DESCRIPTION

Title of Invention: PYRIMIDINE COMPOUND OR SALT THEREOF

Technical Field

[0001]

The present invention relates to a novel pyrimidine compound having HER2 inhibitory activity, or a salt thereof, and a pharmaceutical composition comprising the same as an active ingredient.

Background Art

[0002]

HER2 (which is also referred to as "ErbB2") is receptor tyrosine kinase belonging to the ErbB family.

HER2 is considered to be a proto-oncogene. It has been reported that HER2 gene amplification, overexpression, mutation and the like occur in various types of cancers. From non-clinical and clinical research data, it is considered that activation of HER2 and downstream signals plays an important role in the survival and/or proliferation, etc. of cancer cells associated with the genetic abnormality, overexpression and the like of HER2 (Non Patent Literature 1).

Accordingly, an inhibitor capable of regulating the kinase activity of HER2 is assumed to inhibit HER2 and downstream signals in cancer cells having HER2 gene amplification, overexpression or mutation, so as to exhibit antitumor effects on the cancer cells. Therefore, such an inhibitor is considered to be useful for the treatment, life-prolonging, or QOL improvement of cancer patients.

[0003]

It has been reported that brain metastasis occurs in approximately 25% to 40% of lung cancer cases, in approximately 15% to 30% of breast cancer cases, and in certain percentages of other multiple cancer cases (Non Patent Literatures 2 and 3). As a matter of fact, it has been reported that brain metastasis occurs in approximately 20% to 30% of HER2-positive breast cancer cases (Non Patent Literature 4).

[0004]

Compounds having HER2 inhibitory activity, such as Lapatinib and Neratinib, have been approved as therapeutic agents against HER2-positive breast cancer. However, it has been reported that since all of these therapeutic agents are substrates of p-gp or Bcrp, the brain penetration properties of these agents are limited in non-clinical

tests (Non Patent Literature 5). In fact, in clinical tests using Lapatinib or Neratinib, sufficient effects of these agents could not be obtained against brain metastatic cancer (Non Patent Literatures 6, 7, 8, and 9).

From the viewpoint of the control of pathological conditions including brain metastasis nidus, it has been desired to develop a HER2 inhibitor having inhibitory activity against HER2 and also having brain penetration properties.

[0005]

One of HER2 mutations, HER2ex20ins mutation has been reported to be an activating mutation in lung cancer, etc. (Non Patent Literature 10), and regarding such HER2ex20ins mutation, multiple clinical trials have been carried out. However, under the current circumstances, a therapeutic method therefor has not yet been established. Therefore, it has been desired to develop a HER2 inhibitor having inhibitory activity against HER2ex20ins mutation.

Citation List

Patent Literature

[0006]

Patent Literature 1: International Publication No. WO 2017/146116
Patent Literature 2: International Publication No. WO 2017/038838

Non Patent Literature

[0007]

Non Patent Literature 1: Cancer Treatment Reviews, 40, pp. 770-780 (2014)
Non Patent Literature 2: Current Oncology, 25, pp. S103-S114 (2018)
Non Patent Literature 3: Breast Cancer Research, 18(1), 8, pp. 1-9 (2016)
Non Patent Literature 4: Journal of Clinical Oncology, 28, pp. 3271-3277 (2010)
Non Patent Literature 5: Journal of Medicinal Chemistry, 59, pp. 10030-10066 (2016)
Non Patent Literature 6: Journal of Medicinal Chemistry, 26, pp. 2999-3005 (2008)
Non Patent Literature 7: Journal of Clinical Oncology, 26, pp. 1993-1999 (2008)
Non Patent Literature 8: Journal of Clinical Oncology, 28, pp. 1301-1307 (2010)
Non Patent Literature 9: Journal of Clinical Oncology, 34, pp. 945-952 (2016)
Non Patent Literature 10: Proc Natl Acad Sci USA., 106, pp. 474-479 (2009)

Summary of Invention

[0008]

It is an object of the present invention to provide a novel pyrimidine compound

that inhibits HER2 activity and exhibits brain penetration properties, or a salt thereof, and a pharmaceutical composition comprising the same.

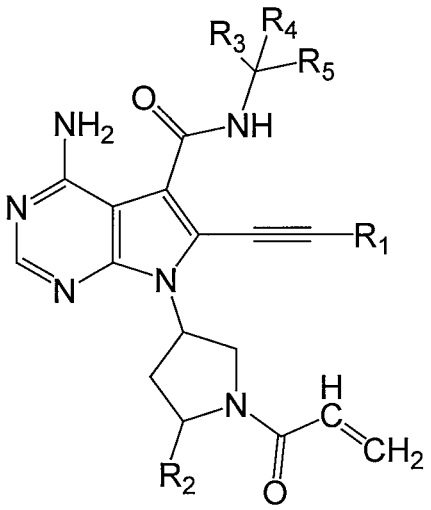
[0009]

As a result of intensive studies, the present inventors have found a novel compound represented by the following formula (I) having pyrimidine as a basic skeleton. This is a novel compound characterized in that it has a structure, in which pyrrolo[2,3-d]pyrimidine is a basic skeleton, the position 5 thereof is substituted with carboxamide, the position 6 thereof is substituted with alkyne, and further a pyrrolidine group substituted with acrylamide is present at the position 7 thereof.

[0010]

Specifically, one embodiment of the present invention provides the following [1] to [25]:

[1] A compound represented by the following formula (I), or a salt thereof:



(I)

wherein R_1 represents a C1-C4 alkyl group optionally having a C1-C4 alkoxy group as a substituent, or a C3-C4 cycloalkyl group;

R_2 represents a hydrogen atom, a halogen atom, a C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups or fluorine atoms each as a substituent(s), or a C1-C6 alkoxy group;

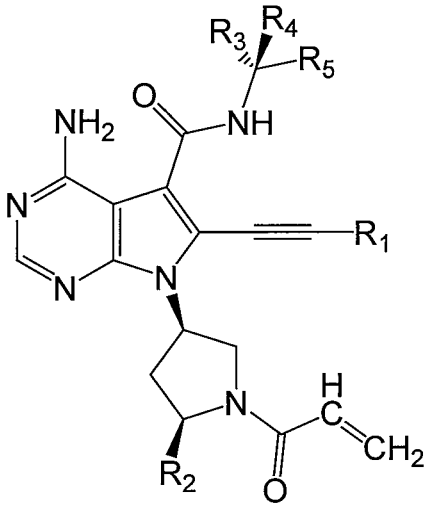
R_3 represents a hydrogen atom, or a C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s);

R_4 represents a hydrogen atom or a C1-C4 alkyl group; and

R_5 represents a phenyl group optionally having 1 to 3 substituents selected from fluorine atoms and chlorine atoms.

[2] The compound according to the above [1] represented by the following formula

(II), or a salt thereof:



(II)

wherein R_1 represents a C1-C4 alkyl group optionally having a C1-C4 alkoxy group as a substituent, or a C3-C4 cycloalkyl group;

R_2 represents a hydrogen atom, a halogen atom, a C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups or fluorine atoms each as a substituent(s), or a C1-C6 alkoxy group;

R_3 represents a hydrogen atom, or a C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s);

R_4 represents a hydrogen atom or a C1-C4 alkyl group; and

R_5 represents a phenyl group optionally having 1 to 3 substituents selected from fluorine atoms and chlorine atoms.

[3] The compound according to the above [1] or [2], or a salt thereof, wherein R_2 is a C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups as a substituent(s).

[4] The compound according to any one of the above [1] to [3], or a salt thereof, wherein R_3 is a C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s).

[5] The compound according to any one of the above [1] to [4], or a salt thereof, wherein R_5 is a phenyl group optionally having 1 or 2 substituents selected from the group consisting of fluorine atoms and chlorine atoms.

[6] The compound according to any one of the above [1] to [5], or a salt thereof, wherein R_1 is a methyl group, a tert-butyl group, or a cyclopropyl group.

[7] The compound according to any one of the above [1] to [6], or a salt thereof, wherein R_2 is a methyl group, an ethyl group, a methoxymethyl group, or an ethoxymethyl group.

[8] The compound according to any one of the above [1] to [7], or a salt thereof, wherein R_3 is a methyl group.

[9] The compound according to any one of the above [1] to [8], or a salt thereof, wherein R_4 is a hydrogen atom.

[10] The compound according to any one of the above [1] to [9], or a salt thereof, wherein R_5 is a phenyl group.

[11] The compound according to any one of the above [1] to [10], or a salt thereof, wherein the compound is selected from the following (1) to (3):

(1) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-phenylethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,

(2) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide, and

(3) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(3,3-dimethylbut-1-yn-1-yl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide.

[12] A pharmaceutical composition comprising the compound according to any one of the above [1] to [11] or a salt thereof.

[13] An antitumor agent comprising, as an active ingredient, the compound according to any one of the above [1] to [11] or a salt thereof.

[14] An antitumor agent for oral administration, comprising, as an active ingredient, the compound according to any one of the above [1] to [11] or a salt thereof.

[15] Use of the compound according to any one of the above [1] to [11] or a salt thereof for the production of a pharmaceutical composition.

[16] Use of the compound according to any one of the above [1] to [11] or a salt thereof for the production of an antitumor agent.

[17] Use of the compound according to any one of the above [1] to [11] or a salt thereof for the production of an antitumor agent for oral administration.

[18] The compound according to any one of the above [1] to [11] or a salt thereof, for use as a medicament.

[19] The compound according to any one of the above [1] to [11] or a salt thereof, for use in the prevention and/or treatment of tumor.

[20] The compound according to any one of the above [1] to [11] or a salt thereof, for use in the prevention and/or treatment of tumor by oral administration thereof.

[21] A method for preventing and/or treating tumor, comprising administering an effective amount of the compound according to any one of the above [1] to [12] or a salt thereof to a subject in need thereof.

[22] The compound according to any one of the above [1] to [11] or a salt thereof, for

use in the prevention and/or treatment of primary brain tumor or metastatic brain tumor (e.g., brain metastasis of lung cancer, breast cancer, stomach cancer, colorectal cancer, bladder cancer, biliary tract cancer, uterine cancer, esophageal cancer, head and neck cancer, etc.).

[23] Use of the compound according to any one of the above [1] to [11] or a salt thereof for the production of a pharmaceutical composition used in the prevention and/or treatment of primary brain tumor or metastatic brain tumor (e.g., brain metastasis of lung cancer, breast cancer, stomach cancer, colorectal cancer, bladder cancer, biliary tract cancer, uterine cancer, esophageal cancer, head and neck cancer, etc.).

[24] The compound according to any one of the above [1] to [11] or a salt thereof, for use as a medicament in the prevention or treatment of primary brain tumor or metastatic brain tumor (e.g., brain metastasis of lung cancer, breast cancer, stomach cancer, colorectal cancer, bladder cancer, biliary tract cancer, uterine cancer, esophageal cancer, head and neck cancer, etc.)..

[25] A method for preventing and/or treating primary brain tumor or metastatic brain tumor (e.g., brain metastasis of lung cancer, breast cancer, stomach cancer, colorectal cancer, bladder cancer, biliary tract cancer, uterine cancer, esophageal cancer, head and neck cancer, etc.), wherein the method comprises administering an effective amount of the compound according to any one of the above [1] to [11] or a salt thereof to a subject in need thereof.

[0011]

The present invention has the following one or more effects.

(1) According to the present invention, provided is a novel compound represented by the above formula (I) that is useful as a HER2 inhibitor having brain penetration properties, a salt thereof, a pharmaceutical composition, an antitumor agent, or an antitumor agent for oral administration.

(2) The compound of the present invention or a salt thereof has excellent HER2 selective inhibitory activity and exhibits growth inhibitory effect against cancer cell lines.

(3) The compound of the present invention or a salt thereof can be expected to have brain penetration properties.

(4) The compound of the present invention or a salt thereof can be expected not to have serious side effects but to have medicinal effects.

(5) The compound of the present invention or a salt thereof exhibits excellent inhibitory activity against mutant HER2 (e.g., HER2 having YVMA insertion mutation in exon 20).

(6) The compound of the present invention or a salt thereof is useful as a preventive

and/or therapeutic agent for tumor.

(7) The compound of the present invention or a salt thereof provides the novel compound represented by the above formula (I) that is useful for treating cancer patients, a salt thereof, a pharmaceutical composition, an antitumor agent, or an antitumor agent for oral administration.

Brief Description of Drawings

[0012]

[Figure 1] Figure 1 shows the antitumor effects of the compound of Example 2 against models involving direct brain transplantation of the Luciferase gene-introduced HER2 expressing cell line (NCI-N87-luc).

[Figure 2] Figure 2 shows the antitumor effects of the compound of Example 11 against models involving direct brain transplantation of the Luciferase gene-introduced HER2 expressing cell line (NCI-N87-luc).

[Figure 3] Figure 3 shows the antitumor effects of the compound of Example 12 against models involving direct brain transplantation of the Luciferase gene-introduced HER2 expressing cell line (NCI-N87-luc).

[Figure 4] Figure 4 shows the body weight reduction percentage of models involving direct brain transplantation of the Luciferase gene-introduced HER2 expressing cell line (NCI-N87-luc) caused by the compound of Example 2.

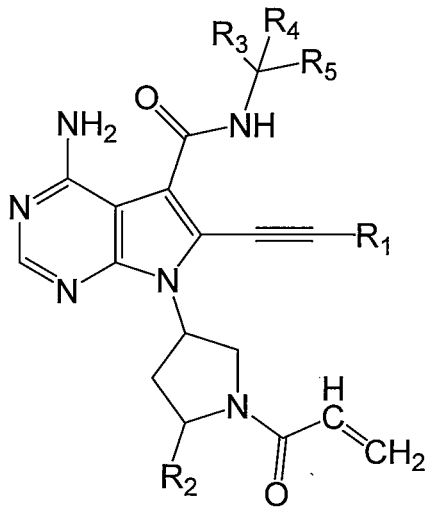
[Figure 5] Figure 5 shows the body weight reduction percentage of models involving direct brain transplantation of the Luciferase gene-introduced HER2 expressing cell line (NCI-N87-luc) caused by the compound of Example 11.

[Figure 6] Figure 6 shows the body weight reduction percentage of models involving direct brain transplantation of the Luciferase gene-introduced HER2 expressing cell line (NCI-N87-luc) caused by the compound of Example 12.

Description of Embodiments

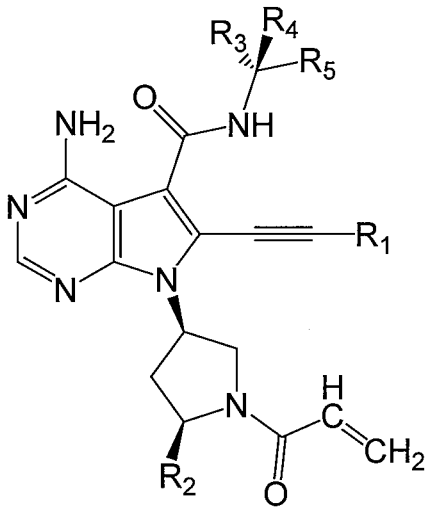
[0013]

One embodiment of the present invention relates to a compound represented by the following formula (I), or a salt thereof:



(I)

One preferred embodiment of the present invention relates to a compound represented by the following formula (II), or a salt thereof:



(II)

[0014]

The compound represented by the above formula (I) or formula (II) of the present invention is a compound having pyrrolo[2,3-d]pyrimidine as a basic structure, and this is a novel compound described in none of the aforementioned prior art publications, etc.

[0015]

In the present description, specific examples of the "halogen atom" may include a chlorine atom, a bromine atom, a fluorine atom, and an iodine atom. Among these, a chlorine atom and a fluorine atom are preferable, and a fluorine atom is more preferable.

[0016]

In the present description, the "alkyl group" means a linear or branched saturated

hydrocarbon group. Specific examples of the alkyl group may include a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, and a hexyl group. Among these, a linear or branched alkyl group containing 1 to 4 carbon atoms is preferable, and a methyl group and a tert-butyl group are more preferable.

[0017]

In the present description, the "haloalkyl group" means a linear or branched saturated hydrocarbon group, in which one to all hydrogen atoms are substituted with the above-described halogen atoms. Specific examples of the haloalkyl group may include a monofluoromethyl group, a difluoromethyl group, a trifluoromethyl group, a 1-fluoroethyl group, a 2-fluoroethyl group, a 1,1-difluoroethyl group, a 1,2-difluoroethyl group, a 2,2-difluoroethyl group, a 2,2,2-trifluoroethyl group, a monochloromethyl group, a dichloromethyl group, a trichloromethyl group, a 1-chloroethyl group, a 2-chloroethyl group, and a 1,1-dichloroethyl group. Among these, a linear or branched saturated hydrocarbon group containing 1 to 6 carbon atoms, in which 1 to 3 hydrogen atoms are substituted with the above-described halogen atoms, is preferable, and a monofluoromethyl group is more preferable.

[0018]

In the present description, the "cycloalkyl group" means a monocyclic or polycyclic saturated hydrocarbon group containing 3 to 7 carbon atoms. Specific examples of the cycloalkyl group may include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. Among these, a cyclopropyl group and a cyclobutyl group are preferable.

[0019]

In the present description, the "aromatic hydrocarbon group" means a cyclic substituent consisting of carbon and hydrogen, having an unsaturated bond, in which $4e + 2$ (wherein e represents an integer of 1 or greater) electrons are contained in the cyclic π electron system.

[0020]

In the present description, the "C6-C14 aromatic hydrocarbon group" means a monocyclic or polycyclic aromatic hydrocarbon group containing 6 to 14 carbon atoms. Specific examples of the C6-C14 aromatic hydrocarbon group may include a phenyl group, a naphthyl group, a tetrahydronaphthyl group, and an anthracenyl group. Among these, a phenyl group is preferable.

[0021]

In the present description, the "aralkyl group" means the above-described alkyl

group substituted with the above-described aromatic hydrocarbon group. Specific examples of the aralkyl group may include C7-C16 aralkyl groups such as a benzyl group, a phenylethyl group, a phenylpropyl group, a naphthylmethyl group, and a naphthylethyl group. Among these, a benzyl group is preferable.

[0022]

In the present description, the "unsaturated hydrocarbon group" means a linear or branched hydrocarbon group containing 2 to 6 carbon atoms, which comprises at least one carbon-carbon double bond or triple bond. Specific examples of the unsaturated hydrocarbon group may include a vinyl group, an allyl group, a methylvinyl group, a propenyl group, a butenyl group, a pentenyl group, a hexenyl group, an ethynyl group, and a 2-propynyl group. Among these, a vinyl group, an allyl group, and a 1-propenyl group are preferable.

[0023]

In the present description, the "alkenyl group" means a linear or branched hydrocarbon group containing 2 to 6 carbon atoms, which comprises at least one carbon-carbon double bond. Specific examples of the alkenyl group may include C2-C6 alkenyl groups, such as a vinyl group, an allyl group, a 2-methyl-2-propenyl group, an isopropenyl group, a 1-, 2- or 3-butenyl group, a 2-, 3- or 4-pentenyl group, a 2-methyl-2-butenyl group, a 3-methyl-2-butenyl group, and a 5-hexenyl group. Among these, a vinyl group, an allyl group, a 1-propenyl group, and a 2-methyl-2-propenyl group are preferable.

[0024]

In the present description, the "alkynyl group" means a linear or branched unsaturated hydrocarbon group having at least one triple bond (for example, 1 or 2, and preferably 1 triple bond). Specific examples of the alkynyl group may include C2-C6 alkynyl groups such as an ethynyl group, a 1- or 2-propynyl group, a 1-, 2- or 3-butynyl group, and a 1-methyl-2-propynyl group. Among these, an ethynyl group and a 2-propynyl group are preferable.

[0025]

In the present description, the "C3-C10 cyclic unsaturated hydrocarbon group" means a monocyclic or polycyclic hydrocarbon group containing 3 to 10 carbon atoms, which comprises at least one carbon-carbon double bond. Specific examples of the C3-C10 cyclic unsaturated hydrocarbon group may include a cyclopropenyl group, a cyclobutenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a cyclooctenyl group, and a cyclononyl group. Among these, a monocyclic or polycyclic hydrocarbon group containing 3 to 7 carbon atoms, which comprises at least

one carbon-carbon double bond, is preferable, and a cyclopropenyl group is more preferable.

[0026]

In the present description, the "alkoxy group" means an oxy group having the above-described alkyl group. Specific examples of the alkoxy group may include C1-C6 alkoxy groups such as a methoxy group, an ethoxy group, an n-propoxy group, an isopropoxy group, an n-butoxy group, an isobutoxy group, a sec-butoxy group, a tert-butoxy group, a pentyloxy group, an isopentyloxy group, and a hexyloxy group. Among these, a methoxy group and an ethoxy group are preferable, and a methoxy group is more preferable.

[0027]

In the present description, the "haloalkoxy group" may include the above-described alkoxy group having at least one halogen atom (preferably 1 to 13, and more preferably 1 to 3 halogen atoms). Specific examples of the haloalkoxy group may include C1-C6 haloalkoxy groups such as a fluoromethoxy group, a difluoromethoxy group, a trifluoromethoxy group, a trichloromethoxy group, a fluoroethoxy group, a 1,1,1-trifluoroethoxy group, a monofluoro-n-propoxy group, a perfluoro-n-propoxy group, and a perfluoro-isopropoxy group.

[0028]

In the present description, the "cycloalkoxy group" means an oxy group having the above-described cycloalkyl group. Specific examples of the cycloalkoxy group may include C3-C7 cycloalkoxy groups such as a cyclopropoxy group, a cyclobutoxy group, a cyclopentyloxy group, a cyclohexyloxy group, and a cycloheptyloxy group. Among these, a cyclobutoxy group, a cyclopentyloxy group, and a cyclohexyloxy group are preferable.

[0029]

In the present description, the "aralkyloxy group" means an oxy group having the above-described aralkyl group. Specific examples of the aralkyloxy group may include C7-C20 aralkyloxy groups such as a benzyloxy group, a phenethyloxy group, a naphthylmethyloxy group, and a fluorenylmethyloxy group. Among these, a benzyloxy group is preferable.

[0030]

In the present description, the "alkylthio group" means a thioxy group having the above-described alkyl group. Specific examples of the alkylthio group may include C1-C6 alkylthio groups such as a methylthio group, an ethylthio group, an n-propylthio group, an isopropylthio group, an n-butylthio group, an isobutylthio group, a tert-butylthio group,

an n-pentylthio group, an isopentylthio group, and a hexylthio group. Among these, a methylthio group, an ethylthio group, and an n-propylthio group are preferable.

[0031]

In the present description, the "alkoxyalkyl group" means the above-described alkyl group having at least one of the above-described alkoxy groups. Specific examples of the alkoxyalkyl group may include C1-C6 alkoxy-C1-C6 alkyl groups such as a methoxymethyl group, an ethoxyethyl group, a methoxyethyl group, and a methoxypropyl group.

[0032]

In the present description, the "alkylamino group" means an amino group in which 1 or 2 hydrogen atoms are substituted with a linear or branched hydrocarbon group(s) containing 1 to 6 carbon atoms. Specific examples of the alkylamino group may include a methylamino group, an ethylamino group, a dimethylamino group, a diethylamino group, and an ethylmethylamino group. Among these, preferable is an amino group in which 1 or 2 hydrogen atoms are substituted with a linear or branched hydrocarbon group containing 1 to 3 carbon atoms.

[0033]

In the present description, the "monoalkylamino group" means an amino group in which one hydrogen atom is substituted with a linear or branched hydrocarbon group. Specific examples of the monoalkylamino group may include a methylamino group, an ethylamino group, an n-propylamino group, an isopropylamino group, an n-butylamino group, an isobutylamino group, a sec-butylamino group, a tert-butylamino group, a pentylamino group, and a hexylamino group. Among these, preferable is an amino group in which one hydrogen atom is substituted with a linear or branched hydrocarbon group containing 1 to 3 carbon atoms.

[0034]

In the present description, the "dialkylamino group" means an amino group in which two hydrogen atoms are substituted with linear or branched hydrocarbon groups containing 1 to 6 carbon atoms. Specific examples of the dialkylamino group may include a dimethylamino group, a diethylamino group, and an ethylmethylamino group. Among these, an amino group in which two hydrogen atoms are substituted with linear or branched hydrocarbon groups containing 1 to 3 carbon atoms is preferable, and a dimethylamino group is more preferable.

[0035]

In the present description, the "acyl group" means a formyl group in which a hydrogen atom is substituted with a linear or branched hydrocarbon group. Specific

examples of the acyl group may include an acetyl group, an n-propanoyl group, an isopropanoyl group, an n-butyloyl group, and a tert-butyloyl group. Among these, a formyl group in which a hydrogen atom is substituted with a linear or branched hydrocarbon group containing 1 to 3 carbon atoms is preferable, and an acetyl group is more preferable.

[0036]

In the present description, the "acyloxy group" means an oxy group having the above-described acyl group. Specific examples of the acyloxy group may include an alkylcarbonyloxy group and an arylcarbonyloxy group. Among these, an oxy group in which a hydrogen atom of formyl group is substituted with a linear or branched hydrocarbon group containing 1 to 3 carbon atoms is preferable, and an alkylcarbonyloxy group is more preferable.

[0037]

In the present description, the "alkoxycarbonyl group" means a carbonyl group having the above-described alkoxy group. Specific examples of the alkoxycarbonyl group may include (C1-C6alkoxy)carbonyl groups such as a methoxycarbonyl group, an ethoxycarbonyl group, a propoxycarbonyl group, an isopropoxycarbonyl group, a butoxycarbonyl group, an isobutoxycarbonyl group, a tert-butoxycarbonyl group, a pentyloxycarbonyl group, an isopentyloxycarbonyl group, and a hexyloxycarbonyl group. Among these, a tert-butoxycarbonyl group is preferable.

[0038]

In the present description, the "aralkyloxycarbonyl group" means a carbonyl group having the above-described aralkyloxy. Specific examples of the aralkyloxycarbonyl group may include (C6-C20 aralkyl)oxycarbonyl groups such as a benzyloxycarbonyl group, a phenethyloxycarbonyl group, a naphthylmethyloxycarbonyl group, and a fluorenylmethyloxycarbonyl group. Among these, a benzyloxycarbonyl group is preferable.

[0039]

In the present description, the "saturated heterocyclic group" means a monocyclic or polycyclic saturated heterocyclic group having at least one heteroatom (preferably 1 to 5, and more preferably 1 to 3 heteroatoms) selected from nitrogen atoms, oxygen atoms, and sulfur atoms. Specific examples of the saturated heterocyclic group may include an aziridinyl group, an azetidinyl group, an imidazolidinyl group, a morpholino group, a pyrrolidinyl group, a piperidinyl group, a piperazinyl group, a tetrahydrofuranyl group, a tetrahydropyranyl group, a tetrahydrothiophenyl group, a thiazolidinyl group, and an oxazolidinyl group. Among these, an azetidinyl group, a

pyrrolidinyl group, and a piperidinyl group are preferable, and an azetidinyl group and a pyrrolidinyl group are more preferable.

[0040]

In the present description, the "unsaturated heterocyclic group" means a monocyclic or polycyclic completely unsaturated or partially unsaturated heterocyclic group having at least one heteroatom (preferably 1 to 5, and more preferably 1 to 3 heteroatoms) selected from nitrogen atoms, oxygen atoms, and sulfur atoms. Specific examples of the unsaturated heterocyclic group may include an imidazolyl group, a thienyl group, a pyrrolyl group, an oxazolyl group, an isoxazolyl group, a thiazolyl group, an isothiazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazolyl group, a triazolyl group, a tetrazolyl group, a pyridyl group, a pyrazyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a triazolopyridyl group, a benzimidazolyl group, a benzoxazolyl group, a benzothiazolyl group, a benzothienyl group, a furanyl group, a benzofuranyl group, a purinyl group, a quinolyl group, an isoquinolyl group, a quinazolinyl group, a quinoxalyl group, a methylenedioxyphenyl group, an ethylenedioxyphenyl group, and a dihydrobenzofuranyl group. Among these, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isoxazolyl group, and a furanyl group are preferable; an imidazolyl group, a pyrazolyl group, and a thiazolyl group are more preferable; and an imidazolyl group is most preferable.

[0041]

In the present description, the "saturated heterocyclic oxy group" means an oxy group having the above-described saturated heterocyclic group. Specific examples of the saturated heterocyclic oxy group may include a morpholinyloxy group, a 1-pyrrolidinyloxy group, a piperidinooxy group, a piperazinyloxy group, a 4-methyl-1-piperazinyloxy group, a tetrahydrofuranyloxy group, a tetrahydropyranyloxy group, a tetrahydrothiophenyloxy group, a thiazolidinyloxy group, and an oxazolidinyloxy group. Among these, a 1-pyrrolidinyloxy group, a piperidinooxy group, and a piperazinyloxy group are preferable.

[0042]

In the compound represented by the formula (I) or the formula (II) of the present invention, R_1 is a C1-C4 alkyl group optionally having a C1-C4 alkoxy group as a substituent, or a C3-C4 cycloalkyl group.

[0043]

The "C1-C4 alkoxy group" in the "C1-C4 alkyl group optionally having a C1-C4 alkoxy group as a substituent" represented by R_1 is preferably a methoxy group or an

ethoxy group, and most preferably a methoxy group. Herein, the number of substituents is preferably 1 to 3, and most preferably 1. When the C1-C4 alkyl group has two or more substituents, the substituents may be identical to or different from each other.

[0044]

The "C1-C4 alkyl group" in the "C1-C4 alkyl group optionally having a C1-C4 alkoxy group as a substituent" represented by R_1 is preferably a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group, more preferably a methyl group, an ethyl group, an isopropyl group, or a tert-butyl group, and most preferably a methyl group or a tert-butyl group.

[0045]

The "C1-C4 alkyl group optionally having a C1-C4 alkoxy group as a substituent" represented by R_1 is preferably a C1-C4 alkyl group having 1 to 3 methoxy groups as substituents, more preferably a methyl group, an ethyl group, an isopropyl group, a tert-butyl group, or a 1-methyl-1-methoxyethyl group, and most preferably a methyl group or a tert-butyl group.

[0046]

The "C3-C4 cycloalkyl group" represented by R_1 is preferably a cyclopropyl group or a cyclobutyl group, and most preferably a cyclopropyl group.

[0047]

R_1 is preferably a C1-C4 alkyl group optionally having 1 to 3 C1-C4 alkoxy groups as substituents, or a C3-C4 cycloalkyl group.

[0048]

R_1 is more preferably a C1-C4 alkyl group optionally having 1 to 3 methoxy groups as substituents, or a C3-C4 cycloalkyl group.

[0049]

R_1 is further preferably a methyl group, an ethyl group, an isopropyl group, a tert-butyl group, a 1-methyl-1-methoxyethyl group, or a cyclopropyl group.

[0050]

R_1 is most preferably a methyl group, a tert-butyl group, or a cyclopropyl group.

[0051]

In the compound represented by the formula (I) or the formula (II) of the present invention, R_2 is a hydrogen atom, a halogen atom, a C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups or fluorine atoms each as a substituent(s), or a C1-C6 alkoxy group.

[0052]

The "halogen atom" represented by R_2 is preferably a fluorine atom or a chlorine

atom.

[0053]

The "C1-C4 alkoxy group" in the "C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups or fluorine atoms each as a substituent(s)" represented by R_2 is preferably a methoxy group or an ethoxy group, and most preferably a methoxy group.

[0054]

The "C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups or fluorine atoms each as a substituent(s)" represented by R_2 is preferably a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group, and most preferably a methyl group.

[0055]

The "C1-C6 alkyl group" in the "C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups or fluorine atoms each as a substituent(s)" represented by R_2 is preferably a C1-C6 alkyl group optionally having 1 to 5 methoxy groups, ethoxy groups, or fluorine atoms as a substituent(s) (specifically, a methyl group, a methoxymethyl group, an ethoxymethyl group, a methoxyethyl group, an ethoxyethyl group, a fluoromethyl group, a difluoromethyl group, a trifluoromethyl group, etc.), more preferably a C1-C6 alkyl group, further preferably a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group, and most preferably a methyl group.

[0056]

The "C1-C6 alkoxy group" represented by R_2 is preferably a methoxy group or an ethoxy group, and most preferably a methoxy group.

[0057]

R_2 is preferably a C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups or fluorine atoms each as a substituent(s). In one embodiment, R_2 is a C1-C6 alkyl group optionally having 1 to 5 methoxy groups, ethoxy groups, or fluorine atoms as a substituent(s). In another embodiment, R_2 is a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group (preferably a methyl group or an ethyl group, and more preferably a methyl group), each optionally having 1 to 5 methoxy groups, ethoxy groups, or fluorine atoms as a substituent(s).

[0058]

R_2 is more preferably a C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups as a substituent(s). In one embodiment, R_2 is a C1-C6 alkyl group optionally having 1 to 5 methoxy groups or ethoxy groups as a substituent(s). In another embodiment, R_2 is a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group (preferably a methyl group or an ethyl group, and more preferably a

methyl group) each optionally having 1 to 5 methoxy groups or ethoxy groups as a substituent(s). In a further embodiment, R_2 is a methyl group, an ethyl group, a methoxymethyl group, or an ethoxymethyl group.

[0059]

R_2 is even more preferably a C1-C6 alkyl group.

[0060]

R_2 is further preferably a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group.

R_2 is particularly preferably a methyl group or an ethyl group.

R_2 is most preferably a methyl group.

[0061]

In the compound represented by the formula (I) or the formula (II) of the present invention, R_3 is a hydrogen atom, or a C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s).

[0062]

The "C1-C4 alkyl group" in the "C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s)" represented by R_3 is preferably a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group, more preferably a methyl group or an ethyl group, and most preferably a methyl group.

[0063]

The "C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s)" represented by R_3 is preferably a methyl group, a fluoromethyl group, a difluoromethyl group, a trifluoromethyl group, or an ethyl group, more preferably a methyl group, a trifluoromethyl group, or an ethyl group, and most preferably a methyl group.

[0064]

R_3 is preferably a C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s).

[0065]

R_3 is more preferably a methyl group, a fluoromethyl group, a difluoromethyl group, a trifluoromethyl group, an ethyl group, a fluoroethyl group, a difluoroethyl group, a trifluoroethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group.

[0066]

R_3 is even more preferably a methyl group, a fluoromethyl group, a difluoromethyl group, a trifluoromethyl group, or an ethyl group.

[0067]

R_3 is further preferably a methyl group, a trifluoromethyl group, or an ethyl group.

R_3 is particularly preferably a methyl group or an ethyl group.

R_3 is most preferably a methyl group.

[0068]

In the compound represented by the formula (I) or the formula (II) of the present invention, R_4 is a hydrogen atom or a C1-C4 alkyl group.

[0069]

The "C1-C4 alkyl group" represented by R_4 is preferably a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group, more preferably a methyl group or an ethyl group, and most preferably a methyl group.

[0070]

R_4 is preferably a hydrogen atom, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group.

[0071]

R_4 is more preferably a hydrogen atom, a methyl group, or an ethyl group.

[0072]

R_4 is further preferably a hydrogen atom or a methyl group.

R_4 is most preferably a hydrogen atom.

[0073]

In the compound represented by the formula (I) or the formula (II) of the present invention, R_5 is a phenyl group optionally having 1 to 3 substituents selected from the group consisting of fluorine atoms and chlorine atoms.

[0074]

R_5 is preferably a phenyl group optionally having 1 or 2 substituents selected from the group consisting of fluorine atoms and chlorine atoms.

[0075]

R_5 is more preferably a phenyl group, a 2-fluorophenyl group, a 3-chlorophenyl group, a 2,3-difluorophenyl group, a 2,4-difluorophenyl group, or a 3,5-difluorophenyl group.

[0076]

R_5 is most preferably a phenyl group.

[0077]

The compound of the present invention is preferably the compound represented by the formula (I) or the formula (II), or a salt thereof, wherein, in the formula (I) or the formula (II),

R_1 is a C1-C4 alkyl group optionally having a C1-C4 alkoxy group as a substituent, or a C3-C4 cycloalkyl group,

R_2 is a C1-C6 alkyl group,

R_3 is a C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s),

R_4 is a hydrogen atom or a C1-C4 alkyl group, and

R_5 is a phenyl group optionally having 1 or 2 substituents selected from the group consisting of fluorine atoms and chlorine atoms.

[0078]

The compound of the present invention is more preferably the compound represented by the formula (I) or the formula (II), or a salt thereof, wherein, in the formula (I) or the formula (II),

R_1 is a methyl group, an ethyl group, an n-propyl group, an isopropyl group, a tert-butyl group, a 1-methyl-1-methoxyethyl group, a cyclopropyl group, or a cyclobutyl group,

R_2 is a methyl group, an ethyl group, an n-propyl group, or a tert-butyl group,

R_3 is a methyl group, a fluoromethyl group, a difluoromethyl group, a trifluoromethyl group, an ethyl group, a fluoroethyl group, a difluoroethyl group, a trifluoroethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group,

R_4 is a hydrogen atom, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a tert-butyl group, and

R_5 is a phenyl group, a 2-fluorophenyl group, a 3-fluorophenyl group, a 2,4-difluorophenyl group, a 2,3-difluorophenyl group, a 3,5-difluorophenyl group, a 2-chlorophenyl group, a 3-chlorophenyl group, a 2,4-dichlorophenyl group, or a 3,5-dichlorophenyl group.

[0079]

The compound of the present invention is even more preferably the compound represented by the formula (II), or a salt thereof, wherein, in the formula (II),

R_1 is a methyl group, an ethyl group, an isopropyl group, a tert-butyl group, a 1-methyl-1-methoxyethyl group, or a cyclopropyl group,

R_2 is a methyl group,

R_3 is a methyl group, a fluoromethyl group, a difluoromethyl group, a trifluoromethyl group, or an ethyl group,

R_4 is a hydrogen atom, a methyl group, or an ethyl group, and

R_5 is a phenyl group, a 2-fluorophenyl group, a 3-chlorophenyl group, a 2,3-difluorophenyl group, a 2,4-difluorophenyl group, or a 3,5-difluorophenyl group.

[0080]

The compound of the present invention is further preferably the compound represented by the formula (II), or a salt thereof, wherein, in the formula (II),

R_1 is a methyl group, a tert-butyl group, or a cyclopropyl group,

R_2 is a methyl group,

R_3 is a methyl group, a trifluoromethyl group, or an ethyl group,

R_4 is a hydrogen atom or a methyl group, and

R_5 is a phenyl group.

[0081]

The compound of the present invention is particularly preferably the compound represented by the formula (II), or a salt thereof, wherein, in the formula (II),

R_1 is a methyl group, a tert-butyl group, or a cyclopropyl group,

R_2 is a methyl group,

R_3 is a methyl group,

R_4 is a hydrogen atom, and

R_5 is a phenyl group.

[0082]

Specific examples of the compound of the present invention may include compounds produced in the following Examples, but are not limited thereto.

One embodiment of the present invention relates to a compound selected from the following (1) to (18), or a salt thereof. One embodiment of the present invention relates to a compound selected from the following (1) to (15), or a salt thereof.

(1) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-phenylethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,

(2) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,

(3) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(3,3-dimethylbut-1-yn-1-yl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,

(4) 7-(R)-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-(3,5-difluorophenyl)ethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,

(5) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-(2-phenylpropan-2-yl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,

(6) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-phenylpropyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,

(7) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-(2-(2-fluorophenyl)propan-2-yl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-

carboxamide,
(8) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-(3-chlorophenyl)ethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(9) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-(2,4-difluorophenyl)ethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(10) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(prop-1-yn-1-yl)-N-((S)-2,2,2-trifluoro-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(11) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-(2-phenylpropan-2-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(12) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-(2,3-difluorophenyl)ethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(13) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(3-methoxy-3-methylbut-1-yn-1-yl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(14) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(but-1-yn-1-yl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(15) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-(2-(2-fluorophenyl)propan-2-yl)-6-(3-methylbut-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(16) 7-((3R,5S)-1-acryloyl-5-ethylpyrrolidin-3-yl)-4-amino-N-((R)-1-phenylethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(17) 7-((3R,5S)-1-acryloyl-5-ethylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(18) 7-((3R,5R)-1-acryloyl-5-(methoxymethyl)pyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide, and
(19) 7-((3R,5R)-1-acryloyl-5-(ethoxymethyl)pyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide.
[0083]

A preferred example of the compound of the present invention may be a compound selected from the following (1) to (3), or a salt thereof.
(1) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-phenylethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(2) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide, and

(3) 7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(3,3-dimethylbut-1-yn-1-yl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide.

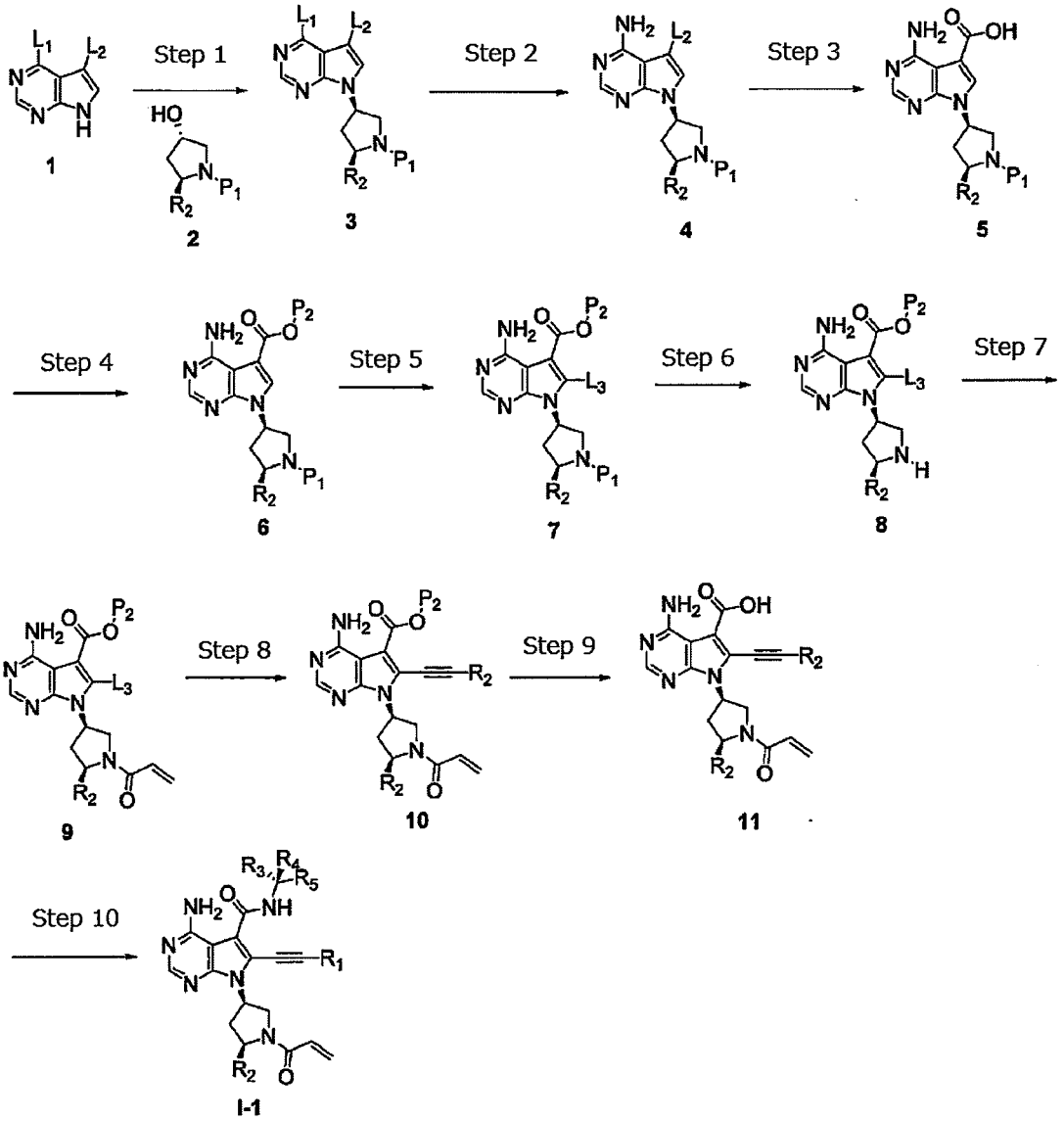
[0084]

< Method for producing compound represented by formula (I) >

The compound according to the present invention can be produced by, for example, the following production method or the methods described in the Examples. However, the method for producing the compound according to the present invention is not limited to these examples.

The compound (I) of the present invention can be produced by applying, for example, the following production method.

< Production Method >



In the above process, L_1, L_2, and L_3, which are the same or different, each represent a leaving group; P_1 and P_2, which are the same or different, each represent a protective group; and other symbols are as defined above.

[0085]

< Step 1 >

This step is a method of obtaining a compound represented by the formula 3 by performing a Mitsunobu reaction between a compound represented by the formula 1 and a compound represented by the formula 2 that is a commercially available compound or can be produced by a known method. The Mitsunobu reaction is generally carried out in the presence of a Mitsunobu reagent and a phosphine reagent.

The compound represented by the formula 2 (in the formula 2, P_1 represents a protective group for an amino group) can be used in an amount of 1 to 10 equivalents, and preferably 1 to 3 equivalents, based on the amount of the compound represented by the formula 1 (1 mole).

The "protective group for an amino group" is not particularly limited, as long as it has a protective function. Examples of the protective group for an amino group may include: aralkyl groups, such as a benzyl group, a p-methoxybenzyl group, a 3,4-dimethoxybenzyl group, an o-nitrobenzyl group, a p-nitrobenzyl group, a benzhydryl group, a trityl group, and a cumyl group; lower alkanoyl groups, such as, for example, a formyl group, an acetyl group, a propionyl group, a butyryl group, a pivaloyl group, a trifluoroacetyl group, and a trichloroacetyl group; for example, benzoyl groups; arylalkanoyl groups, such as, for example, a phenylacetyl group and a phenoxyacetyl group; lower alkoxycarbonyl groups, such as, for example, a methoxycarbonyl group, an ethoxycarbonyl group, a propyloxycarbonyl group, and a tert-butoxycarbonyl group; aralkyloxycarbonyl groups, such as, for example, a p-nitrobenzyloxycarbonyl group and a phenethyloxycarbonyl group; lower alkylsilyl groups, such as, for example, a trimethylsilyl group and a tert-butyldimethylsilyl group; for example, tetrahydropyranyl groups; for example, trimethylsilylethoxymethyl groups; lower alkylsulfonyl groups, etc., such as, for example, a methylsulfonyl group, an ethylsulfonyl group, and a tert-butylsulfonyl group; lower alkylsulfinyl groups, etc., such as for example, a tert-butylsulfinyl group; arylsulfonyl groups, etc., such as, for example, a benzenesulfonyl group and a toluenesulfonyl group; and imide groups, such as, for example, a phthalimide group. Among these, a trifluoroacetyl group, an acetyl group, a tert-butoxycarbonyl group, a benzyloxycarbonyl group, a trimethylsilylethoxymethyl group, or a cumyl group is particularly preferable.

[0086]

As a Mitsunobu reagent, diethyl azodicarboxylate, diisopropyl azodicarboxylate or the like is used. Such a Mitsunobu reagent is used in an amount of generally approximately 1 to 100 moles, and preferably approximately 1 to 10 moles, based on the compound represented by the formula 1 (1 mole).

As a phosphine reagent, triphenylphosphine, tributylphosphine, trifurylphosphine or the like is used. Such a phosphine reagent is used in an amount of generally approximately 1 to 100 moles, and preferably approximately 1 to 10 moles, based on the compound represented by the formula 1 (1 mole).

The solvent is not particularly limited, as long as it does not affect the reaction. Examples of the solvent may include hydrocarbons (e.g., benzene, toluene, xylene, etc.), halogenated hydrocarbons (e.g., chloroform, 1,2-dichloroethane, etc.), nitriles (e.g., acetonitrile, etc.), ethers (e.g., dimethoxyethane, tetrahydrofuran, etc.), alcohols (e.g., methanol, ethanol, etc.), aprotic polar solvents (e.g., N,N-dimethylformamide, dimethyl sulfoxide, hexamethylphosphoramide, etc.), water, and mixtures thereof. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to the temperature at which the solvent is boiled, and preferably 0°C to 100° C.

The thus obtained compound represented by the formula 3 can be isolated and purified by known separation and purification means, or can be subjected to the subsequent step without isolation and purification.

[0087]

< Step 2 >

This step is a method of obtaining a compound represented by the formula 4 by allowing the compound represented by the formula 3 to react with ammonia or a salt thereof.

The ammonia or a salt thereof can be used in an amount of 1 to 1000 equivalents, and preferably 1 to 100 equivalents, based on the amount of the compound represented by the formula 3 (1 mole).

The solvent is not particularly limited, as long as it does not affect the reaction. Examples of the solvent may include hydrocarbons (e.g., benzene, toluene, xylene, etc.), halogenated hydrocarbons (e.g., chloroform, 1,2-dichloroethane, etc.), nitriles (e.g., acetonitrile, etc.), ethers (e.g., dimethoxyethane, tetrahydrofuran, etc.), alcohols (e.g., methanol, ethanol, etc.), aprotic polar solvents (e.g., N,N-dimethylformamide, dimethyl sulfoxide, hexamethylphosphoramide, etc.), water, and mixtures thereof. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to the temperature at which the solvent is boiled, and preferably 0°C

to 150° C.

The thus obtained compound represented by the formula 4 can be isolated and purified by known separation and purification means, or can be subjected to the subsequent step without isolation and purification.

[0088]

< Step 3 >

This step is a method of obtaining a compound represented by the formula 5 by reacting the compound represented by the formula 4 under a carbon monoxide atmosphere, for example, in the presence of a transition metal catalyst, a base and alcohol.

In this step, the pressure of the carbon monoxide is generally from 1 to 20 atmospheres, and preferably 1 to 10 atmospheres.

Examples of the alcohol may include methanol, ethanol, propanol, isopropanol, diethylaminoethanol, isobutanol, 4-(2-hydroxyethyl)morpholine, 3-morpholinopropanol, and diethylaminopropanol.

The alcohol is used in an amount of generally approximately 1 to 100 moles, and preferably approximately 1 to 50 moles, based on the amount of the compound represented by the formula 4 (1 mole).

[0089]

Examples of the transition metal catalyst used herein may include palladium catalysts (e.g., palladium acetate, palladium chloride, tetrakistriphenylphosphine palladium, palladium carbon, etc.). A ligand (e.g., triphenylphosphine, tri-tert-butylphosphine, etc.) may be added, as necessary. The amount of the transition metal catalyst used is different depending on the type of the catalyst. The transition metal catalyst is used in an amount of generally approximately 0.0001 to 1 mole, and preferably approximately 0.01 to 0.5 moles, based on the amount of the compound 4 (1 mole). The ligand is used in an amount of generally approximately 0.0001 to 4 moles, and preferably approximately 0.01 to 2 moles, based on the amount of the compound represented by the formula 4 (1 mole).

[0090]

Examples of the base may include organic amines (e.g., trimethylamine, triethylamine, diisopropylethylamine, N-methylmorpholine, 1,8-diazabicyclo[5,4,0]undec-7-ene, pyridine, N,N-dimethylaniline, etc.), alkaline metal salts (e.g., sodium hydrogen carbonate, potassium hydrogen carbonate, sodium carbonate, potassium carbonate, cesium carbonate, sodium phosphate, potassium phosphate, sodium hydroxide, potassium hydroxide, etc.), metal hydrides (e.g., potassium hydride, sodium hydride, etc.), alkaline metal alkoxides (e.g., sodium methoxide, sodium ethoxide,

sodium-tert-butoxide, potassium-tert-butoxide, etc.), and alkaline metal disilazides (e.g., lithium disilazide, sodium disilazide, potassium disilazide, etc.). Among others, alkaline metal salts such as potassium carbonate, cesium carbonate, sodium phosphate, and potassium phosphate, alkaline metal alkoxides such as sodium-tert-butoxide and potassium-tert-butoxide, organic amines such as triethylamine and diisopropylethylamine, and the like are preferable. The base is used in an amount of generally approximately 0.1 to 50 moles, and preferably approximately 1 to 20 moles, based on the amount of the compound represented by the formula 4 (1 mole).

[0091]

The solvent is not particularly limited, as long as it does not affect the reaction. Examples of the solvent may include hydrocarbons (e.g., benzene, toluene, xylene, etc.), halogenated hydrocarbons (e.g., chloroform, 1,2-dichloroethane, etc.), nitriles (e.g., acetonitrile, etc.), ethers (e.g., dimethoxyethane, tetrahydrofuran, etc.), alcohols (e.g., methanol, ethanol, etc.), aprotic polar solvents (e.g., N,N-dimethylformamide, dimethyl sulfoxide, hexamethylphosphoramide, N-methylpyrrolidone, etc.), water, and mixtures thereof. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to the temperature at which the solvent is boiled, and preferably 0°C to 150° C.

[0092]

After completion of this reaction, an ester form corresponding to the used alcohol, or a mixture of the ester form and the compound represented by the formula 5 is subjected to a hydrolysis reaction, so that it can be converted to the compound represented by the formula 5.

As such a base, sodium hydrogen carbonate, sodium carbonate, potassium carbonate, cesium carbonate, sodium hydroxide, potassium hydroxide, lithium hydroxide, or the like is preferably used. The base is used in an amount of generally approximately 0.5 to 100 moles, and preferably approximately 1 to 10 moles, based on the amount of the compound represented by the formula 4 (1 mole).

The solvent is not particularly limited, as long as it does not affect the reaction. For example, water, methanol, ethanol, isopropanol, tetrahydrofuran, 1,4-dioxane, N,N-dimethylformamide and the like can be used alone or in combination. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to the temperature at which the solvent is boiled, and preferably 0°C to 100° C.

The thus obtained compound represented by the formula 5 can be isolated and purified by known separation and purification means, or can be subjected to the subsequent step without isolation and purification.

[0093]

< Step 4 >

This step is a method of obtaining a compound represented by the formula 6 (wherein P_2 represents a protective group for a carboxyl group) by introducing a protective group into the compound represented by the formula 5. Protection can be carried out according to a generally known method, for example, the method described in Protective Groups in Organic Synthesis third edition, T. W. Greene and P. G. M. Wuts, John Wiley & Sons (1999), or a method equivalent thereto.

The "protective group for a carboxyl group" is not particularly limited, as long as it has a protective function. Examples of the protective group for a carboxyl group may include: lower alkyl groups, such as, for example, a methyl group, an ethyl group, a propyl group, an isopropyl group, and a tert-butyl group; halo lower alkyl groups, such as, for example, a 2,2,2-trichloroethyl group; lower alkenyl groups, such as, for example, an allyl group; for example, a trimethylsilylethoxymethyl group; and aralkyl groups, such as, for example, a benzyl group, a p-methoxybenzyl group, a p-nitrobenzyl group, a benzhydryl group, and a trityl group. In particular, a methyl group, an ethyl group, a tert-butyl group, an allyl group, a benzyl group, a p-methoxybenzyl group, or a trimethylsilylethoxymethyl group is preferable.

In the present reaction, a protective group such as, for example, a tert-butyl ester group, a methyl ester group, or an ethyl ester group, is preferably introduced.

The protective group agent used in the present reaction may be, for example, 2-tert-butyl-1,3-diisopropylisourea. Such a protective group agent is used in an amount of generally approximately 1 to 50 moles, and preferably approximately 1 to 10 moles, based on the amount of the compound represented by the formula 5 (1 mole).

The solvent is not particularly limited, as long as it does not affect the reaction. Examples of the solvent may include hydrocarbons (e.g., benzene, toluene, xylene, etc.), halogenated hydrocarbons (e.g., chloroform, 1,2-dichloroethane, etc.), nitriles (e.g., acetonitrile, etc.), ethers (e.g., dimethoxyethane, tetrahydrofuran, tert-butyl methyl ether, etc.), alcohols (e.g., methanol, ethanol, etc.), aprotic polar solvents (e.g., N,N-dimethylformamide, dimethyl sulfoxide, hexamethylphosphoramide, etc.), water, and mixtures thereof. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to the temperature at which the solvent is boiled, and preferably 0°C to 100° C.

The thus obtained compound represented by the formula 6 can be isolated and purified by known separation and purification means, or can be subjected to the subsequent step without isolation and purification.

[0094]

< Step 5 >

This step is a method of obtaining a compound represented by the formula 7 (wherein L_3 represents a halogen atom) by halogenating the compound represented by the formula 6. Halogenation can be carried out by a method using fluorine, chlorine, bromine, iodine, etc., or by a method using N-chlorosuccinimide, N-bromosuccinimide, N-iodosuccinimide, etc. In the present reaction, the method using N-chlorosuccinimide, N-bromosuccinimide, N-iodosuccinimide, etc. is preferable.

N-chlorosuccinimide, N-bromosuccinimide, N-iodosuccinimide, etc. can be used in an amount of 1 to 10 equivalents, and preferably 1 to 3 equivalents, based on the amount of the compound represented by the formula 6 (1 mole).

The solvent is not particularly limited, as long as it does not affect the reaction. Examples of the solvent may include hydrocarbons (e.g., benzene, toluene, xylene, etc.), halogenated hydrocarbons (e.g., chloroform, 1,2-dichloroethane, etc.), nitriles (e.g., acetonitrile, etc.), ethers (e.g., dimethoxyethane, tetrahydrofuran, etc.), alcohols (e.g., methanol, ethanol, etc.), aprotic polar solvents (e.g., N,N-dimethylformamide, dimethyl sulfoxide, hexamethylphosphoramide, etc.), water, and mixtures thereof. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to the temperature at which the solvent is boiled, and preferably 0°C to 100°.

The thus obtained compound represented by the formula 7 can be isolated and purified by known separation and purification means, or can be subjected to the subsequent step without isolation and purification.

[0095]

< Step 6 >

This step is a method of obtaining a compound represented by the formula 8 by removing the protective group for an amino group (P_1 in the formula 7) from the compound represented by the formula 7 (deprotection). Such deprotection can be carried out according to a generally known method, for example, the method described in Protective Groups in Organic Synthesis third edition, T. W. Greene and P. G. M. Wuts, John Wiley & Sons (1999), or a method equivalent thereto.

The protective group may be, for example, tert-butyloxycarbonyl. When such a tert-butyloxycarbonyl group is used, for example, as a protective group, deprotection is preferably carried out under acidic conditions. Examples of the acid used herein may include hydrochloric acid, acetic acid, trifluoroacetic acid, sulfuric acid, and tosylic acid.

The acid is preferably used in an amount of approximately 1 to 100 equivalents

based on the amount of the compound represented by the formula 7 (1 mole).

The solvent used in the reaction is not particularly limited, as long as it does not affect the reaction. Examples of the solvent used herein may include alcohols (e.g., methanol, etc.), hydrocarbons (e.g., benzene, toluene, xylene, etc.), halogenated hydrocarbons (e.g., methylene chloride, chloroform, 1,2-dichloroethane, etc.), nitriles (e.g., acetonitrile, etc.), ethers (e.g., dimethoxyethane, tetrahydrofuran, etc.), aprotic polar solvents (e.g., N,N-dimethylformamide, dimethyl sulfoxide, hexamethylphosphoramide, etc.), and mixtures thereof. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to 100°C, and preferably 0°C to 50°.

The thus obtained compound represented by the formula 8 can be isolated and purified by known separation and purification means, or can be subjected to the subsequent step without isolation and purification.

[0096]

< Step 7 >

This step is a method of obtaining a compound represented by the formula 9 by performing an amidation reaction between an amino group of the compound represented by the formula 8 and acrylic acid halide or acrylic acid anhydride.

In the case of using acrylic acid halide or acrylic acid anhydride, such acrylic acid halide or acrylic acid anhydride is used in an amount of generally approximately 0.5 to 10 moles, and preferably approximately 1 to 5 moles, based on the amount of the compound represented by the formula 8 (1 mole). It is to be noted that the present acrylic acid halide or acrylic acid anhydride can be obtained as a commercially available product or can be produced according to a known method.

In addition, a base can be added, as necessary. Examples of the base may include organic amines (e.g., trimethylamine, triethylamine, isopropylethylamine, diisopropylethylamine, N-methylmorpholine, 1,8-diazabicyclo[5,4,0]undec-7-ene, pyridine, N,N-dimethylaniline, etc.), alkaline metal salts (e.g., sodium hydrogen carbonate, potassium hydrogen carbonate, sodium carbonate, potassium carbonate, cesium carbonate, sodium phosphate, potassium phosphate, sodium hydroxide, potassium hydroxide, etc.), metal hydrides (e.g., potassium hydride, sodium hydride, etc.), and alkaline metal alkoxides (e.g., sodium methoxide, sodium ethoxide, sodium-tert-butoxide, potassium-tert-butoxide, etc.). The base is used in an amount of generally approximately 1 to 100 moles, and preferably approximately 1 to 10 moles, based on the amount of the compound represented by the formula 8 (1 mole).

The solvent used in the reaction is not particularly limited, as long as it does not

affect the reaction. Examples of the solvent used herein may include alcohols (e.g., methanol, etc.), hydrocarbons (e.g., benzene, toluene, xylene, etc.), halogenated hydrocarbons (e.g., methylene chloride, chloroform, 1,2-dichloroethane, etc.), nitriles (e.g., acetonitrile, etc.), ethers (e.g., dimethoxyethane, tetrahydrofuran, etc.), aprotic polar solvents (e.g., N,N-dimethylformamide, dimethyl sulfoxide, hexamethylphosphoramide, , etc.), and mixtures thereof. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to the temperature at which the solvent is boiled, and preferably 0°C to 100° C.

The thus obtained compound represented by the formula 9 can be isolated and purified by known separation and purification means, or can be subjected to the subsequent step without isolation and purification.

[0097]

< Step 8 >

This step is a method of obtaining a compound represented by the formula 10 by performing a Sonogashira reaction between the compound represented by the formula 9 and an acetylene derivative that is a commercially available product or can be produced by a known method.

The acetylene derivative can be used in an amount of 1 to 50 equivalents, and preferably 1 to 10 equivalents, based on the amount of the compound represented by the formula 9 (1 mole).

Examples of the transition metal catalyst used herein may include palladium catalysts (e.g., palladium acetate, palladium chloride, tetrakistriphenylphosphinepalladium, dichlorobis(triphenylphosphine)palladium, dichlorobis(triphenylphosphine)dipalladium, etc.), and nickel catalysts (e.g., nickel chloride, etc.). As necessary, a ligand (e.g., triphenylphosphine, tri-tert-butylphosphine, etc.) may be added, and a copper catalyst (e.g., copper iodide, copper bromide, or copper chloride) or the like may be used as a co-catalyst. The amount of the transition metal catalyst used is different depending on the type of the catalyst. The transition metal catalyst is used in an amount of generally approximately 0.0001 to 1 mole, and preferably approximately 0.01 to 0.5 moles, based on the amount of the compound represented by the formula 9 (1 mole). The ligand is used in an amount of generally approximately 0.0001 to 4 moles, and preferably approximately 0.01 to 2 moles, based on the amount of the compound represented by the formula 9 (1 mole). The copper catalyst is used in an amount of generally approximately 0.0001 to 4 moles, and preferably approximately 0.010 to 2 moles, based on the amount of the compound represented by the formula 9 (1 mole).

[0098]

Examples of the base may include organic amines (e.g., trimethylamine, triethylamine, diisopropylethylamine, N-methylmorpholine, 1,8-diazabicyclo[5,4,0]undec-7-ene, pyridine, N,N-dimethylaniline, etc.), alkaline metal salts (e.g., sodium hydrogen carbonate, potassium hydrogen carbonate, sodium carbonate, potassium carbonate, cesium carbonate, sodium phosphate, potassium phosphate, sodium hydroxide, potassium hydroxide, etc.), metal hydrides (e.g., potassium hydride, sodium hydride, etc.), alkaline metal alkoxides (e.g., sodium methoxide, sodium ethoxide, sodium-tert-butoxide, potassium-tert-butoxide, etc.), and alkaline metal disilazide (e.g., lithium disilazide, sodium disilazide, potassium disilazide, etc.). Among these, preferred examples of the base may include: alkaline metal salts, such as potassium carbonate, cesium carbonate, sodium phosphate, and potassium phosphate; alkaline metal alkoxides, such as sodium-tert-butoxide and potassium-tert-butoxide; and organic amines, such as triethylamine and diisopropylethylamine. The base is used in an amount of generally approximately 0.1 to 10 moles, and preferably approximately 1 to 5 moles, based on the amount of the compound represented by the formula 9 (1 mole).

The solvent is not particularly limited, as long as it does not affect the reaction. Examples of the solvent may include hydrocarbons (e.g., benzene, toluene, xylene, etc.), halogenated hydrocarbons (e.g., chloroform, 1,2-dichloroethane, etc.), nitriles (e.g., acetonitrile, etc.), ethers (e.g., dimethoxyethane, tetrahydrofuran, etc.), alcohols (e.g., methanol, ethanol, etc.), aprotic polar solvents (e.g., N,N-dimethylformamide, dimethyl sulfoxide, hexamethylphosphoramide, etc.), water, and mixtures thereof. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to the temperature at which the solvent is boiled, and preferably 0°C to 150° C.

The thus obtained compound represented by the formula 10 can be isolated and purified by known separation and purification means, or can be subjected to the subsequent step without isolation and purification.

[0099]

< Step 9 >

This step is a method of obtaining a compound represented by the formula 11 by deprotecting the protective group for a carboxyl group (P_2 in the formula 10) of the compound represented by the formula 10. Deprotection can be carried out according to a generally known method, for example, the method described in Protective Groups in Organic Synthesis third edition, T. W. Greene and P. G. M. Wuts, John Wiley & Sons (1981), or a method equivalent thereto.

The protective group may be, for example, tert-butyl ester. When such a tert-butyl ester group is used as a protective group, for example, deprotection is preferably carried out under acidic conditions. Examples of the acid used herein may include hydrochloric acid, acetic acid, trifluoroacetic acid, sulfuric acid, and tosylic acid.

The acid is preferably used in an amount of approximately 1 to 100 equivalents based on the amount of the compound represented by the formula 10 (1 mole).

The solvent used in the reaction is not particularly limited, as long as it does not affect the reaction. Examples of the solvent used herein may include alcohols (e.g., methanol, etc.), hydrocarbons (e.g., benzene, toluene, xylene, etc.), halogenated hydrocarbons (e.g., methylene chloride, chloroform, 1,2-dichloroethane, etc.), nitriles (e.g., acetonitrile, etc.), ethers (e.g., dimethoxyethane, tetrahydrofuran, etc.), aprotic polar solvents (e.g., N,N-dimethylformamide, dimethyl sulfoxide, hexamethylphosphoramide, , etc.), and mixtures thereof. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to 100°C, and preferably 0°C to 50°.

The thus obtained compound represented by the formula 11 can be isolated and purified by known separation and purification means, or can be subjected to the subsequent step without isolation and purification.

[0100]

< Step 10 >

This step is a method of obtaining a compound represented by the formula (I) by performing an amidation reaction between a carboxyl group of the compound represented by the formula 11 and an amine that is a commercially available product or can be produced by a known method.

Amidation can be carried out according to a conventionally known method. Examples of the amidation method may include a method of performing the reaction in the presence of a condensing agent, and a method comprising activating a carboxylic acid portion according to a conventionally known method to obtain a reactive derivative, and then performing amidation between the derivative and an amine (for both methods, see "*Peptide Gosei no Kiso to Jikken* (Principle of Peptide Synthesis and Experiments)" (Nobuo IZUMIYA et al., Maruzen Co., Ltd., 1983)).

Examples of the condensing agent may include N,N'-dicyclohexylcarbodiimide (DCC), N,N'-diisopropylcarbodiimide (DIC), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (WSC), diphenylphosphoryl azide (DPPA), benzotriazol-1-yl-oxytrisdimethylaminophosphonium hexafluorophosphate (BOP), benzotriazol-1-yl-oxytripyrrolidinophosphonium hexafluorophosphate (PyBOP),

7-azabenzotriazol-1-yloxytrispyrrolidinophosphonium phosphate (PyAOP), bromotrispyrrolidinophosphonium hexafluorophosphate (BroP), chlorotris(pyrrolidin-1-yl)phosphonium hexafluorophosphate (PyCroP), 3-(diethoxyphosphoryloxy)-1,2,3-benzotriazin-4(3H)-one (DEPBT), O-(azabenzotriazol-1-yl)-N,N,N',N'-tetramethyluronium hexafluorophosphate (HATU), and 4-(5,6-dimethoxy-1,3,5-triazin-2-yl)-4-methylmorpholine hydrochloride (DMTMM). Examples of the additive used at that time may include 1-hydroxybenzotriazole (HOBt), 1-hydroxy-7-azabenzotriazole (HOAt), and N-hydroxysuccinimide (HOSu). Such agents are used in an amount of generally approximately 1 to 100 moles, and preferably approximately 1 to 10 moles, based on the amount of the compound represented by the formula 11 (1 mole).

[0101]

In addition, as necessary, a base can be added. Examples of such a base may include organic amines (e.g., trimethylamine, triethylamine, diisopropylethylamine, N-methylmorpholine, 1,8-diazabicyclo[5,4,0]undec-7-ene, pyridine, N,N-dimethylaniline, etc.), alkaline metal salts (e.g., sodium hydrogen carbonate, potassium hydrogen carbonate, sodium carbonate, potassium carbonate, cesium carbonate, sodium phosphate, potassium phosphate, sodium hydroxide, potassium hydroxide, etc.), metal hydrides (e.g., potassium hydride, sodium hydride, etc.), and alkaline metal alkoxides (e.g., sodium methoxide, sodium ethoxide, sodium-tert-butoxide, potassium-tert-butoxide, etc.). The base is used in an amount of generally approximately 1 to 100 moles, and preferably approximately 1 to 10 moles, based on the amount of the compound represented by the formula 11 (1 mole).

The solvent used in the reaction is not particularly limited, as long as it does not affect the reaction. Examples of the solvent used herein may include alcohols (e.g., methanol, etc.), hydrocarbons (e.g., benzene, toluene, xylene, etc.), halogenated hydrocarbons (e.g., methylene chloride, chloroform, 1,2-dichloroethane, etc.), nitriles (e.g., acetonitrile, etc.), ethers (e.g., dimethoxyethane, tetrahydrofuran, etc.), aprotic polar solvents (e.g., N,N-dimethylformamide, dimethyl sulfoxide, hexamethylphosphoramide, , etc.), and mixtures thereof. The reaction time is 0.1 to 100 hours, and preferably 0.5 to 24 hours. Thereafter, the reaction temperature is 0°C to the temperature at which the solvent is boiled, and preferably 0°C to 100° C.

The thus obtained compound (I) can be isolated and purified according to known separation and purification means, such as, for example, concentration , vacuum concentration, crystallization, solvent extraction, re-precipitation, or chromatography.

In the above-described production method, the steps ranging from the "introduction of a protective group into a carboxyl group of the compound represented by

the formula 5" (Step 4) to the "amidation reaction between a carboxyl group of the compound represented by the formula 11 and an amine that is a commercially available product or can be produced by a known method" (Step 10) are successively carried out in this order. However, the order of performing these steps can be changed. Moreover, the "introduction of a protective group into a carboxyl group of the compound represented by the formula 5" (Step 4) and the "removal of the protective group for a carboxy group from the compound represented by the formula 10" (Step 9) can be omitted.

[0102]

Specifically, individual steps are carried out in the order of the "amidation reaction between a carboxyl group of the compound represented by the formula 11 and an amine that is a commercially available product or can be produced by a known method" (Step 10), the "halogenation of the compound represented by the formula 6" (Step 5), the "removal of the protective group for an amino group from the compound represented by the formula 7" (Step 6), the "amidation reaction between an amino group of the compound represented by the formula 8 and acrylic acid halide or acrylic acid anhydride" (Step 7), and the "Sonogashira reaction between the compound represented by the formula 9 and an acetylene derivative that is a commercially available product or can be produced by a known method, when L3 of the compound represented by the formula 9 has a leaving group such as halogen" (Step 8), so that the concerned compound can be induced to the compound represented by the formula (I). The conditions applied in individual steps are the same as those as described above.

[0103]

When the compound of the present invention has an isomer, such as an optical isomer, a stereoisomer, a rotational isomer, or a tautomer, all of these isomers or mixtures thereof are included in the compound of the present invention, unless otherwise stated. For example, when the compound of the present invention has an optical isomer, both a racemate, and an optical isomer obtained as a result of racemic resolution are included in the compound of the present invention, unless otherwise stated.

[0104]

The salt of the compound of the present invention means a pharmaceutically acceptable salt, and it may be, for example, a base-added salt or an acid-added salt.

[0105]

The compound of the present invention or a salt thereof also includes a prodrug. The "prodrug" means a compound that is converted to the compound of the present invention or a salt thereof as a result of the reaction with an enzyme, stomach acid, etc. under physiological conditions in a living body; namely, a compound that enzymatically

causes oxidation, reduction, hydrolysis, etc., so that it is converted to the compound of the present invention or a salt thereof, or a compound that causes hydrolysis, etc. with stomach acid or the like, so that it is converted to the compound of the present invention or a salt thereof. Otherwise, it may also be a compound that is converted to the compound of the present invention or a salt thereof under physiological conditions as described in "*Iyakuhin no Kaihatsu* (Development of Pharmaceutical Products)," Hirokawa Shoten, 1990, Vol. 7, *Bunshi Sekkei* (Molecular Designing), pp. 163 to 198.

[0106]

The compound of the present invention or a salt thereof may be an amorphous material or a crystal. Although the crystal form thereof may be a single crystal or a polymorphic mixture, they are included in the compound of the present invention or a salt thereof. The crystal can be produced by crystallizing the compound of the present invention or a salt thereof, applying a known crystallization method. The compound of the present invention or a salt thereof may be either a solvate (e.g., a hydrate, etc.), or a non-solvate, and both of them are included in the compound of the present invention or a salt thereof. Compounds labeled with radioisotopes (e.g., ^{3}H, ^{14}C, ^{35}S, ^{125}I, etc.) and the like are also included in the compound of the present invention or a salt thereof.

[0107]

The compound of the present invention or a salt thereof has excellent HER2 inhibitory activity. Moreover, the compound of the present invention or a salt thereof has excellent selectivity to HER2. Accordingly, the compound of the present invention or a salt thereof is useful as an antitumor agent against malignant tumor having HER2 overexpression, HER2 gene amplification, HER2 mutation, etc. In addition, since significant weight reduction was not found in mice, the present compound or a salt thereof is advantageous in that it has a few side effects.

In the present description, the term "HER2" includes the HER2 of a human or a non-human mammal, and it is preferably human HER2. Furthermore, the term "HER2" includes isoforms.

[0108]

Since the compound of the present invention or a salt thereof has excellent HER2 inhibitory activity, it is useful as a medicament for preventing or treating disease associated with HER2.

The "disease associated with HER2" means disease, in which a reduction in the incidence, or the remission, alleviation and/or complete recovery of the symptoms thereof is achieved by deleting, suppressing and/or inhibiting the function of HER2. Examples of such disease may include malignant tumors, but are not limited thereto. Preferred

examples of the disease may include malignant tumors having HER2 overexpression, HER2 gene amplification, or HER2 mutation.

One embodiment of the present invention provides an inhibitor against HER2, comprising the compound of the present invention or a salt thereof. In addition, one embodiment of the present invention provides a method for inhibiting HER2, comprising administering an effective amount of the compound of the present invention or a salt thereof to a subject in need thereof. Moreover, one embodiment of the present invention provides use of the compound of the present invention or a salt thereof for the production of a HER2 inhibitor. Furthermore, one embodiment of the present invention provides the compound of the present invention or a salt thereof for use as a HER2 inhibitor. Furthermore, one embodiment of the present invention provides use of the compound of the present invention or a salt thereof for inhibiting HER2. In another embodiment, the present invention provides use of the compound of the present invention or a salt thereof for preventing or treating disease associated with HER2.

Another embodiment of the present invention provides an antitumor agent comprising the compound of the present invention or a salt thereof. In addition, one embodiment of the present invention provides a method for preventing and/or treating tumor, comprising administering an effective amount of the compound of the present invention or a salt thereof to a subject in need thereof. One embodiment of the present invention provides use of the compound of the present invention or a salt thereof for the production of an antitumor agent.

Moreover, one embodiment of the present invention provides the compound of the present invention or a salt thereof for use in the prevention and/or treatment of tumor.

[0109]

The compound according to one embodiment of the present invention or a salt thereof selectively inhibits wild-type HER2, and mutant HER2 having one or more insertion mutations, point mutations, deletion mutations, etc. in the HER2 domain thereof, such as exon 20 insertion mutation. One embodiment of the present invention provides: a compound having inhibitory activity against wild-type HER2, and mutant HER2 including HER2 having YVMA insertion mutation that is one of exon 20 insertion mutations, or a salt thereof; or a medicament or a pharmaceutical composition each comprising the same. One embodiment of the present invention provides an inhibitor against wild-type HER2, and mutant HER2 including HER2 having YVMA insertion mutation, etc., wherein the inhibitor comprises the compound of the present invention or a salt thereof. In addition, one embodiment of the present invention provides a method for inhibiting wild-type HER2, and mutant HER2 including HER2 having YVMA

insertion mutation, etc., wherein the method comprises administering an effective amount of the compound of the present invention or a salt thereof to a subject in need thereof. Moreover, one embodiment of the present invention provides use of the compound of the present invention or a salt thereof for the production of an inhibitor against wild-type HER2, and mutant HER2 including HER2 having YVMA insertion mutation, etc. Furthermore, one embodiment of the present invention provides the compound of the present invention or a salt thereof for use as an inhibitor against wild-type HER2, and mutant HER2 including HER2 having YVMA insertion mutation, etc. Further, one embodiment of the present invention provides use of the compound of the present invention or a salt thereof for inhibiting wild-type HER2, and mutant HER2 including HER2 having YVMA insertion mutation, etc. In another embodiment, the present invention provides use of the compound of the present invention or a salt thereof for preventing or treating disease associated with wild-type HER2, and mutant HER2 including HER2 having YVMA insertion mutation, etc.

[0110]

The human HER2 gene is shown in, for example, SEQ ID NO: 1, SEQ ID NO: 3, or SEQ ID NO: 5. The wild-type HER2 protein consists of the amino acid sequence set forth in, for example, SEQ ID NO: 2, SEQ ID NO: 4, or SEQ ID NO: 6. The nucleotide sequence information of the human HER2 gene and the amino acid sequence information of the wild-type HER2 protein can be obtained from, for example, Accession No. NM_004448, NM_001289936, NM_001005862, or the like.

[0111]

In several embodiments, the compound of one embodiment of the present invention or a salt thereof exhibits inhibitory activity against mutant HER2 comprising one or more mutations from G309A, S310F, R678Q, L755S, L755_T759del, D769H, A775_G776insYVMA, V777L, V842I and R896C, using the amino acid sequence set forth in SEQ ID NO: 2 as a reference. In another embodiment, the compound of one embodiment of the present invention or a salt thereof exhibits inhibitory activity against mutant HER2 comprising A775_G776insYVMA, using the amino acid sequence set forth in SEQ ID NO: 2 as a reference.

In several embodiments, the compound of one embodiment of the present invention or a salt thereof exhibits inhibitory activity against mutant HER2 comprising one or more mutations from G294A, S295F, R663Q, L740S, L740_T744del, D754H, A760_G761insYVMA, V762L, V827I and R881C, using the amino acid sequence set forth in SEQ ID NO: 4 as a reference. In another embodiment, the compound of one embodiment of the present invention or a salt thereof exhibits inhibitory activity against

mutant HER2 comprising A760_G761insYVMA, using the amino acid sequence set forth in SEQ ID NO: 4 as a reference.

In several embodiments, the compound of one embodiment of the present invention or a salt thereof exhibits inhibitory activity against mutant HER2 comprising one or more mutations from G279A, S280F, R648Q, L725S, L725_T729del, D739H, A745_G746insYVMA, V747L, V812I and R866C, using the amino acid sequence set forth in SEQ ID NO: 6 as a reference. In another embodiment, the compound of one embodiment of the present invention or a salt thereof exhibits inhibitory activity against mutant HER2 comprising A745_G746insYVMA, using the amino acid sequence set forth in SEQ ID NO: 6 as a reference.

[0112]

Further, in several embodiments, with regard to a mutation in a certain HER2 isoform, even when the position of the mutation is different from the position of an amino acid shown in SEQ ID NO: 2 due to deletion or insertion of an amino acid(s), it is understood that the mutation is the same as the mutation at a position corresponding to the position of the amino acid shown in SEQ ID NO: 2. Hence, for example, the glycine at position 309 in the HER2 shown in SEQ ID NO: 2 corresponds to glycine at position 294 in HER2 consisting of the amino acid sequence set forth in SEQ ID NO: 4. For example, the term "G309A" means that the glycine at position 309 in the HER2 shown in SEQ ID NO: 2 is mutated to alanine. Since such "G309" is at a position corresponding to the amino acid at position 294 in HER2 consisting of the amino acid sequence set forth in SEQ ID NO: 4, "G294A" in the HER2 consisting of the amino acid sequence set forth in SEQ ID NO: 4 corresponds to "G309A" in the HER2 shown in SEQ ID NO: 2. Besides, the position of an amino acid in SEQ ID NO: 2 that corresponds to a certain amino acid in a certain HER2 isoform can be confirmed by Multiple Alignment of BLAST.

[0113]

Sequence Listing

[Table A]

SEQ ID NO: 1

Accession No.: NM_004448

CDS: 262..4029

```
   1 gcttgctccc aatcacagga gaaggaggag gtggaggagg agggctgctt gaggaagtat
  61 aagaatgaag ttgtgaagct gagattcccc tccattggga ccggagaaac caggggagcc
 121 ccccgggcag ccgcgcgccc cttcccacgg ggccctttac tgcgccgcgc gcccggcccc
 181 cacccctcgc agcaccccgc gccccgcgcc ctcccagccg ggtccagccg gagccatggg
 241 gccggagccg cagtgagcac catggagctg gcggccttgt gccgctgggg gctcctcctc
 301 gccctcttgc cccccggagc cgcgagcacc caagtgtgca ccggcacaga catgaagctg
 361 cggctccctg ccagtcccga gacccacctg gacatgctcc gccacctcta ccagggctgc
 421 caggtggtgc agggaaacct ggaactcacc tacctgccca ccaatgccag cctgtccttc
 481 ctgcaggata tccaggaggt gcagggctac gtgctcatcg ctcacaacca agtgaggcag
 541 gtcccactgc agaggctgcg gattgtgcga ggcacccagc tctttgagga caactatgcc
 601 ctggccgtgc tagacaatgg agacccgctg aacaatacca cccctgtcac aggggcctcc
 661 ccaggaggcc tgcgggagct gcagcttcga agcctcacag agatcttgaa aggaggggtc
 721 ttgatccagc ggaaccccca gctctgctac caggacacga ttttgtggaa ggacatcttc
 781 cacaagaaca accagctggc tctcacactg atagacacca accgctctcg ggcctgccac
 841 ccctgttctc cgatgtgtaa gggctcccgc tgctggggag agagttctga ggattgtcag
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SEQ ID NO: 2
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1861 agggaactgg gcagtggact ggccctcatc caccataaca cccacctctg cttcgtgcac
1921 acggtgccct gggaccagct ctttcggaac ccgcaccaag ctctgctcca cactgccaac
1981 cggccagagg acgagtgtgt gggcgagggc ctggcctgcc accagctgtg cgcccgaggg
2041 cactgctggg gtccagggcc cacccagtgt gtcaactgca gccagttcct tcggggccag
2101 gagtgcgtgg aggaatgccg agtactgcag gggctcccca gggagtatgt gaatgccagg
2161 cactgtttgc cgtgccaccc tgagtgtcag ccccagaatg gctcagtgac ctgttttgga
2221 ccggaggctg accagtgtgt ggcctgtgcc cactataagg accctccctt ctgcgtggcc
2281 cgctgcccca gcggtgtgaa acctgacctc tcctacatgc ccatctggaa gtttccagat
2341 gaggagggcg catgccagcc ttgccccatc aactgcaccc actcctgtgt ggacctggat
2401 gacaagggct gccccgccga gcagagagcc agccctctga cgtccatcat ctctgcggtg
2461 gttggcattc tgctggtcgt ggtcttgggg gtggtctttg ggatcctcat caagcgacgg
2521 cagcagaaga tccggaagta cacgatgcgg agactgctgc aggaaacgga gctggtggag
2581 ccgctgacac ctagcggagc gatgcccaac caggcgcaga tgcggatcct gaaagagacg
2641 gagctgagga aggtgaaggt gcttggatct ggcgcttttg gcacagtcta caagggcatc
2701 tggatccctg atggggagaa tgtgaaaatt ccagtggcca tcaaagtgtt gagggaaaac
2761 acatccccca aagccaacaa agaaatctta gacgaagcat acgtgatggc tggtgtgggc
2821 tccccatatg tctcccgcct tctgggcatc tgcctgacat ccacggtgca gctggtgaca
2881 cagcttatgc cctatggctg cctcttagac catgtccggg aaaaccgcgg acgcctgggc
2941 tcccaggacc tgctgaactg gtgtatgcag attgccaagg ggatgagcta cctggaggat
3001 gtgcggctcg tacacaggga cttggccgct cggaacgtgc tggtcaagag tcccaaccat
3061 gtcaaaatta cagacttcgg gctggctcgg ctgctggaca ttgacgagac agagtaccat
3121 gcagatgggg gcaaggtgcc catcaagtgg atggcgctgg agtccattct ccgccggcgg
3181 ttcacccacc agagtgatgt gtggagttat ggtgtgactg tgtgggagct gatgactttt
3241 ggggccaaac cttacgatgg gatcccagcc cgggagatcc ctgacctgct ggaaaagggg
3301 gagcggctgc cccagccccc catctgcacc attgatgtct acatgatcat ggtcaaatgt
3361 tggatgattg actctgaatg tcggccaaga ttccgggagt tggtgtctga attctcccgc
3421 atggccaggg acccccagcg ctttgtggtc atccagaatg aggacttggg cccagccagt
3481 cccttggaca gcaccttcta ccgctcactg ctggaggacg atgacatggg ggacctggtg
3541 gatgctgagg agtatctggt accccagcag ggcttcttct gtccagaccc tgccccgggc
3601 gctgggggca tggtccacca caggcaccgc agctcatcta ccaggagtgg cggtggggac
3661 ctgacactag ggctggagcc ctctgaagag gaggccccca ggtctccact ggcaccctcc

3721 gaaggggctg gctccgatgt atttgatggt gacctgggaa tgggggcagc caaggggctg
3781 caaagcctcc ccacacatga ccccagccct ctacagcggt acagtgagga ccccacagta
3841 cccctgccct ctgagactga tggctacgtt gcccccctga cctgcagccc ccagcctgaa
3901 tatgtgaacc agccagatgt tcggccccag ccccccttcgc cccgagaggg ccctctgcct
3961 gctgcccgac ctgctggtgc cactctggaa aggcccaaga ctctctcccc agggaagaat
4021 ggggtcgtca aagacgtttt tgcctttggg ggtgccgtgg agaaccccga gtacttgaca
4081 ccccagggag gagctgcccc tcagccccac cctcctcctg ccttcagccc agccttcgac
4141 aacctctatt actgggacca ggacccacca gagcgggggg ctccacccag caccttcaaa
4201 gggacaccta cggcagagaa cccagagtac ctgggtctgg acgtgccagt gtgaaccaga
4261 aggccaagtc cgcagaagcc ctgatgtgtc ctcagggagc agggaaggcc tgacttctgc
4321 tggcatcaag aggtgggagg gccctccgac cacttccagg ggaacctgcc atgccaggaa
4381 cctgtcctaa ggaaccttcc ttcctgcttg agttcccaga tggctggaag gggtccagcc
4441 tcgttggaag aggaacagca ctggggagtc tttgtggatt ctgaggccct gcccaatgag
4501 actctagggt ccagtggatg ccacagccca gcttggccct ttccttccag atcctgggta
4561 ctgaaagcct tagggaagct ggcctgagag gggaagcggc cctaagggag tgtctaagaa
4621 caaaagcgac ccattcagag actgtccctg aaacctagta ctgcccccca tgaggaagga
4681 acagcaatgg tgtcagtatc caggctttgt acagagtgct tttctgttta gtttttactt
4741 tttttgtttt gtttttttaa agatgaaata aagacccagg gggagaatgg gtgttgtatg
4801 gggaggcaag tgtgggggt ccttctccac acccactttg tccatttgca aatatatttt
4861 ggaaaacagc taaaaaaaaa aaaaaaaaa

SEQ ID NO: 6

Accession No.: NM_001005862

MKLRLPASPE THLDMLRHLY QGCQVVQGNL ELTYLPTNAS LSFLQDIQEV QGYVLIAHNQ 60
VRQVPLQRLR IVRGTQLFED NYALAVLDNG DPLNNTTPVT GASPGGLREL QLRSLTEILK 120
GGVLIQRNPQ LCYQDTILWK DIFHKNNQLA LTLIDTNRSR ACHPCSPMCK GSRCWGESSE 180
DCQSLTRTVC AGGCARCKGP LPTDCCHEQC AAGCTGPKHS DCLACLHFNH SGICELHCPA 240
LVTYNTDTFE SMPNPEGRYT FGASCVTACP YNYLSTDVGS CTLVCPLHNQ EVTAEDGTQR 300
CEKCSKPCAR VCYGLGMEHL REVRAVTSAN IQEFAGCKKI FGSLAFLPES FDGDPASNTA 360
PLQPEQLQVF ETLEEITGYL YISAWPDSLP DLSVFQNLQV IRGRILHNGA YSLTLQGLGI 420
SWLGLRSLRE LGSGLALIHH NTHLCFVHTV PWDQLFRNPH QALLHTANRP EDECVGEGLA 480
CHQLCARGHC WGPGPTQCVN CSQFLRGQEC VEECRVLQGL PREYVNARHC LPCHPECQPQ 540
NGSVTCFGPE ADQCVACAHY KDPPFCVARC PSGVKPDLSY MPIWKFPDEE GACQPCPINC 600
THSCVDLDDK GCPAEQRASP LTSIISAVVG ILLVVVLGVV FGILIKRRQQ KIRKYTMRRL 660
LQETELVEPL TPSGAMPNQA QMRILKETEL RKVKVLGSGA FGTVYKGIWI PDGENVKIPV 720

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AIKVLRENTS PKANKEILDE AYVMAGVGSP YVSRLLGICL TSTVQLVTQL MPYGCLLDHV  780
RENRGRLGSQ DLLNWCMQIA KGMSYLEDVR LVHRDLAARN VLVKSPNHVK ITDFGLARLL  840
DIDETEYHAD GGKVPIKWMA LESILRRRFT HQSDVWSYGV TVWELMTFGA KPYDGIPARE  900
IPDLLEKGER LPQPPICTID VYMIMVKCWM IDSECRPRFR ELVSEFSRMA RDPQRFVVIQ  960
NEDLGPASPL DSTFYRSLLE DDDMGDLVDA EEYLVPQQGF FCPDPAPGAG GMVHHRHRSS 1020
STRSGGGDLT LGLEPSEEEA PRSPLAPSEG AGSDVFDGDL GMGAAKGLQS LPTHDPSPLQ 1080
RYSEDPTVPL PSETDGYVAP LTCSPQPEYV NQPDVRPQPP SPREGPLPAA RPAGATLERP 1140
KTLSPGKNGV VKDVFAFGGA VENPEYLTPQ GGAAPQPHPP PAFSPAFDNL YYWDQDPPER 1200
GAPPSTFKGT PTAENPEYLG LDVPV                                       1225
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SEQ ID NO: 7 Mutant HER2 (having the amino acid sequence set forth in SEQ ID NO: 2 as a base and comprising the mutation A775_G776insYVMA (HER2ex20insYVMA))

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MELAALCRWG LLLALLPPGA ASTQVCTGTD MKLRLPASPE THLDMLRHLY QGCQVVQGNL   60
ELTYLPTNAS LSFLQDIQEV QGYVLIAHNQ VRQVPLQRLR IVRGTQLFED NYALAVLDNG  120
DPLNNTTPVT GASPGGLREL QLRSLTEILK GGVLIQRNPQ LCYQDTILWK DIFHKNNQLA  180
LTLIDTNRSR ACHPCSPMCK GSRCWGESSE DCQSLTRTVC AGGCARCKGP LPTDCCHEQC  240
AAGCTGPKHS DCLACLHFNH SGICELHCPA LVTYNTDTFE SMPNPEGRYT FGASCVTACP  300
YNYLSTDVGS CTLVCPLHNQ EVTAEDGTQR CEKCSKPCAR VCYGLGMEHL REVRAVTSAN  360
IQEFAGCKKI FGSLAFLPES FDGDPASNTA PLQPEQLQVF ETLEEITGYL YISAWPDSLP  420
DLSVFQNLQV IRGRILHNGA YSLTLQGLGI SWLGLRSLRE LGSGLALIHH NTHLCFVHTV  480
PWDQLFRNPH QALLHTANRP EDECVGEGLA CHQLCARGHC WGPGPTQCVN CSQFLRGQEC  540
VEECRVLQGL PREYVNARHC LPCHPECQPQ NGSVTCFGPE ADQCVACAHY KDPPFCVARC  600
PSGVKPDLSY MPIWKFPDEE GACQPCPINC THSCVDLDDK GCPAEQRASP LTSIISAVVG  660
ILLVVVLGVV FGILIKRRQQ KIRKYTMRRL LQETELVEPL TPSGAMPNQA QMRILKETEL  720
RKVKVLGSGA FGTVYKGIWI PDGENVKIPV AIKVLRENTS PKANKEILDE AYVMAYVMAG  780
VGSPYVSRLL GICLTSTVQL VTQLMPYGCL LDHVRENRGR LGSQDLLNWC MQIAKGMSYL  840
EDVRLVHRDL AARNVLVKSP NHVKITDFGL ARLLDIDETE YHADGGKVPI KWMALESILR  900
RRFTHQSDVW SYGVTVWELM TFGAKPYDGI PAREIPDLLE KGERLPQPPI CTIDVYMIMV  960
KCWMIDSECR PRFRELVSEF SRMARDPQRF VVIQNEDLGP ASPLDSTFYR SLLEDDDMGD 1020
LVDAEEYLVP QQGFFCPDPA PGAGGMVHHR HRSSSTRSGG GDLTLGLEPS EEEAPRSPLA 1080
PSEGAGSDVF DGDLGMGAAK GLQSLPTHDP SPLQRYSEDP TVPLPSETDG YVAPLTCSPQ 1140
PEYVNQPDVR PQPPSPREGP LPAARPAGAT LERPKTLSPG KNGVVKDVFA FGGAVENPEY 1200
LTPQGGAAPQ PHPPPAFSPA FDNLYYWDQD PPERGAPPST FKGTPTAENP EYLGLDVPV  1259
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[0114]

In the present description, the term "effective amount" used regarding the compound of the present invention means the amount of the compound of the present invention that induces the biological or medical response of a subject, such as, for example, reduction or inhibition of enzyme or protein activity; or ameliorates symptoms, alleviates conditions, and retards or delays the progression of disease; or prevents disease; etc. (therapeutically effective amount).

In the present description, the term "subject" includes mammals and non-mammals. Examples of the mammal may include, but are not limited to, a human, a chimpanzee, an ape, a monkey, a bovine, a horse, sheep, a goat, a swine, a rabbit, a dog, a cat, a rat, a mouse, a Guinea pig, a hedgehog, a kangaroo, a mole, a wild pig, a bear, a tiger, and a lion. Examples of the non-mammal may include, but are not limited to, birds, fish, and reptiles. In one embodiment, the subject is a human, and may be a human who has been diagnosed to need the treatment for the symptoms, conditions or disease disclosed in the present description.

[0115]

Upon the use of the compound of the present invention or a salt thereof as a medicament, a pharmaceutically acceptable carrier is mixed into it, as necessary, and various types of dosage forms can be adopted depending on the preventive or therapeutic purpose. Examples of the dosage form may include all of an oral agent, an injection, a suppository, an ointment, and a patch. Preferably, an oral agent is adopted. These dosage forms can be produced by commonly used production methods that are known to skilled persons.

One embodiment of the present invention provides an antitumor agent for oral administration, comprising the compound of the present invention or a salt thereof as an active ingredient. In addition, one embodiment of the present invention provides a method for preventing and/or treating tumor, comprising administering an effective amount of the compound of the present invention or a salt thereof to a subject in need thereof by oral administration. Moreover, one embodiment of the present invention provides use of the compound of the present invention or a salt thereof for the production of an antitumor agent for oral administration. Furthermore, one embodiment of the present invention provides the compound of the present invention or a salt thereof for use in the prevention and/or treatment of tumor by oral administration thereof.

[0116]

One embodiment of the present invention provides a pharmaceutical

composition comprising the compound of the present invention or a salt thereof. The pharmaceutical composition according to one embodiment of the present invention comprises the compound of the present invention or a salt thereof, and a pharmaceutically acceptable carrier. Further, one embodiment of the present invention provides use of the compound of the present invention or a salt thereof for the production of a pharmaceutical composition. Another embodiment of the present invention provides the compound of the present invention or a salt thereof for use as a medicament.

[0117]

As pharmaceutically acceptable carriers, various types of organic or inorganic carrier substances, which are commonly used as preparation materials, are used. When the compound of the present invention is processed into a solid preparation, examples of the pharmaceutically acceptable carrier mixed into the compound of the present invention may include an excipient, a binder, a disintegrator, a lubricant, a coating agent, and a coloring agent. When the compound of the present invention is processed into a liquid preparation, examples of the pharmaceutically acceptable carrier mixed into the compound of the present invention may include a solvent, a solubilizer, a suspending agent, a tonicity agent, a buffer, and a soothing agent. In addition, preparation additives such as an antiseptic, an antioxidant, a sweetener, and a stabilizer can also be used, as necessary.

[0118]

In the case of preparing a solid preparation for oral administration, an excipient, and as necessary, a binder, a disintegrator, a lubricant, a coloring agent, a corrigent, etc. are added to the compound of the present invention, and thereafter, a tablet, a coated tablet, a granule, a powder agent, a capsule, etc. can be produced according to ordinary methods.

In the case of preparing an injection, a pH adjuster, a buffer, a stabilizer, a tonicity agent, a local anesthetic, etc. are added to the compound of the present invention, and thereafter, subcutaneous, intramuscular, and intravenous injections can be produced according to ordinary methods.

[0119]

The amount of the compound of the present invention to be mixed into the above-described each dosage unit form depends on the symptoms of a subject to whom the present compound should be applied, the dosage form and the like, and thus, the amount of the compound of the present invention is not constant. In general, it is preferable that the applied dose is set to be 0.05 to 1000 mg per dosage unit form in the case of an oral agent, it is set to be 0.01 to 500 mg per dosage unit form in the case of an injection, and it is set to be 1 to 1000 mg per dosage unit form in the case of a suppository.

The daily dose of a drug having the above-described dosage form is different depending on the symptoms, body weight, age, sex and the like of a subject, and thus, it cannot be generally determined. However, the compound of the present invention may be administered to an adult (body weight: 50 kg) at a daily dose of generally 0.05 to 5000 mg, and preferably 0.1 to 1000 mg.

[0120]

The tumor that is the target of the present invention is not particularly limited. Examples of the tumor may include brain tumor, head and neck cancer, digestive cancer (esophageal cancer, stomach cancer, duodenal cancer, liver cancer, biliary tract cancer (gallbladder and/or bile duct cancer, etc.), pancreatic cancer, colorectal cancer (colon cancer, rectal cancer, etc.), etc.), lung cancer (non-small cell lung cancer, small cell lung cancer, mesothelioma, etc.), breast cancer, genital cancer (ovarian cancer, uterine cancer (cervical cancer, endometrial cancer, etc.), etc.), urinary organ cancer (kidney cancer, bladder cancer, prostate cancer, testicular tumor, etc.), hematopoietic tumor (leukemia, malignant lymphoma, multiple myeloma, etc.), bone and/or soft tissue tumor, and skin cancer. Among these, preferable is lung cancer, breast cancer, stomach cancer, colorectal cancer, bladder cancer, biliary tract cancer or uterine cancer, and more preferable is lung cancer, breast cancer, stomach cancer, bladder cancer, or biliary tract cancer.

[0121]

In one embodiment, the tumor is a brain tumor. The compound of the present invention may be useful for the treatment of the symptoms of brain that is required to pass through the blood-brain barrier. The compound of one embodiment has favorable permeability through the blood-brain barrier for the delivery thereof into the brain, namely, excellent brain penetration properties. As an indicator of the penetration properties of the compound into the brain, the concentration of the compound in the brain or a Kp value (brain-to-plasma drug concentration ratio) is applied.

The brain tumor treated with the compound of the present invention includes metastatic brain tumor and primary brain tumor.

Examples of the brain tumor may include, but are not particularly limited to, metastatic brain tumor (e.g., brain metastasis of lung cancer, breast cancer, stomach cancer, colorectal cancer, bladder cancer, biliary tract cancer, uterine cancer, etc. (preferably, lung cancer, breast cancer, or stomach cancer)), piliocytic astrocytoma, diffuse astrocytoma, oligodendroma and/or oligodendroastrocytoma, anaplastic astrocytoma and/or anaplastic oligodendroglioma, anaplastic oligodendroastrocytoma, glioblastoma, ependymoma, anaplastic ependymoma, ganglioglioma, central

neurocytoma, medulloblastoma, germinoma, central nervous system malignant lymphoma, meningioma, neurilemmoma, GH secreting pituitary adenoma, PRL-secreting pituitary adenoma, ACTH-secreting pituitary adenoma, nonfunctional pituitary adenoma, craniopharyngioma, chordoma, hemangioblastoma, and epidermoid tumor.

EXAMPLES

[0122]

Hereinafter, the present invention will be described in detail in the following examples. However, these examples are not intended to limit the scope of the present invention.

In the present description, "room temperature" generally means a temperature that is from approximately 10°C to approximately 35°C. In addition, in the following Examples regarding compounds, "%" indicates weight percent, unless otherwise specified.

Various types of reagents used in the Examples were commercially available products, unless otherwise specified. Silica gel chromatography was carried out using Biotage SNAP Cartridge Ultra, manufactured by Biotage Japan Ltd. Basic silica gel chromatography was carried out using Biotage SNAP Cartridge Isolute Flash-NH2, manufactured by Biotage Japan Ltd.

Preparative thin-layer chromatography was carried out using Kieselgel TM60F254, Art. 5744, manufactured by Merck, or NH2 Silica Gel 60F254 Plate-Wako, manufactured by Wako Pure Chemical Industries, Ltd.

^{1}H-NMR was measured using tetramethylsilane as a reference material, and employing AL400 (400 MHz) manufactured by JEOL, Mercury (400 MHz) manufactured by Varian, or Inova (400 MHz) manufactured by Varian. Moreover, mass spectrum was measured using Micromass ZQ or SQD manufactured by Waters, according to electrospray ionization (ESI) or atmospheric pressure chemical ionization (APCI). Microwave reaction was carried out using Initiator manufactured by Biotage Japan Ltd.

Abbreviations have the following meanings.

s: Singlet

d: Doublet

t: Triplet

q: Quartet

dd: Double doublet

dt: Double triplet

td: Triple doublet

tt: Triple triplet
ddd: Double double doublet
ddt: Double double triplet
dtd: Double triple doublet
tdd: Triple double doublet
m: Multiplet
br: Broad
ATP: Adenosine triphosphate
DMSO-d6: Deuterated dimethyl sulfoxide
$CDCl_3$: Deuterated chloroform
EDTA: Ethylenediaminetetraacetic acid
THF: Tetrahydrofuran
DMF: N,N-dimethylformamide
DMSO: Dimethyl sulfoxide
NMP: N-methyl pyrrolidone
HATU: O-(7-azabenzotriazol-1-yl)-N,N,N',N'-tetramethyluronium hexafluorophosphate
HPMC: Hypromellose
$PdCl_2(PPh_3)_2$: Dichlorobis(triphenylphosphine)palladium(II)
[0123]
Reference Example 1
Reference Example 1(1)
tert-Butyl (2S,4R)-4-(4-amino-5-iodo-7H-pyrrolo[2,3-d]pyrimidin-7-yl)-2 - methylpyrrolidine-1-carboxylate

tert-Butyl (2S,4S)-4-hydroxy-2-methylpyrrolidine-1-carboxylate (19.0 g) and 4-chloro-5-iodo-7H-pyrrolo[2,3-d]pyrimidine (13.1 g) were dissolved in THF (190 mL), and the obtained solution was then cooled to 0°C. Thereafter, triphenylphosphine (37.2 g) and diisopropyl azodicarboxylate (28.1 mL) were added to the reaction solution, and the temperature of the mixture was then increased to room temperature, followed by stirring for 1 hour. Thereafter, the reaction mixture was concentrated under reduced pressure, and the obtained residue was then purified by silica gel chromatography (hexane : ethyl acetate) to obtain the corresponding coupling body. The obtained compound was used in the subsequent reaction without being further purified.

The obtained coupling body, THF (114 mL) and ammonia water (114 mL) were added into a pressure resistant tube, and the obtained mixture was then stirred at 100°C for 14 hours. Thereafter, the reaction mixture was cooled to room temperature, and was then poured into water (285 mL). The thus obtained mixture was stirred at room

temperature for 5 hours. Thereafter, the precipitated solid was collected by filtration, was then washed with water, and was then dried to obtain a product of interest (34.5 g).
^{1}HNMR ($CDCl_3$)δ: 8.27(s,1H) 7.15(s,1H) 5.55-5.73(m,2H) 5.12-5.25(m,1H) 3.86-4.18(m,2H) 3.43-3.57(m,1H) 2.59-2.69(m,1H) 1.92-2.03(m,1H) 1.48(s,9H) 1.30-1.40(m,3H)
ESI-MS m/z 444 (MH+)
[0124]
Reference Example 1(2)
4-Amino-7-((3R,5S)-1-(tert-butoxycarbonyl)-5-methylpyrrolidin-3-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxylic acid

The compound of Reference Example 1(1) (28.0 g), 10% palladium carbon catalyst (720 mg), NMP (84 mL), methanol (26 mL), and triethylamine (17.6 mL) were added into a pressure resistant tube, followed by carbon monoxide substitution, and the obtained mixture was stirred at 100°C for 2 hours. Thereafter, the reaction mixture was cooled to room temperature, a 2 M sodium hydroxide aqueous solution (79 mL) was then added thereto, and the obtained mixture was then stirred at 80°C for 2 hours. Thereafter, the reaction mixture was cooled to room temperature, was then filtrated through Celite, and was then washed with methanol. Subsequently, methanol in the filtrate was concentrated under reduced pressure. Water was further added, and the water layer was then washed with tert-butyl methyl ether. A 1 M potassium hydrogen sulfate aqueous solution was added to the water layer to adjust the pH to approximately 3. The precipitated solid was collected by filtration, was then washed with water, and was then dried to obtain a product of interest (23.4 g).
^{1}HNMR (400MHz, DMSO-d6)δ: 8.14 (s, 1H) 8.08 (s, 1H) 5.16-4.93(m,1H) 4.07-3.79(m,2H) 3.61-3.45(m,1H) 2.53(m,1H) 2.33-2.02(m,1H) 1.42(s,9H) 1.29(d,J = 6.1Hz,3H) ESI-MS m/z 362 (MH+)
[0125]
Examples
Example 1(1)
tert-Butyl-4-amino-6-bromo-7-((3R,5S)-1-(tert-butoxycarbonyl)-5-methylpyrrolidin-3-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxylate

Under a nitrogen atmosphere, the compound of Reference Example 1(2) (15.0 g) was dissolved in chloroform (150 mL), and 2-tert-butyl-1,3-diisopropylisourea (25 mL) was then added to the above obtained solution. The temperature of the obtained mixture was increased to 60°C, and the mixture was then stirred for 2 hours. Thereafter, 2-tert-butyl-1,3-diisopropylisourea (25 mL) was further added to the reaction mixture,

and the thus obtained mixture was then stirred for 2 hours. Thereafter, the reaction mixture was cooled to room temperature, and was then concentrated under reduced pressure. To the obtained residue, tert-butyl methyl ether was added, and the precipitated solid was collected by filtration and was then washed with tert-butyl methyl ether. The filtrate was concentrated under reduced pressure, and tert-butyl methyl ether was then added to the obtained residue. The precipitated solid was collected by filtration, and was then washed with tert-butyl methyl ether. The obtained residue was purified by silica gel chromatography (hexane : ethyl acetate) to obtain a tert-butyl ester form. The obtained compound was used in the subsequent halogenation reaction without being further purified.

The obtained tert-butyl ester form was dissolved in chloroform (140 mL), and N-bromosuccinimide (11.8 g) was then added to the above obtained solution. The obtained mixture was stirred at room temperature for 24 hours. Thereafter, to the reaction mixture, chloroform and 10% sodium bisulfite aqueous solution were successively added, and the obtained mixture was then extracted with chloroform. The gathered organic layer was washed with saturated saline, was then dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : ethyl acetate) to obtain a product of interest (13.8 g).

^{1}HNMR (CDCl3)δ: 8.02 (s, 1H) 5.74-5.13(m,2H) 4.07-3.64(m,2H) 2.43-2.29(m,1H) 2.07-1.97(m,1H) 1.63(s,9H) 1.48(m,12H)

ESI-MS m/z 496,498 (MH+)

[0126]

Example 1(2)

tert-Butyl-7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-bromo-7H-pyrrolo[2,3-d]pyrimidine-5-carboxylate

The compound of Example 1(1) (11.4 g) was dissolved in THF (57 mL), and the obtained solution was then cooled to 0°C. Thereafter, 4 M hydrogen chloride in 1,4-dioxane solution (114 mL) was added to the mixture, and the thus obtained mixture was then stirred at 0°C for 10 hours. Subsequently, to the reaction mixture, a 5 M sodium hydroxide aqueous solution (92 mL), acetonitrile (57 mL), diisopropylethylamine (20 mL), and acryloyl chloride (2.0 mL) were added, and the obtained mixture was then stirred for 30 minutes. Thereafter, the reaction mixture was extracted with ethyl acetate, and the gathered organic layer was washed with saturated saline, was then dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : acetone) to obtain

a product of interest (7.72 g).
^{1}HNMR ($CDCl_3$)δ: 8.26-8.16(m,1H) 6.62-6.30(m,2H) 5.81-5.64(m,1H) 5.33-5.14(m,1H) 4.81-3.75(m,3H) 3.07-2.86(m,1H) 2.67-2.33(m,1H) 1.69-1.61(m,9H) 1.60-1.51(m,3H)
ESI-MS m/z 450,452 (MH+)
[0127]
Example 1(3)
tert-Butyl-7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxylate

1.0 M Propyne in DMF solution (85.7 mL) was added to the compound of Example 1(2) (7.72 g), acetonitrile (154 mL), triethylamine (7.2 mL), $PdCl_2(PPh_3)_2$ (1.2 g), and copper(I) iodide (330 mg), followed by nitrogen substitution. Thereafter, the mixture was stirred at 70°C for 4 hours. Thereafter, the reaction mixture was cooled to room temperature, and ethyl acetate and a saturated sodium hydrogen carbonate aqueous solution were added to the mixture. Thereafter, the obtained mixture was extracted with ethyl acetate, and the gathered organic layer was washed with water, and then with saturated saline. The resultant was dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : acetone) to obtain a product of interest (4.06 g).
^{1}HNMR ($CDCl_3$)δ: 8.29-8.17(m,1H) 6.63-6.30(m,2H) 5.81-5.63(m,1H) 5.42-5.15(m,1H) 4.66-3.81(m,3H) 3.01-2.82(m,1H) 2.65-2.32(m,1H) 2.92-2.13(m,3H) 1.65-1.59(m,9H) 1.57-1.49(m,3H)
ESI-MS m/z 410 (MH+)
[0128]
Example 1(4)
7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-carboxylic acid

The compound of Example 1(3) (1.52 g) was dissolved in chloroform (5 mL), and trifluoroacetic acid (5 mL) was then added to the above obtained solution. The mixture was stirred at room temperature for 2 hours, and the reaction mixture was then concentrated under reduced pressure. To the residue, chloroform was added, and the obtained mixture was concentrated under reduced pressure again. The residue was dried under reduced pressure to obtain a product of interest (1.25 g).
ESI-MS m/z 354 (MH+)
[0129]
Example 1(5)
7-(R)-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-(3,5-

difluorophenyl)ethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

To the compound of Example 1(4) (100 mg) in DMF (1.0 mL) solution, (R)-1-(3,5-difluorophenyl)ethan-1-amine (89.0 mg), diisopropylethylamine (0.25 mL), and HATU (215 mg) were added, and the obtained mixture was then stirred at room temperature for 2 hours. Thereafter, to the reaction mixture, a saturated sodium hydrogen carbonate aqueous solution was added, and the obtained mixture was then extracted with ethyl acetate. The gathered organic layer was washed with saturated saline, was then dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : acetone) to obtain the title compound (60 mg).

^{1}HNMR (DMSO-d6)δ: 8.51(d,*J* = 7.3Hz,1H) 8.16 (s, 1H) 7.25-7.07(m,3H) 6.74-6.47(m,1H) 6.25-6.08(m,1H) 5.78-5.58(m,1H) 5.41-5.21(m,1H) 5.21-5.06(m,1H) 4.45-4.29(m,1H) 4.24-3.91(m,2H) 2.78-2.58(m,1H) 2.52-2.41(m,1H) 2.23(s,3H) 1.48(d,*J* = 7.1Hz,3H) 1.39(d,*J* = 6.1Hz,3H)

ESI-MS m/z 493 (MH+)

[0130]

Example 2

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-phenylethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exception that (R)-1-phenylethan-1-amine was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).

^{1}HNMR (DMSO-d6)δ: 8.35(d,*J* = 7.8Hz,1H) 8.17-8.13(m,1H) 7.48-7.23(m,5H) 6.76-6.46(m,1H) 6.28-6.06(m,1H) 5.81-5.58(m,1H) 5.43-5.02(m,2H) 4.42-4.28(m,1H) 4.21-3.96(m,2H) 2.74-2.59(m,1H) 2.54-2.41(m,1H) 2.17(s,3H) 1.50(d,*J* = 6.8Hz,3H) 1.42-1.33(m,3H)

ESI-MS m/z 457 (MH+)

[0131]

Example 3

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-(2-phenylpropan-2-yl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exception that 2-phenylpropan-2-amine was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).

^{1}HNMR (DMSO-d6)δ: 8.26(s,1H) 8.16-8.08(m,1H) 7.44(dd,*J* = 8.8,1.2Hz,2H) 7.38-7.28(m,2H) 7.21(tt,*J* = 7.3,1.27Hz,1H) 6.76-6.50(m,1H) 6.25-6.10(m,1H) 5.79-

5.62(m,1H) 5.45-5.19(m,1H) 4.45-4.30(m,1H) 4.26-4.01(m,2H) 2.79-2.42(m,2H) 2.29-2.22(m,3H) 1.71(s,6H) 1.43-1.36(m,3H)
ESI-MS m/z 471 (MH+)
[0132]
Example 4
7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-phenylpropyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exception that (R)-1-phenylpropan-1-amine was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).
^{1}HNMR (DMSO-d6)δ: 8.35(brd,*J* = 8.0Hz,1H) 8.17-8.11(m,1H) 7.46-7.22(m,5H) 6.74-6.50(m,1H) 6.26-6.08(m,1H) 5.79-5.60(m,1H) 5.40-5.21(m,1H) 4.99-4.87(m,1H) 4.43-4.30(m,1H) 4.23-3.94(m,2H) 2.76-2.42(m,2H) 2.21(s,3H) 1.95-1.74(m,2H) 1.44-1.34(m,3H) 0.91(t,*J* = 7.3Hz,3H)
ESI-MS m/z 471 (MH+)
[0133]
Example 5
7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-(2-(2-fluorophenyl)propan-2-yl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exception that 2-(2-fluorophenyl)propan-2-amine was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).
^{1}HNMR (CDCl3)δ: 8.28(s,1H) 8.11(d,J = 4.4Hz,1H) 8.02(s,1H) 7.47-7.42(m,1H) 7.29-7.23(m,1H) 7.15(t,J = 7.7Hz,1H) 7.02(ddd,J = 12.5,8.1,1.1Hz,1H) 6.58-6.35(m,2H) 5.79-5.70(m,1H) 5.30-5.19(m,1H) 4.53(t,J = 10.1Hz,0.7H) 4.38-4.25(m,1.6H) 3.92(t,J = 8.8Hz,0.7H) 2.91-2.78(m,1H) 2.70-2.60(m,0.3H) 2.54-2.43(m,0.7H) 2.28(d,J = 7.0Hz,3H) 1.88(dt,J = 10.0,5.0Hz,6H) 1.53(t,J = 6.2Hz,3H)
ESI-MS m/z 489 (MH+)
[0134]
Example 6
7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-(3-chlorophenyl)ethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exception that (R)-(+)-1-(3-chlorophenyl)ethylamine hydrochloride was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).
^{1}HNMR (CDCl3)δ: 8.22(d,J = 5.9Hz,1H) 7.75(d,J = 7.0Hz,1H) 7.38(s,1H) 7.35-

7.27(m,3H) 6.58-6.33(m,2H) 5.78-5.66(m,1H) 5.29-5.19(m,2H) 4.56(t,J = 10.3Hz,0.7H) 4.39-4.20(m,1.6H) 3.89(t,J = 8.8Hz,0.7H) 2.94-2.82(m,1H) 2.66-2.58(m,0.3H) 2.46(dt,J = 14.5,6.1Hz,0.7H) 2.18(d,J = 11.0Hz,3H) 1.60(d,J = 7.0Hz,3H) 1.55-1.51(m,3H)
ESI-MS m/z 491,493 (MH+)
[0135]
Example 7
7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-(2,4-difluorophenyl)ethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exception that (R)-(+)-1-(2,4-difluorophenyl)ethylamine hydrochloride was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).
^{1}HNMR ($CDCl_3$)δ: 8.20(d,*J* = 5.9Hz,1H) 7.98(d,*J* = 7.7Hz,1H) 7.37-7.31(m,1H) 6.90-6.81(m,2H) 6.58-6.35(m,2H) 5.78-5.65(m,1H) 5.44-5.37(m,1H) 5.30-5.19(m,1H) 4.56(t,*J* = 10.1Hz,0.7H) 4.38-4.23(m,1.6H) 3.88(t,*J* = 8.8Hz,0.7H) 2.94-2.83(m,1H) 2.66-2.57(m,0.3H) 2.51-2.42(m,0.7H) 2.27(d,*J* = 9.2Hz,3H) 1.61(d,*J* = 7.0Hz,3H) 1.56-1.51(m,3H)
ESI-MS m/z 493 (MH+)
[0136]
Example 8
7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(prop-1-yn-1-yl)-N-((S)-2,2,2-trifluoro-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exception that (S)-2,2,2-trifluoro-1-phenylethan-1-amine was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).
^{1}HNMR ($CDCl_3$)δ: 8.40(d,*J* = 8.8Hz,1H) 8.16(s,1H) 7.44(s,5H) 6.58-6.38(m,2H) 5.92-5.84(m,1H) 5.81-5.69(m,1H) 5.29-5.19(m,1H) 4.55(t,*J* = 10.3Hz,0.7H) 4.41-4.24(m,1.6H) 3.91(t,*J* = 8.6Hz,0.7H) 2.92-2.80(m,1H) 2.70-2.61(m,0.3H) 2.54-2.46(m,0.7H) 2.35(d,*J* = 8.4Hz,3H) 1.54(t,*J* = 7.3Hz,3H)
ESI-MS m/z 511 (MH+)
[0137]
Example 9
7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-(2-phenylpropan-2-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exceptions that cyclopropylacetylene was used instead of 1.0 M propyne in DMF solution in Example 1(3), and that 2-phenylpropan-2-amine was used instead of (R)-1-

(3,5-difluorophenyl)ethan-1-amine in Example 1(5).

^{1}HNMR ($CDCl_3$)δ: 8.15(s,1H) 8.00(s,1H) 7.44(d,*J* = 7.7Hz,2H) 7.37(t,*J* = 7.7Hz,2H) 7.32-7.27(m, 1H) 6.66-6.30(m,2H) 5.81-5.69(m,1H) 5.38-5.24(m,1H) 4.48(t,*J* = 9.9Hz,0.7H) 4.42-4.29(m,1.6H) 4.22(t,*J* = 10.4Hz,0.7H) 2.77-2.68(m,1H) 2.67-2.60(m,0.3H) 2.59-2.52(m,0.7H) 1.83(s,6H) 1.60-1.52(m,4H) 1.08-1.01(m,2H) 0.92-0.88(m,2H)

ESI-MS m/z 497 (MH+)

[0138]

Example 10

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-(2,3-difluorophenyl)ethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exceptions that cyclopropylacetylene was used instead of 1.0 M propyne in DMF solution in Example 1(3), and that (R)-(+)-1-(2,3-difluorophenyl)ethylamine was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).

^{1}HNMR ($CDCl_3$)δ: 8.17(d,*J* = 4.0Hz,1H) 8.04(d,*J* = 8.1Hz,1H) 7.15-7.05(m,3H) 6.58-6.36(m,2H)5.80-5.68(m,1H) 5.49-5.42(m,1H) 5.34-5.24(m,1H) 4.52(t,*J* = 10.1Hz,0.7H) 4.37-4.23(m,1.6H) 3.92(t,*J* = 8.8Hz,0.7H) 2.86-2.76(m,1H) 2.69-2.63(m,0.3H) 2.52-2.46(m,0.7H) 1.73-1.63(m,4H) 1.55(t,*J* = 5.3Hz,3H) 1.14-1.07(m,2H) 1.01-0.92(m,2H)

ESI-MS m/z 519 (MH+)

[0139]

Example 11

Example 11(1)

tert-Butyl(2S,4R)-4-(4-amino-6-bromo-5-(((R)-1-phenylethyl)carbamoyl)-7H-pyrrolo[2,3-d]pyrimidin-7-yl)-2-methylpyrrolidine-1-carboxylate

The compound of Reference Example 1(2) (1.00 g), (R)-(+)-1-phenylethylamine (0.503 g), diisopropylethylamine (1.79 g), and N,N-dimethylformamide (10 mL) were added, and subsequently, HATU (1.58 g) was added. The obtained mixture was stirred at room temperature overnight. Thereafter, to the reaction mixture, ethyl acetate and a saturated sodium hydrogen carbonate aqueous solution were added, and the obtained mixture was then extracted with ethyl acetate. The gathered organic layer was washed with water, and then with saturated saline. The resultant was dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : acetone) to obtain an amide form (1.53 g). The obtained compound was used in the subsequent reaction without being further purified.

To the amide form (1.53 g), chloroform (15 mL) was added, and the obtained mixture was then cooled to 0°C. Thereafter, N-bromosuccinimide (0.88 g) was added to the reaction mixture, and the obtained mixture was then stirred at 0°C for 1 hour. Thereafter, the reaction mixture was concentrated under reduced pressure, and the obtained residue was purified by silica gel chromatography (hexane : ethyl acetate) to obtain a product of interest (1.39 g).

^{1}HNMR ($CDCl_3$)δ: 8.21 (s, 1H) 7.42-7.28(m,5H) 6.97(d,J = 7.3Hz,1H) 5.36-5.29(m,1H) 5.20-5.07(m,1H) 4.30(t,J = 10.3Hz,1H) 4.04-3.72(m,2H) 3.00-2.86(m,1H) 2.38(dt,J = 14.3,6.0Hz,1H) 1.63(d,J = 7.0Hz,3H) 1.53-1.43(m,12H)

ESI-MS m/z 543,545 (MH+)

[0140]

Example 11(2)

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-bromo-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

To the compound of Example 11(1) (600 mg), chloroform(3 mL) was added, and the obtained mixture was then cooled to 0°C. Thereafter, trifluoroacetic acid (4.44 g) was added to the reaction mixture, and the thus obtained mixture was then stirred at room temperature for 1 hour. Thereafter, the reaction mixture was concentrated under reduced pressure, and acetonitrile (5 mL) was then added to the residue. The obtained mixture was concentrated under reduced pressure again to obtain an amine form. The obtained compound was used in the subsequent reaction without being further purified.

To the obtained amine form, acetonitrile (3 mL) was added, and the obtained mixture was then cooled to 0°C. Thereafter, acryloyl chloride (99.9 mg) and diisopropylethylamine (713 mg) were added, and the obtained mixture was then stirred at 0°C for 1 hour. Thereafter, the reaction mixture was concentrated under reduced pressure, and the obtained residue was purified by silica gel chromatography (ethyl acetate : methanol) to obtain a product of interest (281 mg).

^{1}HNMR ($CDCl_3$)δ: 8.20(d,J = 7.3Hz,1H) 7.42-7.36(m,4H) 7.32-7.28(m,1H) 7.00-6.94(m,1H) 6.57-6.33(m,2H) 5.76-5.66(m,1H) 5.36-5.29(m, 1H) 5.14-5.08(m,1H) 4,71(t,J = 9.9Hz,0.7H) 4.42-4.23(m,1.6H) 3.83(t,J = 8.6Hz,0.7H) 3.03-2.92(m,1H) 2.60-2.57(m,0.3H) 2.44-2.40(m, 0.7H) 1.64(d,J = 6.6Hz,3H) 1.56(dd,J = 11.7,6.2Hz,3H)

ESI-MS m/z 497,499 (MH+)

[0141]

Example 11(3)

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The compound of Example 11(2) (65 mg), dichlorobis(triphenylphosphine)dipalladium (9.2 mg), copper(I) iodide (5.0 mg), cyclopropylacetylene (13.0 mg), triethylamine (39.7 mg), and N,N-dimethylformamide (1.3 mL) were added, and the inside of the reaction system was then substituted with nitrogen. After that, the mixture was stirred at 70°C for 2.5 hours. Thereafter, to the reaction mixture, ethyl acetate and a saturated ammonium chloride aqueous solution were added, and the obtained mixture was then extracted with ethyl acetate. The gathered organic layer was washed with water, and then with saturated saline. The resultant was dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (chloroform : methanol) to obtain a product of interest (50 mg).

^{1}HNMR ($CDCl_3$)δ: 8.22(d,*J* = 5.1Hz,1H) 7.82(d,*J* = 7.3Hz,1H) 7.43-7.35(m,4H) 7.30(t,*J* = 6.8Hz,1H) 6.58-6.34(m,2H) 5.77-5.66(m,1H) 5.35-5.20(m,2H) 4.54(t,*J* = 10.1Hz,0.7H) 4.35-4.25(m,1.6H) 3.88(t,*J* = 8.8Hz,0.7H) 2.90-2.78(m,1H) 2.65-2.56(m,0.3H) 2.49-2.40(m,0.7H) 1.63(d,*J* = 7.0Hz,3H) 1.56-1.45(m,4H) 1.03-0.91(m,2H) 0.84-0.69(m,2H)

ESI-MS m/z 483 (MH+)

[0142]

Example 12

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(3,3-dimethylbut-1-yn-1-yl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 11, with the exception that 3,3-dimethyl-1-butyne was used instead of cyclopropylacetylene in Example 11(3).

^{1}HNMR ($CDCl_3$)δ: 8.22(d,*J* = 5.9Hz,1H) 7.75(d,*J* = 7.7Hz,1H) 7.38(dt,*J* = 15.5,7.1Hz,4H) 7.31-7.25(m,1H) 6.57-6.34(m,2H) 5.77-5.65(m,1H) 5.44-5.35(m,1H) 5.33-5.15(m,1H) 4.63(t,*J* = 10.1Hz,0.7H) 4.40-4.20(m,1.6H) 3.89(t,*J* = 8.8Hz,0.7H) 2.90-2.76(m,1H) 2.65-2.55(m,0.3H) 2.49-2.40(m,0.7H) 1.85(s,1H) 1.64(d,*J* = 7.0Hz,3H) 1.55(d,*J* = 5.9Hz,3H) 1.26(s,9H)

ESI-MS m/z 499 (MH+)

[0143]

Example 13

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(3-methoxy-3-methylbut-1-yn-1-yl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 11, with the exception that 3-methoxy-3-methyl-1-butyne was used instead of

cyclopropylacetylene in Example 11(3).

^{1}HNMR ($CDCl_3$)δ: 8.17 (s, 1H) 7.61(d,*J* = 7.7Hz,1H) 7.43-7.35(m,4H) 7.30(d,*J* = 7.0Hz,1H) 6.57-6.33(m,2H) 5.81-5.68(m,1H) 5.43-5.33(m,1H) 5.29-5.12(m,1H) 4.59(t,*J* = 10.1Hz,0.7H) 4.38-4.22(m,1.6H) 3.92(t,*J* = 8.6Hz,0.7H) 3.30(s,3H) 2.86-2.72(m,1H) 2.70-2.60(m,1.3H) 2.52-2.44(m,0.7H) 1.64(d,*J* = 7.0Hz,3H) 1.55(t,*J* = 5.5Hz,3H) 1.46(d,*J* = 2.2Hz,6H)

ESI-MS m/z 515 (MH+)

[0144]

Example 14

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(but-1-yn-1-yl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 11, with the exception that 1-trimethylsilyl-1-butyne and tetra-n-butylammonium fluoride were used instead of cyclopropylacetylene in Example 11(3).

^{1}HNMR ($CDCl_3$)δ: 8.26-8.25(m,1H) 7.79(d,*J* = 7.3Hz,1H) 7.42-7.36(m,4H) 7.32-7.30(m,1H) 6.57-6.37(m,2H) 5.76-5.66(m,1H) 5.33-5.20(m,2H) 4.57(t,*J* = 10.3Hz,0.7H) 4.36-4.22(m,1.6H) 3.88(t,*J* = 8.8Hz,0.7H) 2.92-2.81(m,1H) 2.65-2.57(m,0.3H) 2.48-2.38(m,2.7H) 1.63(d,*J* = 7.0Hz,3H) 1.54-1.51(m,3H) 1.17-1.12(m,3H)

ESI-MS m/z 471 (MH+)

[0145]

Example 15

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-(2-(2-fluorophenyl)propan-2-yl)-6-(3-methylbut-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 11, with the exceptions that 2-(2-fluorophenyl)propan-2-amine was used instead of (R)-(+)-1-phenylethylamine in Example 11(1), and that 3-methyl-1-butyne was used instead of cyclopropylacetylene in Example 11(3).

^{1}HNMR ($CDCl_3$)δ: 7.92 (s, 1H) 7.44(t,*J* = 7.9Hz,1H) 7.30-7.23(m,1H) 7.14(t,*J* = 7.5Hz,1H) 7.02(dd,*J* = 12.6,8.2Hz,1H) 6.58-6.35(m,2H) 5.80-5.69(m,1H) 5.33-5.16(m,1H) 4.58(t,*J* = 9.9Hz,0.7H) 4.38-4.23(m,1.6H) 3.91(t,*J* = 8.4Hz,0.7H) 3.03-2.93(m,1H) 2.89-2.75(m,1H) 2.69-2.60(m,0.3H) 2.53-2.43(m,0.7H) 1.88(s,6H) 1.55(d,*J* = 5.1Hz,3H) 1.36(d,*J* = 6.6Hz,6H)

ESI-MS m/z 517 (MH+)

[0146]

Example 16

Example 16(1)

tert-Butyl (2R,4S)-4-(benzyloxy)-2-((tosyloxy)methyl)pyrrolidine-1-carboxylate

tert-Butyl (2R,4S)-4-(benzyloxy)-2-(hydroxymethyl)pyrrolidine-1-carboxylate (2.0 g) was dissolved in methylene chloride (20 mL), and the obtained solution was then cooled to 0°C. Thereafter, 1,4-diazabicyclo[2.2.2]octane (2.2 g) and tosylate chloride (1.9 g) were added to the reaction solution, and the temperature of the mixture was then increased to room temperature. The mixture was stirred for 4 hours. Thereafter, a saturated sodium hydrogen carbonate aqueous solution was added to the reaction mixture, and the obtained mixture was then extracted with ethyl acetate. The gathered organic layer was washed with saturated saline, was then dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : ethyl acetate) to obtain a product of interest (4.32 g).

^{1}HNMR ($CDCl_3$)δ: 7.78(d,J = 8.1Hz,2H), 7.42-7.29(m,7H), 4.57-4.41(m,2H), 4.39-3.96(m,4H), 3.61-3.20(m,2H),2.46(s,3H), 2.27-2.02(m,2H), 1.48-1.31(m,9H)

ESI-MS m/z 462 (MH^+)

[0147]

Example 16(2)

tert-Butyl (2S,4S)-4-(benzyloxy)-2-ethylpyrrolidine-1-carboxylate

Under a nitrogen atmosphere, copper iodide (2.04 g) was suspended in diethyl ether (12 mL), and the obtained suspension was then cooled to 0°C. Thereafter, 1.04 M methyl lithium in diethyl ether solution (0.36 mL) was added, and the obtained mixture was then stirred at 0°C for 30 minutes. Subsequently, the compound of Example 16(1) (1.98 g) in methylene chloride (4.0 mL) solution was added to the reaction mixture, and the temperature of the obtained mixture was then increased to room temperature. The mixture was stirred for 1 hour. Thereafter, the reaction mixture was cooled to 0°C, and a saturated ammonium chloride aqueous solution was then added to the reaction mixture. The thus obtained mixture was extracted with ethyl acetate. The gathered organic layer was washed with saturated saline, was then dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : ethyl acetate) to obtain a product of interest (707 mg).

^{1}HNMR ($CDCl_3$)δ 7.42-7.25(m,5H), 4.66-4.40(m,2H), 4.17-4.03(m,1H), 4.00-3.26(m,3H), 2.24-2.09(m,1H), 1.96-1.71(m,2H), 1.48(s,9H),1.45- 1.31(m,1H), 0.86(t,J = 7.4Hz,3H)

ESI-MS m/z 306 (MH^+)

[0148]

Example 16(3)

tert-Butyl (2S,4S)-2-ethyl-4-hydroxypyrrolidine-1-carboxylate

The compound of Example 16(2) (1.06 g) and a 10% palladium hydroxide carbon catalyst (160 mg) were suspended in ethanol (11 mL) and THF (11 mL), followed by hydrogen substitution, and the resultant was then stirred at room temperature for 20 hours. Thereafter, the reaction mixture was filtrated through Celite, and was then washed with ethanol, and the filtrate was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : ethyl acetate) to obtain a product of interest (709 mg).

^{1}HNMR ($CDCl_3$)δ 4.46-4.36(m,1H), 4.02-3.81(m,1H), 3.71-3.35(m,2H), 2.15-1.99(m,1H), 1.95-1.72(m,2H), 1.49(s,9H), 1.46-1.35(m,1H), 0.86(t,J = 7.5Hz,3H)

ESI-MS m/z 216 (MH^+)

[0149]

Example 16(4)

tert-Butyl (2S,4R)-4-(4-chloro-5-iodo-7H-pyrrolo[2,3-d]pyrimidin-7-yl)-2-ethylpyrrolidine-1-carboxylate

The compound of Example 16(3) (709 mg) and 4-chloro-5-iodo-7H-pyrrolo[2,3-d]pyrimidine (1.11 g) were dissolved in THF (7.1 mL), and the obtained solution was then cooled to 0°C. Thereafter, triphenylphosphine (1.3 g) and diisopropyl azodicarboxylate (1.00 mL) were added, and the temperature of the obtained mixture was then increased to room temperature, followed by stirring the mixture for 1 hour. Thereafter, the reaction mixture was concentrated under reduced pressure, and the obtained residue was then purified by silica gel chromatography (hexane : ethyl acetate) to obtain the corresponding coupling body. The obtained compound was used in the subsequent reaction without being further purified. Into a pressure resistant tube, the obtained coupling body, THF (5.4 mL), and ammonia water (5.4 mL) were added, and the obtained mixture was then stirred at 100°C for 14 hours. Thereafter, the reaction mixture was cooled to room temperature, and was then poured into water (12.8 mL), and the mixed solution was then extracted with ethyl acetate. The gathered organic layer was washed with saturated saline, was then dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : acetone) to obtain a product of interest (797 mg).

^{1}HNMR ($CDCl_3$)δ 8.29(s,1H), 7.14(s,1H), 5.67(br s,2H), 5.32-5.09(m,1H), 4.24-4.08(m,1H), 3.95-3.79(m,1H), 3.46(dd,J = 9.3,11.0Hz,1H), 2.70-2.55(m,1H), 2.06-1.95(m,1H), 1.59-1.51(m,2H), 1.49(s,9H), 0.91(t,J = 7.5Hz,3H)

ESI-MS m/z 458 (MH^+)

[0150]

Example 16(5)

tert-Butyl (2S,4R)-4-(4-amino-6-bromo-5-(((R)-1-phenylethyl)carbamoyl)-7H-pyrrolo [2,3-d]pyrimidin-7-yl)-2-ethylpyrrolidine-1-carboxylate

The compound of Example 16(4) (797 mg), dichlorobis(triphenylphosphine)dipalladium (25 mg), and (R)-(+)-1-phenylethylamine (0.55 mL) were suspended in DMF (8.0 mL), followed by carbon monoxide substitution, and the resultant was then stirred at 80°C for 2 hours. Thereafter, the reaction mixture was cooled to room temperature, water was then added thereto, and the obtained mixture was then extracted with ethyl acetate. The gathered organic layer was washed with saturated saline, was then dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : acetone) to obtain the corresponding amide form. The obtained compound was used in the subsequent reaction without being further purified. The obtained amide form was dissolved in acetonitrile (8.2 mL), and the obtained solution was then cooled to -10°C. Thereafter, N-bromosuccinimide (457 mg) in acetonitrile (8.2 mL) solution was slowly added dropwise to the solution, and the reaction mixture was then stirred for 30 minutes. Thereafter, to the reaction mixture, a sodium sulfite aqueous solution and a sodium hydrogen carbonate aqueous solution were added, and the obtained mixture was then extracted with ethyl acetate. The gathered organic layer was washed with saturated saline, was then dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : acetone) to obtain a product of interest (650 mg).

^{1}HNMR ($CDCl_3$)δ 8.23(s,1H), 7.49-7.29(m,5H), 6.98(d,J = 7.4Hz,1H), 5.41-5.28(m,1H), 5.24-5.04(m,1H), 4.38-4.22(m,1H), 4.07-3.68(m,1H), 3.19-2.83(m,1H), 2.43-2.29(m,1H), 2.25-1.67(m,3H), 1.66(d,J = 6.9Hz,3H), 1.51(s,9H), 0.98(t,J = 7.4Hz,3H)

ESI-MS m/z 557,559 (MH^+)

[0151]

Example 16(6)

7-((3R,5S)-1-acryloyl-5-ethylpyrrolidin-3-yl)-4-amino-6-bromo-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

To the compound of Example 16(5) (650 mg), acetonitrile (9.7 mL) was added, and the obtained mixture was then cooled to 0°C. Thereafter, sodium iodide (1.05 g) and trimethylsilyl chloride (0.89 mL) were added, and the obtained mixture was then stirred at 0°C for 1 hour. Thereafter, to the reaction mixture, ethanol (9.7 mL), isopropylethylamine (2.0 mL), and acrylic acid anhydride (0.16 mL) were successively added, and the obtained mixture was then stirred at 0°C for 30 minutes. Thereafter, to

the reaction mixture, ammonia water and water were added, and the obtained mixture was then extracted with ethyl acetate. The gathered organic layer was washed with saturated saline, was then dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : acetone) to obtain a product of interest (256 mg).

^{1}HNMR ($CDCl_3$)δ 8.27-8.16(m,1H), 7.47-7.29(m,5H), 6.98(d,J = 7.3Hz,1H), 6.61-6.29(m,2H), 5.84-5.63(m,1H), 5.43-5.26(m,1H), 5.22-5.01(m,1H), 4.80-3.82(m,3H), 3.23-2.92(m,1H), 2.58-2.30(m,1H), 2.22-1.79(m,2H),1.66(d,J = 7.0Hz,3H),1.07-0.96(m,3H)

ESI-MS m/z 511,513 (MH^+)

[0152]

Example 16(7)

7-((3R,5S)-1-acryloyl-5-ethylpyrrolidin-3-yl)-4-amino-N-((R)-1-phenylethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

1.0 M Propyne in DMF solution (0.70 mL) was added to the compound of Example 16(6) (120 mg), acetonitrile (1.2 mL), triethylamine (0.10 mL), $PdCl_2(PPh_3)_2$ (8.2 mg), and copper(I) iodide (0.4 mg), followed by nitrogen substitution, and the mixture was then stirred at 60°C for 2 hours. Thereafter, the reaction mixture was cooled to room temperature, and ethyl acetate and a saturated ammonium chloride aqueous solution were added to the mixture. The thus obtained mixture was extracted with ethyl acetate, and the gathered organic layer was washed with water, and then with saturated saline. The resultant was dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (ethyl acetate : methanol) to obtain a product of interest (102 mg).

^{1}HNMR ($CDCl_3$)δ: 8.26(s,1H), 7.79(br d,J = 7.0Hz,1H), 7.46-7.30(m,5H), 6.58-6.31(m,2H), 5.80-5.65(m,1H), 5.33-5.15(m,2H), 4.59-3.85(m,3H), 3.03-2.33(m,2H), 2.25-1.70(m,5H), 1.65(d,J = 6.8Hz,6H), 1.09-0.91(m,3H)

ESI-MS m/z 471 (MH^+)

[0153]

Example 17

7-((3R,5S)-1-acryloyl-5-ethylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 16, with the exception that cyclopropylacetylene was used instead of 1.0 M propyne in DMF solution in Example 16(7).

^{1}HNMR ($CDCl_3$)δ: 8.31-8.16(m,1H), 7.84(d,J = 7.4Hz,1H), 7.46-7.30(m,5H), 6.64-

6.32(m,2H), 5.82-5.67(m,1H), 5.39-5.17(m,2H), 4.67-3.81(m,3H), 3.02-2.80(m,1H), 2.62-1.71(m,3H), 1.65(d,J = 6.9Hz,3H), 1.58-1.47(m,1H), 1.06-0.92(m,5H), 0.85-0.70(m,2H)

ESI-MS m/z 497 (MH^+)

[0154]

Example 18

7-((3R,5R)-1-acryloyl-5-(methoxymethyl)pyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 16, with the exceptions that tert-butyl (2R,4S)-4-hydroxy-2-(methoxymethyl)pyrrolidine-1 - carboxylate was used instead of the compound of Example 16(3) in Example 16(4), and that cyclopropylacetylene was used instead of 1.0 M propyne in DMF solution in Example 16(7).

^{1}HNMR ($CDCl_3$)δ: 8.29-8.22(m,1H), 7.86-7.80(m,1H), 7.36-7.44(m,4H), 7.34-7.28(m,1H), 6.48-6.37(m,2H), 5.78-5.69(m,1H), 5.29-5.15(m,2H), 4.55-4.30(m,2H), 3.96-3.65(m,3H), 3.42(s,3H), 3.18-3.06(m,0.3H), 2.90-2.80(m,0.3H), 2.64-2.58(m,0.3H), 2.47-2.35(m,0.7H),1.64(d,3H,J = 6.9Hz), 1.58-1.47(m,1H), 1.04-0.94(m,2H), 0.87-0.69(m,2H)

ESI-MS m/z 513 (MH^+)

[0155]

Example 19

7-((3R,5R)-1-acryloyl-5-(ethoxymethyl)pyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 16, with the exceptions that tert-butyl (2R,4S)-2-(ethoxymethyl)-4-hydroxypyrrolidine-1 - carboxamide was used instead of the compound of Example 16(3) in Example 16(4), and that cyclopropylacetylene was used instead of 1.0 M propyne in DMF solution in Example 16(7).

^{1}HNMR ($CDCl_3$)δ: 8.28-8.18(m,1H),7.84(br d,J = 7.0Hz,1H), 7.47-7.29(m,5H), 6.82-6.35(m,2H), 5.79-5.68(m,1H), 5.40-5.14(m,2H), 4.63-3.53(m,7H), 3.20-2.79(m,1H), 2.69-2.40(m,1H), 1.67-1.63(m,3H), 1.59-1.47(m,1H),1.22(t,J = 7.0Hz,3H), 1.05-0.92(m,2H), 0.87-0.72(m,2H)

ESI-MS m/z 527 (MH^+)

[0156]

Comparative Example 1

4-Amino-N-(4-(methoxymethyl)phenyl)-7-(1-methylcyclopropyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained by the method described in Example 95 of International Publication No. WO 2017/146116.

ESI-MS m/z 390 (MH+)

[0157]

Comparative Example 2

1-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-(4-(2-(dimethylamino)-2-oxoethyl)-2,3-dimethylphenyl)-1H-pyrazolo[3,4-d]pyrimidine-3-carboxamide

The title compound was obtained by the method described in Example 79 of International Publication No. WO 2017/038838.

ESI-MS m/z 505 (MH+)

[0158]

Comparative Example 3

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-(cyclohexylmethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exception that cyclohexylmethanamine was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).

^{1}HNMR (DMSO-d6)δ:8.68-8.31(m,1H) 8.20-8.10(m,1H) 8.09-7.97(m,1H) 7.59-7.20(m,1H) 6.74-6.49(m,1H) 6.25-6.09(m,1H) 5.78-5.60(m,1H) 5.40-5.20(m,1H) 4.44-4.29(m,1H) 4.23-3.92(m,2H) 3.25-3.12(m,2H) 2.76-2.40(m,2H) 2.25(s,3H) 1.81-1.45(m,5H) 1.43-1.34(m,3H) 1.30-0.90(m,6H)

ESI-MS m/z 449 (MH+)

[0159]

Comparative Example 4

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-(2-methylbenzyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exception that o-tolylmethanamine was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).

^{1}HNMR (DMSO-d6)δ:8.37-8.27(m,1H) 8.19-8.09(m,1H) 7.39-7.30(m,1H) 7.26-7.11(m,4H) 6.68-6.48(m,1H) 6.24-6.07(m,1H) 5.80-5.60(m,1H) 5.36-5.17(m,1H) 4.52(d,J = 5.7Hz,2H) 4.42-4.28(m,1H) 4.22-3.92(m,2H) 2.73-2.42(m,2H) 2.33(s,3H) 2.02(s,3H) 1.43-1.32(m,3H)

ESI-MS m/z 457 (MH+)

[0160]

Comparative Example 5

7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-methyl-N-((R)-1-phenylethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

The title compound was obtained in the same manner as that of Example 1, with the exception that (R)-N-methyl-1-phenylethan-1-amine was used instead of (R)-1-(3,5-difluorophenyl)ethan-1-amine in Example 1(5).

^{1}HNMR ($CDCl_3$)δ: 8.23(d,*J* = 5.9Hz,1H) 7.50-7.28(m,4H) 7.09-6.88(m,1H) 6.57-6.34(m,2H) 5.79-5.64(m,1H) 5.22(t,*J* = 9.3Hz,1H) 4.48(t,*J* = 9.7Hz,0.6H) 4.39-4.20(m,1.9H) 3.90(t,*J* = 8.6Hz,0.5H) 2.85(s,4H) 2.66-2.63(m,0.4H) 2.51-2.44(m,0.6H) 2.07(s,2H) 1.66(d,*J* = 4.8Hz,3H) 1.52(d,*J* = 5.9Hz,3H)

ESI-MS m/z 471 (MH+)

[0161]

Comparative Example 6(1)

tert-Butyl (2S,4R)-4-(4-amino-5-(((R)-1-phenylethyl)carbamoyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidin-7-yl)-2-methylpyrrolidine-1-carboxylate

1.0 M Propyne in DMF solution(2.1 mL) was added to the compound of Example 11(1) (230 mg), acetonitrile (4.6 mL), triethylamine (0.29 mL), $PdCl_2(PPh_3)_2$ (5.9 mg), and copper(I) iodide (1.6 mg), followed by nitrogen substitution, and the obtained mixture was then stirred at 70°C for 1 hour. Thereafter, the reaction mixture was cooled to room temperature, and ethyl acetate and a saturated sodium hydrogen carbonate aqueous solution were then added to the mixture. The thus obtained mixture was extracted with ethyl acetate, and the gathered organic layer was washed with water and then with saturated saline. The resultant was dried over anhydrous sodium sulfate, and was then concentrated under reduced pressure. The obtained residue was purified by silica gel chromatography (hexane : ethyl acetate) to obtain a product of interest (193 mg).

^{1}HNMR ($CDCl_3$)δ: 8.23 (s, 1H) 7.79(d,*J* = 6.8Hz,1H)7.46-7.27(m,5H) 5.40-5.17(m,2H) 4.28-3.64(m,3H) 2.85-2.68(m,1H) 2.46-2.36(m,1H) 2.15-1.97(m,3H) 1.62(d,*J* = 6.8Hz,3H) 1.56-1.32(m,12H)

ESI-MS m/z 503 (MH+)

[0162]

Comparative Example 6(2)

4-Amino-7-((3R,5S)-5-methylpyrrolidin-3-yl)-N-((R)-1-phenylethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide hydrochloride

To the compound of Comparative Example 6(1) (530 mg), 4 M hydrochloric acid in 1,4-dioxane solution (5 mL) was added, and the obtained mixture was then stirred at room temperature for 2 hours. Thereafter, the reaction mixture was concentrated under reduced pressure to obtain a product of interest (420 mg).

ESI-MS m/z 403 (MH+)

[0163]

Comparative Example 6(3)

4-Amino-7-((3R,5S)-1-((E)-but-2-enoyl)-5-methylpyrrolidin-3-yl)-N-((R)-1-phenylethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide

To the compound of Comparative Example 6(2) (18 mg), acetonitrile (0.5 mL) was added, and the obtained mixture was then cooled to 0°C. Thereafter, acryloyl chloride (0.004 mL) and diisopropylethylamine (0.036 mL) were added to the reaction mixture, and the thus obtained mixture was then stirred at 0°C for 1 hour. Thereafter, the reaction mixture was concentrated under reduced pressure, and was then subjected to reverse phase preparative HPLC (water : acetonitrile (0.1% formic acid)) to obtain a product of interest (8.7 mg).

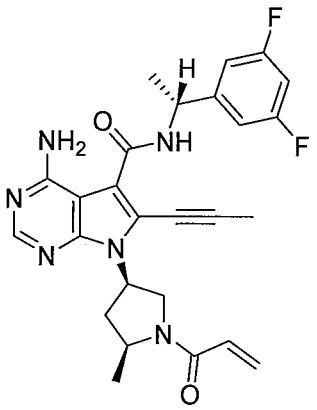
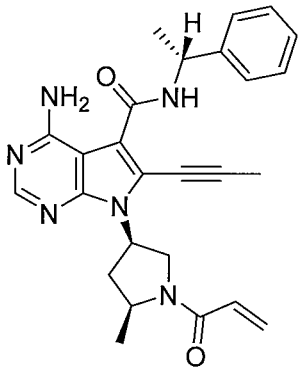
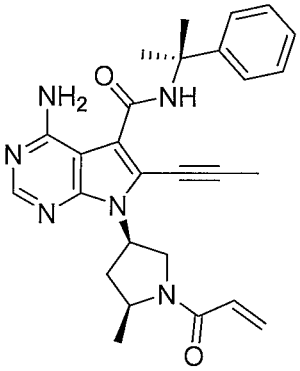
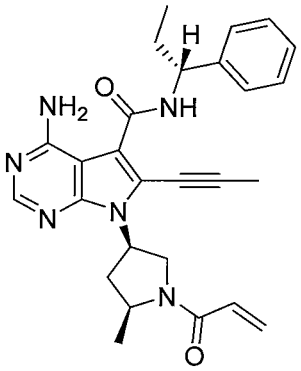
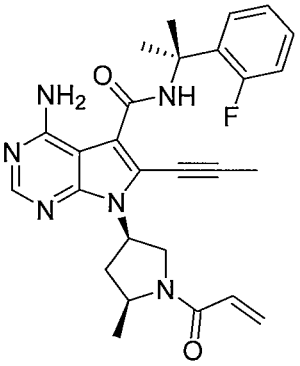
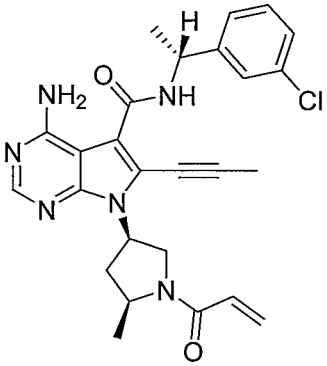
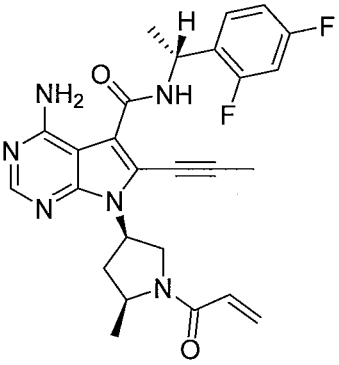
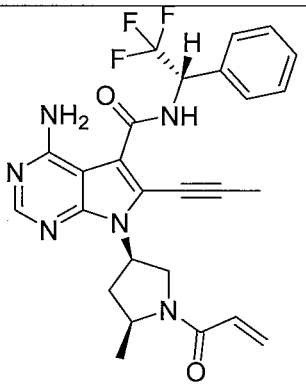
^{1}HNMR ($CDCl_3$)δ: 8.31 (s, 1H) 8.14(d,*J* = 6.2Hz,1H)7.77(d,*J* = 7.0Hz,1H) 7.39-7.36(m,4H) 7.33-7.31(m,1H) 7.03-6.90(m,1H) 6.06(dd,*J* = 14.3Hz,1H) 5.28-5.17(m,2H) 4.48(t,*J* = 10.1Hz,1H) 4.35-4.20(m,2H) 3.88(t,8.8Hz,1H) 2.84-2.76(m,1H) 2.64-2.40(m,1H) 2.05(d,*J* = 10.6Hz,3H) 1.92(d,*J* = 6.6Hz,1H) 1.85(d,*J* = 7.0Hz,2H) 1.62(d,*J* = 7.0Hz,3H) 1.55(dd,*J* = 9.0,5.7Hz,3H)

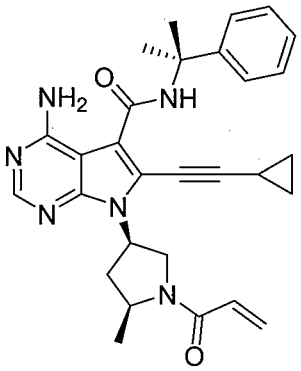
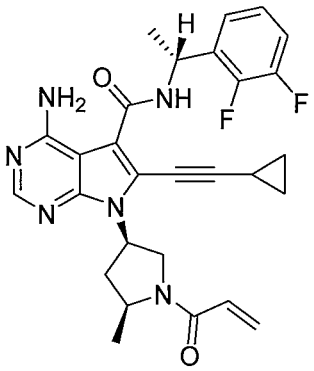
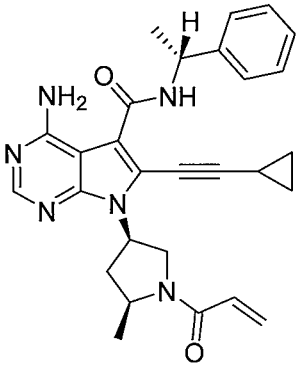
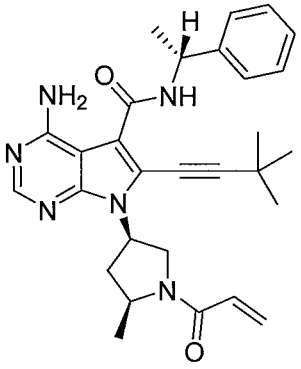
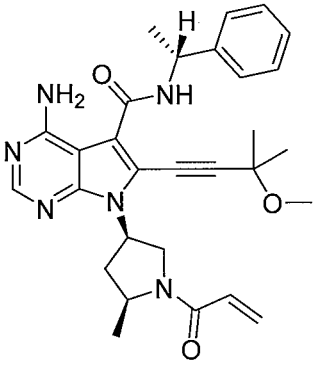
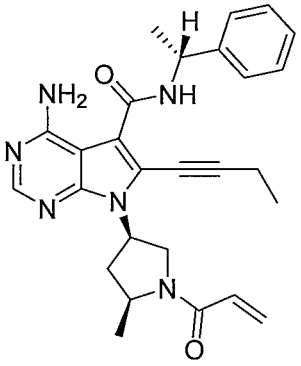
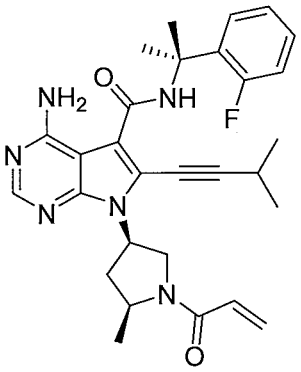
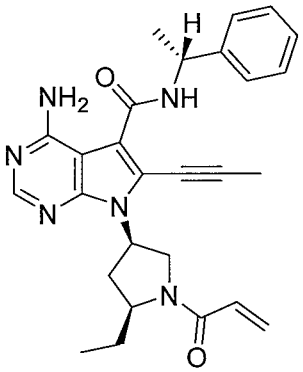
ESI-MS m/z 471 (MH+)

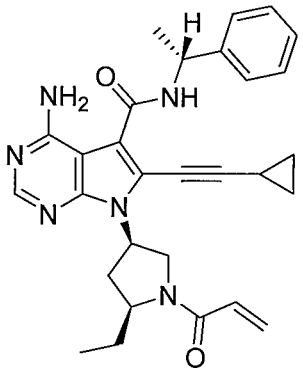
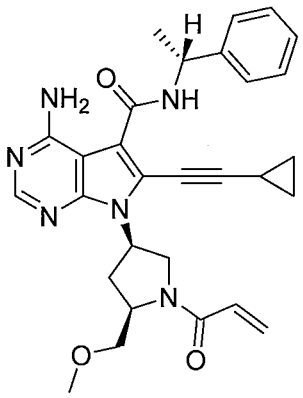
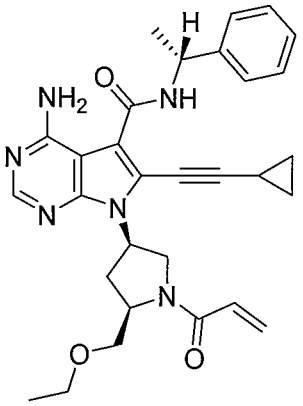
[0164]

The compounds synthesized in the above-described Examples and Comparative Examples are shown below.

[Table B]

Example No.	Structural Formula	Example No.	Structural Formula
1		2	
3		4	
5		6	
7		8	

9		10	
11		12	
13		14	
15		16	

17		18	
19			

[0165]

[Table C]

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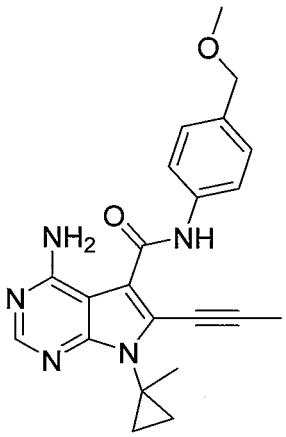
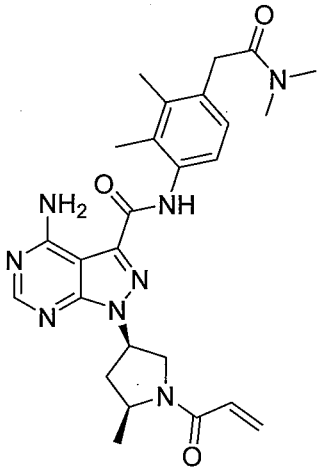
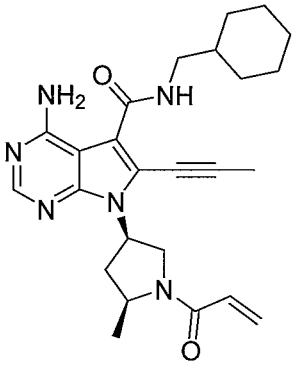
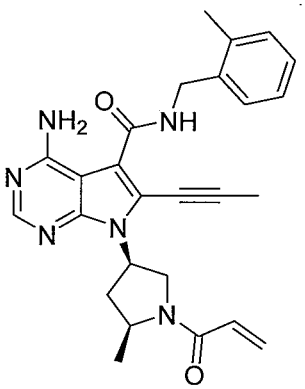
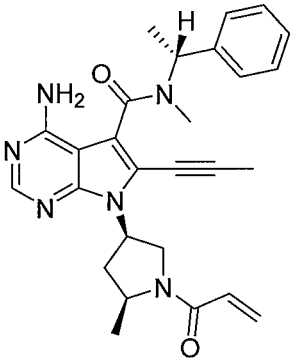
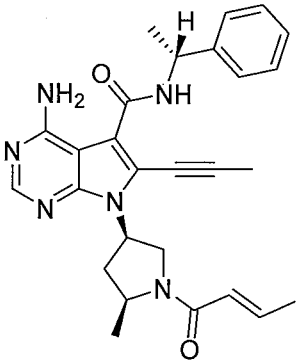
1		2	
3		4	
5		6	

[0166]

Test Example 1 Measurement of inhibitory effect (*in vitro*) on HER2 phosphorylation activity

In order to determine conditions for a method of measuring the *in vitro* inhibitory activity of a compound against HER2 phosphorylation activity, based on the report

regarding a HER2 kinase reaction using, as a substrate, a peptide having the same sequence (5-FAM-EEPLYWSFPAKKK-$CONH_2$) as that of ProfilerPro Peptide 22 of PerkinElmer (Xie H et al., PLoS One.2011; 6(7): e21487), ProfilerPro Peptide 22 was used as a substrate. A purified recombinant human HER2 protein used in the present test was purchased from Carna Biosciences, Inc. Upon the measurement of the inhibitory activity of the compound, first, the compound of the present invention was diluted stepwise with dimethyl sulfoxide (DMSO). Subsequently, the HER2 protein, the substrate peptide (final concentration: 1 μM), manganese chloride (final concentration: 10 mM), ATP (final concentration: 5 μM), and the compound of the present invention in DMSO solution (final concentration of DMSO: 5%) were added to a buffer for the kinase reaction (13.5 mM Tris (pH 7.5), 2 mM dithiothreitol, and 0.009% Tween 20), and the obtained mixture was then incubated at 25°C for 30 minutes, so that the kinase reaction was carried out. To the reaction solution, EDTA was added to a final concentration of 30 mM, so as to terminate the reaction. Finally, using LabChip (registered trademark) EZ Reader II (PerkinElmer), an unphosphorylated substrate peptide (S) and a phosphorylated peptide (P) were separated and detected according to microchannel capillary electrophoresis. From the peak heights of S and P, the amount of the phosphorylation reaction was obtained, and the concentration of the compound capable of inhibiting the phosphorylation reaction by 50% was defined as an IC50 value (nM). The results are shown in Table 1.

[0167]

Test Example 2 Measurement of inhibitory action (*in vitro*) against HER2 exon 20 insertion mutant (HER2ex20insYVMA) phosphorylation activity

In order to determine conditions for a method of measuring the *in vitro* inhibitory activity of a compound against HER2 exon 20 insertion mutant phosphorylation activity, as in the case of HER2, ProfilerPro Peptide 22 was used as a substrate. A purified recombinant human HER2 exon 20 insertion mutant (A775_G776insYVMA) protein is shown in SEQ ID NO: 7, and was purchased from SignalChem. Upon the measurement of the inhibitory activity of the compound, first, the compound of the present invention was diluted stepwise with dimethyl sulfoxide (DMSO). Subsequently, the HER2 exon 20 insertion mutant protein and the compound of the present invention in DMSO solution (final concentration of DMSO: 5%) were added into a buffer for the kinase reaction (13.5 mM Tris (pH 7.5), 2 mM dithiothreitol, and 0.009% Tween 20), and the obtained mixture was then pre-incubated at 25°C for 30 minutes. Thereafter, the substrate peptide (final concentration: 1 μM), manganese chloride (final concentration: 25 mM), magnesium chloride (final concentration: 20 mM), and ATP (final concentration: 200 μM) were added

into the reaction mixture, and the thus obtained mixture was then incubated at 25°C for 220 minutes, so that the kinase reaction was carried out. To the reaction solution, EDTA was added to a final concentration of 30 mM, so as to terminate the reaction. Finally, using LabChip (registered trademark) EZ Reader II (PerkinElmer), an unphosphorylated substrate peptide (S) and a phosphorylated peptide (P) were separated and detected according to microchannel capillary electrophoresis. From the peak heights of S and P, the amount of the phosphorylation reaction was obtained, and the concentration of the compound capable of inhibiting the phosphorylation reaction by 50% was defined as an IC50 value (nM). The results are shown in Table 1.

[0168]

[Table 1]

Example No.	HER2 inhibitory activity IC50 value (nM)	HER2ex20insYVMA inhibitory activity IC50 value (nM)
1	2.7	0.34
2	2.5	< 0.30
3	5.8	< 0.30
4	3.9	0.37
5	7.7	0.38
6	2.8	< 0.30
7	4.9	0.39
8	10	< 0.30
9	5.6	0.32
10	2.2	< 0.30
11	3.2	< 0.30
12	3.4	0.39
13	5.2	0.44
14	2.2	< 0.30
15	4.6	0.42
16	3.3	0.44
17	2.9	0.54
18	2.3	< 0.30
19	4.4	1.1
Comp. Ex. 1	> 10000	> 10000
Comp. Ex. 2	19	4.4
Comp. Ex. 3	630	380
Comp. Ex. 4	54	11
Comp. Ex. 5	130	14
Comp. Ex. 6	390	> 10000

[0169]

From the above results, it was found that the compound of the present invention has excellent inhibitory activity against phosphorylation of HER2 and against phosphorylation of HER2 exon 20 insertion mutant.

[0170]

Test Example 3 Measurement of growth inhibitory activity against HER2 expressing cell line

SK-BR-3 cells as a HER2 overexpressing human breast cancer cell line were suspended in a McCoy's 5a medium (manufactured by Life Technologies) supplemented with 10% fetal bovine serum. The cell suspension was seeded in each well of a 384-well flat-bottom microplate, and was then cultured in a 5% carbon dioxide gas-containing culture vessel at 37°C for 1 day. Thereafter, the compound of the present invention was dissolved in DMSO, and the compound was diluted to 500 times the final concentration in DMSO. The compound in the DMSO solution was diluted with DMSO solution or the medium used in the suspension of the cells, and the obtained solution was then added to each well of the culture plate so that the final concentration of DMSO was 0.2%. The obtained mixture was further cultured in the 5% carbon dioxide gas-containing culture vessel at 37°C for 3 days. After completion of the culture for 3 days in the presence of the compound, the cells were counted using CellTiter-Glo 2.0 (manufactured by Promega), and the growth inhibition percentage was then calculated according to the following equation. The concentration of the compound, in which the growth of the cells can be inhibited by 50%, was defined as IC50 (nM).

Growth inhibitory percentage (%) = (C-T) / (C) x 100

T: Emission intensity from the well to which the test compound was added

C: Emission intensity from the well to which the test compound was not added

The results are shown in the following Table 2.

[0171]

Test Example 4 Measurement of growth inhibitory activity against HER2 exon 20 insertion mutant expressing cell line

Growth inhibitory activity against the HER2 exon 20 insertion mutant was measured using Ba/F3 cells that were a mouse B lymphocyte precursor cell line, into which a human HER2 exon 20 insertion mutant gene had been introduced. The Ba/F3 cells were maintained in an RPMI-1640 medium (Thermo Fisher Scientific) supplemented with 10% fetal bovine serum (FBS), 100 U/mL penicillin, 100 μg/mL streptomycin (Thermo Fisher Scientific) and 1 ng/mL mouse interleukin-3 (mIL-3) (CST). Thereafter, a pCDNA3.1-hyg(+) vector, into which a human HER2 exon 20 insertion mutant gene (A775_G776insYVMA (HER2ex20insYVMA)), Internal Ribosome Binding Sequence (IRES), and a Kusabira orange gene had been incorporated, was introduced into the Ba/F3 cells according to an electroporation method using Amaxa (registered trademark) Cell Line Nucleofector (registered trademark) Kit V. The Ba/F3 cells expressing the HER2 exon 20 insertion mutant (Ba/F3-HER2insYVMA), which

were selected with hygromycin B (Nacalai Tesque), exhibited mIL-3-independent growth.

Upon evaluation of cell growth inhibitory activity, the Ba/F3-HER2insYVMA cells were suspended in an RPMI-1640 medium supplemented with 10% FBS, 100 U/mL penicillin, and 100 μg/mL streptomycin. The cell suspension was seeded in each well of a 96-well flat-bottom microplate, and was then cultured in a 5% carbon dioxide gas-containing culture vessel at 37°C for 1 day. The compound of the present invention was dissolved in DMSO, and was then diluted with DMSO or the medium used in the suspension of the cells. The obtained solution was then added to each well of the culture plate, so that the final concentration of DMSO became 0.2%. The obtained mixture was further cultured in the 5% carbon dioxide gas-containing culture vessel at 37°C for 3 days. After completion of the culture for 3 days in the presence of the compound, the cells were counted using CellTiter-Glo 2.0 (manufactured by Promega), and the growth inhibition percentage was then calculated according to the following equation. The concentration of the compound, in which the growth of the cells can be inhibited by 50%, was defined as IC50 (nM).

Growth inhibitory percentage (%) = (C-T) / (C) x 100

T: Emission intensity from the well to which the test compound was added

C: Emission intensity from the well to which the test compound was not added

The results are shown in the following Table 2.

[0172]

[Table 2]

Example No.	SK-BR-3 cell growth inhibitory activity IC50 value (nM)	HER2ex20insYVMA cell growth inhibitory activity IC50 value (nM)
1	9.3	17
2	2.8	12
3	4.5	25
4	5.6	20
5	4.0	14
6	10	28
7	12	40
8	14	26
9	4.2	24
10	13	29
11	6.6	29
12	17	43
13	14	23
14	8.1	27
15	7.0	40
16	1.4	9.7
17	4.0	20
18	3.4	14
19	17	50
Comp. Ex. 1	> 10000	> 10000
Comp. Ex. 2	25	1900
Comp. Ex. 3	4300	3400
Comp. Ex. 4	340	900
Comp. Ex. 5	400	1300
Comp. Ex. 6	3000	4100

[0173]

From the above results, it was found that the compound group of the present invention has excellent cell growth inhibitory activity even against the HER2 expressing cell line (SK-BR-3) and also, against the HER2 exon 20 insertion mutant expressing cell line (Ba/F3-HER2insYVMA).

[0174]

Test Example 5 Measurement of growth inhibitory activity against HER2 expressing cell line (NCI-N87)

NCI-N87 cells as a HER2 overexpressing human stomach cancer cell line (American Type Culture Collection, Cat No. ATCC (registered trademark) CRL-5822) were suspended in an RPMI1640 medium (Wako Pure Chemical Industries, Ltd.) supplemented with 10% fetal bovine serum. Subsequently, the cell suspension was seeded in each well of a 96-well flat-bottom microplate, and was then cultured in a 5% carbon dioxide gas-containing culture vessel at 37°C for 1 day. Thereafter, the compound of the present invention was dissolved in DMSO, and the compound was diluted to 1000 times the final concentration in DMSO. The compound in the DMSO solution was diluted with the medium used in the suspension of the cells, and the obtained solution was then added to each well of the culture plate, so that the final concentration of DMSO became 0.1%. Regarding a control well, DMSO was diluted with the medium used in the suspension of the cells, and the obtained solution was then added to each well of the culture plate, so that the final concentration of DMSO became 0.1%. After addition of a drug solution, the obtained mixture was further cultured in the 5% carbon dioxide gas-containing culture vessel at 37°C for 3 days. After completion of the culture for 3 days in the presence of the compound, the cells were counted using CellTiter-Glo 2.0 (manufactured by Promega) in accordance with the protocols recommended by Promega. The growth inhibition percentage was calculated according to the following equation. The concentration of the compound, in which the growth of the cells can be inhibited by 50%, was defined as IC50 (nM).

Growth inhibitory percentage (%) = (C-T) / (C) x 100

T: Emission intensity from the well to which the test compound was added

C: Emission intensity from the well to which the test compound was not added

The results are shown in the following Table 3.

[0175]

[Table 3]

Example No.	NCI-N87 cell growth inhibitory activity IC50 value (nM)
1	10.7
2	3.0
3	4.7
4	5.6
5	7.0
6	8.5
7	11.1
8	9.7
9	6.2
10	10.5
11	9.9
12	15.0
13	11.7
14	9.1
15	11.6
16	0.9
17	2.2
18	2.6
19	7.9

[0176]

From the above results, it was found that the compound of the present invention has excellent cell growth inhibitory activity even against the HER2 overexpressing cell line (NCI-N87).

[0177]

Test Example 6 Evaluation of oral absorbability

The compound of the present invention was suspended or dissolved in 0.5% HPMC aqueous solution and 0.1 N hydrochloric acid, and the obtained suspension or solution was orally administered to BALB/cA mice (CLEA Japan, Inc.) at a dose of 50 mg/kg/day. At 0.5, 1, 2, 4 and 6 hours after completion of the oral administration, blood was collected from the facial vein over time, so as to obtain plasma. The concentration of the compound in the obtained plasma was measured by LC-MS/MS, and the oral

absorbability of the present compound was evaluated.

The results are shown in the following Table 4.

[0178]

[Table 4]

Example No.	AUC 0 - 6 hr (μM·hr)	Example No.	AUC 0 - 6 hr (μM·hr)
1	50	2	15
3	24	4	12
5	20	6	17
7	15	8	15
9	51	10	50
11	31	12	36
13	18	14	27
15	34	16	15
17	21	18	15
19	6.1	Comp. Ex. 2	1.5

[0179]

From the above results, it was found that the compound of the present invention was contained in a sufficient concentration in the plasma, so that the present compound exhibited favorable oral absorbability. In contrast, the compound of Comparative Example 2 had oral absorbability that was more than 4 times more attenuated than the compound of the present invention.

[0180]

Test Example 7 Evaluation of brain penetration properties

The compound of the present invention was suspended or dissolved in 0.5% HPMC aqueous solution and 0.1 N hydrochloric acid, and the obtained suspension or solution was orally administered to BALB/cA mice (CLEA Japan, Inc.) at a dose of 50 mg/kg/day. At 0.5 hours after completion of the oral administration, blood was collected from the facial vein, and whole brain was then excised, so as to obtain plasma and brain samples. Water was added to the obtained brain sample in 3 times the volume of the brain sample, and the resultant was then homogenized using an ultrasonic homogenizer, so as to obtain a brain homogenate. The concentration of the compound in the obtained plasma and brain homogenate was measured by LC-MS/MS, and the brain penetration properties of the present compound were evaluated from the brain/plasma concentration of the compound.

The results are shown in the following Table 5.

[0181]

[Table 5]

Example No.	Compound concentration in plasma (μM)	Compound concentration in brain (μM)	Kp value (Compound concentration in brain/plasma)
1	9.1	1.4	0.15
2	6.6	1.8	0.27
3	11	1.4	0.13
4	8.3	2.8	0.34
5	15	2.2	0.15
6	7.5	1.3	0.17
7	7.9	1.1	0.14
8	9.9	3.3	0.33
9	13	2.4	0.18
10	13	2.4	0.18
11	12	2.7	0.23
12	11	3.2	0.29
13	13	2.8	0.22
14	9.9	2.1	0.21
15	8.1	1.2	0.15
16	12	4.4	0.35
17	17	6.5	0.39
18	7.7	1.6	0.22
19	4.9	0.7	0.14
Comp. Ex. 2	1.6	0.008	0.005

[0182]

From the above results, it was found that the compound of the present invention had a high brain/plasma compound concentration (Kp value) and thus, exhibited favorable brain penetration properties. On the other hand, the brain concentration of the compound of Comparative Example 2 was more than 80 times more attenuated than that of the compound of the present invention.

[0183]

Test Example 8 Antitumor effect confirmation test (*in vivo*) on direct brain transplantation models, into which luciferase gene-introduced HER2 expressing cell line (NCI-N87-luc) is directly transplanted

In order to confirm the antitumor effects of a test compound on direct brain transplantation models, NCI-N87-Luc, which was obtained by introducing a luciferase

gene into NCI-N87 that was a human stomach cancer tumor cell line purchased from American Type Culture Collection, was used. The NCI-N87-Luc was added into a 10% fetal bovine serum (FBS)-containing RPMI-1640 medium (supplemented with 4.5 g/L glucose, 10 mM HEPES, and 1 mM sodium pyruvate) (Wako Pure Chemical Industries, Ltd.), and this cell line was then cultured in a 5% CO2 incubator at 37°C.

The NCI-N87-Luc cells were re-suspended in PBS in a concentration of 6.25 x 10^7 cells/mL.

Using a mouse ear bar, a nude mouse with 6 to 7 weeks old (BALB/cAJcl-nu/nu, CLEA Japan, Inc.) was fixed in a brain stereotaxic apparatus, and the skin on the upper brain portion was disinfected with alcohol cotton and was then excised with a surgical knife.

A microdrill was used to drill a hole in the skull, and then, using a needle, a manipulator, and a syringe pump, 4 μL of the cell suspension was transplanted into the brain at a rate of 0.8 μL/min.

As a reference of the amount of brain tumor, approximately 3 weeks after the transplantation, Total Flux (Photon/sec) was measured in all of the survival cases, using IVIS (PerkinElmer, Inc., model: Lumina II). Based on the obtained results, 6 animals were assigned to each group, using the grouping program of MiSTAT (Ver. 2.00).

The test compound was orally administered to the mice once a day, every day, for 21 days from the following day of the grouping (Days 1 - 21).

For judgment of the presence or absence of effects, the value (Log10) obtained by logarithmic transformation of the total flux on the judgment date was used. The test compound was administered to the mice at a dose of 25 mg/kg/day in Example 2 and Example 11, whereas it was administered at a dose of 50 mg/kg/day in Example 12.

A graph was prepared with the value obtained by logarithmic transformation (Log10) of the average total flux of each group as a vertical axis, and with the number of days (Day) after the transplantation as a horizontal axis. The transition of the total flux over time in the drug administration period was observed.

As test compounds, the compounds of Example 2, Example 11, and Example 12 were used, and as a control, 0.1 N HCl and 0.5% HPMC aqueous solution were used.

[0184]

The results are shown in the following Figure 1 to Figure 3. The value obtained by logarithmic transformation (Log10) of the total flux on Day 22 in each group was analyzed by a Dunnett test or a Student-t test. As a result, it was demonstrated that the aforementioned value of the test compound group was statistically significantly lower than the value of the control group (significance level (both sides): 5%) (Figure 1: the

compound of Example 2 was used, P = 0.0077; Figure 2: the compound of Example 11 was used, P = 0.0007; and Figure 3: the compound of Example 12 was used, P = 0.0012). For the measurement of the body weight, an animal electronic balance was used. A body weight change percentage (BWCn) from the body weight on the nth day (BWn) was calculated according to the following equation:

BWCn (%) = [(body weight on n^{th} day) - (body weight on grouping day)] / [(body weight on grouping day)] x 100.

From the results of this test, it was found that the compound of the present invention has excellent antitumor effects against the HER2 overexpressing cell line (NCI-N87-luc) transplanted into the nude mice. Moreover, a body weight reduction of -20% or more was not observed in all of the mice to which the compound of Example 2 or Example 11 had been administered. Accordingly, it was found that there were no serious side effects.

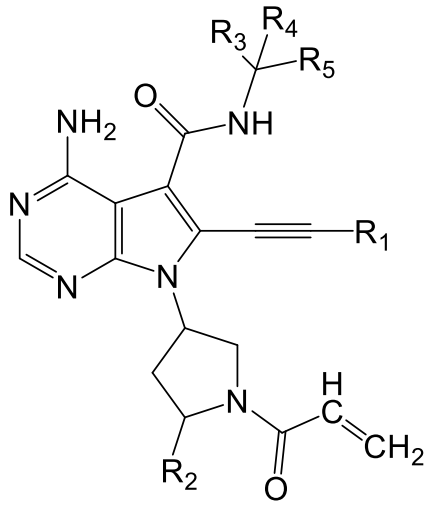
[0185]

It is to be noted that all documents and publications cited in the present description are incorporated herein by reference in their entirety, regardless of the purpose thereof. Moreover, the present description includes the contents disclosed in the claims, specification and drawings of Japanese Patent Application No. 2019-003403 (filed on January 11, 2019), from which the present application claims priority.

Several embodiments of the present invention are described above. However, these embodiments are provided for illustrative purpose only, and thus, are not intended to limit the scope of the present invention. These novel embodiments can be carried out in various other forms, and various abbreviations, substitutions and alternations can be carried out, unless they are deviated from the spirit of the invention. These embodiments and the modifications thereof are included in the scope or spirit of the invention, and are also included in the invention according to the claims and the scope equivalent thereto.

CLAIMS

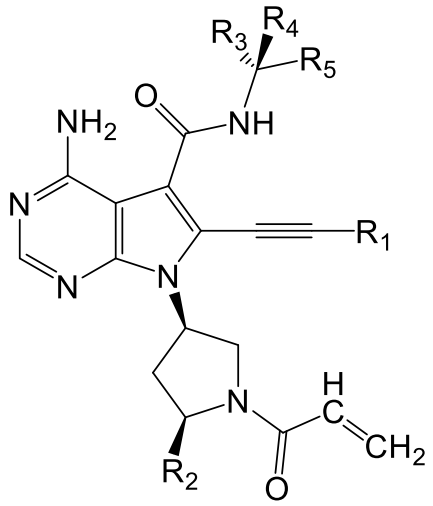
1. A compound represented by the following formula (I), or a salt thereof:



(I)

wherein R_1 represents a C1-C4 alkyl group optionally having a C1-C4 alkoxy group as a substituent, or a C3-C4 cycloalkyl group;
R_2 represents a hydrogen atom, a halogen atom, a C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups or fluorine atoms each as a substituent(s), or a C1-C6 alkoxy group;
R_3 represents a hydrogen atom, or a C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s);
R_4 represents a hydrogen atom or a C1-C4 alkyl group; and
R_5 represents a phenyl group optionally having 1 to 3 substituents selected from fluorine atoms and chlorine atoms.

2. The compound according to claim 1 represented by the following formula (II), or a salt thereof:



(II)

wherein R_1 represents a C1-C4 alkyl group optionally having a C1-C4 alkoxy group as a substituent, or a C3-C4 cycloalkyl group;
R_2 represents a hydrogen atom, a halogen atom, a C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups or fluorine atoms each as a substituent(s), or a C1-C6 alkoxy group;
R_3 represents a hydrogen atom, or a C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s);
R_4 represents a hydrogen atom or a C1-C4 alkyl group; and
R_5 represents a phenyl group optionally having 1 to 3 substituents selected from fluorine atoms and chlorine atoms.

3. The compound according to claim 1 or 2, or a salt thereof, wherein R_2 is a C1-C6 alkyl group optionally having 1 to 5 C1-C4 alkoxy groups as a substituent(s).

4. The compound according to any one of claims 1 to 3, or a salt thereof, wherein R_3 is a C1-C4 alkyl group optionally having 1 to 5 fluorine atoms as a substituent(s).

5. The compound according to any one of claims 1 to 4, or a salt thereof, wherein R_5 is a phenyl group optionally having 1 or 2 substituents selected from the group consisting of fluorine atoms and chlorine atoms.

6. The compound according to any one of claims 1 to 5, or a salt thereof, wherein R_1 is a methyl group, a tert-butyl group, or a cyclopropyl group.

7. The compound according to any one of claims 1 to 6, or a salt thereof, wherein R_2 is a methyl group, an ethyl group, a methoxymethyl group, or an ethoxymethyl group.

8. The compound according to any one of claims 1 to 7, or a salt thereof, wherein R_3 is a methyl group.

9. The compound according to any one of claims 1 to 8, or a salt thereof, wherein R_4 is a hydrogen atom.

10. The compound according to any one of claims 1 to 9, or a salt thereof, wherein R_5 is a phenyl group.

11. The compound according to any one of claims 1 to 10, or a salt thereof, wherein the compound is selected from the following (1) to (3):
(1)
7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-N-((R)-1-phenylethyl)-6-(prop-1-yn-1-yl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide,
(2)
7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(cyclopropylethynyl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide, and
(3)
7-((3R,5S)-1-acryloyl-5-methylpyrrolidin-3-yl)-4-amino-6-(3,3-dimethylbut-1-yn-1-yl)-N-((R)-1-phenylethyl)-7H-pyrrolo[2,3-d]pyrimidine-5-carboxamide.

12. A pharmaceutical composition comprising the compound according to any one of claims 1 to 11 or a salt thereof.

13. An antitumor agent comprising, as an active ingredient, the compound according to any one of claims 1 to 11 or a salt thereof.

14. An antitumor agent for oral administration, comprising, as an active ingredient, the compound according to any one of claims 1 to 11 or a salt thereof.

15. Use of the compound according to any one of claims 1 to 11 or a salt thereof for the production of a pharmaceutical composition.

16. Use of the compound according to any one of claims 1 to 11 or a salt thereof for the production of an antitumor agent.

17. Use of the compound according to any one of claims 1 to 11 or a salt thereof for the production of an antitumor agent for oral administration.

18. The compound according to any one of claims 1 to 11 or a salt thereof, for use as a medicament.

19. Use of the compound according to any one of claims 1 to 11 or a salt thereof, in the manufacture of a medicament for the treatment of a tumor.

20. The use as claimed in claim 19, wherein the medicament is to be administered orally.

21. The use as claimed in claim 19, wherein the medicament is to be administered in an effective amount to a subject in need thereof.