17 (3H, d, $J=6.3\text{Hz}$), 2.27 (1H, dd, $J=16.5, 4.2\text{Hz}$), 2.52 (1H, dd, $J=16.5, 9.3\text{Hz}$), 3.70-3.80 (1H, m), 4.37-4.45 (1H, m), 6.00 (1H, br).

Reference Example 25

5 2-chloro-4-[(4S,5S)-4-(tert-butyldimethylsilyloxy)-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile

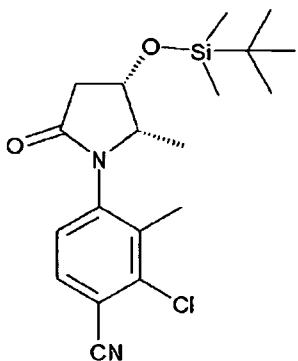


Using (4S,5S)-4-(tert-butyldimethylsilyloxy)-5-methylpyrrolidin-2-one (1.06 g), 4-bromo-2-chlorobenzonitrile (1.0 g), cesium carbonate (2.25 g), tris(dibenzylideneacetone)dipalladium(0) (210 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (399 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 1.2 g, 71%).

15 $^1\text{H-NMR}$ (CDCl_3) δ : 0.12 (6H, s), 0.92-0.93 (9H, m), 1.26 (3H, d, $J=6.3\text{Hz}$), 2.58-2.80 (2H, m), 4.27-4.36 (1H, m), 4.50-4.60 (1H, m), 7.55 (1H, dd, $J=8.7, 2.1\text{Hz}$), 7.64 (1H, d, $J=8.7\text{Hz}$), 7.81 (1H, d, $J=2.1\text{Hz}$).

Reference Example 26

20 2-chloro-4-[(4S,5S)-4-(tert-butyldimethylsilyloxy)-5-methyl-2-oxopyrrolidin-1-yl]-3-methylbenzonitrile



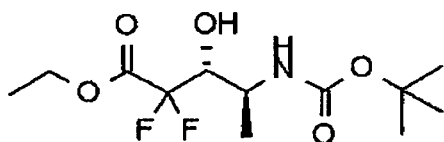
Using (4S,5S)-4-(tert-butyldimethylsilyloxy)-5-methylpyrrolidin-2-one (495 mg), 4-bromo-2-chloro-3-

methylbenzonitrile (500 mg), cesium carbonate (1.05 g),
 tris(dibenzylideneacetone)dipalladium(0) (99 mg) and 4,5-
 bis(diphenylphosphino)-9,9-dimethylxanthene (124 mg), and in the
 same manner as in Reference Example 3, the title compound was
 5 obtained as a colorless solid (yield: 505 mg, 74%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.10–0.13 (6H, m), 0.92 (9H, s), 1.03 (3H, d, $J=6.3\text{Hz}$),
 2.31 (3H, s), 2.49 (1H, dd, $J=16.8, 2.1\text{Hz}$), 2.77 (1H, dd, $J=16.8, 5.1\text{Hz}$),
 4.00–4.30 (1H, m), 4.40–4.55 (1H, m), 7.07 (1H, d, $J=8.1\text{Hz}$),
 7.55 (1H, d, $J=8.1\text{Hz}$).

10 Reference Example 27

Ethyl 4-[(tert-butoxycarbonyl)amino]-2,4,5-trideoxy-2,2-
 difluoro-L-threo-pentionate

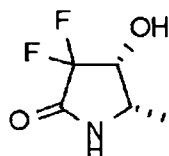


tert-Butyl[(1S)-1-methyl-2-oxoethyl]carbamate (7.21 g) and
 15 ethyl bromodifluoroacetate (25.1 g) were dissolved in THF (65
 mL), and the solution was added dropwise to a suspension of zinc
 powder (25.1 g) in THF (14 mL) at room temperature over 30 min.
 The suspension was heated under reflux for 30 min and cooled to
 0°C. A 1 mol/L aqueous hydrochloric acid solution (200 mL) was
 20 added, and the mixture was extracted with ethyl acetate (100 mL).
 The extracted organic layer was washed with water (100 mL) and
 saturated brine (100 mL), dried over anhydrous magnesium sulfate,
 and concentrated under reduced pressure. The residue was
 purified by silica gel column chromatography (eluent: ethyl
 25 acetate/hexane = 1/10 → 3/10) to give the title compound as a
 pale-yellow oil (yield: 5.45 g, 44%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.33 (3H, d, $J=7.2\text{Hz}$), 1.36 (3H, t, $J=7.1\text{Hz}$), 1.44 (9H, s),
 3.83–4.07 (2H, m), 4.35 (2H, q, $J=7.1\text{Hz}$), 4.80 (1H, brs).

Reference Example 28

30 (4R,5S)-3,3-difluoro-4-hydroxy-5-methylpyrrolidin-2-one



Ethyl 4-[(tert-butoxycarbonyl)amino]-2,4,5-trideoxy-2,2-difluoro-L-threo-pentonate (5.45 g) was dissolved in a 4 mol/L solution (100 mL) of hydrogen chloride/ethyl acetate, and the mixture was stirred at room temperature for 1.5 hr. The reaction solution was concentrated under reduced pressure, THF (200 mL) and diisopropylethylamine (9.9 mL) were added thereto, and the mixture was heated under reflux for 3 hr. The reaction solution was concentrated under reduced pressure and water (50 mL) was added to the residue. The mixture was extracted with ethyl acetate (100mL×5) and ethyl acetate/THF=2/1 (100mL×3). The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was washed with diisopropyl ether to give the title compound as a white powder (yield: 1.55 g, 46%).

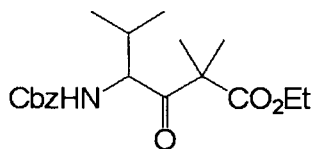
$^1\text{H-NMR}$ (CD_3SOCD_3) δ : 1.07 (3H, d, $J=6.4\text{Hz}$), 3.56–3.85 (1H, m), 4.10–4.40 (1H, m), 6.12 (1H, d, $J=5.9\text{Hz}$), 8.86 (1H, brs).

IR (KBr): 3470, 3250, 1721, 1598 cm^{-1} .

mp: 139–142°C.

Reference Example 29

Ethyl 4-[[(benzyloxy) carbonyl] amino]-2,2,5-trimethyl-3-oxohexanoate



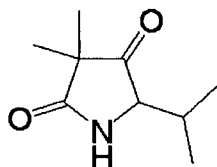
To a solution of N-[(benzyloxy) carbonyl]-L-valine (25.0 g) in dry THF (100 mL) was added 1,1'-carbonylbis-1H-imidazole (19.4 g) at 0°C in small portions, and the mixture was stirred at room temperature overnight (solution 1). To a solution of diisopropylamine (30.2 g) in dry THF (330 mL) was added dropwise a 1.6 mol/L n-butyllithium-hexane solution (186.5 mL) under an argon atmosphere at -78°C and the mixture was stirred for 30 min, and a solution of ethyl acetate (29.2 mL) in dry THF (100 mL) was added dropwise thereto. The mixture was stirred at -78°C for 30 min and solution 1 was added dropwise and, after the completion of the dropwise addition, the mixture was further

stirred at -78°C for 1 hr. Acetic acid (25 mL) was added to the reaction mixture, and the mixture was warmed to room temperature. Water was added and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over
5 magnesium sulfate, and concentrated under reduced pressure. The obtained residue was purified by silica gel column chromatography (eluent: hexane-ethyl acetate=50:1 $\rightarrow$ 1:1) to give ethyl 4-[[(benzyloxy)carbonyl]amino]-5-methyl-3-oxohexanoate as a colorless oil (yield: 24.0 g, 75%). To a solution (150 mL) of
10 ethyl 4-[[(benzyloxy)carbonyl]amino]-5-methyl-3-oxohexanoate (12.0 g) in acetone were added potassium carbonate (10.3 g) and iodomethane (7.0 mL), and the mixture was refluxed overnight. After allowing to room temperature, water was added and the mixture was extracted with ethyl acetate. The extract was
15 washed with saturated brine, dried over magnesium sulfate, and concentrated under reduced pressure. The obtained residue was purified by silica gel column chromatography (eluent: hexane-ethyl acetate=50:1 $\rightarrow$ 1:1) to give the title compound as a colorless oil (yield: 7.35 g, 56%).

20 $^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.78 (3H, d, $J=6.8\text{Hz}$), 0.96 (3H, d, $J=6.8\text{Hz}$), 1.22 (3H, t, $J=7.1\text{Hz}$), 1.41 (3H, s), 1.43 (3H, s), 2.09-2.22 (1H, m), 4.04-4.22 (2H, m), 4.66 (1H, dd, $J=9.8, 4.0\text{Hz}$), 5.07-5.23 (3H, m), 7.30-7.39 (5H, m).

Reference Example 30

25 5-isopropyl-3,3-dimethylpyrrolidine-2,4-dione



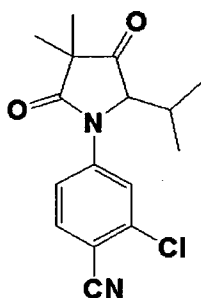
To a solution of ethyl 4-[[(benzyloxy)carbonyl]amino]-2,2,5-trimethyl-3-oxohexanoate (7.2 g) in methanol (80 mL) was added 10% palladium carbon (containing 50% water, 3.0 g), and
30 the mixture was stirred under a hydrogen atmosphere overnight. The reaction mixture was filtered, and the filtrate was concentrated under reduced pressure. The obtained solid was

washed with hexane to give the title compound as a colorless solid (yield: 2.64 g, 76%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.90 (3H, d, $J=6.8\text{Hz}$), 1.04 (3H, d, $J=7.0\text{Hz}$), 1.21 (3H, s), 1.25 (3H, s), 2.10–2.27 (1H, m), 3.91 (1H, d, $J=4.3\text{Hz}$), 6.50 (1H, brs).

5 Reference Example 31

2-chloro-4-(5-isopropyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile



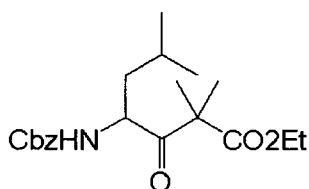
Using 5-isopropyl-3,3-dimethylpyrrolidine-2,4-dione (400 mg), 4-bromo-2-chlorobenzonitrile (614 mg), cesium carbonate (1.16 g), tris(dibenzylideneacetone)dipalladium(0) (216 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (410 mg), and in the same manner as in Reference Example 3, the title compound was obtained as colorless crystals (yield: 343 mg, 48%).

15 $^1\text{H-NMR}$ (CDCl_3) δ : 0.79 (3H, d, $J=7.0\text{Hz}$), 1.21 (3H, d, $J=7.2\text{Hz}$), 1.32 (3H, s), 1.33 (3H, s), 2.09–2.24 (1H, m), 4.51 (1H, d, $J=3.2\text{Hz}$), 7.46–7.51 (1H, m), 7.70–7.75 (1H, m), 7.78–7.81 (1H, m).

mp: 116–117°C.

Reference Example 32

20 Ethyl 4-[(benzyloxy)carbonylamino]-2,2,6-trimethyl-3-oxoheptanoate



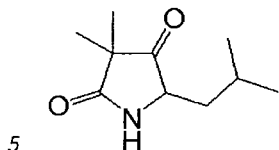
Using N-[(benzyloxy)carbonyl]-L-leucine, and in the same manner as in Reference Example 29, the title compound was obtained as a colorless oil.

$^1\text{H-NMR}$ (CDCl_3) δ : 0.91 (3H, d, $J=6.8\text{Hz}$), 0.96 (3H, d, $J=6.6\text{Hz}$), 1.22 (3H, t, $J=7.2\text{Hz}$), 1.26–1.38 (2H, m), 1.41 (3H, s), 1.43 (3H, s),

1.62-1.77 (1H,m), 4.07-4.24 (2H,m), 4.74 (1H,td,J=10.0,3.7Hz),
5.01-5.19 (3H,m), 7.28-7.42 (5H,m).

Reference Example 33

5-isobutyl-3,3-dimethylpyrrolidine-2,4-dione

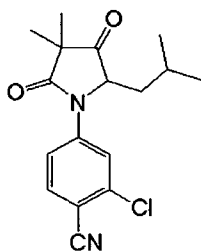


Using ethyl 4-{[(benzyloxy)carbonyl]amino}-2,2,6-trimethyl-3-oxoheptanoate (5.0 g), and in the same manner as in Reference Example 30, the title compound was obtained as a colorless solid (yield: 2.21 g, 87%).

10 ¹H-NMR(CDCl₃)δ:0.97 (6H,t,J=6.2Hz), 1.25 (3H,s), 1.26 (3H,s), 1.34-1.54 (1H,m), 1.67-1.83 (2H,m), 4.01 (1H,dd,J=9.8,3.6Hz), 6.31 (1H,brs).

Reference Example 34

2-chloro-4-(5-isobutyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile

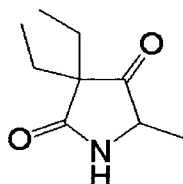


Using 5-isobutyl-3,3-dimethylpyrrolidine-2,4-dione (500 mg), 4-bromo-2-chlorobenzonitrile (709 mg), cesium carbonate (1.33 g), tris(dibenzylideneacetone)dipalladium(0) (125 mg) and
20 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (237 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless oil (yield: 744 mg, 86%).

¹H-NMR(CDCl₃)δ:0.85 (3H,d,J=6.6Hz), 0.96 (3H,d,J=6.4Hz), 1.33 (3H,s), 1.40 (3H,s), 1.58-1.91 (3H,m), 4.54-4.60 (1H,m),
25 7.53 (1H,dd,J=8.6,2.1Hz), 7.72 (1H,d,J=8.6Hz), 7.84 (1H,d,J=2.1Hz).

Reference Example 35

3,3-diethyl-5-methylpyrrolidine-2,4-dione

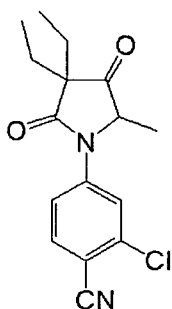


To a solution of ethyl 4-[[[(benzyloxy)carbonyl]amino]-3-oxopentanoate (3.0 g) in acetone (50 mL) were added potassium carbonate (2.83 g) and iodoethane (2.45 mL), and the mixture was
 5 refluxed overnight. After allowing to room temperature, potassium carbonate (2.83 g) and iodoethane (2.45 mL) were added, and the mixture was refluxed for 1 day. After allowing to room temperature, water was added and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine,
 10 dried over magnesium sulfate, and concentrated under reduced pressure. The obtained residue was purified by silica gel column chromatography (eluent: hexane-ethyl acetate=20:1→3:2) to give ethyl 4-[[[(benzyloxy)carbonyl]amino]-2,2-diethyl-3-oxopentanoate as a colorless oil (yield: 1.91 g, 53%). To a
 15 solution of ethyl 4-[[[(benzyloxy)carbonyl]amino]-2,2-diethyl-3-oxopentanoate (1.91 g) in methanol (15 mL) was added 10% palladium carbon (containing 50% water, 1.0 g), and the mixture was stirred under a hydrogen atmosphere overnight. The reaction mixture was filtered, and the filtrate was concentrated under
 20 reduced pressure to give the title compound as a colorless solid (yield: 920 mg, 99%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.80 (3H, t, $J=7.5\text{Hz}$), 0.86 (3H, t, $J=7.6\text{Hz}$), 1.34 (3H, d, $J=6.8\text{Hz}$), 1.68–1.80 (4H, m), 3.88 (1H, q, $J=7.0\text{Hz}$), 6.23 (1H, brs).

25 Reference Example 36

2-chloro-4-(3,3-diethyl-5-methyl-2,4-dioxopyrrolidin-1-yl)benzonitrile

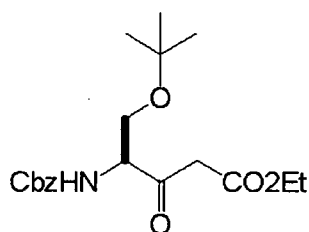


Using 3,3-diethyl-5-methylpyrrolidine-2,4-dione (150 mg), 4-bromo-2-chlorobenzonitrile (230 mg), cesium carbonate (433 mg), tris(dibenzylideneacetone)dipalladium(0) (40.6 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (76.9 mg), and in the same manner as in Reference Example 3, the title compound was obtained as colorless crystals (yield: 101 mg, 37%).
¹H-NMR(CDCl₃) δ: 0.81-0.92 (6H, m), 1.40 (3H, d, J=7.0 Hz), 1.77-1.93 (4H, m), 4.42 (1H, q, J=6.9 Hz), 7.54 (1H, dd, J=8.6, 2.1 Hz), 7.73 (1H, d, J=8.6 Hz), 7.84 (1H, d, J=2.1 Hz).

mp: 93.5-94.5°C.

Reference Example 37

Ethyl (4S)-4-{[(benzyloxy)carbonyl]amino}-5-tert-butoxy-3-oxopentanoate



15

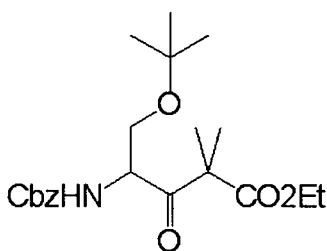
To a solution of N-[(benzyloxy)carbonyl]-O-(tert-butyl)-L-serine (25.0 g) in dry THF (100 mL) was added 1,1'-carbonylbis-1H-imidazole (16.5 g) at 0°C by small portions, and the mixture was stirred at room temperature overnight (solution 1). To a solution of diisopropylamine (25.7 g) in dry THF (330 mL) was added dropwise a 1.6 mol/L n-butyllithium-hexane solution (158.7 mL) under an argon atmosphere at -78°C. The mixture was stirred at -78°C for 30 min, and a solution of ethyl acetate (24.8 mL) in dry THF (100 mL) was added dropwise. After the completion of the dropwise addition, the mixture was stirred for 30 min, and solution 1 was added dropwise. The mixture was stirred at -78°C

for 1 hr, and acetic acid (25 mL) was added to the reaction mixture. After warming to room temperature, water was added and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over magnesium sulfate, and concentrated under reduced pressure. The obtained residue was purified by silica gel column chromatography (eluent: hexane-ethyl acetate=50:1→1:1) to give the title compound as a colorless oil (yield: 19.2 g, 62%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.14 (9H, s), 1.26 (3H, t, $J=7.1\text{Hz}$), 3.48–3.63 (3H, m), 3.85 (1H, dd, $J=9.3, 3.4\text{Hz}$), 4.18 (2H, q, $J=7.1\text{Hz}$), 4.48–4.55 (1H, m), 5.12 (2H, s), 5.70 (1H, d, $J=7.6\text{Hz}$), 7.30–7.40 (5H, m).

Reference Example 38

Ethyl 4-{[(benzyloxy)carbonyl]amino}-5-tert-butoxy-2,2-dimethyl-3-oxopentanoate



15

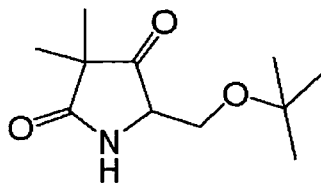
To a solution of ethyl (4S)-4-{[(benzyloxy)carbonyl]amino}-5-tert-butoxy-3-oxopentanoate (9.0 g) in acetone (120 mL) were added potassium carbonate (6.81 g) and iodomethane (4.6 mL), and the mixture was refluxed overnight. After allowing to room temperature, water was added and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over magnesium sulfate, and concentrated under reduced pressure. The obtained residue was purified by silica gel column chromatography (eluent: hexane-ethyl acetate=50:1→1:1) to give the title compound as a colorless oil (yield: 8.83 g, 91%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.11 (9H, s), 1.20 (3H, t, $J=7.1\text{Hz}$), 1.39 (3H, s), 1.40 (3H, s), 3.46 (1H, dd, $J=8.8, 5.1\text{Hz}$), 3.71 (1H, dd, $J=8.8, 3.7\text{Hz}$), 3.98–4.18 (2H, m), 4.71–4.81 (1H, m), 5.10 (2H, s), 5.42 (1H, d, $J=9.1\text{Hz}$), 7.28–7.39 (5H, m).

30

Reference Example 39

5-(tert-butoxymethyl)-3,3-dimethylpyrrolidine-2,4-dione

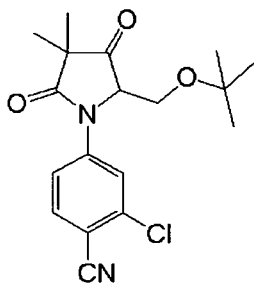


To a solution of ethyl 4-[[(benzyloxy) carbonyl] amino]-5-tert-butoxy-2,2-dimethyl-3-oxopentanoate (8.7 g) in methanol (100 mL) was added 10% palladium carbon (containing 50% water, 4.0 g), and the mixture was stirred overnight under a hydrogen atmosphere. The reaction mixture was filtered, and the filtrate was concentrated under reduced pressure. The obtained solid was washed with hexane to give the title compound as colorless crystals (yield: 3.81 g, 81%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.15 (9H, s), 1.24 (3H, s), 1.25 (3H, s), 3.50-3.64 (2H, m), 4.07-4.12 (1H, m), 6.04 (1H, brs).

Reference Example 40

4-[5-(tert-butoxymethyl)-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl]-2-chlorobenzonitrile



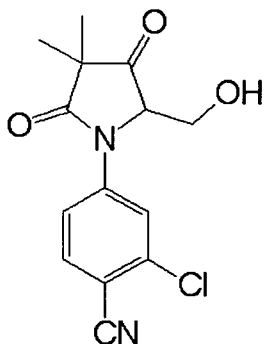
Using 5-(tert-butoxymethyl)-3,3-dimethylpyrrolidine-2,4-dione (1.20 g), 4-bromo-2-chlorobenzonitrile (1.46 g), cesium carbonate (2.75 g), tris(dibenzylideneacetone)dipalladium(0) (258 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (488 mg), and in the same manner as in Reference Example 3, the title compound was obtained as colorless crystals (yield: 1.59 g, 81%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.98 (9H, s), 1.32 (3H, s), 1.37 (3H, s), 3.55 (1H, dd, $J=9.7, 2.5\text{Hz}$), 3.76 (1H, dd, $J=9.7, 1.8\text{Hz}$), 4.55-4.58 (1H, m), 7.56 (1H, dd, $J=8.5, 2.0\text{Hz}$), 7.71 (1H, d, $J=8.5\text{Hz}$), 7.84 (1H, d, $J=2.0\text{Hz}$).

mp:124-125°C

Reference Example 41

2-chloro-4-[5-(hydroxymethyl)-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl]benzonitrile

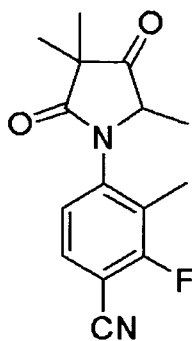


To 4-[5-(tert-butoxy methyl)-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl]-2-chlorobenzonitrile (900 mg) was added trifluoroacetic acid (10 mL) at 0°C, and the mixture was stirred at room temperature for 1 hr. The reaction mixture was cooled
10 to 0°C, and neutralized with saturated sodium hydrogen carbonate solution. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue
15 was purified by silica gel column chromatography (eluent: hexane-ethyl acetate=4:1→1:4), and recrystallized from hexane-ethyl acetate to give the title compound as colorless crystals (yield: 655 mg, 87%).

¹H-NMR(CDCl₃)δ:1.35(3H,s), 1.39(3H,s), 1.75(1H,t,J=4.9Hz), 3.84-
20 3.95(1H,m), 4.06-4.17(1H,m), 4.59(1H,t,J=2.2Hz), 7.57(1H,dd,J=8.5,2.1Hz), 7.73(1H,d,J=8.5Hz), 7.88(1H,d,J=2.1Hz).
mp:150-152°C.

Reference Example 42

2-fluoro-3-methyl-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile
25

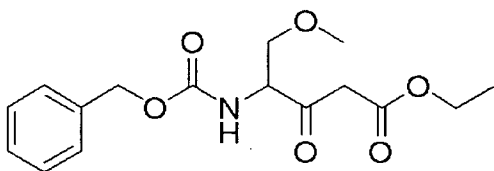


Using 3,3,5-trimethylpyrrolidine-2,4-dione (400 mg), 4-bromo-2-fluoro-3-methylbenzonitrile (667 mg), cesium carbonate (1.39 g), tris(dibenzylideneacetone)dipalladium(0) (130 mg) and
 5 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (246 mg), and in the same manner as in Reference Example 18, the title compound was obtained as colorless crystals (yield: 137 mg, 18%).

¹H-NMR (CDCl₃) δ: 1.30 (3H, d, J=6.8 Hz), 1.38 (3H, s), 1.40 (3H, s),
 2.19 (3H, d, J=2.5 Hz), 4.43 (1H, brs), 7.09 (1H, d, J=8.3 Hz), 7.52-
 10 7.61 (1H, m).

Reference Example 43

Ethyl (4S)-4-{[(benzyloxy)carbonyl]amino}-5-methoxy-3-oxopentanoate



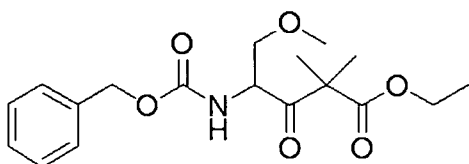
15

Using N-[(benzyloxy)carbonyl]-O-methylserine, and in the same manner as in Reference Example 37, the title compound was obtained as a colorless oil (yield: 11.1 g, 50%).

¹H-NMR (CDCl₃) δ: 1.27 (3H, t, J=7.1 Hz), 3.33 (3H, s), 3.51-3.66 (3H, m),
 20 3.87 (1H, dd, J=9.8, 3.6 Hz), 4.19 (2H, q, J=7.1 Hz), 4.51-4.63 (1H, m),
 5.13 (2H, s), 5.72 (1H, d, J=7.4 Hz), 7.29-7.43 (5H, m).

Reference Example 44

Ethyl 4-{[(benzyloxy)carbonyl]amino}-5-methoxy-2,2-dimethyl-3-oxopentanoate



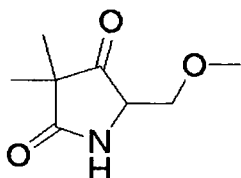
25

Using ethyl 4-[[(benzyloxy) carbonyl] amino]-5-methoxy-3-oxopentanoate (11.0 g), potassium carbonate (9.40 g) and iodomethane (14.5 g, 6.4 mL), and in the same manner as in Reference Example 38, the title compound was obtained as a
5 colorless oil (yield: 10.5 g, 88%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.22 (3H, t, $J=7.1\text{Hz}$), 1.40 (3H, s), 1.41 (3H, s), 3.29 (3H, s), 3.51 (1H, dd, $J=9.7, 4.6\text{Hz}$), 3.68-3.78 (1H, m), 4.02-4.21 (2H, m), 4.77-4.87 (1H, m), 5.11 (2H, s), 5.46 (1H, d, $J=9.1\text{Hz}$), 7.29-7.38 (5H, m).

10 Reference Example 45

5-(methoxymethyl)-3,3-dimethylpyrrolidine-2,4-dione

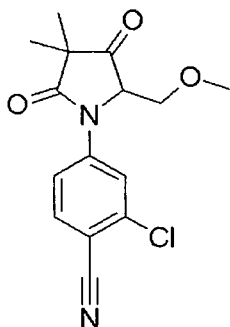


To a solution of 4-[[(benzyloxy) carbonyl] amino]-5-methoxy-2,2-dimethyl-3-oxopentanoate (10.2 g) in methanol (100 mL) was
15 added 10% palladium carbon (containing 50% water, 3.1 g), and the mixture was stirred overnight under a hydrogen atmosphere. Palladium carbon was filtered off, and the filtrate was concentrated under reduced pressure. The obtained solid was washed with hexane to give the title compound as colorless
20 crystals (yield: 4.16 g, 84%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.23 (3H, s), 1.26 (3H, s), 3.35 (3H, s), 3.52-3.67 (2H, m), 4.12-4.16 (1H, m), 6.51 (1H, brs).

Reference Example 46

2-chloro-4-[5-(methoxymethyl)-3,3-dimethyl-2,4-dioxopyrrolidin-
25 1-yl]benzonitrile



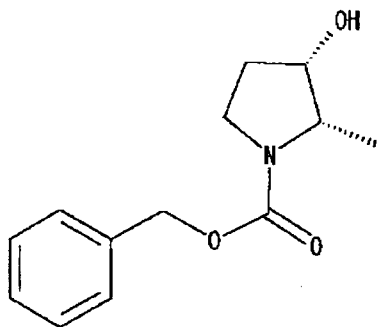
Using 5-(methoxymethyl)-3,3-dimethylpyrrolidine-2,4-dione (700 mg), 4-bromo-2-chlorobenzonitrile (1.06 g), cesium carbonate (2.00 g), tris(dibenzylideneacetone)dipalladium(0) (187 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (355 mg), and in the same manner as in Reference Example 3, the
5 title compound was obtained as colorless crystals (yield: 219 mg, 17%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.33 (3H, s), 1.36 (3H, s), 3.21 (3H, s),
3.60 (1H, d, $J=10.2\text{Hz}$), 3.78 (1H, d, $J=10.2\text{Hz}$), 4.54-4.58 (1H, m),
10 7.55 (1H, d, $J=8.5\text{Hz}$), 7.72 (1H, d, $J=8.3\text{Hz}$), 7.85 (1H, s).

mp: 98-99°C.

Reference Example 47

Benzyl (2S,3S)-3-hydroxy-2-methylpyrrolidine-1-carboxylate

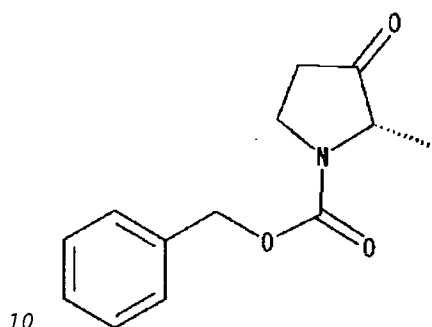


15 To a suspension of (4S,5S)-4-hydroxy-5-methylpyrrolidin-2-one (10.45 g) in dry THF (418 mL) was added dropwise Red-Al (104.9 g: 363 mmol: 70% toluene solution) under ice-cooling and a nitrogen stream. The mixture was stirred at room temperature for 20 min, and further refluxed for 3 hr. The reaction mixture
20 was ice-cooled again, and sodium carbonate decahydrate (41.6 g) was added under a nitrogen stream. The mixture was stirred at room temperature overnight, insoluble materials were filtered through celite and washed with THF. The filtrate and washing were combined and concentrated under reduced pressure to give
25 (2S,3S)-3-hydroxy-2-methylpyrrolidine. Without further purification, this compound was diluted with DMSO to give 0.9 mol/L-DMSO solution. A solution (170 mL) of (2S,3S)-3-hydroxy-2-methylpyrrolidine in 0.9 mol/L-DMSO was diluted with water (200 mL), sodium hydrogen carbonate (24.6 g) and benzyl
30 chloroformate (15 mL) were added, and the mixture was stirred at

room temperature for 18 hr. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous sodium sulfate, and concentrated under reduced pressure to give
5 the title compound as a pale-yellow oil (yield: 20.64 g, 84%).
 $^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.10-1.30 (3H, br), 1.60-2.20 (3H, m), 3.40-4.40 (5H, m), 7.20-7.40 (5H, m).

Reference Example 48

Benzyl (2S)-2-methyl-3-oxopyrrolidine-1-carboxylate

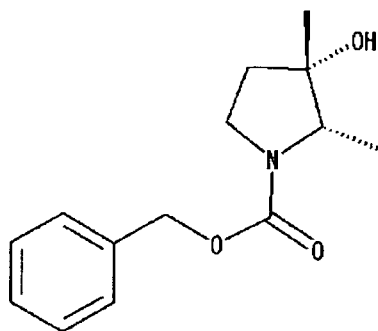


To a solution of benzyl (2S,3S)-3-hydroxy-2-methylpyrrolidine-1-carboxylate (20.5 g) in acetonitrile (150 mL) were added powdery molecular sieves 4A (25 g) and 4-methylmorpholine-N-oxide (20.4 g). After cooling to 0°C, tetra-
15 n-propylammonium perruthenate (3.0 g) was added, and the mixture was stirred at 0°C for 1 hr, and at room temperature for 18 hr. The reaction mixture was concentrated under reduced pressure, and the residue was suspended in ethyl acetate. Insoluble materials were filtered through Hyflo Super-Cel. The filtrate
20 was concentrated under reduced pressure, and the residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=9/1→2/1) to give the title compound as a colorless oil (yield: 18.0 g, 89%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.34 (3H, d, J=6.6Hz), 2.50-2.70 (2H, m), 3.60-
25 3.75 (1H, m), 3.90-4.10 (2H, m), 5.15 (1H, d, J=12.3Hz), 5.20 (1H, d, J=12.3Hz), 7.30-7.40 (5H, m).

Reference Example 49

Benzyl (2S,3S)-3-hydroxy-2,3-dimethylpyrrolidine-1-carboxylate

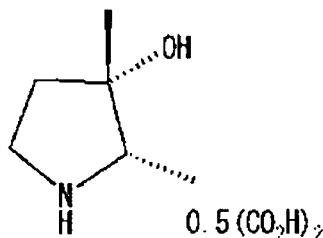


A suspension of cerium chloride (47 g) in THF (300 mL) was cooled to -78°C , methylmagnesium bromide-diethyl ether solution (56 mL, 3 mol/L) was added dropwise while adjusting the solution temperature to -70°C or below. After the completion of the dropwise addition, the mixture was stirred at -78°C for 30 min, a solution of benzyl (2S)-2-methyl-3-oxopyrrolidine-1-carboxylate (18 g) in THF (60 mL) was added dropwise while adjusting the solution temperature to -70°C or below. The reaction mixture was warmed to 0°C over 2 hr, ethyl acetate (1 L) was added, and insoluble materials were filtered off. The filtrate was partitioned with water, and the organic layer was washed with saturated brine, dried over anhydrous sodium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=9/1 $\rightarrow$ 1/1) to give the title compound as a colorless oil (yield: 16.2 g, 84%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.10–1.35 (3H, br), 1.34 (3H, s), 1.47 (1H, s), 1.75–1.90 (1H, m), 1.91–2.00 (1H, m), 3.49 (2H, t, $J=7.2\text{Hz}$), 3.55–3.65 (1H, m), 5.05–5.20 (2H, m), 7.20–7.40 (5H, m).

Reference Example 50

(2S,3S)-2,3-dimethylpyrrolidin-3-ol 0.5 oxalic acid salt



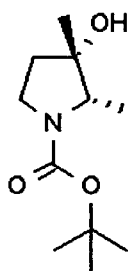
To a solution of benzyl (2S,3S)-3-hydroxy-2,3-dimethylpyrrolidine-1-carboxylate (16.1 g) in methanol (200 mL) was added 50% water containing-10% Pd/C (0.4 g), and the mixture

was vigorously stirred under a hydrogen atmosphere. The catalyst was filtered off, oxalic acid (2.90 g) was added to the filtrate, and the mixture was concentrated under reduced pressure. The residual solid was suspended in ethyl acetate, and filtered to give the title compound as a colorless solid (yield: 9.09 g, 88%).

$^1\text{H-NMR}$ (DMSO-d_6) δ : 1.05 (3H, d, $J=6.6\text{Hz}$), 1.18 (3H, s), 1.74–1.86 (2H, m), 2.80–2.95 (2H, m), 2.98–3.10 (1H, m), 4.00–5.20 (3H, m).

Reference Example 51

tert-Butyl (2S,3S)-3-hydroxy-2,3-dimethylpyrrolidine-1-carboxylate



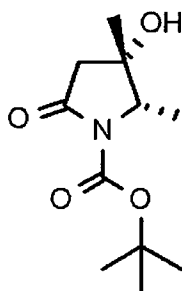
To a solution of (2S,3S)-2,3-dimethylpyrrolidine-3-ol 0.5 oxalic acid salt (3.31 g) in THF (50 mL) were successively added 1 mol/L aqueous sodium hydroxide solution (40 mL) and a solution of di-tert-butyl dicarbonate (5.42 g) in THF (10 mL). The mixture was stirred at room temperature for 20 hr, water (50 mL) was added to the reaction mixture, and the mixture was extracted with ethyl acetate twice. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane = 1/10→4/10) to give the title compound as a white powder (yield: 3.21 g, 72%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.21 (3H, d, $J=6.4\text{Hz}$), 1.33 (3H, s), 1.46 (9H, s), 1.66 (1H, s), 1.73–1.85 (1H, m), 1.86–1.98 (1H, m), 3.40 (2H, dd, $J=7.2, 6.7\text{Hz}$), 3.46–3.57 (1H, m).

mp: 109–112°C.

Reference Example 52

tert-Butyl (2S,3S)-3-hydroxy-2,3-dimethyl-5-oxo-pyrrolidine-1-carboxylate



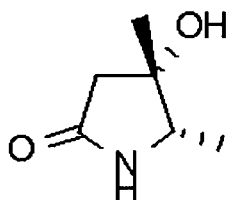
To a solution of tert-butyl (2S,3S)-3-hydroxy-2,3-dimethylpyrrolidine-1-carboxylate (3.05 g) in ethyl acetate (45 mL) were successively added water (68 mL), ruthenium dioxide monohydrate (566 mg) and sodium periodate (4.57 g) at room temperature. The mixture was stirred at room temperature for 40 hr, the organic layer and the aqueous layer were separated, and the aqueous layer was extracted with ethyl acetate. The obtained organic layers were mixed, isopropanol (0.7 mL) was added, and the mixture was stirred at room temperature for 5 min. The reaction solution was dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane =1/10→4/10) to give the title compound as a white powder (yield: 1.11 g, 34%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.34 (3H, d, $J=6.4\text{Hz}$), 1.46 (3H, s), 1.54 (9H, s), 1.72 (1H, s), 2.47 (1H, d, $J=17.0\text{Hz}$), 2.73 (1H, d, $J=17.0\text{Hz}$), 3.91 (1H, q, $J=6.4\text{Hz}$).

mp: 122–125°C.

Reference Example 53

(4S,5S)-4-hydroxy-4,5-dimethylpyrrolidin-2-one



tert-Butyl (2S,3S)-3-hydroxy-2,3-dimethyl-5-oxo-pyrrolidine-1-carboxylate (1.00 g) was dissolved in hydrogen chloride-ethyl acetate solution (10 mL, 4 mol/L), and the mixture was stirred at room temperature for 14 hr. The reaction solution was concentrated under reduced pressure, and

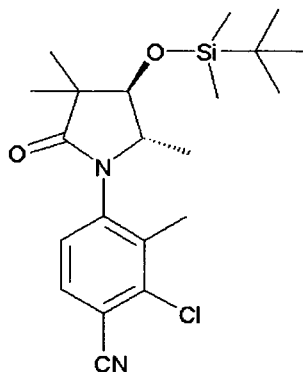
recrystallized from isopropanol/n-hexane to give the title compound (309 mg, 55%) as colorless crystals. Furthermore, the filtrate was concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate→methanol/ethyl acetate=1/10), and the obtained solid was crystallized from diisopropyl ether to give the title compound (220 mg, 39%) as a white powder.

$^1\text{H-NMR}$ (DMSO- d_6) δ : 1.00 (3H, d, $J=6.4\text{Hz}$), 1.20 (3H, s), 2.06 (1H, d, $J=16.2\text{Hz}$), 2.23 (1H, d, $J=16.2\text{Hz}$), 3.33 (1H, q, $J=6.4\text{Hz}$), 4.70 (1H, brs), 7.48 (1H, brs).

mp: 169–173°C.

Reference Example 54

rac-4-((4R,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-yl)-2-chloro-3-methylbenzonitrile

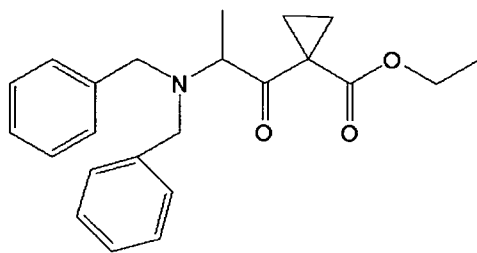


Using (4RS,5SR)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one (200 mg), 2-chloro-4-iodo-3-methylbenzonitrile (250 mg), cesium carbonate (380 mg), tris(dibenzylideneacetone)dipalladium(0) (36 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (45 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a pale-yellow oil (yield: 103mg, yield: 33.7%).

$^1\text{H-NMR}$ (CDCl₃) δ : 0.13 (3H, s), 0.15 (3H, s), 0.94 (9H, s), 1.04–1.36 (9H, m), 2.26 (3H, s), 3.60–3.91 (2H, m), 7.01–7.17 (1H, m), 7.50–7.60 (1H, m).

Reference Example 55

Ethyl 1-[2-(dibenzylamino)propanoyl]cyclopropanecarboxylate

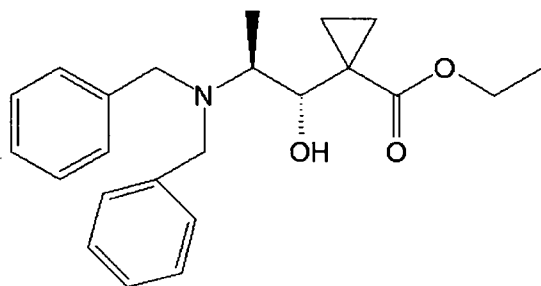


A solution of ethyl (4S)-4-(dibenzylamino)-3-oxopentanoate (500 mg) synthesized according to the method described in Journal of Organic Chemistry, vol. 62, pp. 2292-2297 (1997),
 5 1,2-dibromoethane (0.19 mL) and potassium carbonate (405 mg) in acetone (15 mL), was stirred under reflux overnight. The reaction mixture was added to water, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and
 10 concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=1/0→2/1) to give the title compound as a colorless oil (yield: 231.4 mg, 43.0%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.01 (3H, t, $J=7.2\text{Hz}$), 1.07-1.19 (2H, m),
 15 1.20 (3H, d, $J=6.8\text{Hz}$), 1.58-1.73 (2H, m), 3.56 (2H, d, $J=14.0\text{Hz}$),
 3.61 (2H, d, $J=14.0\text{Hz}$), 3.72 (1H, 10.8, 7.2Hz),
 3.96 (1H, dq, $J=10.8, 7.2\text{Hz}$), 4.40 (1H, q, $J=6.8\text{Hz}$), 7.19-7.27 (2H, m),
 7.27-7.39 (8H, m).

Reference Example 56

20 Ethyl 1-[(1RS,2RS)-2-(dibenzylamino)-1-hydroxypropyl]cyclopropanecarboxylate



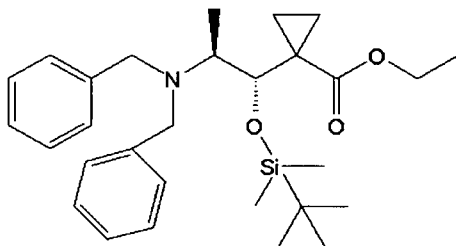
A solution of ethyl 1-[2-(dibenzylamino)propanoyl]cyclopropanecarboxylate (1.31 g) in
 25 methanol (60 mL) was cooled to 0°C, 90% sodium borohydride (350 mg) was added, and the mixture was stirred at room temperature

for 17 hr. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue
 5 was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=1/0→1/1) to give the title compound as a colorless oil (yield: 1.31 g, 99%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.53-0.66 (1H, m), 0.95-1.09 (2H, m), 1.05 (3H, d, $J=6.7\text{Hz}$), 1.06 (3H, t, $J=7.1\text{Hz}$), 1.14-1.22 (1H, m),
 10 3.03 (1H, dq, $J=9.6, 6.7\text{Hz}$), 3.33 (2H, d, $J=13.2\text{Hz}$), 3.60 (1H, d, $J=9.6\text{Hz}$), 3.83 (2H, d, $J=13.2\text{Hz}$), 3.96 (1H, q, $J=7.1\text{Hz}$), 3.97 (1H, q, $J=7.1\text{Hz}$), 4.20 (1H, brs), 7.17-7.38 (10H, m).

Reference Example 57

Ethyl 1-[(1RS,2RS)-1-(tert-butyldimethylsilyloxy)-2-(dibenzylamino)propyl]cyclopropanecarboxylate
 15



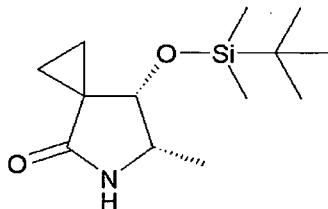
A solution of ethyl 1-[(1RS,2RS)-2-(dibenzylamino)-1-hydroxypropyl]cyclopropanecarboxylate (1.30 g) in THF (15 mL) was cooled to 0°C, tert-butyl(dimethyl)silyl
 20 trifluoromethanesulfonate (0.98 mL) and 2,6-dimethylpyridine (0.621 mL) were added, and the mixture was stirred at room temperature for 17 hr. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium
 25 sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=1/0→4/1) to give the title compound as a colorless oil (yield: 1.30 g, 76%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.04 (3H, s), 0.11 (3H, s), 0.81-1.36 (4H, m),
 30 0.88 (9H, s), 1.03 (3H, t, $J=7.1\text{Hz}$), 1.11 (3H, d, $J=7.0\text{Hz}$),

3.19 (1H, dd, J=6.9, 4.4Hz), 3.40 (2H, d, J=14.0Hz), 3.80 (2H, q, J=7.1Hz),
4.02 (2H, d, J=14.0Hz), 4.06-4.17 (1H, m), 7.10-7.42 (10H, m).

Reference Example 58

(6RS,7RS)-7-(tert-butyldimethylsilyloxy)-6-methyl-5-
5 azaspiro[2.4]heptan-4-one

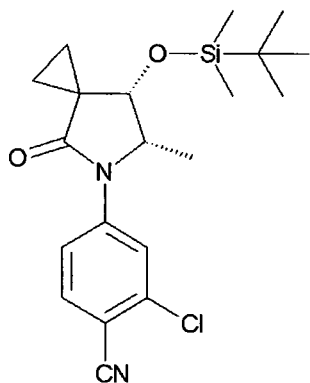


To a solution of ethyl 1-[(1RS,2RS)-1-(tert-
butyldimethylsilyloxy)-2-
(dibenzylamino)propyl]cyclopropanecarboxylate (1.36 g) in
10 methanol (16 mL) was added 10% palladium hydroxide-carbon
(containing 50% water, 280 mg), and the mixture was stirred at
room temperature for 18 hr under a hydrogen atmosphere. The
reaction mixture was filtered. The filtrate was concentrated
under reduced pressure and the residue was purified by silica
15 gel column chromatography (eluent: hexane/ethyl
acetate=10/1→1/4) to give the title compound as a colorless
solid (yield: 164 mg, yield:22.8%).

¹H-NMR(CDCl₃) δ: 0.02 (3H, s), 0.05 (3H, s), 0.61-0.71 (1H, m), 0.85-
1.21 (3H, m), 0.90 (9H, s), 1.17 (3H, d, J=6.6Hz), 3.75-3.88 (1H, m),
20 4.43 (1H, d, J=6.8Hz), 5.45 (1H, brs).

Reference Example 59

rac-4-((6R,7R)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-
azaspiro[2.4]hept-5-yl)-2-chlorobenzonitrile



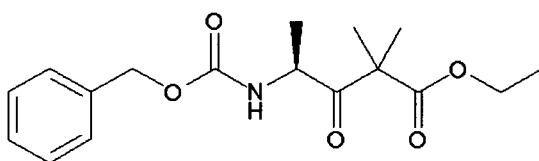
25 Using (6RS,7RS)-7-(tert-butyldimethylsilyloxy)-6-methyl-5-
azaspiro[2.4]heptan-4-one (162 mg), 4-bromo-2-chlorobenzonitrile

(157 mg), cesium carbonate (310 mg),
 tris(dibenzylideneacetone)dipalladium(0) (30 mg) and 4,5-
 bis(diphenylphosphino)-9,9-dimethylxanthene (75 mg), and in the
 same manner as in Reference Example 3, the title compound was
 5 obtained as a colorless solid (yield: 140 mg, 56%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.07 (3H, s), 0.12 (3H, s), 0.67-0.79 (1H, m), 0.88-
 1.37 (3H, m), 0.93 (9H, s), 1.30 (3H, d, $J=6.4\text{Hz}$), 4.29-4.41 (1H, m),
 4.59 (1H, d, $J=7.2\text{Hz}$), 7.01-8.04 (3H, m).

Reference Example 60

10 ethyl (4S)-4-{[(benzyloxy)carbonyl]amino}-2,2-dimethyl-3-
 oxopentanoate

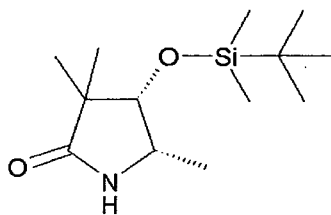


A solution of diisopropylamine (0.665 mL) in THF (25 mL)
 was cooled to -78°C , and n-butyllithium-hexane solution (2.93 mL,
 15 1.6 mol/L) was added dropwise. After the completion of the
 dropwise addition, the mixture was stirred at -78°C for 1 hr.
 Subsequently, ethyl 2-methylpropanoate (0.675 mL) was added
 dropwise, and the mixture was further stirred at -78°C for 1 hr.
 A solution of benzyl (4S)-4-methyl-2,5-dioxo-1,3-oxazolidine-3-
 20 carboxylate (900 mg) in THF (5.0 mL) was added dropwise at -78°C ,
 and the mixture was further stirred at -78°C for 20 min. Acetic
 acid (2.0 mL) was added to the reaction mixture and, after
 warming to room temperature, water was added, and the mixture
 was extracted with ethyl acetate. The extract was washed with
 25 saturated brine, dried over anhydrous magnesium sulfate, and
 concentrated under reduced pressure. The residue was purified
 by silica gel column chromatography (eluent: hexane/ethyl
 acetate=1/0 $\rightarrow$ 1/1) to give the title compound as a colorless oil
 (yield: 905 mg, yield: 78.0%).

30 $^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.22 (3H, t, $J=7.2\text{Hz}$), 1.31 (3H, d, $J=6.8\text{Hz}$), 1.41 (3H, s),
 1.43 (3Hs), 4.06-4.22 (2H, m), 4.74 (1H, dd, $J=8.5, 7.2\text{Hz}$), 5.02-
 5.17 (2H, m), 5.23-5.37 (1H, m), 7.28-7.46 (5H, m).

Reference Example 61

(4S,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one



A solution of ethyl (4S)-4-[[(benzyloxy) carbonyl] amino]-
 5 2,2-dimethyl-3-oxopentanoate (905 mg) in methanol (30 mL) was
 cooled to 0°C, 90% sodium borohydride (180 mg) was added, and the
 mixture was stirred at 0°C for 2 hr. Saturated aqueous ammonium
 chloride solution was added to the reaction mixture, and the
 mixture was extracted with ethyl acetate. The extract was
 10 washed with saturated brine, dried over anhydrous magnesium
 sulfate, and concentrated under reduced pressure. The residue
 was purified by silica gel column chromatography (eluent:
 hexane/ethyl acetate=30/1→1/3) to give ethyl (4S)-4-
 [[(benzyloxy) carbonyl] amino]-2,2-dimethyl-3-hydroxypentanoate as
 15 a colorless oil (yield: 720 mg, 79%).

A solution of ethyl (4S)-4-[[(benzyloxy) carbonyl] amino]-
 2,2-dimethyl-3-hydroxypentanoate (720 mg) in THF (20 mL) was
 cooled to 0°C, tert-butyl(dimethyl)silyl
 trifluoromethanesulfonate (0.589 mL) and 2,6-dimethylpyridine
 20 (0.390 mL) were added, and the mixture was stirred at room
 temperature for 3 hr. Water was added to the reaction mixture,
 and the mixture was extracted with ethyl acetate. The extract
 was washed with saturated brine, dried over anhydrous magnesium
 sulfate, and concentrated under reduced pressure. The residue
 25 was purified by silica gel column chromatography (eluent:
 hexane/ethyl acetate=1/0→1/1) to give ethyl (4S)-4-
 [[(benzyloxy) carbonyl] amino]-3-(tert-butyldimethylsilyloxy)-2,2-
 dimethylpentanoate as a colorless oil (yield: 0.916 g, 94%).

To a solution of ethyl (4S)-4-
 30 [[(benzyloxy) carbonyl] amino]-3-(tert-butyldimethylsilyloxy)-2,2-
 dimethylpentanoate (0.916 g) in methanol (20 mL) was added 10%
 palladium carbon (containing 50% water, 89 mg), and the mixture

was stirred at room temperature for 16 hr under a hydrogen atmosphere and filtered. The filtrate was concentrated under reduced pressure, and the residue was dissolved in THF (15 mL). Diisopropylethylamine (1.5 mL) was added, and the mixture was
 5 fluxed for 3 hr. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=30/1→1/3) to give
 10 the title compound (yield: 161.8 mg, yield: 30.1%) and (4R,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one (yield: 289 mg, yield: 53.7%), each as a colorless solid.

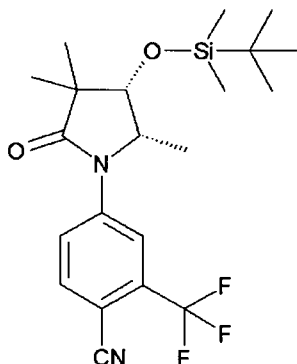
$^1\text{H-NMR}$ (CDCl_3) δ : 0.07 (6H, s), 0.90 (9H, s), 1.17 (3H, d, $J=6.3\text{Hz}$), 2.27 (1H, dd, $J=16.5, 4.2\text{Hz}$), 2.25 (1H, dd, $J=16.5, 9.3\text{Hz}$), 3.70-
 15 3.80 (1H, m), 4.37-4.45 (1H, m), 6.00 (1H, brs).

(4R,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one

$^1\text{H-NMR}$ (CDCl_3) δ : 0.09 (6H, s), 0.90 (9H, s), 1.06 (3H, s), 1.15 (3H, s), 1.25 (3H, d, $J=6.2\text{Hz}$), 3.31-3.44 (1H, m), 3.55 (1H, d, $J=6.8\text{Hz}$), 5.17-
 20 5.42 (1H, m).

Reference Example 62

4-((4S,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-yl)-2-(trifluoromethyl)benzonitrile



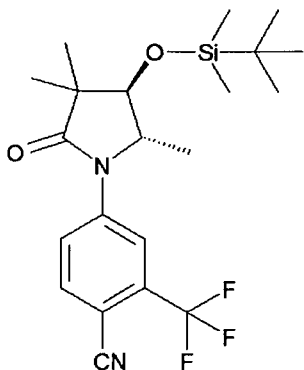
25 Using (4S,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one (161.8 mg), 4-iodo-2-(trifluoromethyl)benzonitrile (205 mg), cesium carbonate (307 mg), tris(dibenzylideneacetone)dipalladium(0) (30 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (73 mg), and in the

same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 232.2 mg, yield: 87%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.14 (3H, s), 0.15 (3H, s), 0.96 (9H, s), 1.23 (3H, s), 1.24 (3H, s), 1.30 (3H, d, $J=6.6\text{Hz}$), 4.20 (1H, d, $J=7.4\text{Hz}$), 4.30-
5 4.44 (1H, m), 7.77-7.93 (2H, m), 8.16 (1H, d, $J=2.1\text{Hz}$).

Reference Example 63

4-[(4R,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile

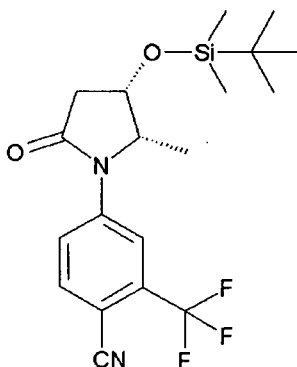


10 Using (4R,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one (266.6 mg), 4-iodo-2-(trifluoromethyl)benzonitrile (340 mg), cesium carbonate (505 mg), tris(dibenzylideneacetone)dipalladium(0) (47 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (120 mg), and in the
15 same manner as in Reference Example 3, the title compound was obtained as a colorless oil (yield: 391.7 mg, yield: 89%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.15 (6H, s), 0.95 (9H, s), 1.13 (3H, s), 1.30 (3H, s), 1.31 (3H, d, $J=6.2\text{Hz}$), 3.75 (1H, d, $J=6.2\text{Hz}$), 3.89-4.02 (1H, m), 7.58-7.74 (1H, m), 7.80-7.93 (2H, m).

20 Reference Example 64

4-[(2S,3S)-3-(tert-butyldimethylsilyloxy)-2-methyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile



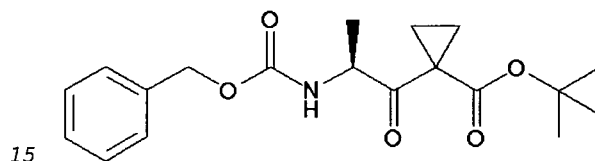
Using (4S,5S)-4-(tert-butyldimethylsilyloxy)-5-methylpyrrolidin-2-one (5.00 g), 4-iodo-2-(trifluoromethyl)benzonitrile (6.80 g), cesium carbonate (10.65 g), tris(dibenzylideneacetone)dipalladium(0) (1.00 g) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (2.52 g), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 5.617 g, yield: 64.7%).

¹H-NMR(CDCl₃) δ: 0.13 (6H, s), 0.93 (9H, s), 1.28 (3H, d, J=6.4 Hz), 2.65 (1H, dd, J=17.0, 7.0 Hz), 2.76 (1H, dd, J=17.0, 7.0 Hz), 4.30-4.44 (1H, m), 4.57 (1H, q, J=7.0 Hz), 7.82 (1H, d, J=8.7 Hz), 7.89 (1H, dd, J=8.7, 2.1 Hz, 1H), 8.04 (1H, d, J=2.1 Hz).

Reference Example 65

tert-butyl 1-((2S)-2-

{[(benzyloxy)carbonyl]amino}propanoyl)cyclopropanecarboxylate



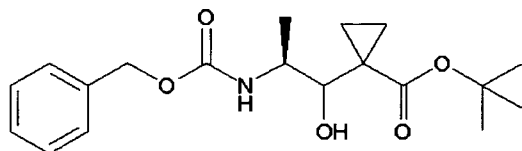
A solution of diisopropylamine (0.740 mL) in THF (25 mL) was cooled to -78°C, n-butyllithium-hexane solution (3.26 mL, 1.6 mol/L) was added dropwise and, after the completion of the dropwise addition, the mixture was stirred at -78°C for 1 hr.

Subsequently, a solution of tert-butyl cyclopropanecarboxylate (0.800 g) in THF (5 mL) was added dropwise, and the mixture was further stirred at -78°C for 30 min. A solution of benzyl (4S)-4-methyl-2,5-dioxo-1,3-oxazolidine-3-carboxylate (1.00 g) in THF (10 mL) was added dropwise at -78°C over 10 min, and the mixture was further stirred at -78°C for 30 min. Acetic acid (2.0 mL) was added to the reaction mixture and, after warming to room temperature, water was added, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=50/1→1/1) to give the title compound as a colorless oil (yield: 401 mg, 29%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.10–1.54 (2H, m), 1.41 (3H, d, $J=7.0\text{ Hz}$), 1.49 (9H, s), 1.54–1.78 (2H, m), 5.11 (2H, s), 5.16–5.33 (1H, m), 5.46–5.62 (1H, m), 7.27–7.43 (5H, m).

Reference Example 66

5 tert-butyl 1-((2S)-2-{[(benzyloxy)carbonyl]amino}-1-hydroxypropyl)cyclopropanecarboxylate

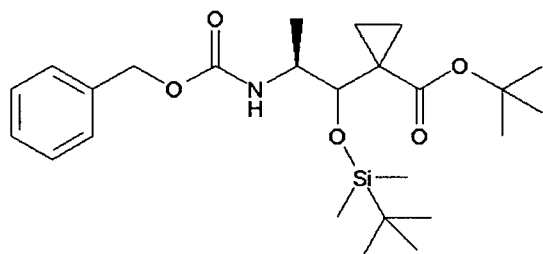


A solution of tert-butyl 1-((2S)-2-
{[(benzyloxy)carbonyl]amino}propanoyl)cyclopropanecarboxylate
10 (1.66 g) in methanol (25 mL) was cooled to 0°C , 90% sodium borohydride (305 mg) was added, and the mixture was stirred at 0°C for 30 min. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium
15 sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=30/1 $\rightarrow$ 1/1) to give the title compound as a colorless oil (yield: 1.58 g, 94%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.68–1.35 (7H, m), 1.44 (9H, s), 2.87–3.05 (1H, m),
20 3.53–4.20 (2H, m), 4.91–5.17 (3H, m), 7.29–7.40 (5H, m).

Reference Example 67

tert-butyl 1-((2S)-2-{[(benzyloxy)carbonyl]amino}-1-(tert-butyl-
dimethylsilyloxy)propyl)cyclopropanecarboxylate



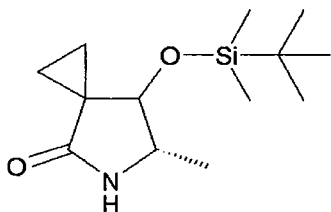
25 A solution of tert-butyl 1-((2S)-2-
{[(benzyloxy)carbonyl]amino}-1-
hydroxypropyl)cyclopropanecarboxylate (1.58 g) in THF (15 mL) was cooled to 0°C , tert-butyl(dimethyl)silyl trifluoromethanesulfonate (1.56 mL) and 2,6-dimethylpyridine

(1.05 mL) were added, and the mixture was stirred at room temperature for 16 hr. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=1/0→1/1) to give the title compound as a colorless oil (yield: 1.57 g, 75%).

¹H-NMR(CDCl₃)δ:0.03-0.14(6H,m), 0.78-1.29(7H,m), 0.88(9H,s), 1.41(9H,s), 3.83-4.28(3H,s), 3.84-4.99(2H,m), 7.28-7.41(5H,m).

Reference Example 68

(6S)-7-(tert-butyldimethylsilyloxy)-6-methyl-5-azaspiro[2.4]heptan-4-one

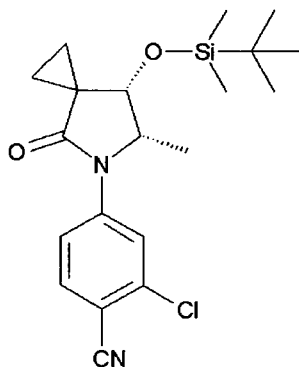


To a solution of tert-butyl 1-((2S)-2-
{[(benzyloxy)carbonyl]amino}-1-(tert-
butyldimethylsilyloxy)propyl)cyclopropanecarboxylate (693.9 mg)
in methanol (8 mL) was added 10% palladium carbon (containing
50% water, 80 mg), and the mixture was stirred at room
temperature for 3 hr under a hydrogen atmosphere and filtered.
The filtrate was concentrated under reduced pressure, and the
residue was dissolved in methanol (10 mL). Sodium methoxide
(404 mg) was added and the mixture was refluxed for 4 hr. A
saturated aqueous ammonium chloride solution was added to the
reaction mixture, and the mixture was extracted with ethyl
acetate. The extract was washed with saturated brine, dried
over anhydrous magnesium sulfate, and concentrated under reduced
pressure. The residue was purified by silica gel column
chromatography (eluent: hexane/ethyl acetate=30/1→1/3) to give
the title compound as a colorless solid (yield: 200.8 mg, yield:
60%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.00–0.09 (6H, m), 0.57–1.38 (4H, m), 0.86–0.92 (9H, m), 1.26–1.33 (3H, m), 3.47–4.49 (2H, m), 5.66–5.95 (1H, m).

Reference Example 69

4-[(6S,7S)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-chlorobenzonitrile



Using (6S)-7-(tert-butyldimethylsilyloxy)-6-methyl-5-azaspiro[2.4]heptan-4-one (200.8 mg), 4-bromo-2-chlorobenzonitrile (194.3 mg), cesium carbonate (384 mg), tris(dibenzylideneacetone)dipalladium(0) (36 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (91 mg), and in the same manner as in Reference Example 3, the title compound (yield: 68.4 mg, yield: 22.2%) and 4-[(6S,7R)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-chlorobenzonitrile (yield: 161 mg, yield: 52.4%) were obtained each as a colorless solid.

4-[(6S,7S)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-chlorobenzonitrile;

$^1\text{H-NMR}$ (CDCl_3) δ : 0.07 (3H, s), 0.12 (3H, s), 0.67–0.79 (1H, m), 0.88–1.37 (3H, m), 0.93 (9H, s), 1.30 (3H, d, $J=6.4\text{Hz}$), 4.29–4.41 (1H, m), 4.59 (1H, d, $J=7.2\text{Hz}$), 7.01–8.04 (3H, m).

4-[(6S,7R)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-chlorobenzonitrile

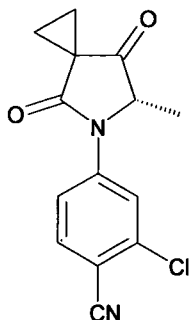
$^1\text{H-NMR}$ (CDCl_3) δ : 0.06 (3H, s), 0.10 (3H, s), 0.89 (9H, s), 0.97–1.17 (2H, m), 1.21–1.42 (2H, m), 1.36 (3H, d, $J=6.6\text{Hz}$), 3.79–3.82 (1H, m), 4.06–4.19 (1H, m), 7.54–7.69 (2H, m), 7.91–7.95 (1H, m).

mp: 169–172°C.

Reference Example 70

2-chloro-4-[(6S)-6-methyl-4,7-dioxo-5-azaspiro[2.4]hept-5-

yl]benzonitrile



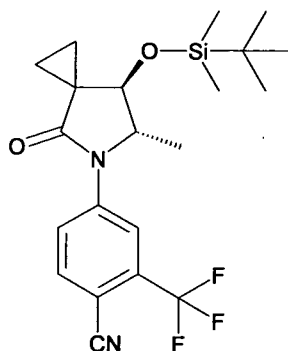
A solution of oxalyl chloride (0.050 mL) in methylene chloride (2.0 mL) was cooled to -60°C , dimethyl sulfoxide (0.062 mL) was added dropwise, and the mixture was stirred at the same temperature for 30 min. A solution of 2-chloro-4-[(6S,7R)-7-hydroxy-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]benzonitrile (40.1 mg) in methylene chloride (2.5 mL) was added dropwise to the reaction mixture, and the mixture was stirred at -40°C for 1 hr. Triethylamine (0.202 mL) was added, and the mixture was stirred at 0°C for 30 min. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent:hexane/ethyl acetate=50/1 $\rightarrow$ 1/1) to give the title compound as a pale-yellow oil (yield: 35 mg, 88%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.50 (3H, d, $J=6.8\text{Hz}$), 1.78-1.96 (4H, m), 4.68 (1H, q, $J=6.9\text{Hz}$), 7.57 (1H, dd, $J=8.6, 2.1\text{Hz}$), 7.72 (1H, d, $J=8.6\text{Hz}$), 7.90 (1H, d, $J=2.1\text{Hz}$).

mp: $169-172^{\circ}\text{C}$

Reference Example 71

4-[(6S,7R)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-(trifluoromethyl)benzonitrile



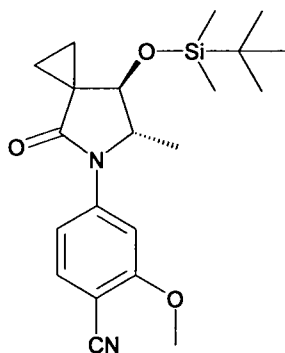
Using (6S)-7-(tert-butyldimethylsilyloxy)-6-methyl-5-azaspiro[2.4]heptan-4-one (720.5 mg), 4-iodo-2-trifluoromethylbenzonitrile (921.3 mg), cesium carbonate (1.38 g), tris(dibenzylideneacetone)dipalladium(0) (129 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (326 mg), and in the same manner as in Reference Example 3, the title compound (yield: 670 mg, yield 56%) and 4-[(6S,7S)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-(trifluoromethyl)benzonitrile (yield: 309 mg, 26%) were obtained each as a colorless solid.

4-[(6S,7R)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-(trifluoromethyl)benzonitrile
¹H-NMR(CDCl₃)δ:0.06(3H,s), 0.10(3H,s), 0.90(9H,s), 0.99-1.18(2H,m), 1.21-1.33(1H,m), 1.31-1.44(1H,m), 1.37(3H,d,J=6.4Hz), 3.79-3.86(1H,m), 4.09-4.25(1H,m), 7.79-7.86(2H,m), 8.23(1H,s).

4-[(6S,7S)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-(trifluoromethyl)benzonitrile
¹H-NMR(CDCl₃)δ:0.08(3H,s), 0.13(3H,s), 0.69-0.81(1H,m), 0.93(9H,s), 0.93-1.09(1H,m), 1.18-1.41(2H,m), 1.32(3H,d,J=6.4Hz), 4.43-4.46(1H,m), 4.61(1H,d,J=7.2Hz), 7.80(1H,d,J=8.7Hz), 7.95(1H,dd,J=8.7,2.3Hz), 8.25(1H,d,J=2.3Hz).

Reference Example 72

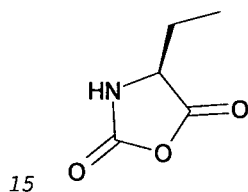
4-[(6S,7R)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-methoxybenzonitrile



Using (6S)-7-(tert-butyldimethylsilyloxy)-6-methyl-5-azaspiro[2.4]heptan-4-one (762.2 mg), 4-bromo-2-methoxybenzonitrile (724 mg), cesium carbonate (1.46 g),
 5 tris(dibenzylideneacetone)dipalladium(0) (136.6 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (345.3 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 760 mg, 66%).
¹H-NMR(CDCl₃)δ: 0.06(3H,s), 0.09(3H,s), 0.90(9H,s), 0.96-
 10 1.14(2H,m), 1.19-1.38(2H,m), 1.36(3H,d,J=6.6Hz), 3.80(1H,d,J=1.9Hz), 3.93(3H,s), 4.11-4.21(1H,m), 6.80(1H,dd,J=8.5,1.9Hz), 7.53(1H,d,J=8.5Hz), 7.92(1H,d,J=1.9Hz).

Reference Example 73

(4S)-4-ethyl-1,3-oxazolidine-2,5-dione

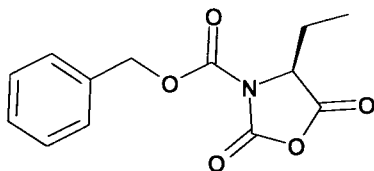


To a suspension of (2S)-2-aminobutanoic acid (10 g) and activated carbon (116 mg) in tetrahydrofuran (50 mL) was added dropwise a solution of triphosgene (10.07 g) in tetrahydrofuran (50 mL) at room temperature, and the mixture
 20 was stirred at 50°C for 2 hr. The same experimental process was performed twice, in each of which insoluble materials were filtered off with celite, and the filtrates were combined and concentrated under reduced pressure. The residue was washed with hexane to give the title compound as a solid (yield:
 25 22.39 g, 89%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.06 (3H, t, $J=7.5\text{Hz}$), 1.81-2.03 (2H, m), 4.29-4.38 (1H, m), 5.79 (1H, brs).

Reference Example 74

Benzyl (4S)-4-ethyl-2,5-dioxo-1,3-oxazolidine-3-carboxylate



5

A solution of (4S)-4-ethyl-1,3-oxazolidine-2,5-dione (69.57 g) and benzyl chloroformate (101.1 g) in tetrahydrofuran (800 mL) was cooled to 0°C , N-methylmorpholine (81.74 g) was added dropwise, and the mixture was stirred at 0°C for 2 hr. A 4 mol/L hydrogen chloride - ethyl acetate solution (86.9 mL) was added dropwise at 0°C to the reaction mixture, and the precipitated morpholine hydrochloride was filtered off with celite. The filtrate was concentrated under reduced pressure to give the title compound as a pale-yellow oil (yield: 91.58 g, 52%).

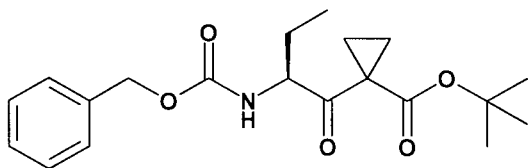
15

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.95 (3H, t, $J=7.5\text{Hz}$), 1.75-2.35 (2H, m), 4.74 (1H, dd, $J=6.0, 3.2\text{Hz}$), 5.27-5.44 (2H, m), 7.28-7.49 (5H, m).

Reference Example 75

tert-butyl 1-((2S)-2-

20 {[(benzyloxy)carbonyl]amino}butanoyl)cyclopropanecarboxylate



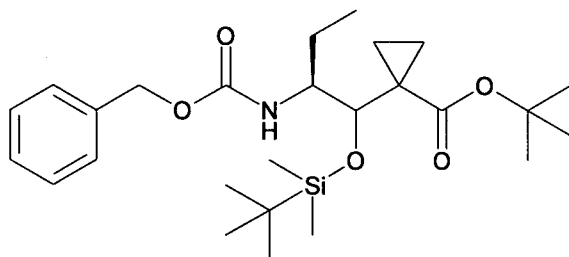
A solution of diisopropylamine (3.76 mL) in tetrahydrofuran (50 mL) was cooled to -78°C , n-butyllithium-hexane solution (16.56 mL, 1.6 mol/L) was added dropwise and, after the completion of the dropwise addition, the mixture was stirred at -78°C for 1 hr. Subsequently, a solution of tert-butyl cyclopropanecarboxylate (3.77 g) in tetrahydrofuran (10 mL) was added dropwise, and the mixture was further stirred at -78°C for 30 min. A solution of benzyl (4S)-4-ethyl-2,5-dioxo-

1,3-oxazolidine-3-carboxylate (3.49 g) in tetrahydrofuran (50 mL) was added dropwise at -78°C for 30 min and the mixture was stirred at -78°C for 30 min. Acetic acid was added to the reaction mixture at -78°C, water was added and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=1/0→2/1) to give the title compound as a colorless oil (yield: 1.16 g, 24%).

¹H-NMR (CDCl₃) δ: 0.89 (3H, t, J=7.6 Hz), 1.04-1.79 (6H, m), 1.50 (9H, s), 5.07-5.17 (2H, m), 5.25-5.38 (1H, m), 5.42-5.52 (1H, m), 7.29-7.40 (5H, m).

Reference Example 76

tert-butyl 1-((2S)-2-{[(benzyloxy)carbonyl]amino}-1-(tert-butylidimethylsilyloxy)butyl)cyclopropanecarboxylate



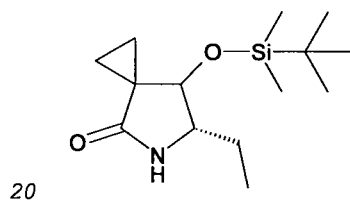
To a solution of tert-butyl 1-((2S)-2-{[(benzyloxy)carbonyl]amino}butanoyl)cyclopropanecarboxylate (1.16 g) in methanol (25 mL) was added sodium borohydride (180 mg) at 0°C, and the mixture was stirred at 0°C for 30 min. Aqueous ammonium chloride was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=50/1→1/1) to give tert-butyl 1-((2S)-2-{[(benzyloxy)carbonyl]amino}-1-hydroxybutyl)cyclopropanecarboxylate as a colorless oil (yield: 914.8 mg, yield: 78%).

To a solution of tert-butyl 1-((2S)-2-
 {[(benzyloxy)carbonyl]amino}-1-
 hydroxybutyl)cyclopropanecarboxylate (914.8 mg) and 2,6-lutidine
 (0.632 mL) in tetrahydrofuran (20 mL) was added under ice-
 5 cooling tert-butyldimethylsilane trifluoromethanesulfonate
 (0.934 mL) and, after warming to room temperature, the mixture
 was stirred for 1 hr. The reaction mixture was added to water,
 and the mixture was extracted with ethyl acetate. The extract
 was washed with saturated brine, dried over anhydrous magnesium
 10 sulfate, and concentrated under reduced pressure. The residue
 was purified by silica gel column chromatography (eluent:
 hexane/ethyl acetate=50/1→2/1) to give the title compound as a
 colorless oil (yield: 1.18 g, 98%).

¹H-NMR(CDCl₃)δ:0.03-0.10(6H,m), 0.77-1.48(9H,m), 0.81-0.92(9H,m),
 15 1.36-1.47(9H,m), 3.61-3.77(1H,m), 4.19-4.28(1H,m), 4.71-
 4.84(1H,m), 5.03-5.18(2H,m), 7.13-7.41(5H,m).

Reference Example 77

(6S)-7-(tert-butyldimethylsilyloxy)-6-ethyl-5-
 azaspiro[2.4]heptan-4-one



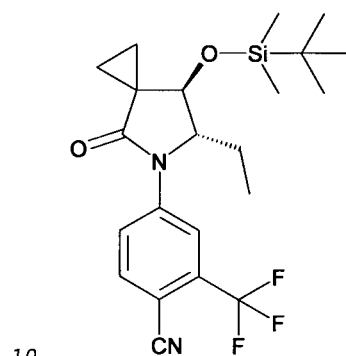
To a solution of tert-butyl 1-((2S)-2-
 {[(benzyloxy)carbonyl]amino}-1-(tert-
 butyldimethylsilyloxy)butyl)cyclopropanecarboxylate (1.18 g) in
 methanol (20 mL) was added 10% palladium carbon (150 mg), and
 25 the mixture was stirred at room temperature for 18 hr under a
 hydrogen atmosphere and filtered. The filtrate was concentrated
 under reduced pressure and the residue was dissolved in methanol
 (20 mL). Sodium methoxide (230 mg) was added and the mixture
 was refluxed for 2.5 hr. Water was added to the reaction
 30 mixture, and the mixture was extracted with ethyl acetate. The
 extract was dried over anhydrous magnesium sulfate and
 concentrated under reduced pressure. The residue was purified

by silica gel column chromatography (eluent: hexane/ethyl acetate=30/1→1/2) to give the title compound as a colorless oil (yield: 397.8 mg, 60%).

¹H-NMR(CDCl₃)δ:0.00-0.07(6H,m), 0.59-1.29(7H,m), 0.87-0.92(9H,m),
 5 1.40-1.57(1H,m), 1.60-1.81(1H,m), 3.34-3.66(1H,m), 3.84-
 3.90(1H,m), 5.51-5.73(1H,m).

Reference Example 78

4-[(6S,7R)-7-(tert-butyldimethylsilyloxy)-6-ethyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-(trifluoromethyl)benzonitrile

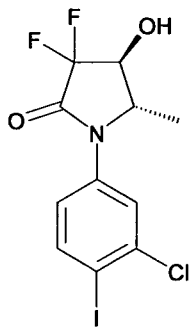


Using (6S)-7-(tert-butyldimethylsilyloxy)-6-ethyl-5-azaspiro[2.4]heptan-4-one (397.8 mg), 4-iodo-2-trifluoromethylbenzonitrile (482 mg), cesium carbonate (721 mg), tris(dibenzylideneacetone)dipalladium(0) (68 mg) and 4,5-
 15 bis(diphenylphosphino)-9,9-dimethylxanthene (171 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 433.7mg, yield: 67%).

¹H-NMR(CDCl₃)δ:0.07(3H,s), 0.11(3H,s), 0.90(9H,s),
 0.96(3H,t,J=7.6Hz), 1.02-1.17(2H,m), 1.30-1.38(2H,m), 1.65-
 20 1.83(2H,m), 3.83-3.91(1H,m), 4.05-4.16(1H,m), 7.80-7.86(2H,m),
 8.28(1H,s).

Reference Example 79

(4S,5S)-1-(3-chloro-4-iodophenyl)-3,3-difluoro-4-hydroxy-5-methylpyrrolidin-2-one

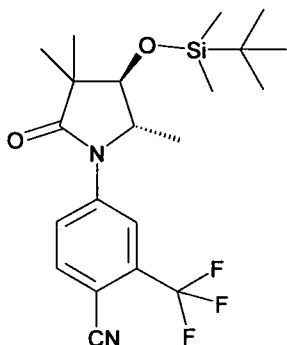


To a solution of (4S,5S)-1-(3-chlorophenyl)-3,3-difluoro-4-hydroxy-5-methylpyrrolidin-2-one (110.5 mg) and N-iodosuccinimide (130 mg) in acetic acid (3 mL) was added
 5 dropwise conc. sulfuric acid (3 drops), and the mixture was stirred at room temperature for 18 hr. The reaction mixture was concentrated, water was added and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue
 10 was purified by silica gel column chromatography (eluent:hexane/ethyl acetate=50/1→1/2) to give the title compound as a pale-yellow oil (yield: 113 mg, 69%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.38 (3H, dd, $J=6.5, 1.2\text{Hz}$), 2.38 (1H, brs), 4.05-4.23 (2H, m), 7.14 (1H, dd, $J=8.7, 2.5\text{Hz}$), 7.64 (1H, d, $J=2.5\text{Hz}$),
 15 7.90 (1H, d, $J=8.7\text{Hz}$).

Reference Example 80

4-[(4R,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile



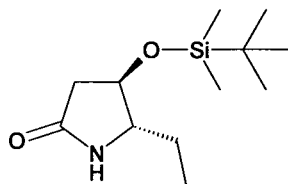
20 Using (4R,5S)-4-(tert-butyldimethylsilyloxy)-3,3,5-trimethylpyrrolidin-2-one (266.6 mg), 4-iodo-2-trifluoromethylbenzonitrile (340 mg), cesium carbonate (505 mg), tris(dibenzylideneacetone)dipalladium(0) (47 mg) and 4,5-

bis(diphenylphosphino)-9,9-dimethylxanthene (120 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a pale-yellow oil (yield: 391.7 mg, yield: 89%).

¹H-NMR(CDCl₃)δ: 0.15(3H,s), 0.15(3H,s), 0.95(9H,s), 1.13(3H,s),
 5 1.30(3H,s), 1.31(3H,d,J=6.2Hz), 3.75(1H,d,J=6.2Hz), 3.89-
 4.02(1H,m), 7.58-7.74(1H,m), 7.80-7.93(2H,m).

Reference Example 81

(4R,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one



10 A solution of diisopropylamine (74.5 mL) in tetrahydrofuran (1 L) was cooled to -78°C, n-butyllithium-hexane solution (329 mL, 1.6 mol/L) was added dropwise, and the mixture was stirred for 1 hr. Ethyl acetate (51.6 mL) was added dropwise and the mixture was stirred at -78°C for 1 hr. Then, a
 15 solution of benzyl [(1S)-1-(1H-imidazol-1-ylcarbonyl)propyl]carbamate prepared from (2S)-2-
 {[(benzyloxy)carbonyl]amino}butanoic acid (50 g) and N,N'-carbonyldiimidazole (39.5 g) in tetrahydrofuran (300 mL) was added dropwise at -78°C. After stirring at -78°C for 1 hr,
 20 acetic acid was added to the reaction mixture. Water was added and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=1/0→2/1) to
 25 give ethyl (4S)-4-{[(benzyloxy)carbonyl]amino}-3-oxohexanoate as a colorless oil (yield: 36.7 g, 57%).

To a solution of ethyl (4S)-4-
 {[(benzyloxy)carbonyl]amino}-3-oxohexanoate (70.68 g) in methanol (500 mL) was added sodium borohydride (9.66 g) at -78°C,
 30 and the mixture was stirred at -78°C for 1 hr and at room temperature for 1 hr. Saturated aqueous ammonium chloride was added to the reaction mixture, and the mixture was extracted

with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate) to give ethyl (4S)-4-

5 [[(benzyloxy)carbonyl]amino]-3-hydroxyhexanoate (yield: 63.2 g, 89%) as a colorless solid.

To a solution of ethyl (4S)-4-
[[[(benzyloxy)carbonyl]amino]-3-hydroxyhexanoate (63.2 g) and
2,6-lutidine (47.6 mL) in tetrahydrofuran (800 mL) was added
10 tert-butyldimethylsilane trifluoromethanesulfonate (70 mL) under
ice-cooling and, after warming to room temperature, and the
mixture was stirred for 1 hr. Water was added to the reaction
mixture, and the mixture was extracted with ethyl acetate. The
extract was dried over anhydrous magnesium sulfate and
15 concentrated under reduced pressure. The residue was purified
by silica gel column chromatography (eluent: hexane/ethyl
acetate=1/0→1/1) to give ethyl (4S)-4-
[[[(benzyloxy)carbonyl]amino]-3-(tert-
butyldimethylsilyloxy)hexanoate as a colorless oil (yield: 64.0
20 g, 74%).

To a solution of ethyl (4S)-4-
[[[(benzyloxy)carbonyl]amino]-3-(tert-
butyldimethylsilyloxy)hexanoate (64.0 g) in methanol (500 mL)
was added 10% palladium carbon (containing 50% water, 6.5 g),
25 and the mixture was stirred at room temperature for 3.5 hr under
a hydrogen atmosphere and filtered. Sodium methoxide (13.6 g)
was added to the filtrate, and the mixture was stirred at room
temperature for 2 hr. Water was added to the reaction mixture,
and the mixture was extracted with ethyl acetate. The extract
30 was dried over anhydrous magnesium sulfate and concentrated
under reduced pressure. The residue was purified by silica gel
column chromatography (eluent: hexane/ethyl acetate=20/1→1/4)
to give the title compound (yield: 21.6 g, 59%) and (4S,5S)-4-
(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one (yield:

4.64 g, 13%) as a colorless solid and a colorless oil, respectively.

(4R,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one

¹H-NMR(CDCl₃)δ:0.07(3H,s), 0.08(3H,s), 0.88(9H,s),

5 0.96(3H,t,J=7.5Hz), 1.33-1.54(1H,m), 1.54-1.71(1H,m),

2.26(1H,dd,J=16.9,4.6Hz), 2.60(1H,dd,J=16.9,6.9Hz), 3.30-

3.41(1H,m), 4.05-4.18(1H,m), 5.71(1H,brs).

(4S,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one

¹H-NMR(CDCl₃)δ:0.068(3H,s), 0.070(3H,s), 0.89(9H,s),

10 0.95(3H,t,J=7.5Hz), 1.43-1.76(2H,m), 2.26(1H,dd,J=16.9,4.2Hz),

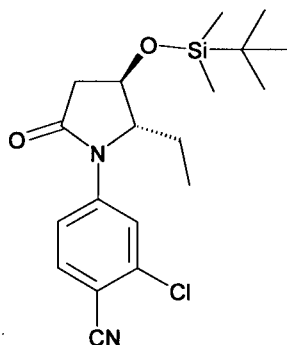
2.51(1H,dd,J=16.7,6.3Hz), 3.43-3.56(1H,m), 4.39-4.50(1H,m),

5.94(1H,brs).

Reference Example 82

4-[(2S,3R)-3-(tert-butyldimethylsilyloxy)-2-ethyl-5-

15 oxopyrrolidin-1-yl]-2-chlorobenzonitrile



Using (4R,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one (320 mg), 4-bromo-2-chlorobenzonitrile (325 mg), cesium carbonate (643 mg),

20 tris(dibenzylideneacetone)dipalladium(0) (60 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (152 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 366 mg, 73%).

¹H-NMR(CDCl₃)δ:0.11(3H,s), 0.12(3H,s), 0.89(9H,s),

25 0.97(3H,t,J=7.5Hz), 1.42-1.58(1H,m), 1.65-1.79(1H,m),

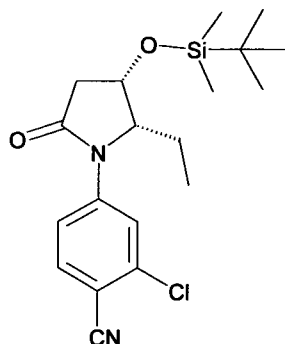
2.48(1H,dd,J=17.6,1.3Hz), 2.91(1H,dd,J=17.6,5.9Hz),

3.97(1H,dd,J=9.3,2.1Hz), 4.21-4.28(1H,m),

7.56(1H,dd,J=8.7,1.9Hz), 7.65(1H,d,J=8.7Hz), 7.90(1H,d,J=1.9Hz).

Reference Example 83

4-[(2S,3S)-3-(tert-butyldimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-chlorobenzonitrile

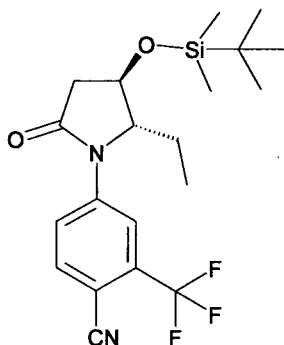


Using (4S,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one (470 mg), 4-bromo-2-chlorobenzonitrile (477 mg), cesium carbonate (944 mg), tris(dibenzylideneacetone)dipalladium(0) (88.5 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (224 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 550 mg, 75%).

¹H-NMR (CDCl₃) δ: 0.13 (3H, s), 0.13 (3H, s), 0.92 (9H, s), 0.96 (3H, t, J=7.6 Hz), 1.60-1.77 (1H, m), 1.76-1.92 (1H, m), 2.63 (1H, dd, J=17.0, 6.8 Hz), 2.73 (1H, dd, J=17.0, 6.8 Hz), 4.09-4.22 (1H, m), 4.63 (1H, q, J=6.8 Hz), 7.49 (1H, dd, J=8.5, 2.1 Hz), 7.65 (1H, d, J=8.5 Hz), 7.76 (1H, d, J=2.1 Hz).

Reference Example 84

4-[(2S,3R)-3-(tert-butyldimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile



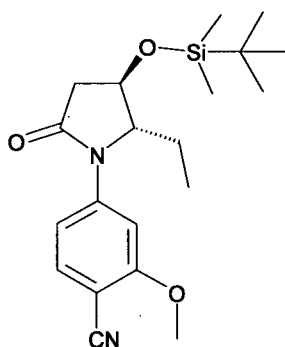
Using (4R,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one (1.00 g), 4-iodo-2-trifluoromethylbenzonitrile (1.46 g), cesium carbonate (2.08 g), tris(dibenzylideneacetone)dipalladium(0) (193 mg) and 4,5-

bis(diphenylphosphino)-9,9-dimethylxanthene (490 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 1.32 g, 78%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.12 (3H, s), 0.13 (3H, s), 0.89 (9H, s),
5 0.98 (3H, t, $J=7.5\text{Hz}$), 1.42–1.61 (1H, m), 1.64–1.80 (1H, m),
2.50 (1H, dd, $J=17.6, 1.5\text{Hz}$), 2.94 (1H, dd, $J=17.6, 5.9\text{Hz}$), 3.97–
4.07 (1H, m), 4.23–4.31 (1H, m), 7.77–7.92 (2H, m), 8.14 (1H, d, $J=2.1\text{Hz}$).

Reference Example 85

4-[(2S,3R)-3-(tert-butyldimethylsilyloxy)-2-ethyl-5-
10 oxopyrrolidin-1-yl]-2-methoxybenzonitrile

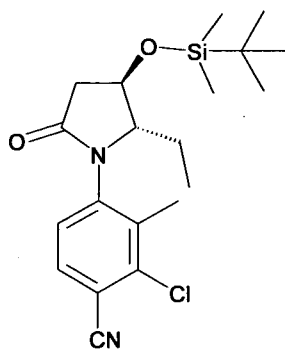


Using (4R,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one (1.00 g), 4-bromo-2-methoxybenzonitrile (1.00 g), cesium carbonate (2.08 g),
15 tris(dibenzylideneacetone)dipalladium(0) (193 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (490 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 1.04 g, 65%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.11 (3H, s), 0.12 (3H, s), 0.89 (9H, s),
20 0.96 (3H, t, $J=7.6\text{Hz}$), 1.39–1.55 (1H, m), 1.63–1.83 (1H, m),
2.48 (1H, dd, $J=17.4, 1.5\text{Hz}$), 2.91 (1H, dd, $J=17.4, 5.9\text{Hz}$), 3.94 (3H, s),
3.94–4.03 (1H, m), 4.19–4.28 (1H, m), 6.82 (1H, dd, $J=8.5, 1.9\text{Hz}$),
7.53 (1H, d, $J=8.5\text{Hz}$), 7.78 (1H, d, $J=1.9\text{Hz}$).

Reference Example 86

4-[(2S,3R)-3-(tert-butyldimethylsilyloxy)-2-ethyl-5-
25 oxopyrrolidin-1-yl]-2-chloro-3-methylbenzonitrile

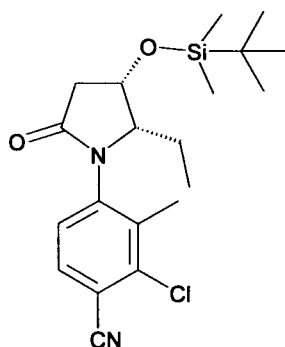


Using (4R,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one (1.00 g), 2-chloro-4-iodo-3-methylbenzonitrile (1.31 g), cesium carbonate (2.08 g),
 5 tris(dibenzylideneacetone)dipalladium(0) (193 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (490 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 650 mg, 39%).

¹H-NMR(CDCl₃)δ: 0.13(3H,s), 0.13(3H,s), 0.89-0.94(3H,m),
 10 0.92(9H,s), 1.33-1.51(1H,m), 1.51-1.67(1H,m), 2.34(3H,s), 2.44(1H,dd,J=17.3,2.1Hz), 2.85(1H,dd,J=17.3,5.8Hz), 3.59-3.76(1H,m), 4.26(1H,m), 7.15(1H,d,J=8.1Hz), 7.57(1H,d,J=8.1Hz).

Reference Example 87

4-[(2S,3S)-3-(tert-butyldimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-chloro-3-methylbenzonitrile
 15

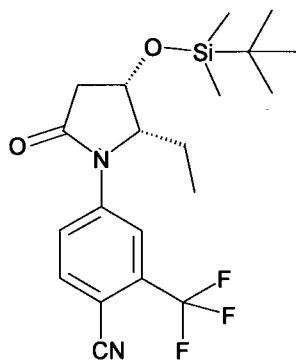


Using (4S,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one (1.00 g), 2-chloro-4-iodo-3-methylbenzonitrile (1.31 g), cesium carbonate (2.08 g),
 20 tris(dibenzylideneacetone)dipalladium(0) (193 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (490 mg), and in the same manner as in Reference Example 3, the title compound was obtained as a colorless solid (yield: 134.5 mg, yield: 8%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.12 (3H, s), 0.15 (3H, s), 0.85 (3H, t, $J=7.4\text{Hz}$), 0.91 (9H, s), 1.49–1.76 (2H, m), 2.31 (3H, s), 2.45–2.56 (1H, m), 2.74 (1H, dd, $J=16.8, 4.9\text{Hz}$), 3.83–3.97 (1H, m), 4.51–4.59 (1H, m), 6.99–7.16 (1H, m), 7.55 (1H, d, $J=8.3\text{Hz}$).

5 Reference Example 88

4-[(2S,3S)-3-(tert-butyldimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile

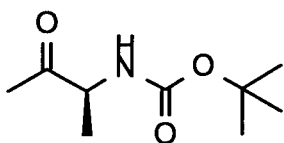


A suspension of (4S,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one (6.00 g), 4-iodo-2-trifluoromethylbenzonitrile (8.42 g), cesium carbonate (12.05 g), tris(dibenzylideneacetone)dipalladium(0) (1.13 g) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (2.14 g) in toluene (70 mL) was stirred at 80°C for 18 hr. Water and ethyl acetate were added to the reaction mixture and insoluble material was filtered off. The filtrate was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=50/1→1/2) to give the title compound as a pale-yellow solid (yield: 7.76 g, 76%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.14 (3H, s), 0.14 (3H, s), 0.93 (9H, s), 0.96 (3H, t, $J=7.5\text{Hz}$), 1.60–1.78 (1H, m), 1.77–1.94 (1H, m), 2.66 (1H, dd, $J=17.0, 6.8\text{Hz}$), 2.76 (1H, dd, $J=17.0, 7.2\text{Hz}$), 4.16–4.26 (1H, m), 4.66 (1H, q, $J=6.9\text{Hz}$), 7.81–7.87 (2H, m), 7.94–7.99 (1H, m).

Reference Example 89

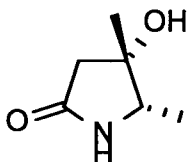
tert-butyl [(1S)-1-methyl-2-oxopropyl]carbamate



A solution of tert-butyl{(1S)-1-[methoxy(methyl)carbamoyl]ethyl}carbamate (5.26 g) in tetrahydrofuran (300 mL) was cooled with dry ice/acetone under a nitrogen atmosphere, and 1.6 mol/L-methylolithium/diethyl ether solution (38.8 mL) was added. After stirring at the same temperature for 1.5 hr, saturated aqueous ammonium chloride solution (100 mL) was added to the reaction solution, and the mixture was extracted with ethyl acetate. The obtained organic layer was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentration under reduced pressure to give the title compound as a colorless oil (yield: 4.48 g).
¹H-NMR(CDCl₃)δ:1.34(3H,d,J=7.2Hz), 1.44(9H,s), 2.21(3H,s), 4.23-4.40(1H,m), 5.26(1H,brs).

15 Reference Example 90

(4S,5S)-4-hydroxy-4,5-dimethylpyrrolidin-2-one



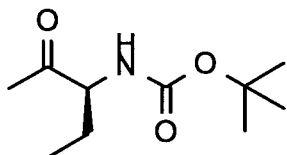
A solution of diisopropylamine (3.44 g) in tetrahydrofuran (50 mL) was ice-cooled under a nitrogen atmosphere and 1.6 mol/L n-butyllithium-hexane solution (20.8 mL) was added. The mixture was stirred at the same temperature for 20 min, and the reaction solution was cooled with dry ice/acetone. Ethyl acetate (3.28 mL) was added to the reaction solution, and the mixture was stirred at the same temperature for 30 min. A solution of tert-butyl [(1S)-1-methyl-2-oxopropyl]carbamate (4.48 g) in tetrahydrofuran (10 mL) was added. The mixture was stirred at the same temperature for 5 hr, saturated aqueous ammonium chloride solution (100 mL) was added, and the mixture was extracted with ethyl acetate. The obtained organic layer was

washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→30%), the obtained oil was dissolved in 4
5 mol/L hydrogen chloride-ethyl acetate solution (50 mL), and the mixture was stirred at room temperature for 2 hr. The reaction solution was concentrated under reduced pressure, the residue was dissolved in tetrahydrofuran (150 mL), and diisopropylethylamine (11.5 mL) was added. The reaction
10 solution was refluxed under heating for 4 hr, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: methanol/ethyl acetate=0→10%), and the obtained solid was recrystallized from isopropanol/hexane to give the title compound as colorless
15 crystals (yield: 1.51 g, 55%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.00 (3H, d, $J=6.4\text{Hz}$), 1.20 (3H, s), 2.06 (1H, d, $J=6.2\text{Hz}$), 2.24 (1H, d, $J=6.2\text{Hz}$), 3.33 (1H, q, $J=6.4\text{Hz}$), 4.72 (1H, s), 7.48 (1H, brs).
mp: 168–171°C.

Reference Example 91

20 tert-butyl [(1S)-1-ethyl-2-oxopropyl]carbamate



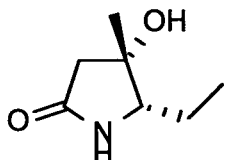
A solution of tert-butyl {(1S)-1-[methoxy(methyl)carbamoyl]propyl}carbamate (15.0 g) in tetrahydrofuran (150 mL) was cooled using dry ice/acetone under
25 a nitrogen atmosphere, and 1.0 mol/L-methylolithium/diethyl ether solution (300 mL) was added. The mixture was stirred at the same temperature for 4 hr, saturated aqueous ammonium chloride solution (300 mL) was added to the reaction solution, and the mixture was extracted with ethyl acetate. The obtained organic
30 layer was washed with saturated aqueous ammonium chloride solution and saturated brine, dried over anhydrous magnesium

sulfate, and concentration under reduced pressure to give the title compound as a colorless oil (yield: 12.75 g).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.89 (3H, dd, $J=7.6, 7.4\text{ Hz}$), 1.44 (9H, s), 1.52-1.73 (1H, m), 1.86-2.03 (1H, m), 2.20 (3H, s), 4.21-4.38 (1H, m),
5 5.22 (1H, brs).

Reference Example 92

(4S,5S)-5-ethyl-4-hydroxy-4-methylpyrrolidin-2-one



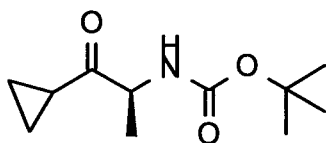
A solution of diisopropylamine (7.50 g) in tetrahydrofuran
10 (110 mL) was ice-cooled under a nitrogen atmosphere, and 1.6
mol/L n-butyllithium-hexane solution (45.4 mL) was added. The
mixture was stirred at the same temperature for 30 min, and the
reaction solution was cooled with dry ice/acetone. Ethyl
acetate (7.17 mL) was added to the reaction solution, and the
15 mixture was stirred at the same temperature for 1 hr. A
solution of tert-butyl [(1S)-1-ethyl-2-oxopropyl]carbamate (9.75
g) in tetrahydrofuran (60 mL) was added, and the mixture was
stirred at the same temperature for 5.5 hr. A saturated aqueous
ammonium chloride solution (200 mL) was added, and the mixture
20 was extracted with ethyl acetate. The obtained organic layer
was washed with saturated aqueous ammonium chloride solution and
saturated brine, dried over anhydrous magnesium sulfate, and
concentrated under reduced pressure. The residue was purified
by silica gel column chromatography (eluent: ethyl
25 acetate/hexane=10→30%) and the obtained oil was dissolved in 4
mol/L hydrogen chloride-ethyl acetate solution (80 mL), and the
mixture was stirred at room temperature for 2 hr. The reaction
solution was concentrated under reduced pressure, the residue
was dissolved in tetrahydrofuran (285 mL), and
30 diisopropylethylamine (22.2 mL) was added. The reaction
solution was refluxed under heating for 4 hr, and concentrated
under reduced pressure. The residue was purified by silica gel

column chromatography (eluent: methanol/ethyl acetate=3→13%), and the obtained solid was recrystallized from ethyl acetate/hexane to give the title compound as colorless crystals (yield: 4.69 g, 68%).

5 $^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.04 (3H, dd, $J=7.5\text{Hz}$), 1.40 (3H, s), 1.44-1.62 (1H, m), 1.62-1.80 (1H, m), 2.46 (2H, d, $J=1.5\text{Hz}$), 2.80 (1H, s), 3.32 (1H, dd, $J=9.4, 4.2\text{Hz}$), 6.78 (1H, brs).
mp: 87-111°C.

Reference Example 93

10 tert-butyl [(1S)-2-cyclopropyl-1-methyl-2-oxoethyl]carbamate

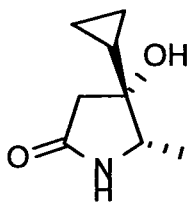


A solution of tert-butyl {(1S)-1-[methoxy(methyl)carbamoyl]ethyl}carbamate (10.0 g) in tetrahydrofuran (110 mL) was cooled using dry ice/acetone under
15 a nitrogen atmosphere, and 1.0 mol/L-cyclopropylmagnesium bromide/tetrahydrofuran solution (100 mL) was added. The mixture was warmed to room temperature and stirred for 5 hr, saturated aqueous ammonium chloride solution (200 mL) was added to the reaction solution, and the mixture was extracted with
20 ethyl acetate. The obtained organic layer was washed with water and saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→30%) to give the title compound as a yellow
25 oil (yield: 3.65 g, 40%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.88-1.01 (2H, m), 1.02-1.17 (2H, m), 1.42 (3H, d, $J=7.4\text{Hz}$), 1.45 (9H, s), 1.95-2.06 (1H, m), 4.43-4.60 (1H, m), 5.35 (1H, brs).

Reference Example 94

30 (4R, 5S)-4-cyclopropyl-4-hydroxy-5-methylpyrrolidin-2-one



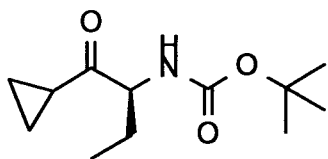
A solution of diisopropylamine (4.06 g) in tetrahydrofuran (40 mL) was ice-cooled under a nitrogen atmosphere, and 1.6 mol/L n-butyllithium-hexane solution (24.6 mL) was added. The mixture was stirred at the same temperature for 20 min, and the reaction solution was cooled with dry ice/acetone. Ethyl acetate (3.88 mL) was added to the reaction solution, the mixture was stirred at the same temperature for 30 min, and a solution of tert-butyl [(1S)-2-cyclopropyl-1-methyl-2-oxoethyl]carbamate (3.65 g) in tetrahydrofuran (10 mL) was added. The mixture was stirred at the same temperature for 7 hr, saturated aqueous ammonium chloride solution (100 mL) was added, and the mixture was extracted with ethyl acetate. The obtained organic layer was washed with water and saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→30%), the obtained oil was dissolved in 4 mol/L hydrogen chloride-ethyl acetate solution (30 mL), and the mixture was stirred at room temperature for 2 hr. The reaction solution was concentrated under reduced pressure, the residue was dissolved in tetrahydrofuran (80 mL), and diisopropylethylamine (8.09 mL) was added. The reaction solution was refluxed under heating for 4 hr, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: methanol/ethyl acetate=0→5%), and the obtained solid was recrystallized from ethyl acetate/hexane to give the title compound as colorless crystals (yield: 1.65 g, 71%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.27-0.61 (4H, m), 0.93-1.06 (1H, m), 1.24 (3H, d, $J=6.6\text{Hz}$), 2.04 (1H, s), 2.22 (1H, d, $J=17.2\text{Hz}$), 2.38 (1H, d, $J=17.2\text{Hz}$), 3.71 (1H, q, $J=6.6\text{Hz}$), 5.90 (1H, brs).

mp:133-140°C.

Reference Example 95

tert-butyl [(1S)-1-(cyclopropylcarbonyl)propyl]carbamate

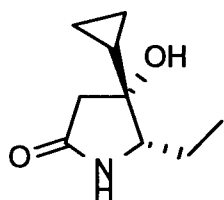


5 A solution of tert-butyl {(1S)-1-[methoxy(methyl)carbamoyl]propyl}carbamate (14.3 g) in tetrahydrofuran (130 mL) was ice-cooled under a nitrogen atmosphere, and 1.0 mol/L-cyclopropylmagnesium bromide/tetrahydrofuran solution (300 mL) was added. The mixture was stirred at the same temperature for 4.5 hr, saturated aqueous ammonium chloride solution (300 mL) was added to the reaction solution, and the mixture was extracted with ethyl acetate. The obtained organic layer was washed with saturated aqueous ammonium chloride solution and saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→16%) to give the title compound as a colorless oil (yield: 10.7 g, 94%).

10
15
20
¹H-NMR(CDCl₃)δ:0.90(3H,dd,J=7.6,7.4Hz), 0.88-1.16(4H,m), 1.44(9H,s), 1.67-1.81(1H,m), 1.92-2.11(2H,m), 4.44-4.59(1H,m), 5.32(1H,brs).

Reference Example 96

(4R,5S)-4-cyclopropyl-5-ethyl-4-hydroxypyrrolidin-2-one



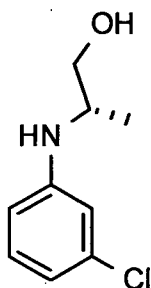
25 A solution of diisopropylamine (7.28 g) in tetrahydrofuran (110 mL) was ice-cooled under a nitrogen atmosphere, and 1.6 mol/L n-butyllithium-hexane solution (44.1 mL) was added. The mixture was stirred at the same temperature for 20 min, and the

reaction solution was cooled with dry ice/acetone. Ethyl acetate (6.96 mL) was added to the reaction solution, the mixture was stirred at the same temperature for 1 hr, and a solution of tert-butyl [(1S)-1-(cyclopropylcarbonyl)propyl]carbamate (10.7 g) in tetrahydrofuran (60 mL) was added. The mixture was stirred at the same temperature for 5 hr, saturated aqueous ammonium chloride solution (300 mL) was added, and the mixture was extracted with ethyl acetate. The obtained organic layer was washed with saturated aqueous ammonium chloride solution and saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=5→25%), the obtained oil was dissolved in 4 mol/L hydrogen chloride-ethyl acetate solution (100 mL), and the mixture was stirred at room temperature for 2 hr. The reaction solution was concentrated under reduced pressure, the residue was dissolved in tetrahydrofuran (300 mL), and diisopropylethylamine (22.7 mL) was added. The reaction solution was refluxed under heating for 4 hr, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: methanol/ethyl acetate=3→10%), and the obtained solid was recrystallized from ethyl acetate/diethyl ether/hexane to give the title compound as colorless crystals (yield: 2.80 g, 39%).

¹H-NMR(CDCl₃) δ: 0.29-0.55 (4H, m), 0.95-1.08 (1H, m), 1.04 (3H, dd, J=7.6, 7.4 Hz), 1.45-1.63 (1H, m), 1.65-1.82 (1H, m), 2.23 (1H, d, J=17.0 Hz), 2.37 (1H, d, J=17.0 Hz), 2.44 (1H, s), 3.45 (1H, dd, J=9.4, 4.0 Hz), 6.69 (1H, brs).
mp: 87-102°C.

Reference Example 97

(2S)-2-[(3-chlorophenyl)amino]propan-1-ol

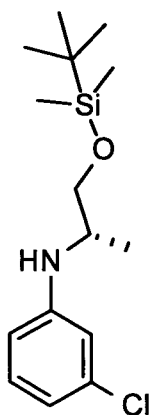


A solution of (2S)-2-aminopropan-1-ol (11.7 g), 1-chloro-3-iodobenzene (36.1 g), tripotassium phosphate (66.4 g), copper iodide (1.42 g) and ethylene glycol (16.7 mL) in propane-2-ol
 5 (155 mL) was stirred at 80°C for 24 hr under an argon atmosphere. Water (500 mL) was added to the reaction solution, and the mixture was extracted with diethyl ether. The obtained organic layer was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The
 10 residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→30%) to give the title compound as a colorless oil (yield: 26.9 g, 97%).

¹H-NMR(CDCl₃)δ: 1.21 (3H, d, J=6.0Hz), 1.78 (1H, brs), 3.47-3.68 (3H, m), 3.72 (1H, brd, J=10.0Hz), 6.51 (1H, ddd, J=8.1, 2.3, 0.8Hz),
 15 6.63 (1H, dd, J=2.3, 2.1Hz), 6.68 (1H, ddd, J=7.9, 2.1, 0.8Hz), 7.07 (1H, dd, J=8.1, 7.9Hz).

Reference Example 98

N-[(1S)-2-(tert-butyldimethylsilyloxy)-1-methylethyl]-3-chloroaniline



20

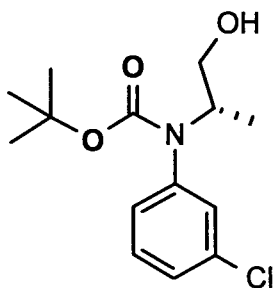
To a solution of (2S)-2-[(3-chlorophenyl)amino]propane-1-ol (7.00 g) in N,N-dimethylformamide (19 mL) were added

imidazole (2.82 g) and tert-butyl(chloro)dimethylsilane (6.38 g), and the mixture was stirred at 50°C for 14 hr. Water (200 mL) was added to the reaction solution, and the mixture was extracted with diethyl ether. The obtained organic layer was
5 dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→40%) to give the title compound as a colorless oil (yield: 7.40 g, 65%).

¹H-NMR(CDCl₃)δ:0.04(3H,s), 0.05(3H,s), 0.90(9H,s),
10 1.19(3H,d,J=6.2Hz), 3.46-3.57(1H,m), 3.61(2H,d,J=4.2Hz),
3.90(1H,d,J=7.4Hz), 6.46(1H,d,J=8.1Hz), 6.58(1H,s),
6.63(1H,d,J=7.9Hz), 7.05(1H,dd,J=8.1,7.9Hz).

Reference Example 99

tert-butyl (3-chlorophenyl)[(1S)-2-hydroxy-1-
15 methylethyl]carbamate



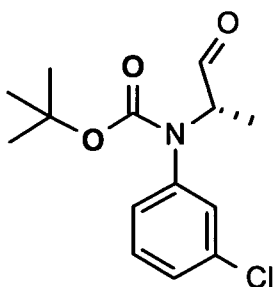
A solution of N-[(1S)-2-(tert-butyldimethylsilyloxy)-1-methylethyl]-3-chloroaniline (2.66 g) in tetrahydrofuran (20 mL) was cooled using dry ice/acetone under a nitrogen atmosphere,
20 and 1.6 mol/L n-butyllithium-hexane solution (6.65 mL) was added. The mixture was stirred at the same temperature for 30 min, a solution of di-tert-butyl-dicarbonate (2.52 g) in tetrahydrofuran (5 mL) was added. The reaction solution was warmed to room temperature and stirred for 4 hr, water (50 mL)
25 was added, and the mixture was extracted with ethyl acetate. The obtained organic layer was dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→5%), the obtained oil was dissolved in
30 tetrahydrofuran (25 mL). 1.0 mol/L Tetrabutylammonium

fluoride/tetrahydrofuran solution (11.5 mL) was added to the reaction solution, and the mixture was stirred at room temperature for 4 hr. Water (50 mL) was added to the reaction solution, and the mixture was extracted with ethyl acetate. The
5 obtained organic layer was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→40%) to give the title compound as a colorless oil (yield: 1.61 g, 64%).

10 $^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.08 (3H, d, $J=7.2\text{Hz}$), 1.37 (9H, s), 2.42 (1H, brs), 3.46-3.59 (1H, m), 3.62-3.74 (1H, m), 4.29-4.45 (1H, m), 7.04-7.08 (1H, m), 7.16-7.19 (1H, m), 7.26-7.30 (2H, m).

Reference Example 100

tert-butyl (3-chlorophenyl)[(1S)-1-methyl-2-oxoethyl]carbamate



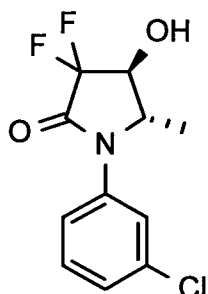
15

A solution of oxalyl chloride (318 mg) in methylene chloride (6 mL) was cooled using dry ice/acetone under a nitrogen atmosphere, and a solution of DMSO (258 mg) in methylene chloride (6 mL) was added. The mixture was stirred at
20 the same temperature for 10 min, a solution of tert-butyl (3-chlorophenyl)[(1S)-2-hydroxy-1-methylethyl]carbamate (500 mg) in methylene chloride (8 mL) was added, and the mixture was stirred at the same temperature for 10 min. Triethylamine (0.925 mL) was added, and the mixture was stirred at the same temperature
25 for 30 min. Water (30 mL) was added, and the mixture was extracted with ethyl acetate. The obtained organic layer was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentration under reduced pressure to give the title compound as a colorless oil (yield: 480 mg, 96%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.38–1.44 (3H, m), 1.42 (9H, s), 4.09–4.20 (1H, m), 7.09–7.16 (1H, m), 7.22–7.34 (3H, m), 9.75 (1H, s).

Reference Example 101

(4S, 5S)-1-(3-chlorophenyl)-3,3-difluoro-4-hydroxy-5-methylpyrrolidin-2-one



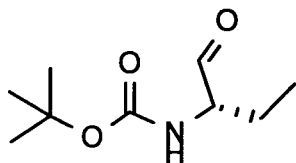
tert-Butyl (3-chlorophenyl)[(1S)-1-methyl-2-oxoethyl]carbamate (19.5 g) and ethyl bromodifluoroacetate (41.3 g) were dissolved in tetrahydrofuran (110 mL), and to a suspension of a zinc powder (13.6 g) in tetrahydrofuran (25 mL) was added dropwise the solution at room temperature. After heating under reflux for 1 hr, the mixture was cooled to room temperature, 1 mol/L aqueous potassium hydrogen sulfate solution (300 mL) was added, and the mixture was extracted with ethyl acetate. The extracted organic layer was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→10%), the obtained oil was dissolved in 4 mol/L hydrogen chloride/ethyl acetate solution (100 mL), and the mixture was stirred at room temperature for 2 hr. The reaction solution was concentrated under reduced pressure, tetrahydrofuran (275 mL) and diisopropylethylamine (21.3 mL, 119 mmol) were added, and the mixture was heated under reflux for 12 hr. The reaction solution was cooled to room temperature, water (200 mL) was added, and the mixture was extracted with ethyl acetate. The obtained organic layer was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column

chromatography (eluent: ethyl acetate/hexane=10→40%) to give the title compound as a yellow oil (yield: 3.76 g, 21%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.37 (3H, dd, $J=6.4, 1.3\text{Hz}$), 2.47 (1H, brs), 4.02-4.19 (2H, m), 7.26-7.31 (1H, m), 7.33-7.43 (2H, m), 7.47-7.53 (1H, m).

5 Reference Example 102

tert-butyl [(1S)-1-formylpropyl]carbamate



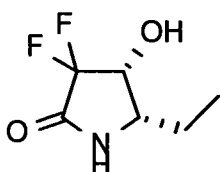
A solution of tert-butyl[(1S)-1-(hydroxymethyl)propyl]carbamate (30.0 g) in dimethyl sulfoxide
 10 (300 mL) was ice-cooled under a nitrogen atmosphere, and triethylamine (64.4 mL) and a solution of sulfur trioxide-pyridine complex (80.7 g) in dimethyl sulfoxide (300 mL) were successively added. The mixture was stirred at the same temperature for 30 min and then at room temperature for 3 hr, 1
 15 mol/L aqueous citric acid solution (500 mL) was added to the reaction solution, and the mixture was extracted with diethyl ether. The obtained organic layer was washed with water and saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified
 20 by silica gel column chromatography (eluent: ethyl acetate/hexane=0→30%) to give the title compound as a white powder (yield: 24.3 g, 85%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 0.97 (3H, dd, $J=7.6, 7.4\text{Hz}$), 1.45 (9H, s), 1.54-1.77 (1H, m), 1.85-2.02 (1H, m), 4.14-4.29 (1H, m), 5.11 (1H, brs),
 25 9.59 (1H, s).

mp: 39-43°C.

Reference Example 103

(4R,5S)-5-ethyl-3,3-difluoro-4-hydroxypyrrolidin-2-one



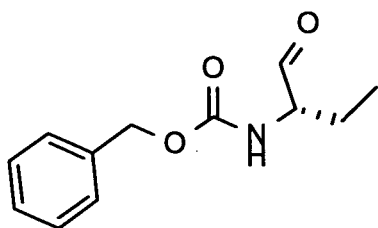
tert-Butyl [(1S)-1-formylpropyl]carbamate (24.00 g) and ethyl bromodifluoroacetate (77.0 g) were dissolved in tetrahydrofuran (220 mL), and to a suspension of a zinc powder (25.4 g) in tetrahydrofuran (50 mL) was added dropwise the
5 solution at room temperature. After heating under reflux for 1 hr, the mixture was cooled to room temperature, 1 mol/L aqueous potassium hydrogen sulfate solution (400 mL) was added, and the mixture was extracted with ethyl acetate. The extracted organic layer was washed with water and saturated brine, dried over
10 anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=10→40%), the obtained oil was dissolved in 4 mol/L hydrogen chloride/ethyl acetate solution (150 mL), and the mixture was stirred at room
15 temperature for 2 hr. The reaction solution was concentrated under reduced pressure, and the residue was dissolved in tetrahydrofuran (600 mL). Diisopropylethylamine (32.8 mL) was added, and the mixture was heated under reflux for 4 hr. The reaction solution was concentrated under reduced pressure, the
20 residue was filtered through silica gel, and the filtrate was concentrated under reduced pressure. The obtained residue was recrystallized from ethyl acetate/hexane to give the title compound as a white powder (yield: 7.20 g, 54%).

$^1\text{H-NMR}$ (CD_3SOCD_3) δ : 0.89 (3H, dd, $J=7.5, 7.5\text{Hz}$), 1.18-1.38 (1H, m), 1.51-
25 1.75 (1H, m), 3.47 (1H, dd, $J=13.0, 6.6\text{Hz}$), 4.14-4.39 (1H, m), 6.12 (1H, brd, $J=5.7\text{Hz}$), 8.99 (1H, brs).

mp: 118-121°C.

Reference Example 104

Benzyl [(1S)-1-formylpropyl]carbamate

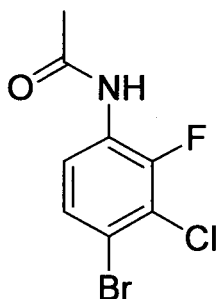


A solution of benzyl [(1S)-1-(hydroxymethyl)propyl]carbamate (30.0 g) in dimethyl sulfoxide (260 mL) was ice-cooled under a nitrogen atmosphere, and triethylamine (56.9 mL) and a solution of sulfur trioxide-pyridine complex (71.3 g) in dimethyl sulfoxide (260 mL) was successively added. The mixture was stirred at the same temperature for 1 hr, and at room temperature for 4 hr. A 1 mol/L aqueous citric acid solution (450 mL) was added to the reaction solution, and the mixture was extracted with diethyl ether. The obtained organic layer was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→30%) to give the title compound as a colorless oil (yield: 16.3 g, 55%).

¹H-NMR(CDCl₃)δ: 0.96(3H, dd, J=7.5, 7.5 Hz), 1.63-1.81(1H, m), 1.90-2.08(1H, m), 4.24-4.39(1H, m), 5.12(2H, s), 5.37(1H, brs), 7.31-7.42(5H, m), 9.59(1H, s).

Reference Example 105

N-(4-bromo-3-chloro-2-fluorophenyl)acetamide



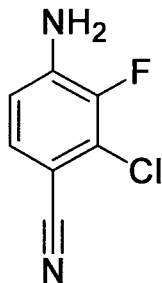
20

To a solution of 4-bromo-3-chloro-2-fluoroaniline (15.0 g) in ethyl acetate (200 mL) was added dropwise acetic anhydride (7.57 mL) at 0°C. Then, pyridine (10.8 mL) was added dropwise, and the mixture was stirred at room temperature overnight. The mixture was diluted with ethyl acetate, washed with water and saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure. The obtained solid was washed with hexane to give the title compound as a colorless solid (yield: 17.1 g, 96%).

$^1\text{H-NMR}$ (DMSO-d_6) δ : 2.10 (3H, s), 7.58 (1H, dd, $J=9.1, 1.9\text{Hz}$), 7.83-7.90 (1H, m), 9.98 (1H, s).

Reference Example 106

4-amino-2-chloro-3-fluorobenzonitrile

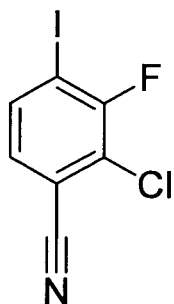


A mixture of N-(4-bromo-3-chloro-2-fluorophenyl)acetamide (17.0 g) and copper(I) cyanide (5.88 g) in N,N-dimethylformamide was stirred at 150°C overnight. After warming to room temperature, water was added, and the mixture was extracted with ethyl acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate, and the solvent was evaporated under reduced pressure to give N-(3-chloro-4-cyano-2-fluorophenyl)acetamide. Ethanol (250 mL)-concentrated hydrogen chloride (26.6 mL) was added to N-(3-chloro-4-cyano-2-fluorophenyl)acetamide, and the mixture was refluxed overnight. The mixture was ice-cooled, and neutralized with saturated aqueous sodium hydrogen carbonate solution, and the mixture was extracted with ethyl acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate, and the solvent was evaporated under reduced pressure. The obtained residue was purified by column, and the obtained solid was washed with hexane to give the title compound as a pale-yellow solid (yield: 7.0 g, 64%).

$^1\text{H-NMR}$ (CDCl_3) δ : 4.35 (2H, br. s.), 6.63-6.71 (1H, m), 7.25 (1H, dd, $J=8.5, 1.7\text{Hz}$).

Reference Example 107

2-chloro-3-fluoro-4-iodobenzonitrile

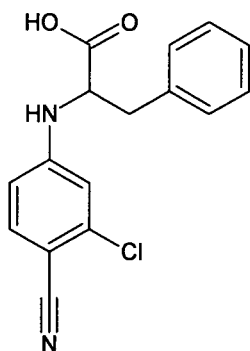


To a suspension of copper iodide (I) (9.24 g) in acetonitrile (100 mL) was added tert-butyl nitrite (90%, 6.95 g) at room temperature. Then, a solution of 4-amino-2-chloro-3-fluorobenzonitrile (6.9 g) in acetonitrile (100 mL) was added dropwise at 65°C over 1 hr. The mixture was stirred for 2 hr, and allowed to room temperature, aqueous sodium thiosulfate solution was added, and the mixture was extracted with ethyl acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate, and the solvent was evaporated under reduced pressure. The obtained residue was purified by basic silica gel column chromatography (eluent: hexane→hexane/ethyl acetate=4:1). The obtained solid was washed with hexane to give the title compound as yellow crystals (yield: 7.1 g, 62%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 7.22 (1H, dd, $J=8.2, 1.4\text{Hz}$), 7.80 (1H, dd, $J=8.2, 5.6\text{Hz}$).

Reference Example 108

N-(3-chloro-4-cyanophenyl)phenylalanine



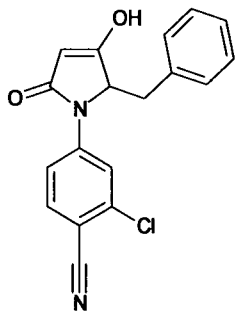
To a solution of 2-chloro-4-fluorobenzonitrile (5.0 g) in dimethyl sulfoxide (100 mL) were added phenylalanine (6.37 g) and cesium carbonate (13.6 g), and the mixture was stirred at 90°C overnight. After allowing to room temperature, ethyl acetate was added, and the mixture was extracted 3 times with

saturated aqueous sodium hydrogen carbonate solution. The aqueous layers were combined, and acidified with citric acid, and the mixture was extracted twice with ethyl acetate. The organic layers were combined, washed with saturated brine, and
5 dried over magnesium sulfate. The solvent was evaporated under reduced pressure to give the title compound as a brown oil (yield: 9.67 g, 100%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 3.09-3.19 (1H, m), 3.24-3.32 (1H, m), 4.37-4.47 (1H, m), 4.67-4.76 (1H, m), 6.44 (1H, dd, $J=8.6, 2.4\text{Hz}$), 6.59 (1H, d, $J=2.3\text{Hz}$),
10 7.12-7.19 (2H, m), 7.27-7.35 (3H, m), 7.40 (1H, d, $J=8.7\text{Hz}$).

Reference Example 109

4-(2-benzyl-3-hydroxy-5-oxo-2,5-dihydro-1H-pyrrol-1-yl)-2-chlorobenzonitrile

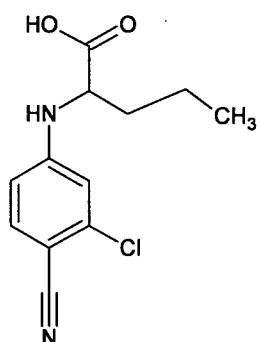


15 To a solution of N-(3-chloro-4-cyanophenyl)phenylalanine (2.0 g), Meldrum's acid (1.05 g) and 4-(N,N-dimethylamino)pyridine (1.22 g) in tetrahydrofuran (30 mL) was added N,N'-carbonyldiimidazole (1.29 g) at 0°C, and the mixture was stirred at room temperature overnight. A 5% aqueous
20 potassium hydrogen sulfate solution was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The organic layer was washed with 5% aqueous potassium hydrogen sulfate solution and saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure.
25 The residue was dissolved in ethyl acetate (30 mL), and the mixture was refluxed for 45 min. After allowing to room temperature, the mixture was extracted 3 times with saturated aqueous sodium hydrogen carbonate solution. The aqueous layers were combined, and acidified with citric acid, and the mixture

was extracted with ethyl acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure, and the obtained residue was recrystallized from tetrahydrofuran-hexane to give
5 the title compound as pale-yellow crystals (yield: 1.41 g, 65%).
 $^1\text{H-NMR}$ (DMSO-d_6) δ : 3.01-3.21 (2H, m), 4.80 (1H, s), 5.25 (1H, t, $J=3.9\text{Hz}$), 6.73-6.81 (2H, m), 7.13-7.18 (3H, m), 7.70 (1H, dd, $J=8.8, 2.2\text{Hz}$), 7.96 (1H, d, $J=8.7\text{Hz}$), 8.00 (1H, d, $J=1.9\text{Hz}$), 12.50 (1H, br. s.).
mp: 188-189°C.

10 Reference Example 110

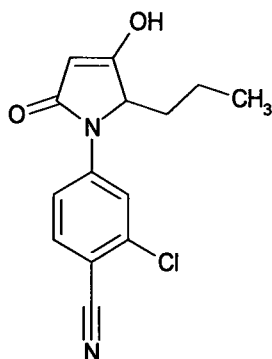
N-(3-chloro-4-cyanophenyl)norvaline



To a solution of 2-chloro-4-fluorobenzonitrile (5.0 g) in dimethyl sulfoxide (80 mL) were added L-norvaline (4.52 g) and
15 cesium carbonate (13.6 g), and the mixture was stirred at 90°C overnight. After allowing to room temperature, ethyl acetate was added, and the mixture was extracted twice with saturated aqueous sodium hydrogen carbonate solution. The aqueous layers were combined, and acidified with citric acid, and the mixture
20 was extracted twice with ethyl acetate. The organic layers were combined, washed with saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure to give the title compound as a brown oil (yield: 8.12 g, 100%).
 $^1\text{H-NMR}$ (CDCl_3) δ : 0.97 (3H, t, $J=7.3\text{Hz}$), 1.40-1.54 (2H, m), 1.71-
25 2.00 (2H, m), 4.08-4.16 (1H, m), 4.71 (1H, br. s.), 6.50 (1H, dd, $J=8.7, 2.5\text{Hz}$), 6.64 (1H, d, $J=2.5\text{Hz}$), 7.42 (1H, d, $J=8.5\text{Hz}$).

Reference Example 111

2-chloro-4-(3-hydroxy-5-oxo-2-propyl-2,5-dihydro-1H-pyrrol-1-yl)benzonitrile



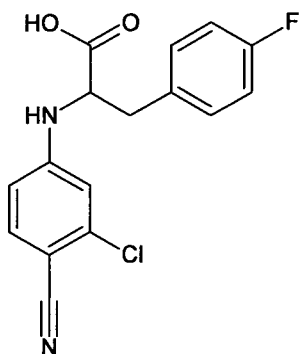
To a solution of N-(3-chloro-4-cyanophenyl)norvaline (4.0 g), Meldrum's acid (2.40 g) and 4-(N,N-dimethyl)aminopyridine (2.90 g) in tetrahydrofuran (60 mL) was added N,N'-carbonyldiimidazole (3.08 g) at 0°C, and the mixture was stirred at room temperature overnight. A 5% aqueous potassium hydrogen sulfate solution was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The organic layer was washed with 5% aqueous potassium hydrogen sulfate solution and saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure. The residue was dissolved in ethyl acetate (60 mL), and the mixture was refluxed for 45 min. After allowing to room temperature, the mixture was extracted twice with saturated aqueous sodium hydrogen carbonate solution. The aqueous layers were combined, and acidified with citric acid, and the mixture was extracted with ethyl acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure, and the obtained residue was washed with ethyl acetate to give the title compound as colorless crystals (yield: 1.89 g, 43%).

¹H-NMR (DMSO-d₆) δ: 0.69-0.80 (3H, m), 0.90-1.14 (2H, m), 1.69-1.81 (2H, m), 5.00 (1H, t, J=4.0 Hz), 5.03 (1H, s), 7.66 (1H, dd, J=8.7, 2.1 Hz), 7.92 (1H, d, J=8.9 Hz), 8.05 (1H, d, J=1.9 Hz), 12.40 (1H, br. s.).

mp: 156-158°C.

Reference Example 112

N-(3-chloro-4-cyanophenyl)-4-fluorophenylalanine

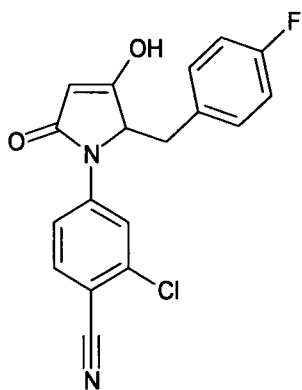


To a solution of 2-chloro-4-fluorobenzonitrile (1.8 g) in dimethyl sulfoxide (30 mL) were added 4-fluorophenylalanine
 5 (2.54 g) and cesium carbonate (4.90 g), and the mixture was stirred at 90°C overnight. After allowing to room temperature, ethyl acetate was added, and the mixture was extracted twice with saturated aqueous sodium hydrogen carbonate solution. The aqueous layers were combined, and acidified with citric acid,
 10 and the mixture was extracted twice with ethyl acetate. The organic layers were combined, washed with saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure to give the title compound as a brown oil (yield: 3.69 g, 100%).

15 $^1\text{H-NMR}$ (CDCl_3) δ : 3.07–3.30 (2H, m), 4.40 (1H, q, $J=5.9\text{Hz}$), 4.72 (1H, d, $J=6.6\text{Hz}$), 6.46 (1H, dd, $J=8.7, 2.3\text{Hz}$), 6.60 (1H, d, $J=2.3\text{Hz}$), 6.94–7.05 (2H, m), 7.07–7.16 (2H, m), 7.41 (1H, d, $J=8.7\text{Hz}$).

Reference Example 113

2-chloro-4-[2-(4-fluorobenzyl)-3-hydroxy-5-oxo-2,5-dihydro-1H-pyrrol-1-yl]benzonitrile
 20



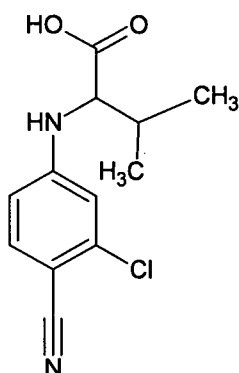
To a solution of N-(3-chloro-4-cyanophenyl)-4-fluorophenylalanine (3.67 g), Meldrum's acid (1.74 g) and 4-(N,N-dimethylamino)pyridine (2.11 g) in tetrahydrofuran (50 mL) was added N,N'-carbonyldiimidazole (2.24 g, 13.8 mmol) at 0°C, and the mixture was stirred at room temperature overnight. A 5% aqueous potassium hydrogen sulfate solution was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The organic layer was washed with 5% aqueous potassium hydrogen sulfate solution and saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure. The residue was dissolved in ethyl acetate (50 mL), and the mixture was refluxed for 45 min. After allowing to room temperature, the organic layer was washed with water and saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure, and the obtained residue was washed with ethyl acetate-isopropyl ether to give the title compound as colorless crystals (yield: 2.54 g, 64%).

$^1\text{H-NMR}$ (DMSO- d_6) δ : 2.99-3.20 (2H, m), 4.82 (1H, s), 5.24 (1H, t, $J=3.8\text{Hz}$), 6.74-6.86 (2H, m), 6.94-7.06 (2H, m), 7.70 (1H, dd, $J=8.8, 2.2\text{Hz}$), 7.95 (1H, d, $J=8.7\text{Hz}$), 8.00 (1H, d, $J=2.1\text{Hz}$), 12.52 (1H, br. s.).

mp: 192-194°C.

Reference Example 114

N-(3-chloro-4-cyanophenyl)valine



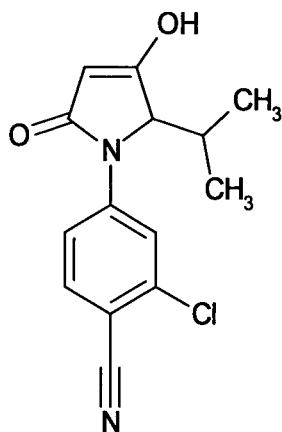
To a solution of 2-chloro-4-fluorobenzonitrile (3.50 g) in dimethyl sulfoxide (60 mL) were added L-valine (3.16 g) and cesium carbonate (9.53 g), and the mixture was stirred at 90°C overnight. After allowing to room temperature, ethyl acetate was added, and the mixture was extracted twice with saturated

aqueous sodium hydrogen carbonate solution. The aqueous layers were combined, and acidified with citric acid, and the mixture was extracted twice with ethyl acetate. The organic layers were combined, washed with saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure to give the title compound as a brown oil (yield: 5.69 g, 100%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.07 (6H, t, $J=6.7\text{Hz}$), 2.16–2.31 (1H, m), 3.91–3.99 (1H, m), 4.71 (1H, d, $J=8.9\text{Hz}$), 6.51 (1H, dd, $J=8.7, 2.3\text{Hz}$), 6.67 (1H, d, $J=2.5\text{Hz}$), 7.42 (1H, d, $J=8.7\text{Hz}$).

Reference Example 115

2-chloro-4-[3-hydroxy-2-(1-methylethyl)-5-oxo-2,5-dihydro-1H-pyrrol-1-yl]benzonitrile



To a solution of N-(3-chloro-4-cyanophenyl)valine (5.66 g), Meldrum's acid (3.39 g) and 4-(N,N-dimethylamino)pyridine (4.11 g) in tetrahydrofuran (70 mL) was added N,N'-carbonyldiimidazole (4.36 g) at 0°C, and the mixture was stirred at room temperature overnight. A 5% aqueous potassium hydrogen sulfate solution was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The organic layer was washed with 5% aqueous potassium hydrogen sulfate solution and saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure. The residue was dissolved in ethyl acetate (70 mL), and the mixture was refluxed for 45 min. After allowing to room temperature, the organic layer was washed with water and saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure, and the

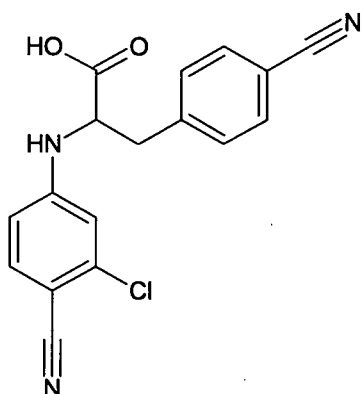
obtained residue was washed with ethyl acetate-isopropyl ether to give the title compound as colorless crystals (yield: 653 mg, 11%).

¹H-NMR (DMSO-d₆) δ: 0.65 (3H, d, J=6.8Hz), 1.12 (3H, d, J=7.0Hz), 2.01-2.16 (1H, m), 4.90 (1H, d, J=2.6Hz), 5.03 (1H, s), 7.61 (1H, dd, J=8.7, 1.9Hz), 7.92 (1H, d, J=8.5Hz), 8.02 (1H, d, J=2.1Hz), 12.33 (1H, br. s.).

mp: 217-219°C.

Reference Example 116

10 N-(3-chloro-4-cyanophenyl)-4-cyanophenylalanine

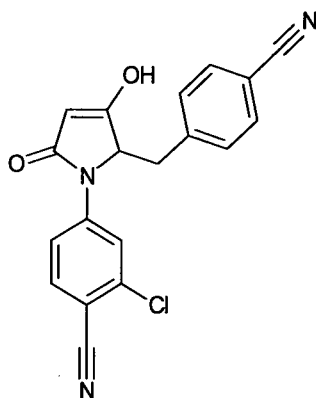


To a solution of 2-chloro-4-fluorobenzonitrile (0.90 g) in dimethyl sulfoxide (20 mL) were added 4-cyanophenylalanine (1.00 g) and cesium carbonate (2.23 g), and the mixture was stirred at 90°C overnight. After warming to room temperature, ethyl acetate was added, and the mixture was extracted twice with saturated aqueous sodium hydrogen carbonate solution. The aqueous layers were combined, and acidified with citric acid, and the mixture was extracted twice with ethyl acetate. The organic layers were combined, washed with saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure to give the title compound as a brown oil (yield: 1.57 g, 92%).

¹H-NMR (CDCl₃) δ: 3.17-3.38 (2H, m), 4.41-4.51 (1H, m), 4.78 (1H, d, J=7.7Hz), 6.49 (1H, dd, J=8.6, 2.4Hz), 6.63 (1H, d, J=2.5Hz), 7.24-7.30 (2H, m), 7.44 (1H, d, J=8.5Hz), 7.56-7.64 (2H, m).

Reference Example 117

2-chloro-4-[2-(4-cyanobenzyl)-3-hydroxy-5-oxo-2,5-dihydro-1H-pyrrol-1-yl]benzonitrile



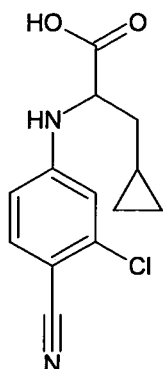
To a solution of N-(3-chloro-4-cyanophenyl)-4-cyanophenylalanine (1.57 g), Meldrum's acid (0.76 g) and 4-(N,N-dimethylamino)pyridine (0.88 g) in tetrahydrofuran (70 mL) was
5 added N,N'-carbonyldiimidazole (0.94 g) at 0°C, and the mixture was stirred at room temperature overnight. A 5% aqueous potassium hydrogen sulfate solution was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The organic layer was washed with 5% aqueous potassium hydrogen
10 sulfate solution and saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure. The residue was dissolved in ethyl acetate (30 mL), and the mixture was refluxed for 45 min. After allowing to room temperature, the organic layer was washed with water and
15 saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure, and the obtained residue was washed with ethyl acetate-isopropyl ether to give the title compound as pale-yellow crystals (yield: 578 mg, 34%).

$^1\text{H-NMR}$ (DMSO- d_6) δ : 3.08-3.30 (2H, m), 4.84 (1H, s), 5.33 (1H, t, $J=4.0\text{Hz}$),
20 6.98 (2H, d, $J=8.1\text{Hz}$), 7.63-7.73 (3H, m), 7.94-8.00 (2H, m), 12.60 (1H, br. s.).

mp: 190-192°C.

Reference Example 118

N-(3-chloro-4-cyanophenyl)-3-cyclopropylalanine

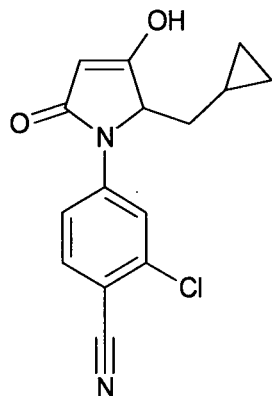


To a solution of 2-chloro-4-fluorobenzonitrile (1.33 g) in dimethyl sulfoxide (20 mL) were added 3-cyclopropyl-L-alanine (1.00 g) and cesium carbonate (3.28 g), and the mixture was
 5 stirred at 90°C overnight. After allowing to room temperature, ethyl acetate was added, and the mixture was extracted twice with saturated aqueous sodium hydrogen carbonate solution. The aqueous layers were combined, and acidified with citric acid, and the mixture was extracted twice with ethyl acetate. The
 10 organic layers were combined, washed with saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure to give the title compound as a brown oil (yield: 2.05 g, 100%).

¹H-NMR(CDCl₃)δ: 0.10-0.21 (2H, m), 0.47-0.58 (2H, m), 0.72-0.87 (1H, m),
 15 1.71-1.92 (2H, m), 4.14-4.24 (1H, m), 4.95 (1H, d, J=7.9 Hz), 6.51 (1H, dd, J=8.7, 2.5 Hz), 6.66 (1H, d, J=2.3 Hz), 7.41 (1H, d, J=8.5 Hz).

Reference Example 119

2-chloro-4-[2-(cyclopropylmethyl)-3-hydroxy-5-oxo-2,5-dihydro-1H-pyrrol-1-yl]benzonitrile



20

To a solution of N-(3-chloro-4-cyanophenyl)-3-cyclopropylalanine (2.05 g), Meldrum's acid (1.35 g) and 4-(N,N-

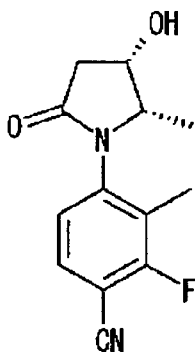
dimethylamino)pyridine (1.56 g) in tetrahydrofuran (40 mL) was added N,N'-carbonyldiimidazole (1.66 g) at 0°C, and the mixture was stirred at room temperature overnight. A 5% aqueous potassium hydrogen sulfate solution was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The organic layer was washed with 5% aqueous potassium hydrogen sulfate solution and saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure. The residue was dissolved in ethyl acetate (40 mL), and the mixture was refluxed for 45 min. After allowing to room temperature, the organic layer was washed with water and saturated brine, and dried over magnesium sulfate. The solvent was evaporated under reduced pressure, and the obtained residue was washed with ethyl acetate-isopropyl ether to give the title compound as pale-yellow crystals (yield: 844 mg, 34%).

¹H-NMR(DMSO-d₆)δ:-0.40 to -0.29(1H,m), -0.10 to 0.02(1H,m), 0.15-0.45(3H,m), 1.64-1.81(2H,m), 5.04(1H,t,J=3.8Hz), 5.08(1H,s), 7.67(1H,dd,J=8.7,2.1Hz), 7.91(1H,d,J=8.7Hz), 8.04(1H,d,J=2.1Hz), 12.39(1H,s).

mp:152-154°C.

Example 1

2-fluoro-4-[(2S,3S)-3-hydroxy-2-methyl-5-oxopyrrolidin-1-yl]-3-methylbenzonitrile



To a solution of 4-[(2S,3S)-3-(tert-butyl dimethylsilyloxy)-2-methyl-5-oxopyrrolidin-1-yl]-2-fluoro-3-methylbenzonitrile (330 mg) in THF (10 mL) was added tetrabutylammonium fluoride-THF solution (1.18 mL, 1 mol/L), and the mixture was stirred at room temperature for 5 hr. The

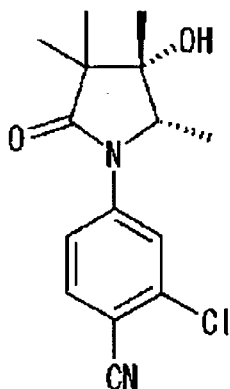
reaction mixture was added to water, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified
5 by silica gel column chromatography, and recrystallized from hexane-ethyl acetate to give the title compound as a colorless solid (yield: 139 mg, 62%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.13 (3H, d, $J=6.4\text{Hz}$), 1.80 (1H, d, $J=4.2\text{Hz}$),
2.20 (3H, d, $J=2.7\text{Hz}$), 2.60 (1H, dd, $J=17.4, 2.3\text{Hz}$),
10 2.87 (1H, dd, $J=17.4, 5.7\text{Hz}$), 4.15-4.26 (1H, m), 4.54-4.61 (1H, m),
6.98 (1H, d, $J=7.6\text{Hz}$), 7.45-7.55 (1H, m).

mp: 114-115°C.

Example 2

rac-2-chloro-4-[(2R,3R)-3-hydroxy-2,3,4,4-tetramethyl-5-oxopyrrolidin-1-yl]benzonitrile
15



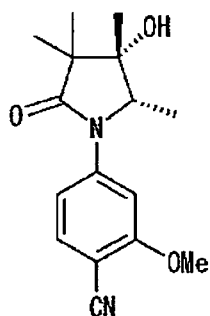
A solution of 2-chloro-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (90 mg) in THF (5 mL) was cooled to -78°C, methylmagnesium bromide-ether solution (0.22 mL, 3 mol/L) was added under a nitrogen atmosphere, and the reaction mixture was warmed to room temperature. The reaction mixture was again cooled to -78°C, a 3mol/L methylmagnesium bromide-ether solution (0.89 mL) was added, and the reaction mixture was warmed to room temperature. The reaction mixture was added to
25 saturated aqueous ammonium chloride solution, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography, and recrystallized from

hexane-ethyl acetate to give the title compound as a colorless solid (yield: 29 mg, 30%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.12 (3H, s), 1.25 (3H, d, $J=6.4\text{Hz}$), 1.25 (3H, s), 1.32 (3H, s), 1.41 (1H, s), 4.11 (1H, q, $J=6.4\text{Hz}$),
 5 7.36 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.56 (1H, d, $J=2.1\text{Hz}$), 7.67 (1H, d, $J=8.5\text{Hz}$).
 mp: 161–163°C.

Example 3

rac-4-[(2R,3R)-3-hydroxy-2,3,4,4-tetramethyl-5-oxopyrrolidin-1-yl]-2-methoxybenzonitrile



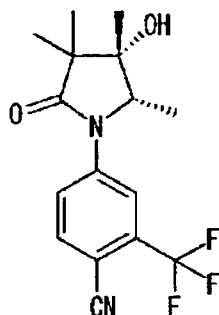
10

Using 2-methoxy-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (100 mg) and methylmagnesium bromide-THF solution (3.67 mL, 1.0 mol/L), and in the same manner as in Example 2, the title compound was obtained as a colorless solid
 15 (yield: 96 mg, 90%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.13 (3H, s), 1.23–1.27 (6H, m), 1.32 (3H, s), 1.45 (1H, s), 3.94 (3H, s), 4.08–4.16 (1H, m), 6.75 (1H, dd, $J=8.3, 1.9\text{Hz}$), 7.26 (1H, d, $J=1.9\text{Hz}$), 7.54 (1H, d, $J=8.3\text{Hz}$).
 mp: 134–135°C.

20 Example 4

rac-4-[(2R,3R)-3-hydroxy-2,3,4,4-tetramethyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile



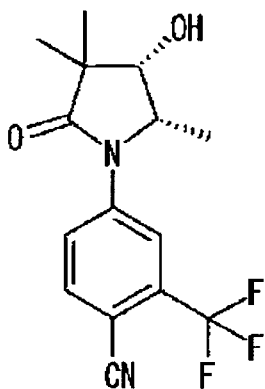
Using 2-(trifluoromethyl)-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (100 mg) and methylmagnesium
 25

bromide-THF solution (3.22 mL, 1.0 mol/L), and in the same manner as in Example 2, the title compound was obtained as a colorless solid (yield: 77 mg, 73%).

¹H-NMR(CDCl₃)δ:1.13(3H,s), 1.26(3H,d,J=6.2Hz), 1.26(3H,s),
5 1.34(3H,s), 1.47(1H,s), 4.18(1H,q,J=6.4Hz),
7.68(1H,dd,J=8.5,2.1Hz), 7.79(1H,d,J=2.1Hz), 7.84(1H,d,J=8.5Hz).
mp:197-199°C.

Example 5

rac-4-[(4R,5R)-4-hydroxy-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-
10 2-(trifluoromethyl)benzonitrile



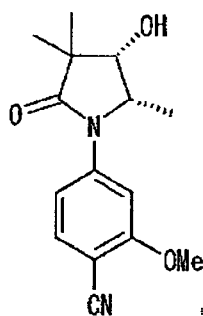
A solution of 2-(trifluoromethyl)-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (50 mg) in THF (5 mL) was cooled to -78°C, lithium tri(sec-butyl)borohydride-THF solution
15 (0.242 mL, 1 mol/L) was added, and the mixture was stirred at -78°C for 30 min. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue
20 was purified by silica gel column chromatography, and the obtained solid was recrystallized from hexane-ethyl acetate to give the title compound as a colorless solid (yield: 32.2 mg, 64%).

¹H-NMR(CDCl₃)δ:1.24(3H,s), 1.31-1.36(6H,m), 1.80(1H,d,J=5.1Hz),
25 4.12(1H,t,J=5.3Hz), 4.42-4.53(1H,m), 7.75(1H,dd,J=8.7,2.3Hz),
7.85(1H,d,J=8.7Hz), 7.93(1H,d,J=2.3Hz).

mp:120.5-121.5°C.

Example 6

rac-4-[(4R,5R)-4-hydroxy-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-
2-methoxybenzonitrile

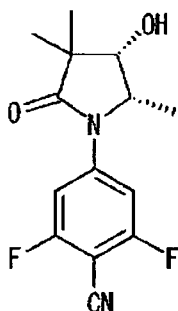


Using 2-methoxy-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (100 mg) and lithium tri(sec-butyl)borohydride-THF solution (0.551 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as a colorless solid (yield: 75 mg, 74%).

¹H-NMR(CDCl₃) δ: 1.23(3H, s), 1.30-1.34(6H, m), 1.78(1H, d, J=5.3Hz),
3.94(3H, s), 4.10(1H, t, J=5.4Hz), 4.37-4.47(1H, m),
6.80(1H, dd, J=8.5, 1.9Hz), 7.46(1H, d, J=1.9Hz), 7.55(1H, d, J=8.5Hz).
mp: 130-132°C.

Example 7

rac-2,6-difluoro-4-[(4R,5R)-4-hydroxy-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]benzonitrile

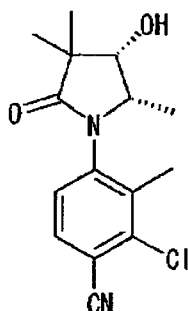


Using 2,6-difluoro-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (100 mg) and lithium tri(sec-butyl)borohydride-THF solution (0.539 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as a colorless solid (yield: 67 mg, 67%).

¹H-NMR(CDCl₃) δ: 1.23(3H, s), 1.30(3H, s), 1.36(3H, d, J=6.6Hz),
1.83(1H, d, J=5.1Hz), 4.13(1H, t, J=5.6Hz), 4.31-4.41(1H, m), 7.25-7.32(2H, m).
mp: 139.5-140.5°C.

Example 8

rac-2-chloro-4-[(4R,5R)-4-hydroxy-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-3-methylbenzonitrile



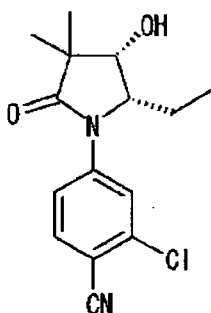
5 Using 2-chloro-3-methyl-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (23 mg) and lithium tri(sec-butyl)borohydride-THF solution (0.119 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as a colorless solid (yield: 15 mg, 66%).

10 $^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.10 (3H, d, $J=6.6\text{Hz}$), 1.27 (3H, brs), 1.31 (3H, s), 1.75 (1H, d, $J=4.3\text{Hz}$), 2.29 (3H, s), 4.05 (1H, t, $J=4.3\text{Hz}$), 4.29 (1H, brs), 7.05 (1H, brs), 7.56 (1H, d, $J=8.1\text{Hz}$).

mp: 219–221°C.

Example 9

15 rac-2-chloro-4-[(4R,5R)-5-ethyl-4-hydroxy-3,3-dimethyl-2-oxopyrrolidin-1-yl]benzonitrile



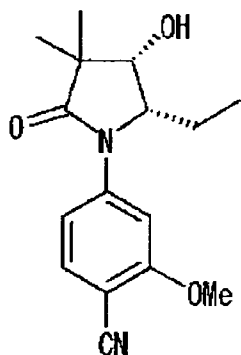
Using 2-chloro-4-(5-ethyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (60 mg) and lithium tri(sec-butyl)borohydride-THF solution (0.307 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as a colorless solid (yield: 50 mg, 84%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.03 (3H, t, $J=7.5\text{Hz}$), 1.20 (3H, s), 1.32 (3H, s), 1.60–1.84 (3H, m), 4.04–4.15 (2H, m), 7.34 (1H, dd, $J=8.5, 2.1\text{Hz}$),
25 7.56 (1H, d, $J=2.1\text{Hz}$), 7.67 (1H, d, $J=8.5\text{Hz}$).

mp:166-168°C.

Example 10

rac-4-[(4R,5R)-5-ethyl-4-hydroxy-3,3-dimethyl-2-oxopyrrolidin-1-yl]-2-methoxybenzonitrile



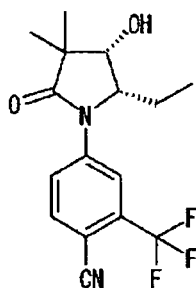
5

Using 4-(5-ethyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)-2-methoxybenzonitrile (120 mg) and lithium tri(sec-butyl)borohydride-THF solution (0.629 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as a colorless solid (yield: 93 mg, 77%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.01 (3H, t, $J=7.5\text{Hz}$), 1.21 (3H, s), 1.32 (3H, s), 1.48-1.88 (3H, m), 3.94 (3H, s), 4.11 (2H, dd, $J=4.0, 1.9\text{Hz}$), 6.74 (1H, dd, $J=8.3, 1.9\text{Hz}$), 7.26 (1H, d, $J=1.9\text{Hz}$), 7.55 (1H, d, $J=8.3\text{Hz}$).
mp:143.4-145°C.

15 Example 11

rac-4-[(4R,5R)-5-ethyl-4-hydroxy-3,3-dimethyl-2-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile



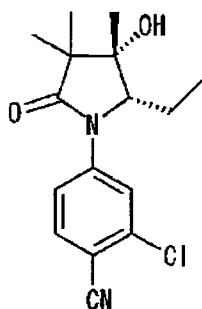
Using 4-(5-ethyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)-2-(trifluoromethyl)benzonitrile (120 mg) and lithium tri(sec-butyl)borohydride-THF solution (0.555 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as a colorless solid (yield: 76 mg, 63%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.04 (3H, t, $J=7.5\text{Hz}$), 1.22 (3H, s), 1.33 (3H, s), 1.64–1.83 (3H, m), 4.11–4.22 (2H, m), 7.65 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.81 (1H, d, $J=2.1\text{Hz}$), 7.84 (1H, d, $J=8.5\text{Hz}$).

mp: 141.5–143°C.

5 Example 12

rac-2-chloro-4-[(2R, 3R)-2-ethyl-3-hydroxy-3,4,4-trimethyl-5-oxopyrrolidin-1-yl]benzonitrile



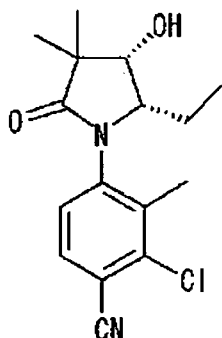
Using 2-chloro-4-(5-ethyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (48 mg) and methylmagnesium bromide-THF solution (1.65 mL, 1.0 mol/L), and in the same manner as in Example 2, the title compound was obtained as a colorless solid (yield: 27 mg, 53%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.01 (3H, t, $J=7.6\text{Hz}$), 1.11 (3H, s), 1.23 (3H, s), 1.39 (3H, s), 1.50 (1H, s), 1.63–1.77 (1H, m), 1.78–1.93 (1H, m), 3.89 (1H, dd, $J=8.7, 3.0\text{Hz}$), 7.34 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.55 (1H, d, $J=2.1\text{Hz}$), 7.67 (1H, d, $J=8.5\text{Hz}$).

mp: 197.1–198.5°C.

Example 13

20 rac-2-chloro-4-[(4R, 5R)-5-ethyl-4-hydroxy-3,3-dimethyl-2-oxopyrrolidin-1-yl]-3-methylbenzonitrile



Using 2-chloro-4-(5-ethyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)-3-methylbenzonitrile (310 mg) and lithium

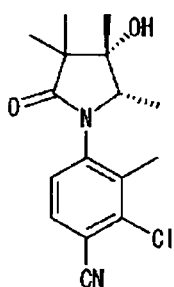
tri(sec-butyl)borohydride-THF solution (1.53 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as a colorless solid (yield: 211 mg, 68%).

¹H-NMR(CDCl₃)δ:0.92(3H,t,J=7.5Hz), 1.13-1.51(8H,m),
5 1.72(1H,d,J=4.2Hz), 2.23-2.35(3H,m), 3.88-4.13(2H,m), 6.99-
7.19(1H,m), 7.55(1H,d,J=8.1Hz).

mp:180.5-181.5°C.

Example 14

rac-2-chloro-4-[(2R,3R)-3-hydroxy-2,3,4,4-tetramethyl-5-
10 oxopyrrolidin-1-yl]-3-methylbenzonitrile



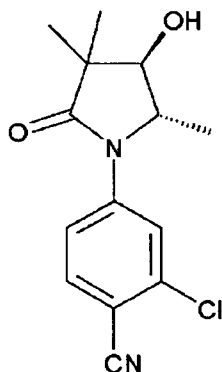
Using 2-chloro-3-methyl-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (40 mg) and methylmagnesium bromide-THF solution (1.38 mL, 1.0 mol/L), and in the same
15 manner as in Example 2, the title compound was obtained as a colorless solid (yield: 24 mg, 57%).

¹H-NMR(CDCl₃)δ:0.95-1.12(3H,m), 1.15-1.25(6H,m), 1.30(3H,s),
1.40-1.47(1H,m), 2.24-2.34(3H,m), 3.93-4.11(1H,m), 6.98-
7.23(1H,m), 7.51-7.59(1H,m).

20 mp:174.5-175.5°C.

Example 15

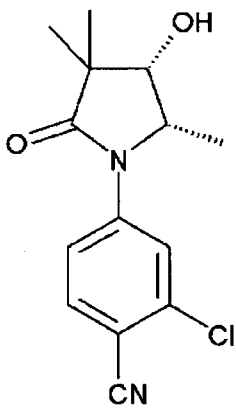
rac-2-chloro-4-[(4R,5S)-4-hydroxy-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]benzonitrile



To a solution of rac-2-chloro-4-[(4R,5S)-4-(tert-butyl-
dimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-
yl]benzonitrile (121 mg) in THF (5.5 mL) was added
tetrabutylammonium fluoride-THF solution (0.5 mL, 1 mol/L), and
5 the mixture was stirred at room temperature for 7 hr. Water was
added to the reaction mixture, and the mixture was extracted
with ethyl acetate. The extract was washed with saturated brine,
dried over anhydrous magnesium sulfate, and concentrated under
reduced pressure. The residue was purified by silica gel column
10 chromatography (eluent: hexane/ethyl acetate=10/1→1/2) to give
the title compound as a colorless solid (yield: 47.2 mg, 55%).
 $^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.17 (3H, s), 1.31 (3H, s), 1.37 (3H, d, $J=6.2\text{Hz}$),
1.91 (1H, d, $J=5.7\text{Hz}$), 3.79 (1H, t, $J=5.9\text{Hz}$), 3.90-4.03 (1H, m),
7.40 (1H, dd, $J=8.4, 2.2\text{Hz}$), 7.61-7.73 (2H, m).
15 mp: 163-164°C.

Example 16

rac-2-chloro-4-[(4R,5R)-4-hydroxy-3,3,5-trimethyl-2-
oxopyrrolidin-1-yl]benzonitrile

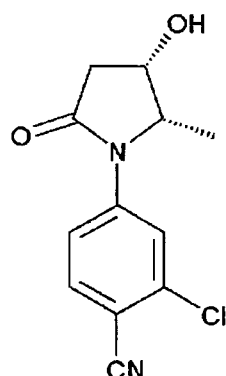


20 Using rac-2-chloro-4-[(4R,5R)-4-(tert-butyl-
dimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-
yl]benzonitrile (400 mg) and tetrabutylammonium fluoride-THF
solution (3 mL, 1 mol/L), and in the same manner as in Example
15, the title compound was obtained as a colorless solid (yield:
25 204 mg, 72%).
 $^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.23 (3H, s), 1.31 (3H, s), 1.32 (3H, d, $J=6.6\text{Hz}$),
1.81 (1H, brs), 4.06-4.16 (1H, m), 4.33-4.48 (1H, m), 7.39-7.50 (1H, m),
7.61-7.73 (2H, m).

mp:143-144°C.

Example 17

2-chloro-4-[(4S,5S)-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile



5

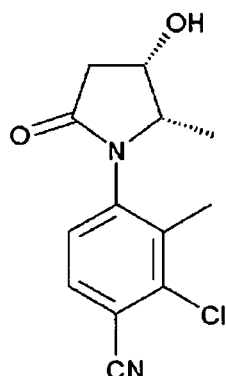
Using 2-chloro-4-[(4S,5S)-4-(tert-butyldimethylsilyloxy)-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile (1.2 g) and tetrabutylammonium fluoride-THF solution (4 mL, 1 mol/L), and in the same manner as in Example 15, the title compound was
10 obtained as a colorless solid (yield: 690 mg, 62%).

¹H-NMR (CDCl₃) δ: 1.32 (3H, d, J=6.3Hz), 2.00 (1H, d, J=4.5Hz), 2.68 (1H, dd, J=17.4, 5.4Hz), 2.85 (1H, dd, J=17.4, 6.6Hz), 4.30-4.42 (1H, m), 4.56-4.65 (1H, m), 7.48 (1H, dd, J=8.7, 1.8Hz), 7.66 (1H, d, J=8.7Hz), 7.73 (1H, d, J=1.8Hz).

15 mp:161-162°C.

Example 18

2-chloro-4-[(4S,5S)-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]-3-methylbenzonitrile



20

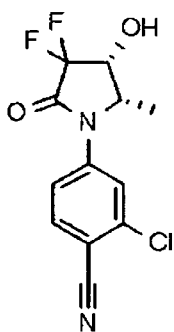
Using 2-chloro-4-[(4S,5S)-4-(tert-butyldimethylsilyloxy)-5-methyl-2-oxopyrrolidin-1-yl]-3-methylbenzonitrile (500 mg) and tetrabutylammonium fluoride-THF solution (1.4 mL, 1 mol/L), and

in the same manner as in Example 15, the title compound was obtained as a colorless solid (yield: 210 mg, 44%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.12 (3H, d, $J=6.6\text{Hz}$), 1.90 (1H, d, $J=4.2\text{Hz}$), 2.32 (3H, s), 2.59 (1H, dd, $J=17.4, 2.1\text{Hz}$), 2.87 (1H, dd, $J=17.4, 5.7\text{Hz}$), 4.10-4.30 (1H, br), 4.50-4.60 (1H, m), 7.00-7.20 (1H, m), 7.56 (1H, d, $J=8.1\text{Hz}$).
mp: 172-173°C.

Example 19

2-chloro-4-[(4R,5S)-3,3-difluoro-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile



10

Using 4-bromo-2-chlorobenzonitrile (556 mg), (4R,5S)-3,3-difluoro-4-hydroxy-5-methylpyrrolidin-2-one (448 mg), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (219 mg), tris(dibenzylideneacetone)dipalladium(0) (113 mg) and cesium carbonate (1.18 g), and in the same manner as in Reference Example 3, the title compound was obtained as a white powder (yield: 34.2 mg, 5%).

$^1\text{H-NMR}$ ($\text{DMSO}-d_6$) δ : 1.38 (3H, d, $J=5.3\text{Hz}$), 2.79 (1H, brs), 4.36-4.72 (2H, m), 7.60 (1H, dd, $J=8.7, 1.7\text{Hz}$), 7.74 (1H, d, $J=8.7\text{Hz}$), 7.85 (1H, d, $J=1.7\text{Hz}$).

20

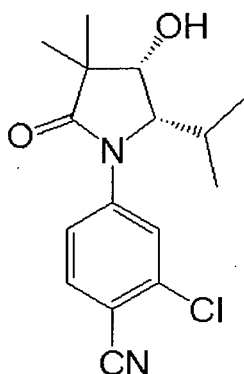
IR (KBr): 3427, 2233, 1730, 1598 cm^{-1} .

mp: 126-127°C.

Example 20

rac-2-chloro-4-[(4R,5R)-4-hydroxy-5-isopropyl-3,3-dimethyl-2-oxopyrrolidin-1-yl]benzonitrile

25



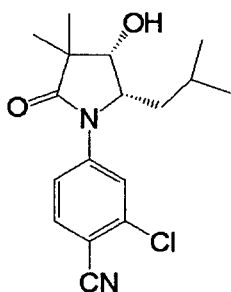
Using 2-chloro-4-(5-isopropyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (300 mg) and lithium tri(sec-butyl)borohydride-THF solution (1.48 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as a colorless solid (yield: 209 mg, 69%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.90 (3H, d, $J=7.0\text{Hz}$), 1.06 (3H, d, $J=7.0\text{Hz}$), 1.19 (3H, s), 1.29 (3H, s), 1.63 (1H, d, $J=5.3\text{Hz}$), 2.24-2.46 (1H, m), 4.07-4.26 (2H, m), 7.36 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.55 (1H, d, $J=2.1\text{Hz}$), 7.67 (1H, d, $J=8.5\text{Hz}$).

mp: 119-121°C.

Example 21

rac-2-chloro-4-[(4R,5R)-4-hydroxy-5-isobutyl-3,3-dimethyl-2-oxopyrrolidin-1-yl]benzonitrile



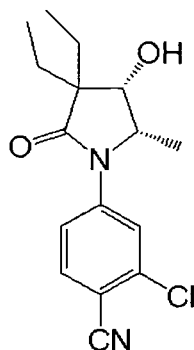
Using 2-chloro-4-(5-isobutyl-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (620 mg) and lithium tri(sec-butyl)borohydride-THF solution (2.92 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as a colorless solid (yield: 363 mg, 58%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.95 (3H, d, $J=6.6\text{Hz}$), 1.03 (3H, d, $J=6.4\text{Hz}$), 1.20 (3H, s), 1.31 (3H, s), 1.35-1.47 (1H, m), 1.64-1.90 (3H, m), 4.09 (1H, t, $J=4.8\text{Hz}$), 4.21-4.33 (1H, m), 7.31 (1H, d, $J=8.5\text{Hz}$), 7.55 (1H, s), 7.67 (1H, d, $J=8.5\text{Hz}$).

mp: 224-226°C.

Example 22

rac-2-chloro-4-[(4R,5R)-3,3-diethyl-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile

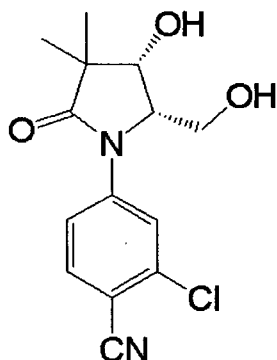


5 Using 2-chloro-4-(3,3-diethyl-5-methyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (67 mg) and lithium tri(sec-butyl)borohydride-THF solution (0.33 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as colorless crystals (yield: 34.5 mg, 51%).

10 ¹H-NMR(CDCl₃)δ:0.92(3H,t,J=7.6Hz), 1.02(3H,t,J=7.6Hz), 1.30(3H,d,J=6.4Hz), 1.57-1.95(5H,m), 4.16(1H,t,J=5.3Hz), 4.34-4.45(1H,m), 7.41(1H,dd,J=8.6,2.0Hz), 7.63-7.69(2H,m).
mp:166-168°C.

Example 23

15 rac-2-chloro-4-[(4R,5R)-4-hydroxy-5-(hydroxymethyl)-3,3-dimethyl-2-oxopyrrolidin-1-yl]benzonitrile

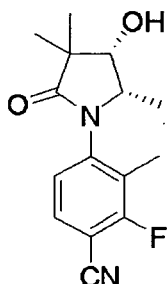


Using 2-chloro-4-[5-(hydroxymethyl)-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl]benzonitrile (80 mg) and lithium tri(sec-butyl)borohydride-THF solution (0.82 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as colorless crystals (yield: 45.4 mg, 56%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.24 (3H, s), 1.32 (3H, s), 2.40 (1H, t, $J=5.9\text{Hz}$), 2.66 (1H, d, $J=4.7\text{Hz}$), 3.90–4.07 (2H, m), 4.33–4.45 (2H, m), 7.48 (1H, dd, $J=8.5, 2.0\text{Hz}$), 7.68 (1H, d, $J=8.5\text{Hz}$), 7.72 (1H, d, $J=2.0\text{Hz}$).
mp: 142–143°C.

5 Example 24

rac-2-fluoro-4-[(4R, 5R)-4-hydroxy-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-3-methylbenzonitrile

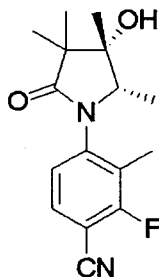


Using 2-fluoro-3-methyl-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (60 mg) and lithium tri(sec-butyl)borohydride-THF solution (0.33 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as colorless crystals (yield: 41.4 mg, 69%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.11 (3H, d, $J=6.6\text{Hz}$), 1.27 (3H, s), 1.31 (3H, s), 1.78 (1H, d, $J=4.3\text{Hz}$), 2.16 (3H, d, $J=2.5\text{Hz}$), 4.05 (1H, t, $J=4.4\text{Hz}$), 4.23–4.34 (1H, m), 6.97 (1H, d, $J=8.5\text{Hz}$), 7.45–7.52 (1H, m).
mp: 177–178°C.

Example 25

rac-2-fluoro-4-[(2R, 3R)-3-hydroxy-2,3,4,4-tetramethyl-5-oxopyrrolidin-1-yl]-3-methylbenzonitrile



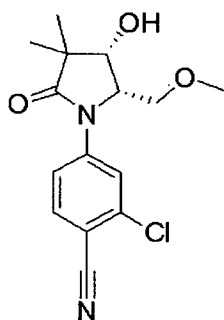
Using 2-fluoro-3-methyl-4-(3,3,5-trimethyl-2,4-dioxopyrrolidin-1-yl)benzonitrile (60 mg) and methylmagnesium bromide-THF solution (2.19 mL, 1.0 mol/L), and in the same manner as in Example 2, the title compound was obtained as colorless crystals (yield: 40 mg, 63%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.02 (3H, d, $J=6.4\text{Hz}$), 1.18 (3H, brs), 1.22 (3H, s), 1.30 (3H, s), 1.43 (1H, brs), 2.18 (3H, brs), 4.04 (1H, brs), 6.83-7.15 (1H, m), 7.47 (1H, t, $J=7.6\text{Hz}$).

mp: 174.5-175.5°C.

5 Example 26

rac-2-chloro-4-[(4R,5R)-4-hydroxy-5-(methoxymethyl)-3,3-dimethyl-2-oxopyrrolidin-1-yl]benzonitrile

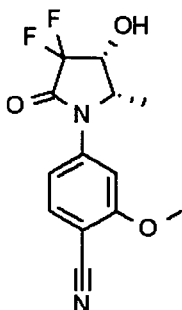


Using 2-chloro-4-[5-(methoxymethyl)-3,3-dimethyl-2,4-dioxopyrrolidin-1-yl]benzonitrile (170 mg) and lithium tri(sec-butyl)borohydride-THF solution (0.83 mL, 1 mol/L), and in the same manner as in Example 5, the title compound was obtained as colorless crystals (yield: 142 mg, 83%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.23 (3H, s), 1.29 (3H, s), 2.84 (1H, d, $J=6.2\text{Hz}$), 3.31 (3H, s), 3.62-3.75 (2H, m), 4.27 (1H, t, $J=6.1\text{Hz}$), 4.39-4.48 (1H, m), 7.47 (1H, dd, $J=8.5, 2.0\text{Hz}$), 7.67 (1H, d, $J=8.5\text{Hz}$), 7.73 (1H, d, $J=2.0\text{Hz}$).
mp: 130.5-131.5°C.

Example 27

2-methoxy-4-[(4R,5S)-3,3-difluoro-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile



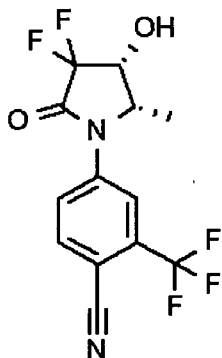
Using 4-bromo-2-methoxybenzonitrile (2.34 g), (4R,5S)-3,3-difluoro-4-hydroxy-5-methylpyrrolidin-2-one (2.00 g), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (976 mg),
tris(dibenzylideneacetone)dipalladium(0) (504 mg) and cesium

carbonate (5.30 g), and in the same manner as in Reference Example 18, the title compound was obtained as a colorless solid (yield: 201 mg, 7%).

¹H-NMR (DMSO-d₆) δ: 1.16 (3H, d, J=6.4Hz), 3.94 (3H, s), 4.50-4.81 (2H, m),
 5 7.36 (1H, dd, J=8.5, 1.9Hz), 7.57 (1H, dd, J=1.9Hz), 7.82 (1H, d, J=8.5Hz).

Example 28

2-trifluoromethyl-4-[(4R,5S)-3,3-difluoro-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile



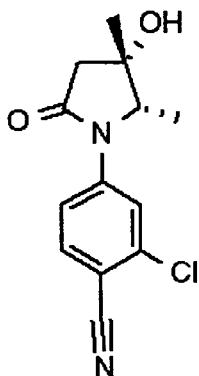
10 Using 2-trifluoromethyl-4-iodobenzonitrile (1.64 g),
 (4R,5S)-3,3-difluoro-4-hydroxy-5-methylpyrrolidin-2-one (1.00 g),
 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (488 mg),
 tris(dibenzylideneacetone)dipalladium(0) (303 mg) and cesium
 carbonate (2.54 g), and in the same manner as in Reference
 15 Example 18, the title compound was obtained as a colorless solid
 (yield: 84.7 mg, 5%).

¹H-NMR (CDCl₃) δ: 1.35-1.46 (3H, m), 2.77 (1H, brs), 4.47-4.73 (2H, m),
 7.93 (2H, s), 8.05 (1H, s).

mp: 128-131°C.

20 Example 29

2-chloro-4-[(2S,3S)-3-hydroxy-2,3-dimethyl-5-oxopyrrolidin-1-yl]benzonitrile



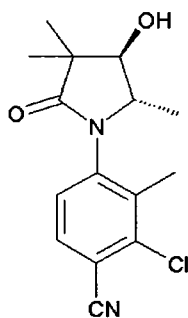
Using 4-bromo-2-chlorobenzonitrile (615 mg), (4S,5S)-4-hydroxy-4,5-dimethylpyrrolidin-2-one (423 mg), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (241 mg), tris(dibenzylideneacetone)dipalladium(0) (125 mg) and cesium carbonate (1.31 g), and in the same manner as in Reference Example 18, the title compound was obtained as a colorless solid (yield: 431 mg, 60%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.28 (3H, d, $J=6.4\text{Hz}$), 1.52 (3H, s), 2.01 (1H, s), 2.63 (1H, d, $J=17.0\text{Hz}$), 2.79 (1H, d, $J=17.0\text{Hz}$), 4.07 (1H, q, $J=6.4\text{Hz}$), 7.46 (1H, d, $J=8.7\text{Hz}$), 7.67 (1H, d, $J=8.7\text{Hz}$), 7.70 (1H, s).

mp: 93–99°C.

Example 30

rac-2-chloro-4-[(4R,5S)-4-hydroxy-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-3-methylbenzonitrile



15

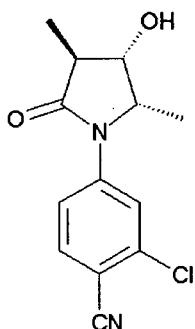
To a solution of rac-4-[(4R,5S)-4-(tert-butyltrimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-2-chloro-3-methylbenzonitrile (103 mg) in THF (5 mL) was added tetrabutylammonium fluoride-THF solution (1.00 mL, 1 mol/L), and the mixture was stirred at room temperature for 17 hr. The reaction mixture was added to water, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=50/1→1/3), and recrystallized from hexane-ethyl acetate to give the title compound as a colorless solid (yield: 41.4 mg, 28.4%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.11–1.25 (3H, m), 1.14 (3H, d, $J=6.0\text{Hz}$), 1.31 (3H, s), 1.93 (1H, d, $J=5.9\text{Hz}$), 2.27 (3H, s), 3.73–3.91 (2H, m), 7.03–7.18 (1H, m), 7.57 (1H, d, $J=8.3\text{Hz}$).

mp: 148–149°C.

5 Example 31

2-chloro-4-[(2S,3S,4S)-3-hydroxy-2,4-dimethyl-5-oxopyrrolidin-1-yl]benzonitrile



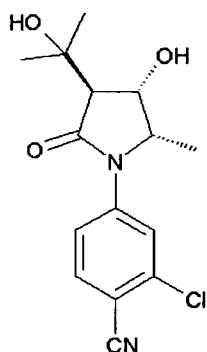
A solution of diisopropylamine (0.150 mL) in THF (7 mL) was cooled to -78°C, and n-butyllithium-hexane solution (0.648 mL, 1.6 mol/L) was added dropwise. After the completion of the dropwise addition, the mixture was stirred at -78°C for 1 hr. Subsequently, a solution of 2-chloro-4-[(2S,3S)-3-hydroxy-2-methyl-5-oxopyrrolidin-1-yl]benzonitrile (100 mg) in THF (2.5 mL) was added dropwise, and the mixture was further stirred at -78°C for 30 min. Methyl iodide (0.124 mL) was added dropwise at -78°C, and the mixture was further stirred at -10°C to -78°C for 30 min. Acetic acid (1.0 mL) was added to the reaction mixture, and the mixture was warmed to room temperature. Water was added, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=10/1→1/3) to give the title compound as a colorless solid (yield: 44.4mg, 42.0%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.30–1.36 (6H, m), 1.92 (1H, brs), 2.63–2.76 (1H, m), 4.11–4.25 (1H, m), 4.29–4.43 (1H, m), 7.61–7.67 (2H, m), 7.95 (1H, t, $J=1.2\text{Hz}$).

mp: 149–151°C.

30 Example 32

2-chloro-4-[(2S,3S,4R)-3-hydroxy-4-(1-hydroxy-1-methylethyl)-2-methyl-5-oxopyrrolidin-1-yl]benzonitrile

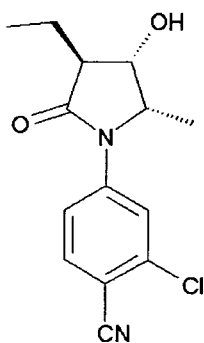


A solution of diisopropylamine (0.150 mL) in THF (7 mL) was cooled to -78°C , and n-butyllithium-hexane solution (0.648 mL, 1.6 mol/L) was added dropwise. After the completion of the dropwise addition, the mixture was stirred at -78°C for 1 hr. Subsequently, a solution of 2-chloro-4-[(2S,3S)-3-hydroxy-2-methyl-5-oxopyrrolidin-1-yl]benzonitrile (100 mg) in THF (1.5 mL) was added dropwise, and the mixture was further stirred at -78°C for 30 min. Acetone (0.124 mL) was added dropwise at -78°C , and the mixture was further stirred at -20°C to -78°C for 40 min. Acetic acid (1.0 mL) was added to the reaction mixture, and the mixture was warmed to room temperature. Water was added, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=10/1 $\rightarrow$ 1/3) to give the title compound as a colorless solid (yield: 30.1 mg, 24.5%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.32 (3H, d, $J=6.4\text{Hz}$), 1.37 (3H, s), 1.49 (3H, s), 2.72 (1H, d, $J=3.4\text{Hz}$), 2.81 (1H, d, $J=9.6\text{Hz}$), 2.91 (1H, brs), 4.33-4.49 (1H, m), 4.48-4.62 (1H, m), 7.56-7.70 (2H, m), 7.98 (1H, d, $J=2.1\text{Hz}$). mp: $131-132^{\circ}\text{C}$.

Example 33

2-chloro-4-[(3S,4S,5S)-3-ethyl-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile



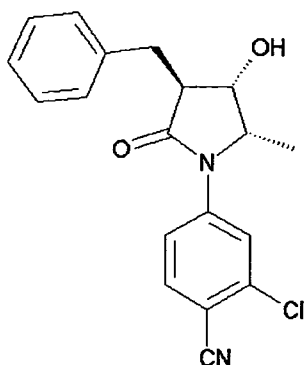
A solution of diisopropylamine (0.150 mL) in THF (8 mL) was cooled to -78°C , and n-butyllithium-hexane solution (0.650 mL, 1.6 mol/L) was added dropwise. After the completion of the dropwise addition, the mixture was stirred at -78°C for 1 hr. Subsequently, a solution of 2-chloro-4-[(2S,3S)-3-hydroxy-2-methyl-5-oxopyrrolidin-1-yl]benzonitrile (100 mg) in THF (2.0 mL) was added dropwise, and the mixture was further stirred at -78°C for 1 hr. Iodoethane (0.150 mL) was added dropwise at -78°C , and the mixture was further stirred at -78°C to -30°C for 1 hr. Acetic acid (1.0 mL) was added to the reaction mixture, and the mixture was warmed to room temperature. Water was added, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=20/1 $\rightarrow$ 1/4) to give the title compound as a colorless solid (yield: 6.7 mg, 6.0%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.10 (3H, t, $J=7.5\text{Hz}$), 1.32 (3H, d, $J=6.0\text{Hz}$), 1.61-1.80 (1H, m), 1.81-1.98 (2H, m), 2.53-2.66 (1H, m), 4.26-4.42 (2H, m), 7.56-7.70 (2H, m), 7.93 (1H, d, $J=1.5\text{Hz}$).

mp: $109-110^{\circ}\text{C}$.

Example 34

4-[(3S,4S,5S)-3-benzyl-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]-2-chlorobenzonitrile



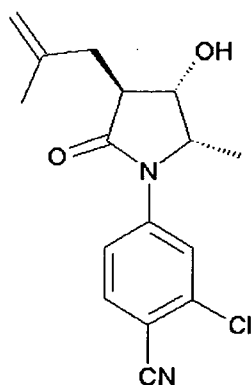
A solution of diisopropylamine (0.150 mL) in THF (8 mL) was cooled to -78°C , and n-butyllithium-hexane solution (0.648 mL, 1.6 mol/L) was added dropwise. After the completion of the dropwise addition, the mixture was stirred at -78°C for 1 hr. Subsequently, a solution of 2-chloro-4-[(2S,3S)-3-hydroxy-2-methyl-5-oxopyrrolidin-1-yl]benzonitrile (100 mg) in THF (2.5 mL) was added dropwise, and the mixture was further stirred at -78°C for 30 min. A solution of benzyl bromide (0.16 mL) in THF (1.5 mL) was added dropwise at -78°C , and the mixture was further stirred at -78°C to -30°C for 1 hr. Acetic acid (1.0 mL) was added to the reaction mixture, and the mixture was warmed to room temperature. Water was added, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=50/1 $\rightarrow$ 1/2) to give the title compound as a colorless solid (yield: 40.8 mg, 30.0%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.25 (3H, d, $J=6.6\text{Hz}$), 1.48 (1H, d, $J=4.2\text{Hz}$), 2.58-3.04 (2H, m), 3.25-3.36 (1H, m), 4.11-4.24 (1H, m), 4.25-4.36 (1H, m), 7.21-7.40 (5H, m), 7.51-7.61 (1H, m), 7.61-7.68 (1H, m), 7.88 (1H, d, $J=2.1\text{Hz}$).

mp: $99-101^{\circ}\text{C}$.

Example 35

2-chloro-4-[(2S,3S,4S)-3-hydroxy-2-methyl-4-(2-methylprop-2-en-1-yl)-5-oxopyrrolidin-1-yl]benzonitrile

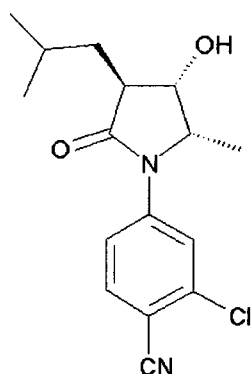


A solution of diisopropylamine (0.300 mL) in THF (15 mL) was cooled to -78°C , and n-butyllithium-hexane solution (1.26 mL, 1.6 mol/L) was added dropwise. After the completion of the dropwise addition, the mixture was stirred at -78°C for 1 hr. Subsequently, a solution of 2-chloro-4-[(2S,3S)-3-hydroxy-2-methyl-5-oxopyrrolidin-1-yl]benzonitrile (200 mg) in THF (4.0 mL) was added dropwise, and the mixture was further stirred at -78°C for 1 hr. 3-Bromo-2-methylpropene (0.10 mL) was added dropwise at -78°C , and the mixture was further stirred at -78°C to -10°C for 1 hr. Acetic acid (1.0 mL) was added to the reaction mixture, and the mixture was warmed to room temperature. Water was added, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=30/1 $\rightarrow$ 1/2) to give the title compound as a colorless solid (yield: 111.8 mg, 46.1%). $^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.32 (3H, d, $J=6.4\text{Hz}$), 1.84 (3H, s), 2.10 (1H, d, $J=3.6\text{Hz}$), 2.22 (1H, dd, $J=14.0, 10.4\text{Hz}$), 2.68–2.80 (1H, m), 2.86 (1H, ddd, $J=10.4, 8.3, 4.2\text{Hz}$), 4.26–4.46 (2H, m), 4.88–4.96 (2H, m), 7.59–7.69 (2H, m), 7.95 (1H, d, $J=0.9\text{Hz}$).

mp: $110-112^{\circ}\text{C}$.

Example 36

2-chloro-4-[(2S,3S,4S)-3-hydroxy-4-isobutyl-2-methyl-5-oxopyrrolidin-1-yl]benzonitrile

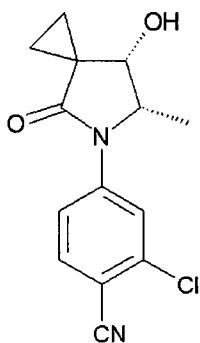


To a solution of 2-chloro-4-[(2S,3S,4S)-3-hydroxy-2-methyl-4-(2-methylprop-2-en-1-yl)-5-oxopyrrolidin-1-yl]benzonitrile (22.3 mg) in methanol (3.0 mL) was added
 5 palladium/fibroin (12.0 mg), and the mixture was stirred for 48 hr under a hydrogen atmosphere. The reaction mixture was filtered, and the filtrate was concentrated under reduced pressure. The obtained residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=50/1→1/1)
 10 to give the title compound as a pale-yellow oil (yield: 4.3 mg, 19.1%).

¹H-NMR(CDCl₃) δ: 0.97-1.02 (6H, m), 1.32 (3H, d, J=6.4 Hz), 1.35-1.53 (1H, m), 1.67-1.83 (1H, m), 1.90-2.16 (2H, m), 2.69 (1H, dt, J=7.8, 6.0 Hz), 4.19-4.43 (2H, m), 7.54-7.72 (2H, m),
 15 7.90 (1H, d, J=1.9 Hz).

Example 37

rac-2-chloro-4-[(6R,7R)-7-hydroxy-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]benzonitrile



20 To a solution of rac-4-[(6R,7R)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-chlorobenzonitrile (140 mg) in THF (5 mL) was added tetrabutylammonium fluoride-THF solution (2.00 mL, 1 mol/L), and

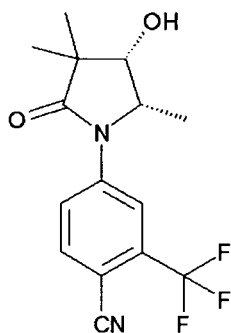
the mixture was stirred at room temperature for 18 hr. The reaction mixture was added to water, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=1/0→3/1) to give the title compound as a colorless solid (yield: 32.3 mg, 32.5%).

¹H-NMR(CDCl₃)δ:0.93-1.08(1H,m), 1.17-1.37(3H,m), 1.37(3H,d,J=6.4Hz), 1.61-1.72(1H,m), 4.34(1H,t,J=6.0Hz), 4.39-4.45(1H,m), 7.51(1H,dd,J=8.6,2.1Hz), 7.66(1H,d,J=8.6Hz), 7.76(1H,d,J=2.1Hz).

mp:134-136°C.

Example 38

4-[(4S,5S)-4-hydroxy-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile



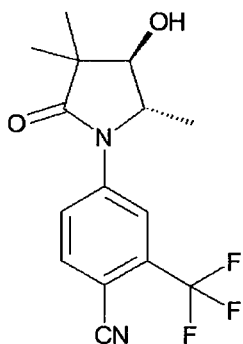
To a solution of 4-((4S,5S)-4-(tert-butylidimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-yl)-2-(trifluoromethyl)benzonitrile (232.2 mg) in THF (6 mL) was added tetrabutylammonium fluoride-THF solution (2.0 mL, 1 mol/L), and the mixture was stirred at room temperature for 1 hr. The reaction mixture was added to water, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=30/1→1/3), and recrystallized from hexane-ethyl acetate to give the title compound as a colorless solid (yield: 38.9 mg, 22.9%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.24 (3H, s), 1.31-1.36 (6H, m), 1.80 (1H, d, $J=5.1\text{Hz}$), 4.12 (1H, t, $J=5.3\text{Hz}$), 4.42-4.53 (1H, m), 7.75 (1H, dd, $J=8.7, 2.3\text{Hz}$), 7.85 (1H, d, $J=8.7\text{Hz}$), 7.93 (1H, d, $J=2.3\text{Hz}$).

mp: 120-121°C.

5 Example 39

4-[(4R,5S)-4-hydroxy-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile

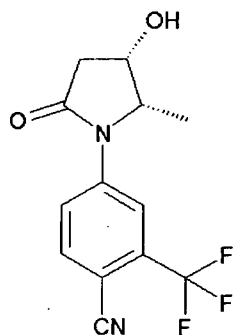


To a mixed solution of 4-[(4R,5S)-4-(tert-butyl-
10 dimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile (391.7 mg) in THF (12 mL) and methanol (12 mL) was added 6 mol/L hydrochloric acid (12.0 mL), and the mixture was stirred at room temperature for 4 hr. The reaction mixture was added to saturated aqueous sodium hydrogen
15 carbonate, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=10/1→1/3) to give
20 the title compound as a colorless oil (yield: 203.6 mg, 66%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.18 (3H, s), 1.33 (3H, s), 1.39 (3H, d, $J=6.2\text{Hz}$), 1.98 (1H, d, $J=5.8\text{Hz}$), 3.82 (1H, t, $J=5.8\text{Hz}$), 3.96-4.09 (1H, m), 7.11 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.85 (1H, d, $J=8.5\text{Hz}$), 7.91 (1H, d, $J=2.1\text{Hz}$).

Example 40

25 4-[(2S,3S)-3-hydroxy-2-methyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile

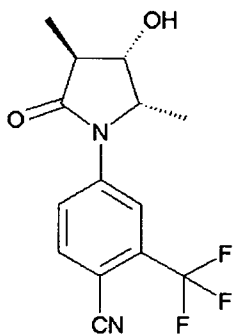


To a solution of 4-[(2S,3S)-3-(tert-butyltrimethylsilyloxy)-2-methyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile (5.61 g) in THF (50 mL) was added
 5 tetrabutylammonium fluoride-THF solution (20.0 mL, 1 mol/L), and the mixture was stirred at room temperature for 24 hr. The reaction mixture was added to water, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and
 10 concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=30/1→1/3) to give the title compound as a colorless oil (yield: 1.42 g, 35%).

¹H-NMR (CDCl₃) δ: 1.34 (3H, d, J=6.6 Hz), 1.84 (1H, d, J=4.7 Hz),
 15 2.71 (1H, dd, J=17.4, 5.4 Hz), 2.88 (1H, dd, J=17.4, 6.8 Hz), 4.37-4.50 (1H, m), 4.57-4.70 (1H, m), 7.77-7.89 (2H, m), 7.92-7.98 (1H, m).

Example 41

4-[(2S,3S,4S)-3-hydroxy-2,4-dimethyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile

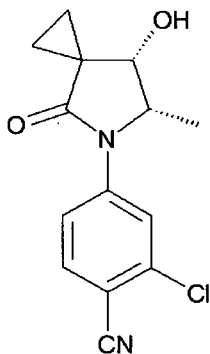


20 A solution of diisopropylamine (0.860 mL) in THF (30 mL) was cooled to -78°C, and n-butyllithium-hexane solution (3.64 mL, 1.6 mol/L) was added dropwise. After the completion of the dropwise addition, the mixture was stirred at -78°C for 1 hr.
 25 Subsequently, a solution of 4-[(2S,3S)-3-hydroxy-2-methyl-5-

oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile (661 mg) in THF (5.0 mL) was added dropwise, and the mixture was further stirred at -78°C for 1 hr. Iodomethane (0.75 mL) was added dropwise at -78°C, and the mixture was further stirred at -78°C for 1 hr. Acetic acid (3.0 mL) was added to the reaction mixture, and the mixture was warmed to room temperature. Water was added, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=10/1→1/3) to give the title compound as a colorless solid (yield: 442.9 mg, 63.7%). ¹H-NMR (CDCl₃) δ: 1.34 (3H, d, J=6.9 Hz), 1.35 (3H, d, J=6.4 Hz), 1.95-2.06 (1H, m), 2.64-2.81 (1H, m), 4.21 (1H, ddd, J=9.2, 7.2, 5.4 Hz), 4.35-4.51 (1H, m), 7.77-7.87 (1H, m), 7.90-8.00 (1H, m), 8.20 (1H, d, J=2.3 Hz). mp: 82-85°C.

Example 42

2-chloro-4-[(6S,7S)-7-hydroxy-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]benzonitrile



20

To a solution of 4-[(6S,7S)-7-(tert-butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-chlorobenzonitrile (89.0 mg) in a mixed solvent of THF (6 mL) and methanol (6 mL) was added 6 mol/L hydrochloric acid (4.0 mL), and the mixture was stirred at room temperature for 18 hr. The reaction mixture was added to saturated aqueous sodium hydrogen carbonate, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced

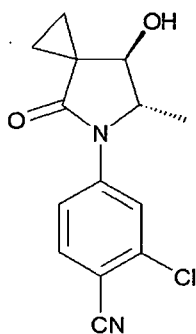
pressure. The residue was purified by silica gel column chromatography, and recrystallized from hexane-ethyl acetate to give the title compound as a colorless solid (yield: 48.7 mg, 66%).

5 $^1\text{H-NMR}$ (CDCl_3) δ : 0.93–1.08 (1H, m), 1.17–1.37 (3H, m), 1.37 (3H, d, $J=6.4\text{Hz}$), 1.61–1.72 (1H, m), 4.34 (1H, t, $J=6.0\text{Hz}$), 4.39–4.45 (1H, m), 7.51 (1H, dd, $J=8.6, 2.1\text{Hz}$), 7.66 (1H, d, $J=8.6\text{Hz}$), 7.76 (1H, d, $J=2.1\text{Hz}$).

mp: 164–166°C.

10 Example 43

2-chloro-4-[(6S, 7R)-7-hydroxy-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]benzonitrile



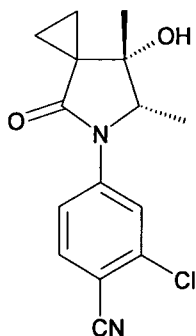
To a solution of 4-[(6S, 7R)-7-(tert-butyl-
15 butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-chlorobenzonitrile (65.7 mg) in a mixed solvent of THF (6 mL) and methanol (6 mL) was added 6 mol/L hydrochloric acid (4.0 mL), and the mixture was stirred at room temperature for 1 hr. The reaction mixture was added to saturated aqueous sodium hydrogen
20 carbonate, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography, and recrystallized from hexane-ethyl acetate to
25 give the title compound as a colorless solid (yield: 42.0 mg, 90%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.07–1.47 (4H, m), 1.39 (3H, d, $J=6.6\text{Hz}$), 1.85–1.95 (1H, m), 3.77 (1H, d, $J=3.8\text{Hz}$), 4.33 (1H, q, $J=6.6\text{Hz}$), 7.59–7.71 (2H, m), 7.99–8.01 (1H, m).

30 mp: 169–172°C.

Example 44

2-chloro-4-[(6S,7S)-7-hydroxy-6,7-dimethyl-4-oxo-5-azaspiro[2.4]hept-5-yl]benzonitrile



5 To a solution of 2-chloro-4-[(6S)-6-methyl-4,7-dioxo-5-azaspiro[2.4]hept-5-yl]benzonitrile (35 mg) in tetrahydrofuran (6.0 mL) was added dropwise 1 mol/L-methylmagnesium bromide /tetrahydrofuran solution (1.3 mL) under ice-cooling, and the mixture was stirred at the same temperature for 1 hr. Brine was
10 added to the reaction mixture, and the mixture was extracted with ethyl acetate.

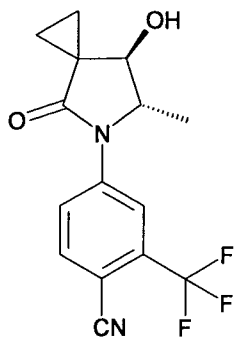
The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent:hexane/ethyl
15 acetate=10/1→1/3) to give the title compound as a colorless solid (yield: 27.5 mg, 74%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.92-1.05 (1H, m), 1.07-1.32 (3H, m), 1.29 (3H, s), 1.35 (3H, d, $J=6.4\text{Hz}$), 1.44 (1H, s), 4.14 (1H, q, $J=6.4\text{Hz}$), 7.51 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.66 (1H, d, $J=8.5\text{Hz}$), 7.75 (1H, d, $J=2.1\text{Hz}$).

20 mp: 150-152°C.

Example 45

4-[(6S,7R)-7-hydroxy-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-(trifluoromethyl)benzonitrile



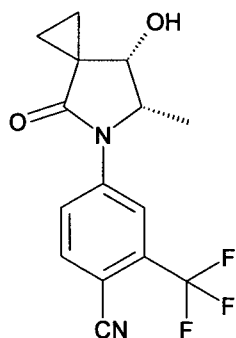
To a solution of 4-[(6S,7R)-7-(tert-butyl-
 butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-
 2-(trifluoromethyl)benzonitrile (670 mg) in tetrahydrofuran (12
 5 mL)-methanol (6 mL) was added 6 mol/L hydrochloric acid (5 mL),
 and the mixture was stirred at room temperature for 2 hr.
 Saturated aqueous sodium hydrogen carbonate was added to the
 reaction mixture, and the mixture was extracted with ethyl
 acetate. The extract was dried over anhydrous magnesium sulfate
 10 and concentrated under reduced pressure. The residue was
 purified by silica gel column chromatography (eluent:
 hexane/ethyl acetate=30/1→1/3) to give the title compound as a
 colorless solid (yield: 381.9 mg, 78%).

¹H-NMR(CDCl₃)δ:1.08-1.24(2H,m), 1.41(3H,d,J=6.6Hz), 1.31-
 15 1.45(2H,m), 1.91(1H,d,J=1.7Hz), 3.80(1H,d,J=4.7Hz),
 4.39(1H,q,J=6.7Hz), 7.81(1H,d,J=8.5Hz), 7.96(1H,d,J=8.5Hz),
 8.27(1H,s).

mp:109-110°C.

Example 46

20 4-[(6S,7S)-7-hydroxy-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-
 (trifluoromethyl)benzonitrile



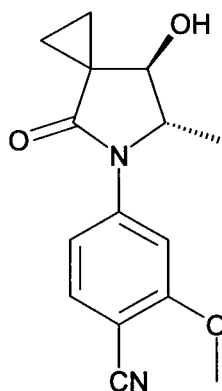
To a solution of 4-[(6S,7S)-7-(tert-butyl-
dimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-
2-(trifluoromethyl)benzonitrile (309.4 mg) in tetrahydrofuran (3
mL)-methanol (3 mL) was added 6 mol/L hydrochloric acid (3 mL),
5 and the mixture was stirred at room temperature for 18 hr.
Saturated aqueous sodium hydrogen carbonate was added to the
reaction mixture, and the mixture was extracted with ethyl
acetate. The extract was dried over anhydrous magnesium sulfate
and concentrated under reduced pressure. The residue was
10 purified by silica gel column chromatography (eluent:
hexane/ethyl acetate=30/1→1/3) to give the title compound as a
colorless solid (yield: 152.3 mg, 67%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.97-1.10 (1H, m), 1.20-1.36 (3H, m),
1.37 (3H, d, $J=6.4\text{Hz}$), 1.66 (1H, d, $J=6.4\text{Hz}$), 4.36 (1H, t, $J=6.2\text{Hz}$),
15 4.48-4.61 (1H, m), 7.76-7.88 (2H, m), 8.02 (1H, d, $J=2.1\text{Hz}$).

mp: 155-156°C.

Example 47

4-[(6S,7R)-7-hydroxy-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-
methoxybenzonitrile



To a solution of 4-[(6S,7R)-7-(tert-
butyldimethylsilyloxy)-6-methyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-
2-methoxybenzonitrile (320 mg) in tetrahydrofuran (8 mL)-
methanol (8 mL) was added 6 mol/L hydrochloric acid (6 mL), and
25 the mixture was stirred at room temperature for 2 hr. Saturated
aqueous sodium hydrogen carbonate was added to the reaction
mixture, and the mixture was extracted with ethyl acetate. The
extract was dried over anhydrous magnesium sulfate and

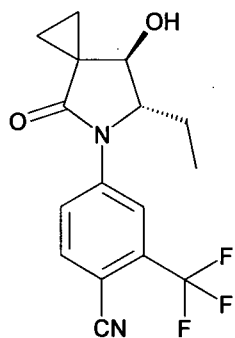
concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=30/1→1/3) to give the title compound as a colorless solid (yield: 49.7 mg, 22%).

5 $^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.10-1.21 (2H, m), 1.30-1.42 (2H, m), 1.39 (3H, d, $J=6.6\text{Hz}$), 1.78 (1H, d, $J=5.1\text{Hz}$), 3.77 (1H, d, $J=5.1\text{Hz}$), 3.93 (3H, s), 4.31-4.41 (1H, m), 6.90 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.54 (1H, d, $J=8.5\text{Hz}$), 7.97 (1H, d, $J=2.1\text{Hz}$).

mp: 167-169°C.

10 Example 48

4-[(6S, 7R)-6-ethyl-7-hydroxy-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-(trifluoromethyl)benzonitrile



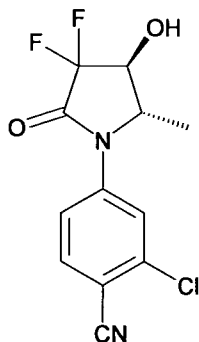
To a solution of 4-[(6S, 7R)-7-(tert-butyl-
15 butyldimethylsilyloxy)-6-ethyl-4-oxo-5-azaspiro[2.4]hept-5-yl]-2-(trifluoromethyl)benzonitrile (433.7 mg) in tetrahydrofuran (6 mL)-methanol (12 mL) was added 6 mol/L hydrochloric acid (5 mL), and the mixture was stirred at room temperature for 18 hr. Saturated aqueous sodium hydrogen carbonate was added to the
20 reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=30/1→1/2) to give the title compound as a
25 colorless solid (yield: 266.1 mg, 83%).

$^1\text{H-NMR}(\text{CDCl}_3)\delta$: 1.01 (3H, t, $J=7.5\text{Hz}$), 1.15-1.24 (2H, m), 1.35-1.45 (2H, m), 1.59-1.72 (1H, m), 1.74-1.89 (2H, m), 3.89 (1H, d, $J=4.9\text{Hz}$), 4.25 (1H, dd, $J=8.9, 2.8\text{Hz}$), 7.82 (1H, d, $J=8.7\text{Hz}$), 7.92 (1H, dd, $J=8.7, 2.1\text{Hz}$), 8.25 (1H, d, $J=2.1\text{Hz}$).

mp:106-110°C.

Example 49

2-chloro-4-[(4S,5S)-3,3-difluoro-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile



To a solution of (4S,5S)-1-(3-chloro-4-iodophenyl)-3,3-difluoro-4-hydroxy-5-methylpyrrolidin-2-one (113 mg) in DMF (3.5 mL) were added zinc cyanide (12 mg) and tetrakis(triphenylphosphine)palladium(0) (34 mg), and the mixture was stirred at 100°C for 4 hr. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was

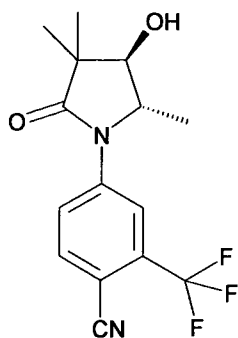
15 (eluent:hexane/ethyl acetate=30/1→1/2) to give the title compound as a colorless solid (yield: 75 mg, 90%).

¹H-NMR(CDCl₃)δ:1.44(3H,dd,J=6.6,1.5Hz), 2.38-2.46(1H,m), 4.15-4.23(1H,m), 4.23-4.30(1H,m), 7.62(1H,dd,J=8.7,2.1Hz), 7.74(1H,d,J=8.7Hz), 7.86(1H,d,J=2.1Hz).

20 mp:133-139°C.

Example 50

4-[(4R,5S)-4-hydroxy-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile

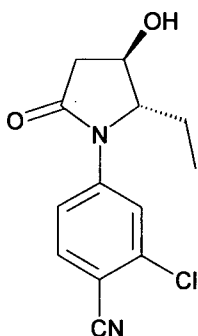


To a solution of 4-[(4R,5S)-4-(tert-butyltrimethylsilyloxy)-3,3,5-trimethyl-2-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile (391.7 mg) in tetrahydrofuran (12 mL)-methanol (12 mL) was added 6 mol/L hydrochloric acid (12 mL), and the mixture was stirred at room temperature for 4 hr. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=10/1→1/3) to give the title compound as a colorless oil (yield: 203.6 mg, 71%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.18 (3H, s), 1.33 (3H, s), 1.39 (3H, d, $J=6.2\text{Hz}$), 1.98 (1H, d, $J=5.8\text{Hz}$), 3.82 (1H, t, $J=5.8\text{Hz}$), 3.96–4.09 (1H, m), 7.11 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.85 (1H, d, $J=8.5\text{Hz}$), 7.91 (1H, d, $J=2.1\text{Hz}$).

Example 51

2-chloro-4-[(2S,3R)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]benzonitrile



To a solution of 4-[(2S,3R)-3-(tert-butyltrimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-chlorobenzonitrile (366 mg) in tetrahydrofuran (5 mL)-methanol (5 mL) was added 6 mol/L hydrochloric acid (5 mL), and the

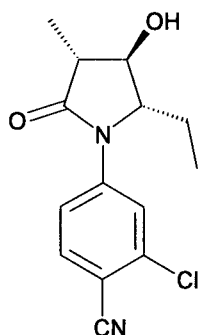
mixture was stirred at room temperature for 18 hr. Saturated aqueous sodium hydrogen carbonate was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent:hexane/ethyl acetate=10/1→1/3) to give the title compound as a colorless solid (yield: 221.2 mg, 87%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.00 (3H, t, $J=7.5\text{Hz}$), 1.41–1.59 (1H, m), 1.69–1.85 (1H, m), 1.97 (1H, brs), 2.55 (1H, dd, $J=18.0, 1.2\text{Hz}$), 3.01 (1H, dd, $J=18.0, 5.9\text{Hz}$), 4.08 (1H, dd, $J=9.3, 3.0\text{Hz}$), 4.32–4.40 (1H, m), 7.59 (1H, dd, $J=8.7, 2.1\text{Hz}$), 7.66 (1H, d, $J=8.7\text{Hz}$), 7.91 (1H, d, $J=2.1\text{Hz}$).

mp: 118–120°C.

Example 52

2-chloro-4-[(2S, 3R, 4R)-2-ethyl-3-hydroxy-4-methyl-5-oxopyrrolidin-1-yl]benzonitrile



A solution of diisopropylamine (0.208 mL) in tetrahydrofuran (8 mL) was cooled to -78°C , n-butyllithium-hexane solution (0.885 mL, 1.6 mol/L) was added dropwise, and the mixture was stirred for 1 hr. A solution of 2-chloro-4-[(2S, 3R)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]benzonitrile (145.5 mg) in tetrahydrofuran (2 mL) was added dropwise and the mixture was stirred at -78°C for 1 hr. A solution of iodomethane (0.176 mL) in tetrahydrofuran (2 mL) was added dropwise at -78°C , and the mixture was stirred at -78°C for 30 min and at 0°C for 30 min. Water was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over

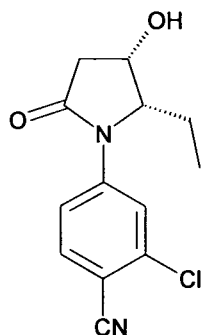
anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=50/1→1/3) to give the title compound as a colorless solid (yield: 57.0 mg, 37%).

5 $^1\text{H-NMR}$ (CDCl_3) δ : 0.90 (3H, t, $J=7.5\text{Hz}$), 1.39 (3H, d, $J=7.4\text{Hz}$), 1.48–1.65 (1H, m), 1.80–1.95 (1H, m), 2.25 (1H, d, $J=4.5\text{Hz}$), 2.55–2.67 (1H, m), 3.89–3.99 (2H, m), 7.42 (1H, dd, $J=8.5, 2.0\text{Hz}$), 7.67 (1H, d, $J=8.5\text{Hz}$), 7.69 (1H, d, $J=2.0\text{Hz}$).

mp: 120–123°C.

10 Example 53

2-chloro-4-[(2S,3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]benzonitrile

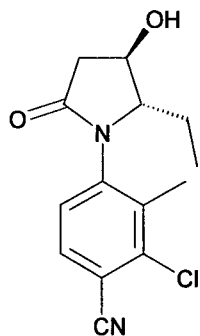


To a solution of 4-[(2S,3S)-3-(tert-butyl-
15 dimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-chlorobenzonitrile (550 mg) in tetrahydrofuran (3 mL)-methanol (3 mL) was added 6 mol/L hydrochloric acid (4 mL), and the mixture was stirred at room temperature for 72 hr. Saturated aqueous sodium hydrogen carbonate was added to the reaction
20 mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=10/1→1/3) to give the title compound as a colorless
25 solid (yield: 93.3 mg, 24%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.02 (3H, t, $J=7.3\text{Hz}$), 1.69–1.82 (3H, m), 2.67 (1H, dd, $J=16.8, 3.9\text{Hz}$), 2.85 (1H, dd, $J=16.8, 6.9\text{Hz}$), 4.06–4.18 (1H, m), 4.62–4.73 (1H, m), 7.40 (1H, d, $J=8.5\text{Hz}$), 7.59–7.72 (2H, m).
mp: 138–140°C.

Example 54

2-chloro-4-[(2S,3R)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-3-methylbenzonitrile



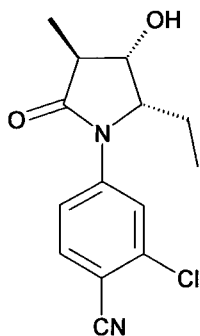
5 To a solution of 4-[(2S,3R)-3-(tert-butyl-
dimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-chloro-3-
methylbenzonitrile (650 mg) in tetrahydrofuran (20 mL)-methanol
(10 mL) was added 6 mol/L hydrochloric acid (10 mL), and the
mixture was stirred at room temperature for 18 hr. Saturated
10 aqueous sodium hydrogen carbonate was added to the reaction
mixture, and the mixture was extracted with ethyl acetate. The
extract was dried over anhydrous magnesium sulfate and
concentrated under reduced pressure. The residue was purified
by silica gel column chromatography (eluent:hexane/ethyl
15 acetate=10/1→1/9) to give the title compound as a colorless
solid (yield: 227.1 mg, 49%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.91 (3H, t, $J=7.4\text{Hz}$), 1.33-1.50 (1H, m), 1.51-
1.68 (1H, m), 2.31 (3H, s), 2.44-2.55 (1H, m),
2.50 (1H, dd, $J=17.6, 2.4\text{Hz}$), 2.94 (1H, dd, $J=17.6, 6.2\text{Hz}$), 3.69-
20 3.82 (1H, m), 4.31-4.41 (1H, m), 7.18 (1H, d, $J=8.3\text{Hz}$),
7.56 (1H, d, $J=8.3\text{Hz}$).

mp: 153-155°C.

Example 55

2-chloro-4-[(2S,3S,4S)-2-ethyl-3-hydroxy-4-methyl-5-
25 oxopyrrolidin-1-yl]benzonitrile



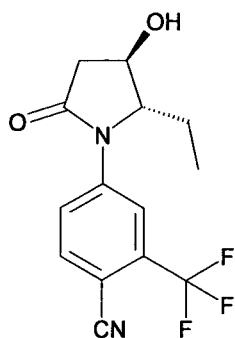
To a solution of diisopropylamine (0.111 mL) in tetrahydrofuran (5 mL) was added dropwise n-butyllithium-hexane solution (0.472 mL, 1.6 mol/L) at -78°C , the mixture was stirred
5 for 1 hr, and a solution of 2-chloro-4-[(2S,3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]benzonitrile (80 mg) in tetrahydrofuran (3 mL) was added dropwise. The mixture was stirred at -78°C for 30 min, iodomethane (0.100 mL) was added dropwise at -78°C , and the mixture was stirred at 0°C for 2 hr.
10 Acetic acid (0.500 mL) was added dropwise to the reaction mixture, water was added, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent:
15 hexane/ethyl acetate=50/1 $\rightarrow$ 1/3) to give the title compound as a colorless solid (yield: 10.8 mg, 13%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.00 (3H, t, $J=7.5\text{Hz}$), 1.30 (3H, d, $J=7.2\text{Hz}$), 1.60-1.80 (1H, m), 1.80-1.99 (1H, m), 2.34 (1H, brs), 2.65-2.81 (1H, m), 4.08-4.31 (2H, m), 7.54 (1H, d, $J=8.5\text{Hz}$), 7.65 (1H, d, $J=8.5\text{Hz}$),
20 7.86 (1H, s).

mp: $121-125^{\circ}\text{C}$.

Example 56

4-[(2S,3R)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile



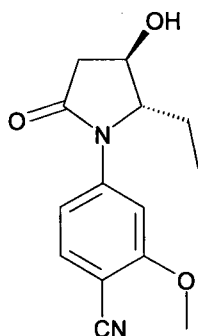
To a solution of 4-[(2S,3R)-3-(tert-butylidimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile (1.32 g) in tetrahydrofuran (30 mL)-ethanol (15 mL) was added 6 mol/L hydrochloric acid (15 mL), and the mixture was stirred at room temperature for 18 hr. Saturated aqueous sodium hydrogen carbonate was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent:hexane/ethyl acetate=6/1→1/9) to give the title compound as a colorless solid (yield: 507.3 mg, 53%).

¹H-NMR(CDCl₃)δ:1.00(3H,t,J=7.5Hz), 1.41-1.59(1H,m), 1.69-1.85(1H,m), 1.97(1H,brs), 2.55(1H,dd,J=18.0,1.2Hz), 3.01(1H,dd,J=18.0,5.9Hz), 4.08(1H,dd,J=9.3,3.0Hz), 4.32-4.40(1H,m), 7.59(1H,dd,J=8.7,2.1Hz), 7.66(1H,d,J=8.7Hz), 7.91(1H,d,J=2.1Hz).

mp:116-118°C.

Example 57

4-[(2S,3R)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-2-methoxybenzonitrile



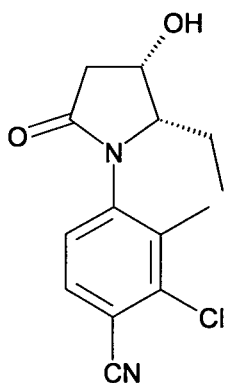
To a solution of 4-[(2S,3R)-3-(tert-butyl-
dimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-
methoxybenzonitrile (1.04 g) in tetrahydrofuran (30 mL)-ethanol
(15 mL) was added 6 mol/L hydrochloric acid (15 mL), and the
5 mixture was stirred at room temperature for 18 hr. Saturated
aqueous sodium hydrogen carbonate was added to the reaction
mixture, and the mixture was extracted with ethyl acetate. The
extract was dried over anhydrous magnesium sulfate and
concentrated under reduced pressure. The residue was purified
10 by silica gel column chromatography (eluent:hexane/ethyl
acetate=5/1→0/1) to give the title compound as a colorless
solid (yield: 528.3 mg, 73%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.99 (3H, t, $J=7.6\text{Hz}$), 1.40-1.61 (1H, m), 1.70-
1.87 (1H, m), 2.01 (1H, d, $J=4.2\text{Hz}$), 2.55 (1H, dd, $J=18.0, 1.3\text{Hz}$),
15 3.01 (1H, dd, $J=18.0, 6.0\text{Hz}$), 3.94 (3H, s), 4.08 (1H, dd, $J=9.3, 2.8\text{Hz}$),
4.30-4.39 (1H, m), 6.87 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.53 (1H, d, $J=8.5\text{Hz}$),
7.76 (1H, d, $J=2.1\text{Hz}$)

mp: 138-141°C.

Example 58

20 2-chloro-4-[(2S,3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-3-
methylbenzonitrile



To a solution of 4-[(2S,3S)-3-(tert-
butyl-
dimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-chloro-3-
25 methylbenzonitrile (134.5 mg) in tetrahydrofuran (10 mL)-
methanol (5 mL) was added 6 mol/L hydrochloric acid (5 mL), and
the mixture was stirred at room temperature for 18 hr.
Saturated aqueous sodium hydrogen carbonate was added to the

reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography

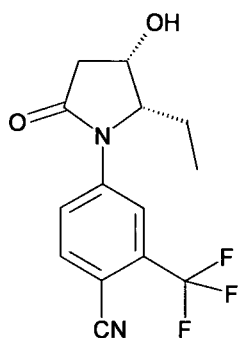
5 (eluent:hexane/ethyl acetate=10/1→1/4) to give the title compound as a colorless solid (yield: 66.2 mg, 69%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.94 (3H, t, $J=7.4\text{Hz}$), 1.29–1.50 (1H, m), 1.55–1.77 (1H, m), 1.72 (1H, brs), 2.32 (3H, brs), 2.58 (1H, d, $J=17.4\text{Hz}$), 2.85 (1H, dd, $J=17.4, 5.3\text{Hz}$), 3.84–4.05 (1H, m), 4.57–4.68 (1H, m),
10 6.99–7.17 (1H, m), 7.56 (1H, d, $J=8.3\text{Hz}$).

mp: 142–146°C.

Example 59

4-[(2S,3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile



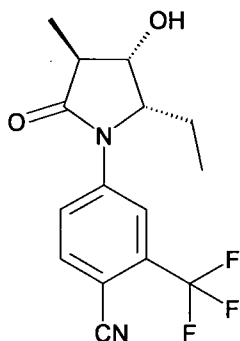
To a solution of 4-[(2S,3S)-3-(tert-butyltrimethylsilyloxy)-2-ethyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile (7.76 g) in tetrahydrofuran (60 mL)-ethanol (30 mL) was added 6 mol/L hydrochloric acid (60 mL),
20 and the mixture was stirred at room temperature for 18 hr. Saturated aqueous sodium hydrogen carbonate was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was
25 purified by silica gel column chromatography (eluent:hexane/ethyl acetate=50/1→1/4), and the obtained solid was recrystallized from ethyl acetate/hexane to give the title compound as a colorless solid (yield: 2.36 g, 42%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.03 (3H, t, $J=7.5\text{Hz}$), 1.70-1.86 (3H, m), 2.70 (1H, dd, $J=17.4, 4.0\text{Hz}$), 2.87 (1H, dd, $J=17.4, 6.6\text{Hz}$), 4.15-4.24 (1H, m), 4.66-4.75 (1H, m), 7.73 (1H, dd, $J=8.5, 2.1\text{Hz}$), 7.85 (1H, d, $J=8.5\text{Hz}$), 7.86 (1H, d, $J=2.1\text{Hz}$).

5 mp: 111-112°C.

Example 60

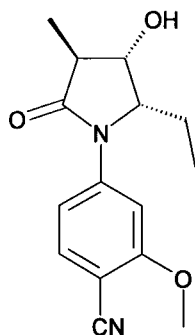
4-[(2S,3S,4S)-2-ethyl-3-hydroxy-4-methyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile



10 To a solution of diisopropylamine (0.603 mL) in tetrahydrofuran (8 mL) was added dropwise n-butyllithium-hexane solution (2.56 mL, 1.6 mol/L) at -78°C, the mixture was stirred for 1 hr, and a solution of 4-[(2S,3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile (490 mg) in
15 tetrahydrofuran (6 mL) was added dropwise. The mixture was stirred at -78°C for 30 min, iodomethane (0.510 mL) was added dropwise at -78°C, and the mixture was stirred at 0°C for 1 hr. Aqueous ammonium chloride solution was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The
20 extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=30/1→1/4) and further purified by basic silica gel chromatography (eluent: hexane/ethyl acetate=30/1→1/4) to give
25 the title compound as a colorless solid (yield: 66.5 mg, 13%).
 $^1\text{H-NMR}$ (CDCl_3) δ : 1.01 (3H, t, $J=7.5\text{Hz}$), 1.32 (3H, d, $J=7.2\text{Hz}$), 1.64-1.81 (1H, m), 1.83-2.00 (2H, m), 2.62-2.82 (1H, m), 4.19-4.37 (2H, m), 7.82 (1H, d, $J=8.5\text{Hz}$), 7.89 (1H, dd, $J=8.5, 2.1\text{Hz}$), 8.09 (1H, d, $J=2.1\text{Hz}$).
mp: 113-119°C.

Example 61

4-[(2S,3S,4S)-2-ethyl-3-hydroxy-4-methyl-5-oxopyrrolidin-1-yl]-
2-methoxybenzonitrile

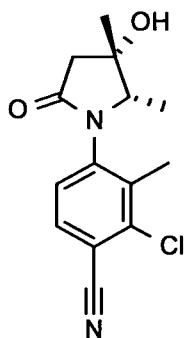


5 To a solution of diisopropylamine (0.291 mL) in tetrahydrofuran (8 mL) was added dropwise n-butyllithium-hexane solution (1.24 mL, 1.6 mol/L) at -78°C, the mixture was stirred for 1 hr, and a solution of 4-[(2S,3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-2-methoxybenzonitrile (206.5 mg) in
10 tetrahydrofuran (6 mL) was added dropwise. The mixture was stirred at -78°C for 30 min, iodomethane (0.247 mL) was added dropwise at -78°C, and the mixture was stirred at 0°C for 1 hr. Aqueous ammonium chloride solution was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The
15 extract was dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: hexane/ethyl acetate=30/1→1/4) to give the title compound as a colorless solid (yield: 108.8 mg, 50%).

20 ¹H-NMR(CDCl₃)δ: 1.00 (3H, t, J=7.5 Hz), 1.31 (3H, d, J=7.2 Hz), 1.62-1.82 (1H, m), 1.81-2.00 (1H, m), 1.91 (1H, d, J=5.1 Hz), 2.65-2.79 (1H, m), 3.93 (3H, s), 4.15-4.33 (2H, m), 6.84 (1H, dd, J=8.5, 1.9 Hz), 7.53 (1H, d, J=8.5 Hz), 7.72 (1H, d, J=1.9 Hz).
mp: 78-81°C.

25 Example 62

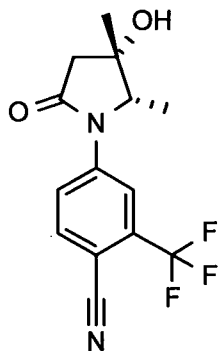
2-chloro-4-[(2S,3S)-3-hydroxy-2,3-dimethyl-5-oxopyrrolidin-1-yl]-3-methylbenzonitrile



A solution of 2-chloro-4-iodo-3-methylbenzonitrile (1.29 g), (4S,5S)-4-hydroxy-4,5-dimethylpyrrolidin-2-one (500 mg), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (343 mg),
 5 tris(dibenzylideneacetone)dipalladium(0) (177 mg) and cesium carbonate (1.86 g) in 1,4-dioxane (4 mL) was tightly sealed, and the mixture was stirred at 120°C for 3 hr using microwave reactor. The reaction mixture was filtered through silica gel, and the filtrate was concentrated under reduced pressure. The residue
 10 was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=30→70%, basic silica gel eluent:ethyl acetate/hexane=30→80%), and the obtained solid was recrystallized from ethyl acetate/hexane to give the title compound as colorless crystals (yield: 603 mg, 56%).
 15 ¹H-NMR(CDCl₃)δ:1.05(3H,d,J=6.6Hz), 1.52(3H,s), 1.68(1H,brs), 2.33(3H,s), 2.67(2H,s), 3.98(1H,brs), 7.00-7.18(1H,m), 7.57(1H,d,J=8.3Hz).
 mp:164-171°C.

Example 63

20 4-[(2S,3S)-3-hydroxy-2,3-dimethyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile

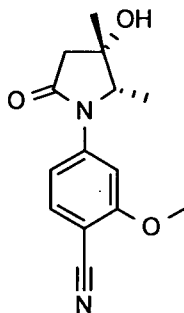


Using 4-iodo-2-(trifluoromethyl)benzonitrile (958 mg), (4S,5S)-4-hydroxy-4,5-dimethylpyrrolidin-2-one (500 mg), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (286 mg), tris(dibenzylideneacetone)dipalladium(0) (148 mg) and cesium carbonate (1.55 g), and in the same manner as in Example 62, the title compound was obtained as colorless crystals (yield: 508 mg, 52%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.30 (3H, d, $J=6.6\text{Hz}$), 1.54 (3H, s), 1.93 (1H, s), 2.65 (1H, d, $J=17.2\text{Hz}$), 2.82 (1H, d, $J=17.2\text{Hz}$), 4.14 (1H, q, $J=6.6\text{Hz}$), 7.78 (1H, dd, $J=8.7, 1.9\text{Hz}$), 7.85 (1H, d, $J=8.7\text{Hz}$), 7.92 (1H, d, $J=1.9\text{Hz}$). mp: 134–137°C (ethyl acetate/hexane).

Example 64

4-[(2S,3S)-3-hydroxy-2,3-dimethyl-5-oxopyrrolidin-1-yl]-2-methoxybenzonitrile



15

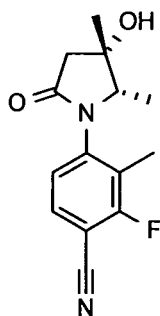
Using 4-bromo-2-methoxybenzonitrile (684 mg), (4S,5S)-4-hydroxy-4,5-dimethylpyrrolidin-2-one (500 mg), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (286 mg), tris(dibenzylideneacetone)dipalladium(0) (148 mg) and cesium carbonate (1.55 g), and in the same manner as in Example 62, the title compound was obtained as a colorless amorphous solid (yield: 410 mg, 48%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.27 (3H, d, $J=6.4\text{Hz}$), 1.52 (3H, s), 1.97 (1H, s), 2.63 (1H, d, $J=17.0\text{Hz}$), 2.79 (1H, d, $J=17.0\text{Hz}$), 3.93 (3H, s), 4.08 (1H, q, $J=6.4\text{Hz}$), 6.82 (1H, dd, $J=8.5, 1.9\text{Hz}$), 7.42 (1H, d, $J=1.9\text{Hz}$), 7.54 (1H, d, $J=8.5\text{Hz}$).

LCMS (m/z): 261 ($M+H$) $^+$.

Example 65

2-fluoro-4-[(2S,3S)-3-hydroxy-2,3-dimethyl-5-oxopyrrolidin-1-yl]-3-methylbenzonitrile



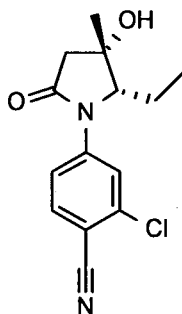
Using 4-bromo-2-fluoro-3-methylbenzonitrile (484 mg),
 5 (4S,5S)-4-hydroxy-4,5-dimethylpyrrolidin-2-one (350 mg), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (200 mg), tris(dibenzylideneacetone)dipalladium(0) (103 mg) and cesium carbonate (1.08 g), and in the same manner as in Example 62, the title compound was obtained as colorless crystals (yield: 376 mg,
 10 63%).

¹H-NMR (CDCl₃) δ: 1.05 (3H, d, J=6.6 Hz), 1.51 (3H, s), 1.81 (1H, s), 2.20 (3H, d, J=2.5 Hz), 2.66-2.66 (2H, m), 3.99 (1H, q, J=6.6 Hz), 6.98 (1H, d, J=8.1 Hz), 7.48 (1H, dd, J=8.1, 7.0 Hz).

mp: 138-141°C (ethyl acetate/hexane).

15 Example 66

2-chloro-4-[(2S,3S)-2-ethyl-3-hydroxy-3-methyl-5-oxopyrrolidin-1-yl]benzonitrile



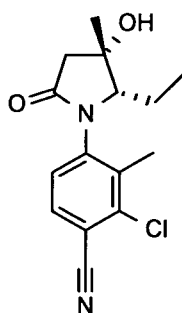
Using 4-bromo-2-chlorobenzonitrile (459 mg), (4S,5S)-5-ethyl-4-hydroxy-4-methylpyrrolidin-2-one (350 mg), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (180 mg), tris(dibenzylideneacetone)dipalladium(0) (93 mg) and cesium carbonate (929 mg), and in the same manner as in Example 62, the

title compound was obtained as colorless crystals (yield: 318 mg, 56%).

$^1\text{H-NMR}$ (CD_3SOCD_3) δ : 0.86 (3H, dd, $J=7.6, 7.4\text{Hz}$), 1.38 (3H, s), 1.44-1.64 (1H, m), 1.66-1.84 (1H, m), 2.49 (1H, d, $J=17.0\text{Hz}$),
 5 2.69 (1H, d, $J=17.0\text{Hz}$), 4.11 (1H, dd, $J=7.7, 3.4\text{Hz}$), 5.30 (1H, s),
 7.65 (1H, dd, $J=8.7, 1.9\text{Hz}$), 7.97 (1H, d, $J=8.7\text{Hz}$), 8.00 (1H, d, $J=1.9\text{Hz}$).
 mp: 144-146°C (ethyl acetate/hexane).

Example 67

2-chloro-4-[(2S,3S)-2-ethyl-3-hydroxy-3-methyl-5-oxopyrrolidin-
 10 1-yl]-3-methylbenzonitrile



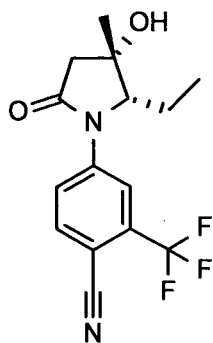
Using 2-chloro-4-iodo-3-methylbenzonitrile (565 mg),
 (4S,5S)-5-ethyl-4-hydroxy-4-methylpyrrolidin-2-one (350 mg),
 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (180 mg),
 15 tris(dibenzylideneacetone)dipalladium(0) (93 mg) and cesium
 carbonate (929 mg), and in the same manner as in Example 62, the
 title compound was obtained as colorless crystals (yield: 132 mg,
 22%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.87 (3H, dd, $J=7.6\text{Hz}$), 1.31-1.51 (1H, m), 1.59 (3H, s),
 20 1.63-1.84 (1H, m), 1.68 (1H, s), 2.32 (3H, s), 2.67 (2H, s), 3.77 (1H, s),
 7.12 (1H, d, $J=8.3\text{Hz}$), 7.57 (1H, d, $J=8.3\text{Hz}$).

mp: 156-158°C (ethyl acetate/hexane).

Example 68

4-[(2S,3S)-2-ethyl-3-hydroxy-3-methyl-5-oxopyrrolidin-1-yl]-2-
 25 (trifluoromethyl)benzonitrile

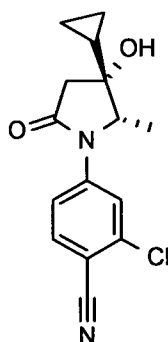


Using 4-iodo-2-(trifluoromethyl)benzonitrile (605 mg),
 (4S,5S)-5-ethyl-4-hydroxy-4-methylpyrrolidin-2-one (350 mg),
 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (180 mg),
 5 tris(dibenzylideneacetone)dipalladium(0) (93 mg) and cesium
 carbonate (929 mg), and in the same manner as in Example 62, the
 title compound was obtained as a white powder (yield: 422 mg,
 66%).

$^1\text{H-NMR}$ (CDCl_3) δ : 1.00 (3H, dd, $J=7.6, 7.4\text{Hz}$), 1.59 (3H, s),
 10 1.71 (1H, dddd, $J=14.7, 7.6, 7.4, 3.2\text{Hz}$), 1.78 (1H, s),
 1.91 (1H, dddd, $J=15.0, 14.7, 7.6, 7.4\text{Hz}$), 2.63 (1H, d, $J=17.2\text{Hz}$),
 2.89 (1H, d, $J=17.2\text{Hz}$), 3.96 (1H, dd, $J=7.7, 3.4\text{Hz}$), 7.75–7.91 (2H, m),
 7.99 (1H, s).
 mp: 137–139°C (ethyl acetate/hexane).

15 Example 69

2-chloro-4-[(2S,3R)-3-cyclopropyl-3-hydroxy-2-methyl-5-oxopyrrolidin-1-yl]benzonitrile



Using 4-bromo-2-chlorobenzonitrile (424 mg), (4R,5S)-4-
 20 cyclopropyl-4-hydroxy-5-methylpyrrolidin-2-one (350 mg), 4,5-
 bis(diphenylphosphino)-9,9-dimethylxanthene (166 mg),
 tris(dibenzylideneacetone)dipalladium(0) (86 mg) and cesium
 carbonate (902 mg), and in the same manner as in Example 62, the

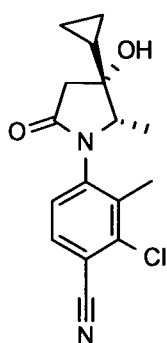
title compound was obtained as a white powder (yield: 58 mg, 11%).

$^1\text{H-NMR}$ (DMSO-d_6) δ : 0.29–0.53 (4H, m), 0.97–1.20 (1H, m),
1.12 (3H, d, $J=6.2\text{Hz}$), 2.37–2.65 (2H, m), 4.33 (1H, q, $J=6.2\text{Hz}$),
5 4.97 (1H, s), 7.61 (1H, dd, $J=8.7, 1.7\text{Hz}$), 7.90 (1H, d, $J=1.7\text{Hz}$),
7.97 (1H, d, $J=8.7\text{Hz}$).

mp: 93–100°C (ethyl acetate/hexane).

Example 70

2-chloro-4-[(2S,3R)-3-cyclopropyl-3-hydroxy-2-methyl-5-oxopyrrolidin-1-yl]-3-methylbenzonitrile



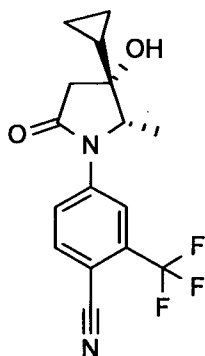
Using 2-chloro-4-iodo-3-methylbenzonitrile (522 mg),
(4R,5S)-4-cyclopropyl-4-hydroxy-5-methylpyrrolidin-2-one (350
mg), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (166 mg),
15 tris(dibenzylideneacetone)dipalladium(0) (86 mg) and cesium
carbonate (902 mg), and in the same manner as in Example 62, the
title compound was obtained as a white powder (yield: 308 mg,
54%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.36–0.53 (2H, m), 0.53–0.66 (2H, m), 0.97–1.21 (1H, m),
20 1.08 (3H, d, $J=6.4\text{Hz}$), 1.69 (1H, brs), 2.33 (3H, s),
2.38 (1H, d, $J=17.0\text{Hz}$), 2.53 (1H, d, $J=17.0\text{Hz}$), 4.13 (1H, brs), 7.06–
7.19 (1H, m), 7.57 (1H, d, $J=8.3\text{Hz}$).

mp: 231–236°C (ethyl acetate/hexane).

Example 71

4-[(2S,3R)-3-cyclopropyl-3-hydroxy-2-methyl-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile



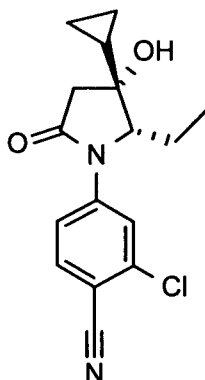
Using 4-iodo-2-(trifluoromethyl)benzonitrile (558 mg), (4R,5S)-4-cyclopropyl-4-hydroxy-5-methylpyrrolidin-2-one (350 mg), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (166 mg),
 5 tris(dibenzylideneacetone)dipalladium(0) (86 mg) and cesium carbonate (902 mg), and in the same manner as in Example 62, the title compound was obtained as a yellow powder (yield: 123 mg, 20%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.38-0.69 (4H, m), 1.09-1.25 (1H, m),
 10 1.32 (3H, d, $J=6.4\text{Hz}$), 1.70 (1H, s), 2.53 (1H, d, $J=17.2\text{Hz}$),
 2.62 (1H, d, $J=17.2\text{Hz}$), 4.26 (1H, q, $J=6.4\text{Hz}$), 7.78 (1H, d, $J=8.5\text{Hz}$),
 7.85 (1H, d, $J=8.5\text{Hz}$), 7.92 (1H, s).

mp: 84-90°C.

Example 72

15 2-chloro-4-[(2S,3R)-3-cyclopropyl-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]benzonitrile



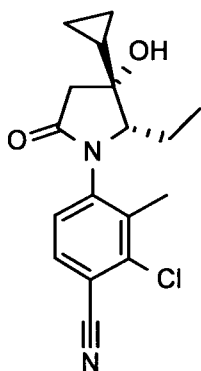
Using 4-bromo-2-chlorobenzonitrile (389 mg), (4R,5S)-4-cyclopropyl-5-ethyl-4-hydroxypyrrolidin-2-one (350 mg), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (153 mg),
 20 tris(dibenzylideneacetone)dipalladium(0) (79 mg) and cesium

carbonate (786 mg), and in the same manner as in Example 62, the title compound was obtained as pale-yellow crystals (yield: 104 mg, 20%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.38–0.53 (2H, m), 0.53–0.69 (2H, m),
 5 0.99 (3H, dd, $J=7.5, 7.4\text{Hz}$), 1.12–1.33 (1H, m), 1.62–1.78 (1H, m),
 1.65 (1H, s), 1.80–2.01 (1H, m), 2.50 (1H, d, $J=17.2\text{Hz}$),
 2.74 (1H, d, $J=17.2\text{Hz}$), 4.00 (1H, dd, $J=7.6, 3.1\text{Hz}$),
 7.54 (1H, dd, $J=8.7, 2.1\text{Hz}$), 7.66 (1H, d, $J=8.7\text{Hz}$), 7.81 (1H, d, $J=2.1\text{Hz}$).
 mp: 128–132°C (ethyl acetate/n-heptane).

10 Example 73

2-chloro-4-[(2S,3R)-3-cyclopropyl-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-3-methylbenzonitrile

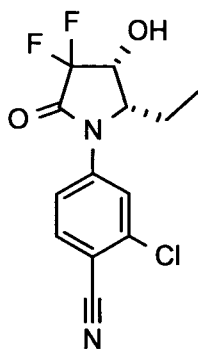


Using 2-chloro-4-iodo-3-methylbenzonitrile (478 mg),
 15 (4R,5S)-4-cyclopropyl-5-ethyl-4-hydroxypyrrolidin-2-one (350 mg),
 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (153 mg),
 tris(dibenzylideneacetone)dipalladium(0) (79 mg) and cesium
 carbonate (786 mg), and in the same manner as in Example 62, the
 title compound was obtained as colorless crystals (yield: 78 mg,
 20 14%).

$^1\text{H-NMR}$ ($\text{DMSO}-d_6$) δ : 0.39–0.53 (4H, m), 0.76 (3H, dd, $J=6.8, 6.6\text{Hz}$), 1.08–
 1.27 (2H, m), 1.60–1.75 (1H, m), 2.24 (3H, s), 2.29 (1H, d, $J=6.2\text{Hz}$),
 2.49–2.62 (1H, m), 4.05 (1H, brs), 4.95 (1H, brs), 7.45–7.49 (1H, m),
 7.90 (1H, d, $J=8.3\text{Hz}$).
 25 mp: 177–179°C (ethyl acetate/n-heptane).

Example 74

2-chloro-4-[(4R,5S)-5-ethyl-3,3-difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]benzonitrile



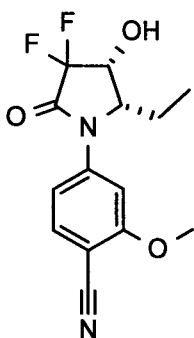
Using 4-bromo-2-chlorobenzonitrile (2.28 g), (4R,5S)-5-ethyl-3,3-difluoro-4-hydroxypyrrolidin-2-one (2.00 g), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (954 mg),
 5 tris(dibenzylideneacetone)dipalladium(0) (554 mg) and cesium carbonate (4.84 g), and in the same manner as in Example 62, the title compound was obtained as pale-yellow crystals (yield: 153 mg, 10%).

¹H-NMR (CD₃SOCD₃) δ: 0.83 (3H, dd, J=7.4, 7.4 Hz), 1.30-1.79 (2H, m), 4.45-
 10 4.78 (2H, m), 6.54 (1H, d, J=4.2 Hz), 7.76 (1H, d, J=8.7 Hz), 8.06 (1H, s), 8.08 (1H, d, J=8.7 Hz).

mp: 137-140°C (ethyl acetate/hexane).

Example 75

4-[(4R,5S)-5-ethyl-3,3-difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]-
 15 2-methoxybenzonitrile



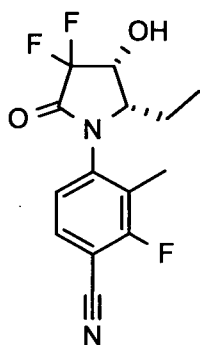
Using 4-bromo-2-methoxybenzonitrile (2.14 g), (4R,5S)-5-ethyl-3,3-difluoro-4-hydroxypyrrolidin-2-one (2.00 g), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (954 mg),
 20 tris(dibenzylideneacetone)dipalladium(0) (554 mg) and cesium carbonate (4.84 g), and in the same manner as in Example 62, the title compound was obtained as a white powder (yield: 895 mg, 30%).

$^1\text{H-NMR}$ (CD_3SOCD_3) δ : 0.83 (3H, dd, $J=7.3\text{Hz}$), 1.35–1.79 (2H, m), 3.93 (3H, s), 4.45–4.74 (2H, m), 6.53 (1H, s), 7.26 (1H, d, $J=8.5\text{Hz}$), 7.47 (1H, s), 7.82 (1H, d, $J=8.5\text{Hz}$).

mp: 161–164°C (ethyl acetate/hexane).

5 Example 76

4-[(4R,5S)-5-ethyl-3,3-difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]-2-fluoro-3-methylbenzonitrile

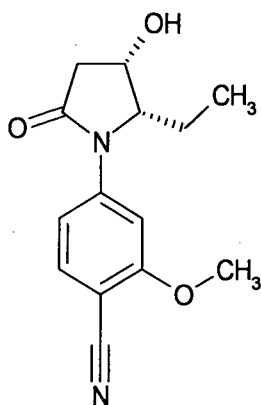


A solution of benzyl [(1S)-1-formylpropyl]carbamate (3.00
10 g) and ethyl bromodifluoroacetate (4.21 g) in acetonitrile (110 mL) was ice-cooled under a nitrogen atmosphere, and tris(triphenylphosphonium)rhodium (I) chloride (126 mg) was added. The mixture was stirred at the same temperature for 30 min, 1.0 mol/L-diethylzinc/hexane solution (20.3 mL) was added,
15 and the mixture was stirred at the same temperature for 4 hr and at room temperature for 14 hr. Water (100 mL) was added to the reaction mixture, and the mixture was extracted with ethyl acetate. The obtained organic layer was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated
20 under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=0→30%). The obtained oil was dissolved in methanol (10 mL), and the solution was ice-cooled. 1 mol/L aqueous sodium hydroxide solution (7.2 mL) was added, and the mixture was stirred at room
25 temperature for 2 hr. The reaction solution was concentrated under reduced pressure, and ethyl acetate and water were added to the obtained residue. The aqueous layer was separated, 6 mol/L hydrochloric acid was added, and the mixture was extracted with ethyl acetate. The obtained organic layer was concentrated

under reduced pressure, the obtained residue was dissolved in methanol (10 mL), and 1 mol/L aqueous sodium hydroxide solution (4.37 mL) and 10% palladium carbon (containing 50% water, 146 mg) were added. The reaction solution was stirred for 20 hr
5 under a hydrogen atmosphere, and filtered through celite. The filtrate was concentrated under reduced pressure, and the obtained residue was dissolved in dimethyl sulfoxide (10 mL). 2,4-Difluoro-3-methylbenzonitrile (982 mg) and diisopropylethylamine (2.47 mL) were added, and the mixture was
10 stirred at 100°C for 12 hr. The reaction solution was cooled to room temperature, 1 mol/L aqueous hydrochloric acid solution (30 mL) was added, and the mixture was extracted with ethyl acetate. The obtained organic layer was concentrated under reduced pressure, acetic acid (5 mL) was added to the residue, and the
15 mixture was stirred at 100°C for 18 hr. The reaction solution was cooled to room temperature, saturated aqueous sodium hydrogen carbonate solution (50 mL) was added, and the mixture was extracted with ethyl acetate. The obtained organic layer was washed with saturated brine, dried over anhydrous magnesium
20 sulfate, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: ethyl acetate/hexane=20→50%, basic silica gel eluent:ethyl acetate/hexane=60→100%), and the obtained solid was recrystallized from ethyl acetate/diethyl ether/hexane to give
25 the title compound as colorless crystals (yield: 91 mg, 2%).
¹H-NMR (DMSO-d₆) δ: 0.79 (3H, dd, J=7.2, 7.0 Hz), 1.17-1.39 (1H, m), 1.46-1.69 (1H, m), 2.08 (3H, s), 4.26 (1H, brs), 4.57-4.70 (1H, m), 6.57 (1H, brs), 7.47 (1H, brd, J=7.6 Hz), 7.91 (1H, dd, J=7.6 Hz).
mp: 176-180°C (ethyl acetate/diethyl ether/hexane).

30 Example 77

4-[(2S, 3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-2-methoxybenzonitrile



A solution of (4S,5S)-4-(tert-butyl dimethylsilyloxy)-5-ethylpyrrolidin-2-one (340 mg), 4-iodo-2-methoxybenzonitrile (434 mg), cesium carbonate (683 mg),
5 tris(dibenzylideneacetone)dipalladium(0) (64.0 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (121 mg) in dioxane (10 mL) was stirred at 80°C for 6.5 hr under an argon atmosphere. After allowing to room temperature, water was added to the reaction mixture, and the mixture was extracted with ethyl
10 acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by basic silica gel column chromatography (eluent: hexane-ethyl acetate=99:1→1:1). The obtained residue was dissolved in ethanol (10 mL)-
15 tetrahydrofuran (10 mL), 6 mol/L hydrochloric acid (4.66 mL) was added, and the mixture was stirred overnight at room temperature. The mixture was neutralized with saturated aqueous sodium hydrogen carbonate solution under ice-cooling, and extracted with ethyl acetate. The organic layer was washed with saturated
20 brine, and dried over magnesium sulfate, and the solvent was evaporated under reduced pressure. The obtained residue was purified by silica gel column chromatography (eluent: hexane:ethyl acetate=9:1→1:9), and recrystallized from tetrahydrofuran-hexane to give the title compound as colorless
25 crystals (yield: 115 mg, 32%).

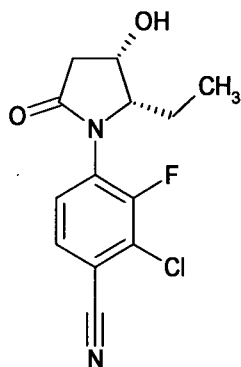
¹H-NMR (CDCl₃) δ: 1.01 (3H, t, J=7.5 Hz), 1.68-1.82 (3H, m), 2.62-2.70 (1H, m), 2.81-2.90 (1H, m), 3.94 (3H, s), 4.08-4.17 (1H, m), 4.62-

4.72 (1H, m), 6.80 (1H, dd, J=8.3, 1.9 Hz), 7.31 (1H, d, J=1.7 Hz),
7.55 (1H, d, J=8.3 Hz).

mp: 158–160°C.

Example 78

- 5 2-chloro-4-[(2S,3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-3-fluorobenzonitrile



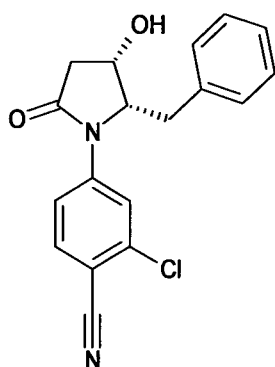
- A solution of (4S,5S)-4-(tert-butyldimethylsilyloxy)-5-ethylpyrrolidin-2-one (300 mg), 2-chloro-3-fluoro-4-iodobenzonitrile (416 mg), cesium carbonate (602 mg),
10 tris(dibenzylideneacetone)dipalladium(0) (56.4 mg) and 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (107 mg) in dioxane (10 mL) was stirred at 80°C overnight under an argon atmosphere. After allowing to room temperature, water was added to the
15 reaction mixture, and the mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried over anhydrous magnesium sulfate, and concentrated under reduced pressure. The residue was purified by basic silica gel column chromatography (eluent: hexane → hexane-ethyl acetate=2:1).
20 The obtained residue was dissolved in ethanol (10 mL)-tetrahydrofuran (10 mL), concentrated hydrochloric acid (2.06 mL) was added, and the mixture was stirred overnight at room temperature. The mixture was neutralized with saturated aqueous sodium hydrogen carbonate solution under ice-cooling, and
25 extracted with ethyl acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate, and the solvent was evaporated under reduced pressure. The obtained residue was purified by silica gel column chromatography

(eluent: hexane → ethyl acetate), and recrystallized from hexane-ethyl acetate to give the title compound as colorless crystals (yield: 86 mg, 25%).

¹H-NMR (CDCl₃) δ: 0.99 (3H, t, J=7.4 Hz), 1.40-1.74 (3H, m),
5 2.61 (1H, dd, J=17.6, 1.5 Hz), 2.86 (1H, dd, J=17.4, 5.7 Hz), 4.06-
4.16 (1H, m), 4.59-4.68 (1H, m), 7.38-7.45 (1H, m), 7.50-7.55 (1H, m).
mp: 142-144°C.

Example 79

rac-4-[(2S,3S)-2-benzyl-3-hydroxy-5-oxopyrrolidin-1-yl]-2-
10 chlorobenzonitrile



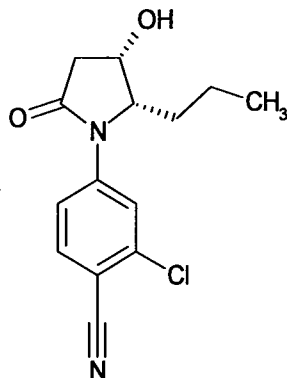
To a mixture of 4-(2-benzyl-3-hydroxy-5-oxo-2,5-dihydro-
1H-pyrrol-1-yl)-2-chlorobenzonitrile (400 mg) and acetic acid
(0.60 mL) in acetonitrile (20 mL) was added sodium borohydride
15 (86 mg) at 0°C in small portions. The mixture was warmed to room
temperature, and stirred for 3 hr. Water was added, and the
mixture was extracted with ethyl acetate. The organic layer was
washed with saturated brine, and dried over magnesium sulfate,
and the solvent was evaporated under reduced pressure. The
20 obtained residue was purified by basic silica gel column
chromatography (eluent: hexane:ethyl acetate=4:1→ethyl acetate),
and recrystallized from tetrahydrofuran-hexane to give the title
compound as colorless crystals (yield: 310 mg, 77%).

¹H-NMR (DMSO-d₆) δ: 2.38 (1H, dd, J=16.8, 5.7 Hz),
25 2.65 (1H, dd, J=16.8, 6.8 Hz), 2.82 (1H, dd, J=13.6, 5.3 Hz),
3.01 (1H, dd, J=13.6, 7.7 Hz), 4.34 (1H, br. s.), 4.65-4.74 (1H, m),
5.61 (1H, d, J=2.6 Hz), 7.09-7.24 (5H, m), 7.58 (1H, dd, J=8.7, 2.1 Hz),
7.76 (1H, d, J=2.1 Hz), 7.89 (1H, d, J=8.7 Hz).

mp:168-169°C.

Example 80

2-chloro-4-[(2S,3S)-3-hydroxy-5-oxo-2-propylpyrrolidin-1-yl]benzonitrile



5

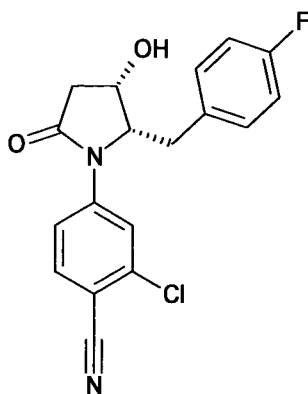
To a mixture of 2-chloro-4-(3-hydroxy-5-oxo-2-propyl-2,5-dihydro-1H-pyrrol-1-yl)benzonitrile (800 mg) and acetic acid (1.82 mL) in acetonitrile (25 mL) was added sodium borohydride (273 mg) at 0°C in small portions. The mixture was warmed to
10 room temperature and stirred for 1 hr. Water and saturated brine were added, and the mixture was extracted with ethyl acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate, and the solvent was evaporated under reduced pressure. The obtained residue was purified by
15 basic silica gel column chromatography (eluent: hexane:ethyl acetate=4:1→ethyl acetate), and recrystallized from tetrahydrofuran-hexane to give the title compound as colorless crystals (yield: 578 mg, 72%).

¹H-NMR(CDCl₃)δ:0.96(3H,t,J=7.2Hz), 1.28-1.81(4H,m),
20 1.90(1H,d,J=4.9Hz), 2.61-2.88(2H,m), 4.14-4.24(1H,m), 4.59-4.69(1H,m), 7.38(1H,dd,J=8.5,2.1Hz), 7.64(1H,d,J=1.9Hz), 7.68(1H,d,J=8.5Hz).

mp:143-146°C.

Example 81

25 rac-2-chloro-4-[(2S,3S)-2-(4-fluorobenzyl)-3-hydroxy-5-oxopyrrolidin-1-yl]benzonitrile

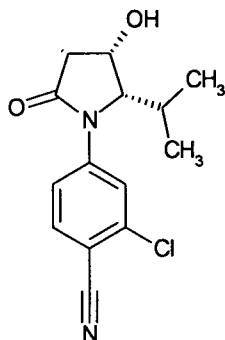


To a mixture of 2-chloro-4-[2-(4-fluorobenzyl)-3-hydroxy-5-oxo-2,5-dihydro-1H-pyrrol-1-yl]benzonitrile (1.00 g) and acetic acid (1.84 mL) in acetonitrile (10 mL) was added sodium borohydride (276 mg) at 0°C in small portions. The mixture was warmed to room temperature and stirred for 1 hr. Water and saturated brine were added, and the mixture was extracted with ethyl acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate, and the solvent was evaporated under reduced pressure. The obtained residue was purified by basic silica gel column chromatography (eluent: hexane:ethyl acetate=4:1→ethyl acetate), and recrystallized from tetrahydrofuran-hexane to give the title compound as colorless crystals (yield: 717 mg, 71%).

¹H-NMR (CDCl₃) δ: 1.89 (1H, d, J=4.3 Hz), 2.47–2.58 (1H, m), 2.70–2.82 (1H, m), 2.93–3.12 (2H, m), 4.44–4.58 (2H, m), 6.94–7.04 (2H, m), 7.13–7.23 (2H, m), 7.47 (1H, dd, J=8.7, 1.9 Hz), 7.65–7.71 (2H, m).
mp: 154–156°C.

Example 82

2-chloro-4-[(2S,3S)-3-hydroxy-2-(1-methylethyl)-5-oxopyrrolidin-1-yl]benzonitrile



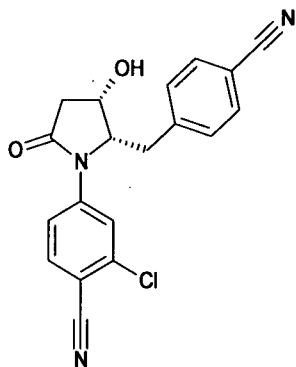
To a mixture of 2-chloro-4-[3-hydroxy-2-(1-methylethyl)-5-oxo-2,5-dihydro-1H-pyrrol-1-yl]benzonitrile (300 mg) and acetic acid (0.68 mL) in acetonitrile (10 mL) was added sodium borohydride (103 mg) at 0°C in small portions. The mixture was warmed to room temperature and stirred for 1 hr. Water was added, and the mixture was extracted with ethyl acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate, and the solvent was evaporated under reduced pressure. The obtained residue was purified by basic silica gel column chromatography (eluent: hexane:ethyl acetate=4:1→ethyl acetate), and recrystallized from hexane-ethyl acetate to give the title compound as colorless crystals (yield: 76 mg, 25%).

¹H-NMR (CDCl₃) δ: 0.93 (3H, d, J=7.2 Hz), 1.08 (3H, d, J=7.2 Hz), 1.90 (1H, d, J=4.9 Hz), 2.19-2.38 (1H, m), 2.65-2.89 (2H, m), 4.22-4.28 (1H, m), 4.79-4.90 (1H, m), 7.45 (1H, dd, J=8.5, 2.1 Hz), 7.67 (1H, d, J=8.5 Hz), 7.70 (1H, d, J=1.9 Hz).

mp: 100-102°C.

Example 83

rac-2-chloro-4-[(2S,3S)-2-(4-cyanobenzyl)-3-hydroxy-5-oxopyrrolidin-1-yl]benzonitrile



To a mixture of 2-chloro-4-[2-(4-cyanobenzyl)-3-hydroxy-5-oxo-2,5-dihydro-1H-pyrrol-1-yl]benzonitrile (300 mg) and acetic acid (0.54 mL) in acetonitrile (10 mL) was added sodium borohydride (81 mg) at 0°C in small portions. The mixture was warmed to room temperature and stirred for 1 hr. Water was added, and the mixture was extracted with ethyl acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate, and the solvent was evaporated under reduced

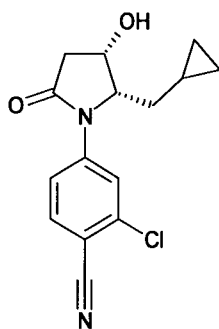
pressure. The obtained residue was purified by basic silica gel column chromatography (eluent: hexane:ethyl acetate=4:1→ethyl acetate), and recrystallized from tetrahydrofuran-hexane to give the title compound as colorless crystals (yield: 162 mg, 54%).

5 $^1\text{H-NMR}$ (CDCl_3) δ : 1.97 (1H, d, $J=4.5\text{Hz}$), 2.52 (1H, dd, $J=17.3, 4.2\text{Hz}$), 2.72–2.85 (1H, m), 3.01–3.24 (2H, m), 4.47–4.58 (2H, m), 7.37 (2H, d, $J=8.5\text{Hz}$), 7.48 (1H, dd, $J=8.6, 2.2\text{Hz}$), 7.60 (2H, d, $J=8.5\text{Hz}$), 7.67 (1H, d, $J=1.9\text{Hz}$), 7.70 (1H, d, $J=8.5\text{Hz}$).

mp: 176–178°C.

10 Example 84

2-chloro-4-[(2S,3S)-2-(cyclopropylmethyl)-3-hydroxy-5-oxopyrrolidin-1-yl]benzonitrile



To a mixture of 2-chloro-4-[2-(cyclopropylmethyl)-3-hydroxy-5-oxo-2,5-dihydro-1H-pyrrol-1-yl]benzonitrile (400 mg)
15 and acetic acid (0.87 mL) in acetonitrile (10 mL) was added sodium borohydride (131 mg) at 0°C in small portions. The mixture was warmed to room temperature and stirred for 1 hr. Water was added, and the mixture was extracted with ethyl
20 acetate. The organic layer was washed with saturated brine, and dried over magnesium sulfate, and the solvent was evaporated under reduced pressure. The obtained residue was purified by basic silica gel column chromatography (eluent: hexane:ethyl acetate=4:1 → ethyl acetate), and recrystallized from
25 tetrahydrofuran-hexane to give the title compound as colorless crystals (yield: 310 mg, 77%).

$^1\text{H-NMR}$ (CDCl_3) δ : 0.06–0.16 (2H, m), 0.46–0.56 (2H, m), 0.66–0.79 (1H, m), 1.41–1.52 (1H, m), 1.74–1.87 (1H, m), 1.96 (1H, d, $J=4.7\text{Hz}$), 2.68–

2.91 (2H,m), 4.31-4.39 (1H,m), 4.71-4.80 (1H,m),
7.45 (1H,dd,J=8.7,2.1Hz), 7.63-7.69 (2H,m).

mp:137-139°C.

Experimental Example 1 AR binding inhibitory test

5 To a solution containing a wild-type androgen receptor (AR) were added radiolabel mibolerone (3 nM) and a compound (100 nM), and the mixture was incubated at 4°C for 3 hr. B (Bound)/F (Free) were separated by the dextran/charcoal method. The label count of B was measured, and the inhibitory rate of the compound
10 was calculated. The results are shown in Table 1.

Table 1

Compound Example No.	Inhibitory rate (%) at 100 nM
8	90
17	90
40	90
41	96
55	99
59	94
74	97
75	95

Experimental Example 2 Compound evaluation in reporter assay system using Cos-7 cell

Cos-7 (5,000,000 cells) were sown in a 150 cm² flask, and
15 cultured in a culture medium (DMEM medium containing 10% Dextran Charcoal (DCC)-Fetal Bovine Serum (FBS), 2 mM glutamine) for 24 hr. Vector DNA containing AR gene, and vector DNA containing luciferase gene bound at the downstream of an androgen responsive promoter derived from MMTV (Mouse Mammary Tumor
20 Virus) were co-transfected by a liposome method. After culturing for 4 hr, the cells were harvested, and 10,000 cells were plated in a 96 well plate and cultured for 2 hr. 5 α -Dihydrotestosterone (1 μ M) or a compound (100 nM) was added, and the cells were further cultured for 24 hr, after which the
25 luciferase activity was measured. The induction rate by the compound was calculated with the luciferase activity induced by the addition of 5 α -dihydrotestosterone (1 μ M) as 100. The results are shown in Table 2.

Table 2

Compound Example No.	Induction rate (%) at 100 nM
8	106
17	23
40	40
41	81
55	80
59	67
74	79
75	69

Formulation Example 1 Injection containing compound of Example 1

- (1) compound of Example 1 5.0 mg
 5 (2) sodium chloride 20.0 mg
 (3) distilled water amount to make total 2 ml

The compound (5.0 mg) of Example 1 and sodium chloride (20.0 mg) were dissolved in distilled water, and water was added to the total amount of 2.0 ml. The solution was filtered, and
 10 aseptically filled in an ampule (2 ml). The ampule is sterilized and tightly sealed to give a solution for injection.

Industrial Applicability

The compound of the present invention has a superior
 15 action as an androgen receptor modulator (particularly agonist), and is useful for the prophylaxis or treatment of hypogonadism, male climacteric disorder, frailty, cachexia, osteoporosis and the like, for which administration of androgen receptor modulator (particularly agonist) is effective.

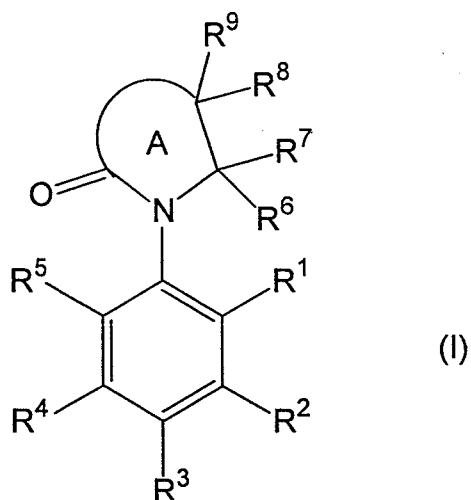
20 This application is based on patent application Nos. 2007-205966 and 2007-299658 filed in Japan, the contents of which are incorporated in full herein by this reference.

Although the present invention have been presented or described by referring to preferred embodiments of this
 25 invention, it will, however, be understood by those of ordinary skill in the art that various modifications may be made to the forms and details without departing from the scope of the invention as set forth in the appended claims. All patents,

patent publications and other publications indicated or cited in the Specification are hereby incorporated in their entireties by reference.

CLAIMS

1. A compound represented by the formula (I)



5 wherein

R¹ is a hydrogen atom, a halogen atom or a lower alkyl group optionally having substituent(s) selected from the group consisting of

- (i) a halogen atom,
- 10 (ii) C₁₋₆ alkoxy,
- (iii) C₂₋₆ alkenyl,
- (iv) C₂₋₆ alkynyl,
- (v) amino,
- (vi) mono-C₁₋₆ alkylamino,
- 15 (vii) di-C₁₋₆ alkylamino,
- (viii) mono-C₁₋₆ alkyl-carbonylamino,
- (ix) di(C₁₋₆ alkyl-carbonyl)amino,
- (x) hydroxy,
- (xi) cyano,
- 20 (xii) amidino,
- (xiii) carboxyl,
- (xiv) C₁₋₆ alkoxy-carbonyl,
- (xv) carbamoyl,
- (xvi) mono-C₁₋₆ alkyl-carbamoyl,
- 25 (xvii) di-C₁₋₆ alkyl-carbamoyl,
- (xviii) cyclic aminocarbonyl,

- (xix) ureido,
 - (xx) C₁₋₆ alkyl-ureido, and
 - (xxi) C₃₋₆ cycloalkyl;
- R² is (1) a halogen atom,
- 5 (2) a lower alkyl group optionally having substituent(s) selected from the group consisting of
- (i) a halogen atom,
 - (ii) C₁₋₆ alkoxy,
 - (iii) C₂₋₆ alkenyl,
 - 10 (iv) C₂₋₆ alkynyl,
 - (v) amino,
 - (vi) mono-C₁₋₆ alkylamino,
 - (vii) di-C₁₋₆ alkylamino,
 - (viii) mono-C₁₋₆ alkyl-carbonylamino,
 - 15 (ix) di(C₁₋₆ alkyl-carbonyl)amino,
 - (x) hydroxy,
 - (xi) cyano,
 - (xii) amidino,
 - (xiii) carboxyl,
 - 20 (xiv) C₁₋₆ alkoxy-carbonyl,
 - (xv) carbamoyl,
 - (xvi) mono-C₁₋₆ alkyl-carbamoyl,
 - (xvii) di-C₁₋₆ alkyl-carbamoyl,
 - (xviii) cyclic aminocarbonyl,
 - 25 (xix) ureido,
 - (xx) C₁₋₆ alkyl-ureido, and
 - (xxi) C₃₋₆ cycloalkyl, or
- (3) a lower alkoxy group optionally having halogen atom(s);
- R³ is a cyano group;
- 30 R⁴ is a hydrogen atom or a halogen atom;
- R⁵ is a hydrogen atom;
- R⁶ is a hydrogen atom;
- R⁷ is (1) a lower alkyl group optionally having substituent(s) selected from the group consisting of
- 35 (i) a halogen atom,

- (ii) C₁₋₆ alkoxy,
- (iii) C₂₋₆ alkenyl,
- (iv) C₂₋₆ alkynyl,
- (v) amino,
- 5 (vi) mono-C₁₋₆ alkylamino,
- (vii) di-C₁₋₆ alkylamino,
- (viii) mono-C₁₋₆ alkyl-carbonylamino,
- (ix) di(C₁₋₆ alkyl-carbonyl)amino,
- (x) hydroxy,
- 10 (xi) cyano,
- (xii) amidino,
- (xiii) carboxyl,
- (xiv) C₁₋₆ alkoxy-carbonyl,
- (xv) carbamoyl,
- 15 (xvi) mono-C₁₋₆ alkyl-carbamoyl,
- (xvii) di-C₁₋₆ alkyl-carbamoyl,
- (xviii) cyclic aminocarbonyl,
- (xix) ureido,
- (xx) C₁₋₆ alkyl-ureido, and
- 20 (xxi) C₃₋₆ cycloalkyl, or
- (2) an aralkyl group optionally having substituent(s) selected from the group consisting of
- (i) a halogen atom,
- (ii) C₁₋₆ alkoxy,
- 25 (iii) C₂₋₆ alkenyl,
- (iv) C₂₋₆ alkynyl,
- (v) amino,
- (vi) mono-C₁₋₆ alkylamino,
- (vii) di-C₁₋₆ alkylamino,
- 30 (viii) mono-C₁₋₆ alkyl-carbonylamino,
- (ix) di(C₁₋₆ alkyl-carbonyl)amino,
- (x) hydroxy,
- (xi) cyano,
- (xii) amidino,
- 35 (xiii) carboxyl,

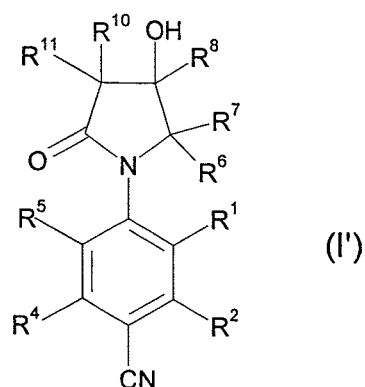
- (xiv) C₁₋₆ alkoxy-carbonyl,
- (xv) carbamoyl,
- (xvi) mono-C₁₋₆ alkyl-carbamoyl,
- (xvii) di-C₁₋₆ alkyl-carbamoyl,
- 5 (xviii) cyclic aminocarbonyl,
- (xix) ureido,
- (xx) C₁₋₆ alkyl-ureido,
- (xxi) C₃₋₆ cycloalkyl, and
- (xxii) lower alkyl;
- 10 R⁸ is (1) a hydrogen atom,
- (2) a lower alkyl group optionally having substituent(s) selected from the group consisting of
- (i) a halogen atom,
- (ii) C₁₋₆ alkoxy,
- 15 (iii) C₂₋₆ alkenyl,
- (iv) C₂₋₆ alkynyl,
- (v) amino,
- (vi) mono-C₁₋₆ alkylamino,
- (vii) di-C₁₋₆ alkylamino,
- 20 (viii) mono-C₁₋₆ alkyl-carbonylamino,
- (ix) di(C₁₋₆ alkyl-carbonyl)amino,
- (x) hydroxy,
- (xi) cyano,
- (xii) amidino,
- 25 (xiii) carboxyl,
- (xiv) C₁₋₆ alkoxy-carbonyl,
- (xv) carbamoyl,
- (xvi) mono-C₁₋₆ alkyl-carbamoyl,
- (xvii) di-C₁₋₆ alkyl-carbamoyl,
- 30 (xviii) cyclic aminocarbonyl,
- (xix) ureido,
- (xx) C₁₋₆ alkyl-ureido, and
- (xxi) C₃₋₆ cycloalkyl, or
- (3) a C₃₋₆ cycloalkyl group optionally having substituent(s)
- 35 selected from the group consisting of

- (i) a halogen atom,
- (ii) C₁₋₆ alkoxy,
- (iii) C₂₋₆ alkenyl,
- (iv) C₂₋₆ alkynyl,
- 5 (v) amino,
- (vi) mono-C₁₋₆ alkylamino,
- (vii) di-C₁₋₆ alkylamino,
- (viii) mono-C₁₋₆ alkyl-carbonylamino,
- (ix) di(C₁₋₆ alkyl-carbonyl)amino,
- 10 (x) hydroxy,
- (xi) cyano,
- (xii) amidino,
- (xiii) carboxyl,
- (xiv) C₁₋₆ alkoxy-carbonyl,
- 15 (xv) carbamoyl,
- (xvi) mono-C₁₋₆ alkyl-carbamoyl,
- (xvii) di-C₁₋₆ alkyl-carbamoyl,
- (xviii) cyclic aminocarbonyl,
- (xix) ureido,
- 20 (xx) C₁₋₆ alkyl-ureido,
- (xxi) C₃₋₆ cycloalkyl, and
- (xxii) lower alkyl;

R⁹ is a hydroxy group; and

Ring A is a pyrrolidine ring which optionally has 1 or 2
25 substituents selected from a halogen atom, a lower alkyl group optionally having a hydroxy group, a lower alkenyl group and an aralkyl group, or a pyrrolidine ring forming a spiro bond with C₃₋₆ cycloalkane, or a salt thereof.

30 2. The compound of claim 1, wherein the formula (I) is the formula (I')



wherein

R¹ is a hydrogen atom, a halogen atom or a lower alkyl group optionally having substituent(s) selected from the group

5 consisting of

(i) a halogen atom,

(ii) C₁₋₆ alkoxy,

(iii) C₂₋₆ alkenyl,

(iv) C₂₋₆ alkynyl,

10 (v) amino,

(vi) mono-C₁₋₆ alkylamino,

(vii) di-C₁₋₆ alkylamino,

(viii) mono-C₁₋₆ alkyl-carbonylamino,

(ix) di(C₁₋₆ alkyl-carbonyl)amino,

15 (x) hydroxy,

(xi) cyano,

(xii) amidino,

(xiii) carboxyl,

(xiv) C₁₋₆ alkoxy-carbonyl,

20 (xv) carbamoyl,

(xvi) mono-C₁₋₆ alkyl-carbamoyl,

(xvii) di-C₁₋₆ alkyl-carbamoyl,

(xviii) cyclic aminocarbonyl,

(xix) ureido,

25 (xx) C₁₋₆ alkyl-ureido, and

(xxi) C₃₋₆ cycloalkyl;

R^2 is a halogen atom, a lower alkyl group optionally having
 halogen atom(s) or a lower alkoxy group optionally having
 halogen atom(s);
 R^4 is a hydrogen atom or a halogen atom;
 5 R^5 and R^6 are each a hydrogen atom;
 R^7 is (1) a lower alkyl group optionally having substituent(s)
 selected from the group consisting of
 (i) a halogen atom,
 (ii) C_{1-6} alkoxy,
 10 (iii) C_{2-6} alkenyl,
 (iv) C_{2-6} alkynyl,
 (v) amino,
 (vi) mono- C_{1-6} alkylamino,
 (vii) di- C_{1-6} alkylamino,
 15 (viii) mono- C_{1-6} alkyl-carbonylamino,
 (ix) di(C_{1-6} alkyl-carbonyl)amino,
 (x) hydroxy,
 (xi) cyano,
 (xii) amidino,
 20 (xiii) carboxyl,
 (xiv) C_{1-6} alkoxy-carbonyl,
 (xv) carbamoyl,
 (xvi) mono- C_{1-6} alkyl-carbamoyl,
 (xvii) di- C_{1-6} alkyl-carbamoyl,
 25 (xviii) cyclic aminocarbonyl,
 (xix) ureido,
 (xx) C_{1-6} alkyl-ureido, and
 (xxi) C_{3-6} cycloalkyl, or
 (2) an aralkyl group optionally having substituent(s) selected
 30 from the group consisting of
 (i) a halogen atom,
 (ii) C_{1-6} alkoxy,
 (iii) C_{2-6} alkenyl,
 (iv) C_{2-6} alkynyl,
 35 (v) amino,

- (vi) mono-C₁₋₆ alkylamino,
 - (vii) di-C₁₋₆ alkylamino,
 - (viii) mono-C₁₋₆ alkyl-carbonylamino,
 - (ix) di(C₁₋₆ alkyl-carbonyl)amino,
 - 5 (x) hydroxy,
 - (xi) cyano,
 - (xii) amidino,
 - (xiii) carboxyl,
 - (xiv) C₁₋₆ alkoxy-carbonyl,
 - 10 (xv) carbamoyl,
 - (xvi) mono-C₁₋₆ alkyl-carbamoyl,
 - (xvii) di-C₁₋₆ alkyl-carbamoyl,
 - (xviii) cyclic aminocarbonyl,
 - (xix) ureido,
 - 15 (xx) C₁₋₆ alkyl-ureido,
 - (xxi) C₃₋₆ cycloalkyl, and
 - (xxii) lower alkyl;
- R⁸ is (1) a hydrogen atom,
- (2) a lower alkyl group optionally having substituent(s)
- 20 selected from the group consisting of
- (i) a halogen atom,
 - (ii) C₁₋₆ alkoxy,
 - (iii) C₂₋₆ alkenyl,
 - (iv) C₂₋₆ alkynyl,
 - 25 (v) amino,
 - (vi) mono-C₁₋₆ alkylamino,
 - (vii) di-C₁₋₆ alkylamino,
 - (viii) mono-C₁₋₆ alkyl-carbonylamino,
 - (ix) di(C₁₋₆ alkyl-carbonyl)amino,
 - 30 (x) hydroxy,
 - (xi) cyano,
 - (xii) amidino,
 - (xiii) carboxyl,
 - (xiv) C₁₋₆ alkoxy-carbonyl,
 - 35 (xv) carbamoyl,

- (xvi) mono-C₁₋₆ alkyl-carbamoyl,
- (xvii) di-C₁₋₆ alkyl-carbamoyl,
- (xviii) cyclic aminocarbonyl,
- (xix) ureido,
- 5 (xx) C₁₋₆ alkyl-ureido, and
- (xxi) C₃₋₆ cycloalkyl, or
- (3) a C₃₋₆ cycloalkyl group optionally having substituent(s) selected from the group consisting of
- (i) a halogen atom,
- 10 (ii) C₁₋₆ alkoxy,
- (iii) C₂₋₆ alkenyl,
- (iv) C₂₋₆ alkynyl,
- (v) amino,
- (vi) mono-C₁₋₆ alkylamino,
- 15 (vii) di-C₁₋₆ alkylamino,
- (viii) mono-C₁₋₆ alkyl-carbonylamino,
- (ix) di(C₁₋₆ alkyl-carbonyl)amino,
- (x) hydroxy,
- (xi) cyano,
- 20 (xii) amidino,
- (xiii) carboxyl,
- (xiv) C₁₋₆ alkoxy-carbonyl,
- (xv) carbamoyl,
- (xvi) mono-C₁₋₆ alkyl-carbamoyl,
- 25 (xvii) di-C₁₋₆ alkyl-carbamoyl,
- (xviii) cyclic aminocarbonyl,
- (xix) ureido,
- (xx) C₁₋₆ alkyl-ureido,
- (xxi) C₃₋₆ cycloalkyl, and
- 30 (xxii) lower alkyl; and

R¹⁰ and R¹¹ are the same or different and each is a hydrogen atom, a halogen atom, a lower alkyl group optionally having a hydroxy group, a lower alkenyl group or an aralkyl group; in this case, R¹⁰ and R¹¹ may form C₃₋₆ cycloalkane together with

35 the adjacent carbon atom.

3. The compound of claim 2, wherein R¹ is a hydrogen atom, a halogen atom or a lower alkyl group;
R² is a halogen atom, a lower alkyl group optionally having
5 halogen atom(s) or a lower alkoxy group optionally having halogen atom(s);
R⁷ is a lower alkyl group optionally having substituent(s) selected from a hydroxy group, a lower alkoxy group and a C₃₋₆ cycloalkyl group, or an aralkyl group optionally having
10 substituent(s) selected from a halogen atom and a cyano group;
R⁸ is a hydrogen atom, a lower alkyl group or a C₃₋₆ cycloalkyl group; and
R¹⁰ and R¹¹ are the same or different and each is a hydrogen atom, a halogen atom, a lower alkyl group, a lower alkenyl group, an
15 aralkyl group, or a lower alkyl group substituted by a hydroxyl group (in this case, R¹⁰ and R¹¹ optionally form cyclopropane together with the adjacent carbon atom).

4. The compound of claim 1, which is 4-[(2S,3S)-2-ethyl-3-hydroxy-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile,
20 or a salt thereof.

5. The compound of claim 1, which is 2-Chloro-4-[(4S,5S)-4-hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile, or a salt
25 thereof.

6. The compound of claim 1, which is 4-[(4R,5S)-5-ethyl-3,3-difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]-2-methoxybenzonitrile, or a salt thereof.

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7. The compound of claim 1, which is 2-Chloro-4-[(2S,3S,4S)-2-ethyl-3-hydroxy-4-methyl-5-oxopyrrolidin-1-yl]benzonitrile, or a salt thereof.

35 8. The compound of claim 1, which is 2-Chloro-4-[(4R,5S)-5-

ethyl-3,3-difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]benzonitrile,
or a salt thereof.

9. The compound of claim 1, which is 4-[(2S,3S)-2-ethyl-3-
5 hydroxy-5-oxopyrrolidin-1-yl]-2-(trifluoromethyl)benzonitrile.

10. The compound of claim 1, which is 2-Chloro-4-[(4S,5S)-4-
hydroxy-5-methyl-2-oxopyrrolidin-1-yl]benzonitrile.

10 11. The compound of claim 1, which is 4-[(4R,5S)-5-ethyl-3,3-
difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]-2-methoxybenzonitrile.

12. The compound of claim 1, which is 2-Chloro-4-[(2S,3S,4S)-2-
ethyl-3-hydroxy-4-methyl-5-oxopyrrolidin-1-yl]benzonitrile.

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13. The compound of claim 1, which is 2-Chloro-4-[(4R,5S)-5-
ethyl-3,3-difluoro-4-hydroxy-2-oxopyrrolidin-1-yl]benzonitrile.

14. A prodrug of the compound of claim 1.

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15. A pharmaceutical agent comprising the compound of claim 1 or
a prodrug thereof.

16. The pharmaceutical agent of claim 15, which is an androgen
25 receptor modulator.

17. The pharmaceutical agent of claim 15, which is an androgen
receptor agonist.

30 18. The pharmaceutical agent of claim 15, which is a tissue-
selective androgen receptor modulator.

19. The pharmaceutical agent of claim 15, which is an agent for
the prophylaxis or treatment of hypogonadism, male climacteric
35 disorder, frailty, cachexia or osteoporosis.

20. The pharmaceutical agent of claim 15, which is a frailty suppressant, a muscle strength enhancer, a muscle increasing agent, a cachexia suppressant, a body weight decrease
5 suppressant, an agent for the prophylaxis or treatment of prostate hypertrophy, amyotrophy or muscle loss caused by a disease or an agent for reducing the prostate weight.

21. Use of the compound of claim 1 or a prodrug thereof for the
10 production of an agent for the prophylaxis or treatment of hypogonadism, male climacteric disorder, frailty, cachexia or osteoporosis.