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(54) Titre : PROCEDE POUR LA PRODUCTION DE DERIVES D'ACIDE GLUTAMIQUES, UN DERIVE DE L'ACIDE
GLUTAMIQUE ET UN NOUVEL INTERMEDIAIRE POUR SA PRODUCTION
(54) Title: PROCESS FOR MANUFACTURING A GLUTAMIC ACID DERIVATIVE AND A PYROGLUTAMIC ACID
DERIVATIVE AND A NOVEL INTERMEDIATE IN THE MANUFACTURE THEREOF

(57) Abrégé/Abstract:

A method of manufacturing a glutamic acid derivative, typically monatin, in which a 4-protected hydroxyl pyroglutamic acid derivative is alkylated by an alkylating agent to prepare a 4-protected hydroxyl-4-alkylglutamic acid derivative, followed by the steps of hydrolyzing it and deprotecting its protecting groups. The 4-protected hydroxyl pyroglutamic acid derivative is easy to produce from hydroxyproline. The 4-protected hydroxyl pyroglutamic acid derivative is particularly suitable for use in the efficient manufacture of monatin of high optical purity, since it can be alkylated selectively at the 4-position and stereoselectively and after its alkylation, it can easily be converted to a glutamic acid derivative.

ABSTRACT

A method of manufacturing a glutamic acid derivative, typically monatin, in which a 4-protected hydroxyl pyroglutamic acid derivative is alkylated by an alkylating agent to prepare a 4-protected hydroxyl-4-alkylglutamic acid derivative, followed by the steps of hydrolyzing it and deprotecting its protecting groups. The 4-protected hydroxyl pyroglutamic acid derivative is easy to produce from hydroxyproline. The 4-protected hydroxyl pyroglutamic acid derivative is particularly suitable for use in the efficient manufacture of monatin of high optical purity, since it can be alkylated selectively at the 4-position and stereoselectively and after its alkylation, it can easily be converted to a glutamic acid derivative.

DESCRIPTION

PROCESS FOR MANUFACTURING A GLUTAMIC ACID DERIVATIVE AND A PYROGLUTAMIC ACID DERIVATIVE AND A NOVEL INTERMEDIATE IN THE MANUFACTURE THEREOF

TECHNICAL FIELD

This invention relates to a process for manufacturing a glutamic acid derivative and a pyroglutamic acid derivative, typically monatin, and a novel intermediate used in the manufacture thereof by that process.

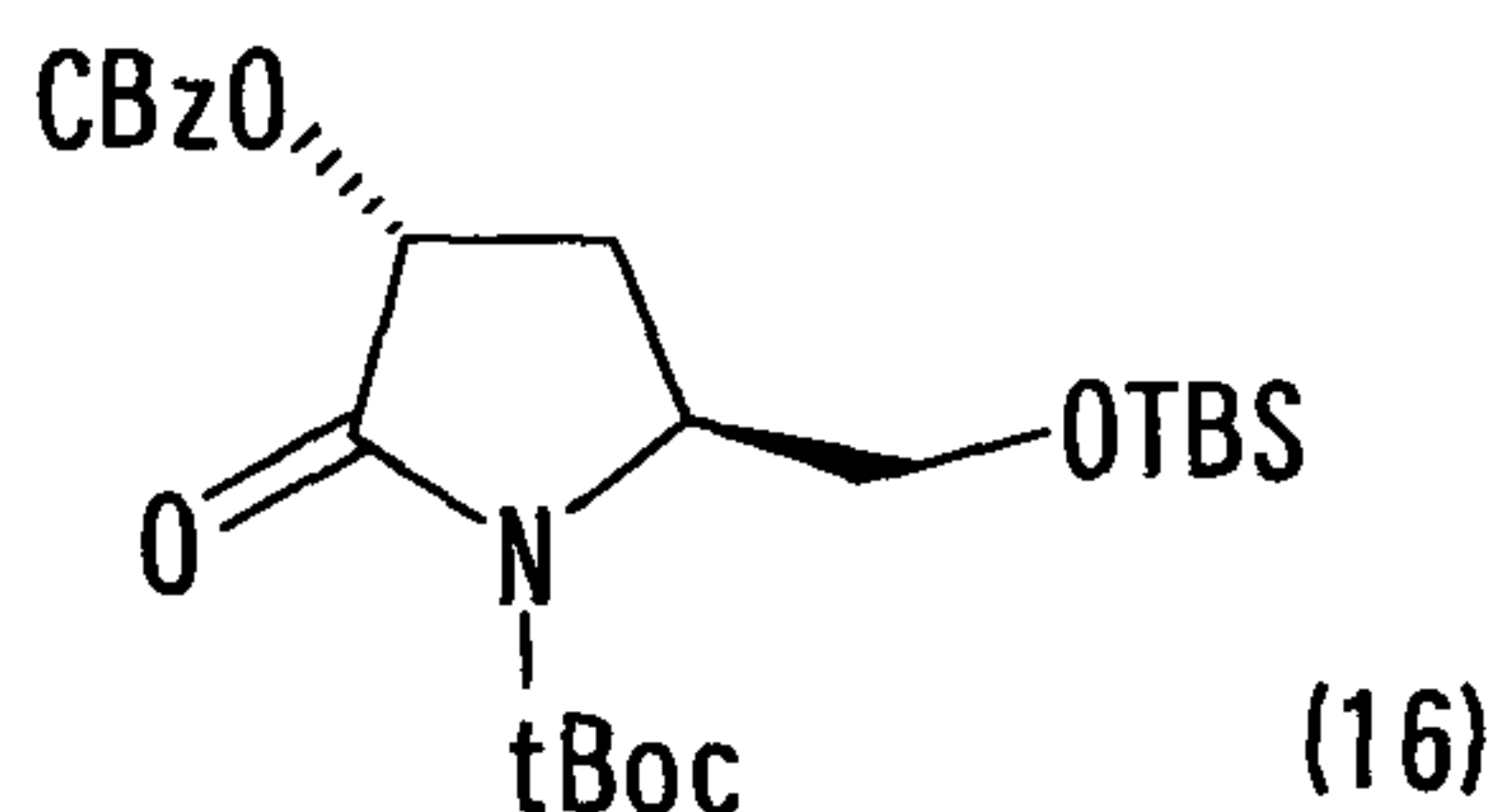
BACKGROUND ART

Specific glutamic acid derivatives including monatin as a typical example are compounds expected to be useful as sweeteners, or intermediates in the manufacture of drugs, etc. Monatin is a naturally occurring amino acid derivative isolated from the bark of the root of *Schlerochiton ilicifolius*, a plant growing naturally in the northern Transvaal area of South Africa and its structure has been reported by R. Vleggaar et al as being of (2S,4S)-2-amino-4-carboxy-4-hydroxy-5-(3-indolyl) pentanoic acid ((2S,4S)-4-hydroxy-4-(3-indolyl-methyl)-glutamic acid; see formula (19) below) (see R. Vleggaar et al, J. Chem. Soc. Perkin Trans., 3095-3098 (1992)).

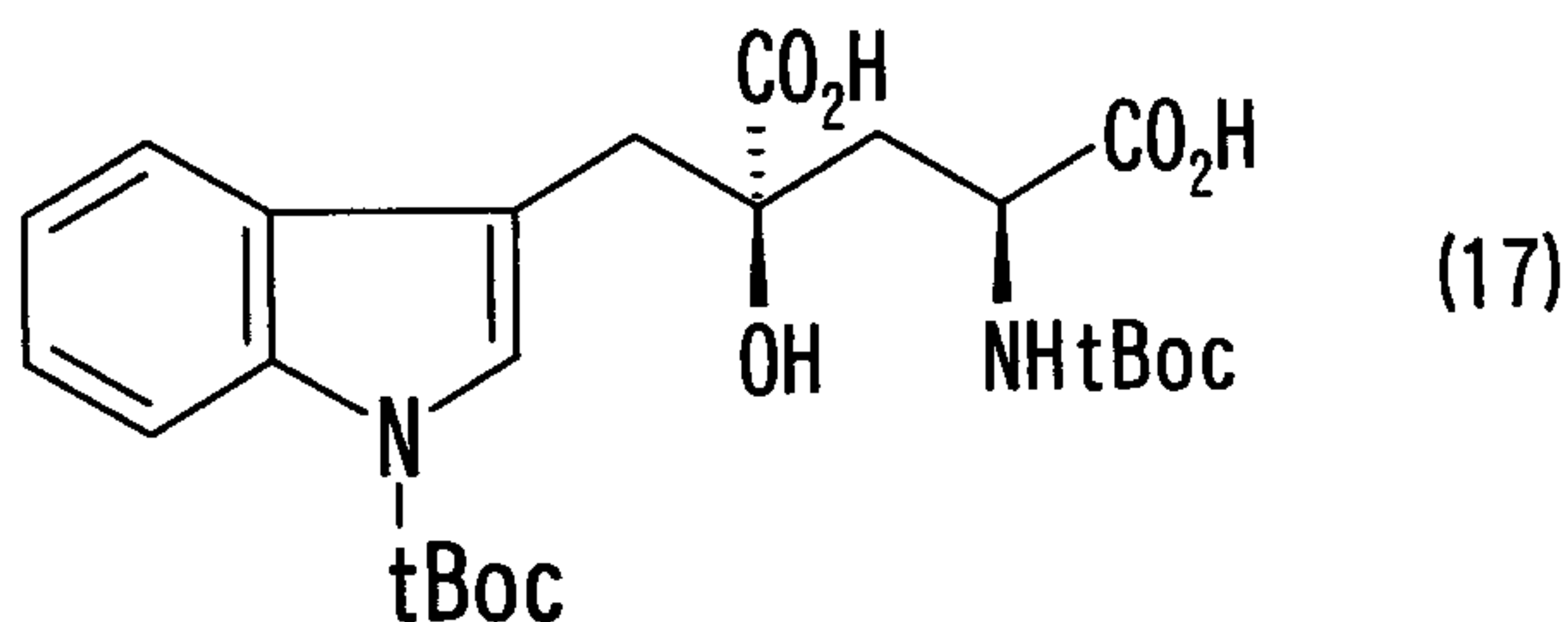
The same literature reports that the (2S, 4S) form of

monatin reportedly obtainable from a natural plant has a sweetness (or sweetness intensity) which is 800 or 1,400 times that of sucrose. Several methods have been reported as methods of synthesizing monatin, but there has not been any industrially suitable method (for examples of synthesis, reference is made to Republic of South Africa Patent Application No. 87/4288 (P.J. van Wyk et al, ZA87/4288), C.W. Holzapfel et al: Synthetic Communications, 24(22), 3197-3211 (1994), United States Patent No. 5,994,559, K. Nakamura et al: Organic Letters, 2, 2967-2970 (2000), etc.).

D.J. Oliveira et al (See Tetrahedron Letters, 42, 6793-6796 (2001)) have reported that a monatin derivative having a protective group as shown by formula (17) below can be synthesized stereoselectively by alkylating a lactum derivative as shown by formula (16) below and subjecting it to hydrolysis and an oxidizing reaction.



[where TBDMS stands for a t-butyldimethylsilyl group, Cbz stands for a benzyloxycarbonyl group, tBoc stands for a t-butoxycarbonyl group and Et stands for an ethyl group.]



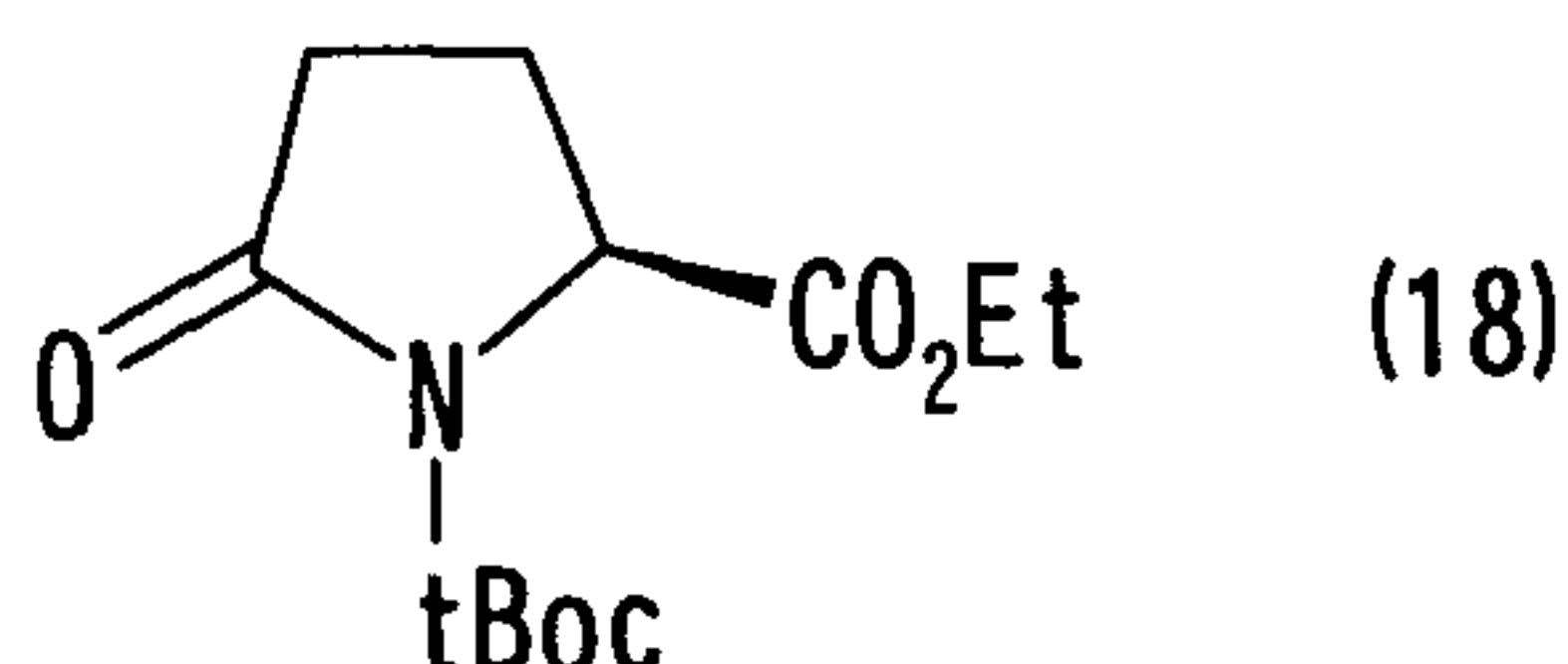
[where tBoc is as defined above.]

This method involves complicated procedures including reducing the carboxyl group of a pyroglutamic acid derivative into a hydroxymethyl group, converting it to a protecting hydroxymethyl group and introducing a hydroxyl group into the 4-position for the preparation of compound (16), and after the alkylation of compound (16), conducting the deprotection of the protecting hydroxymethyl group into a hydroxymethyl group and oxidizing it back into a carboxyl group, though the compound represented by formula (16) is capable of regioselective alkylation as it has only a single active hydrogen atom.

Chromium trioxide (CrO_3) is used in the oxidizing reaction, but the reaction using it presents a great many problems as a method of manufacture, since this reagent is dangerous because of toxicity, etc. Moreover, it is desirable for no process of manufacture to include any oxidizing reaction of any compound having an indole ring, since the indole ring is easily oxidizable.

As regards the alkylation at the 4-position of a pyroglutamic acid derivative having its carboxyl group not reduced, which differs from the above case, J. Ezquerra et al

(See J. Org. Chem., 59, 4327-4331 (1994)) have, for example, reported a method of producing a 4, 4-dialkylpyroglutamic acid derivative by dialkylating the 4-position of a pyroglutamic acid derivative represented by formula (18) below.



[where tBoc and Et are as defined above.]

However, there has not been reported any case of the selective alkylation at the 4-position of a pyroglutamic acid derivative having a protected hydroxyl group at the 4-position and not having its carboxyl group reduced like a compound represented by formula (1) below.

DISCLOSURE OF THE INVENTION

It is an object of this invention to provide a method which can efficiently and easily manufacture a glutamic acid derivative, typically monatin, and a compound useful as an intermediate in the manufacture thereof, and which is suitable for industrial production.

As a result of our intensive study made to attain the above object, we, the inventors of this invention, have paid attention to a 4-protected hydroxy-pyroglutamic acid derivative having a protected hydroxyl group at the 4-position and not having its carboxyl group reduced, as represented by

formula (1), and have found that when the derivative is subjected to an alkylation reaction, its regio- and stereo-selective alkylation at the 4-position is possible.

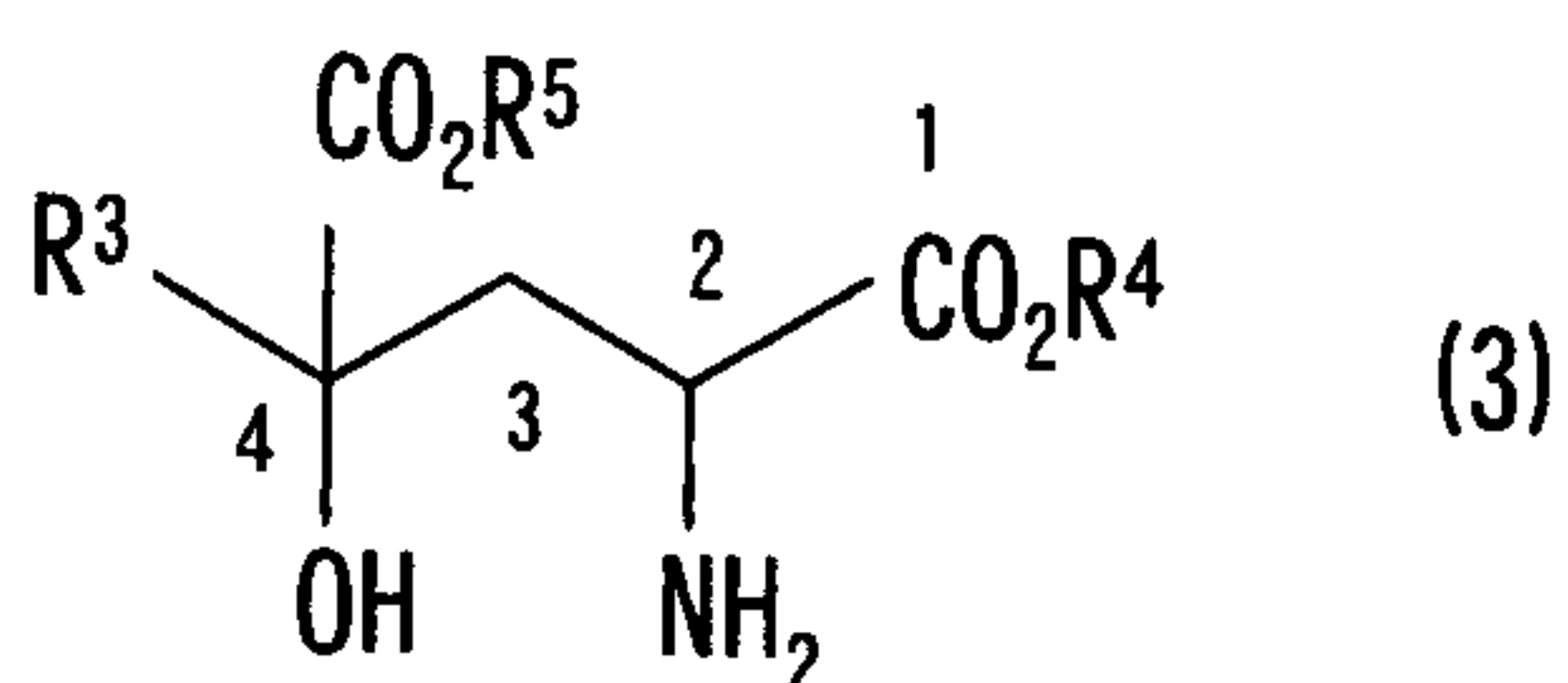
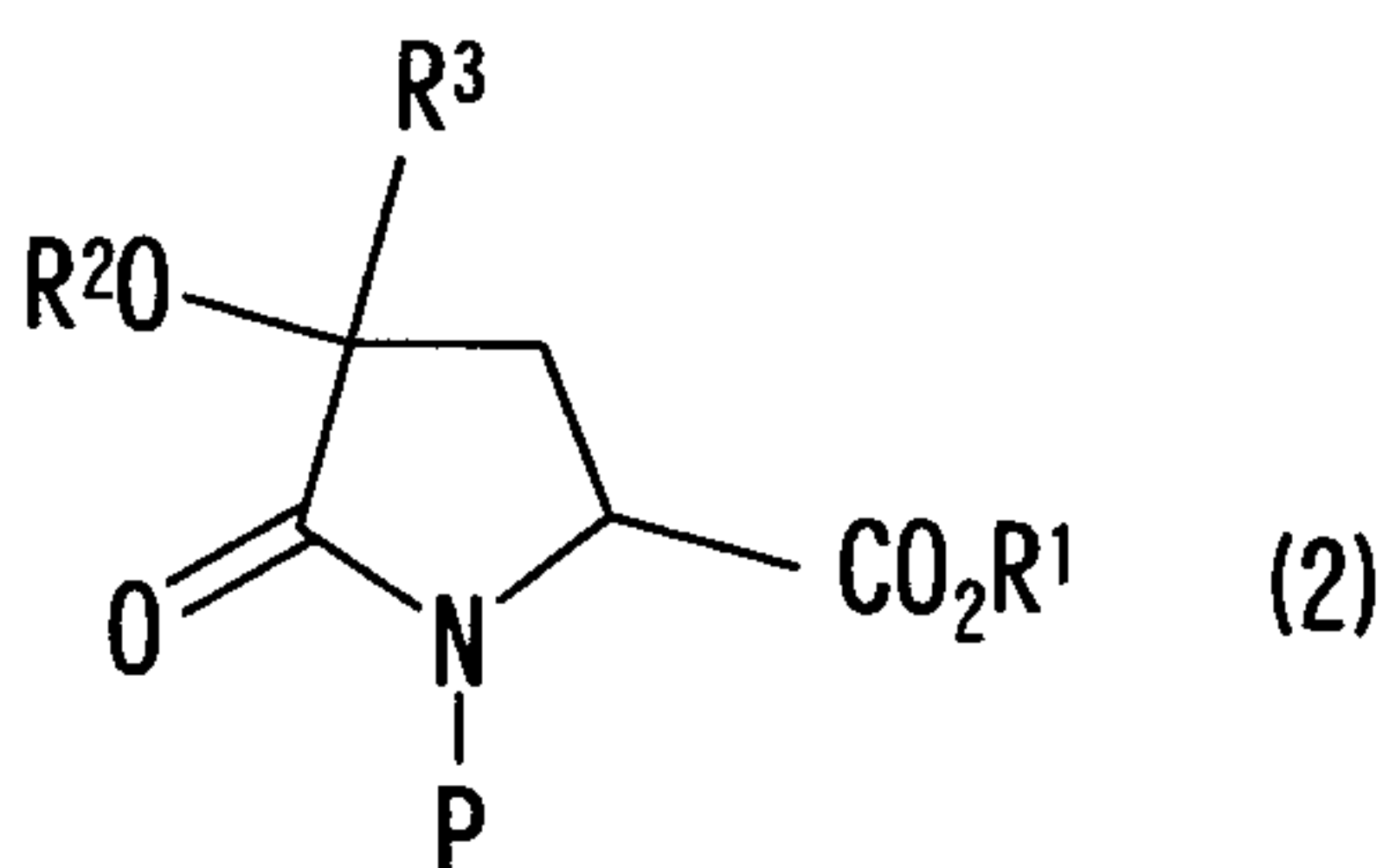
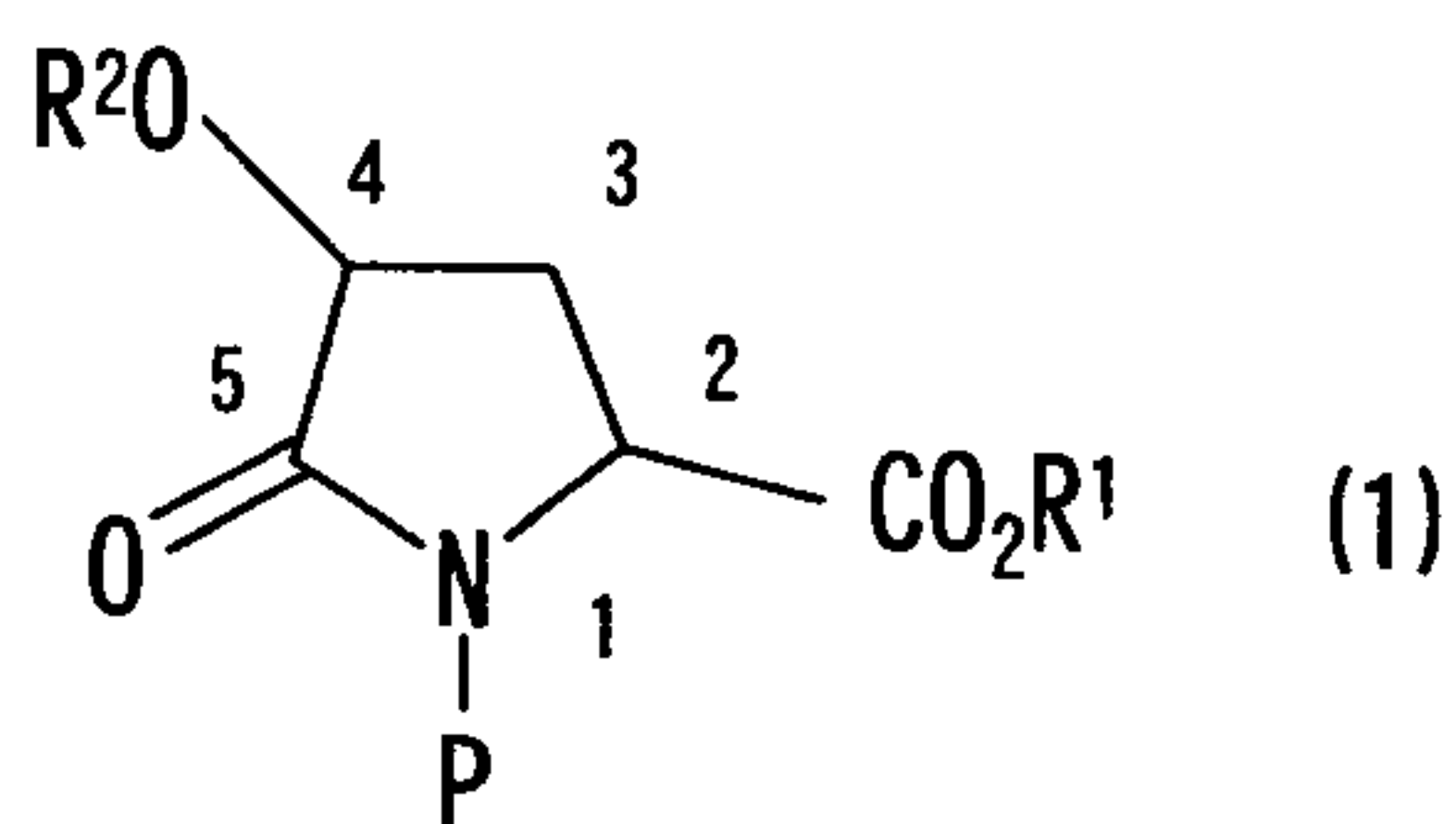
Although two sites, i.e. the 2- and 4-positions, have been considered as the reaction sites for alkylation performed by causing an alkylating agent to react with a 4-protected hydroxypyroglutamic acid derivative as represented by formula (1), we have found from our study that it is possible to alkylate selectively the 4-position of the 4-protected hydroxyl-pyroglutamic acid derivative. We have also found that the alkylation at the 4-position of the 4-protected hydroxypyroglutamic acid derivative proceeds stereoselectively. More specifically, its alkylation at the 4-position proceeds from the opposite side of the pyrrolidone ring from the substituent ($-\text{CO}_2\text{R}^1$) at the 2-position. Accordingly, the relative configuration at the 2- and 4-positions of a 4-protected hydroxy-4-substituted pyroglutamic acid derivative as obtained by an alkylation reaction coincides with the relative configuration at the 2- and 4-positions of (2S, 4S) or (2R, 4R)-monatin among four kinds of stereoisomers of monatin and it is possible to derive monatin having the corresponding configuration.

We have also found that the 4-protected hydroxy-4-substituted pyroglutamic acid derivative obtained by an alkylation reaction makes it possible to manufacture

easily a glutamic acid derivative, typically monatin, simply by the lactum hydrolysis and deprotection of the protecting group.

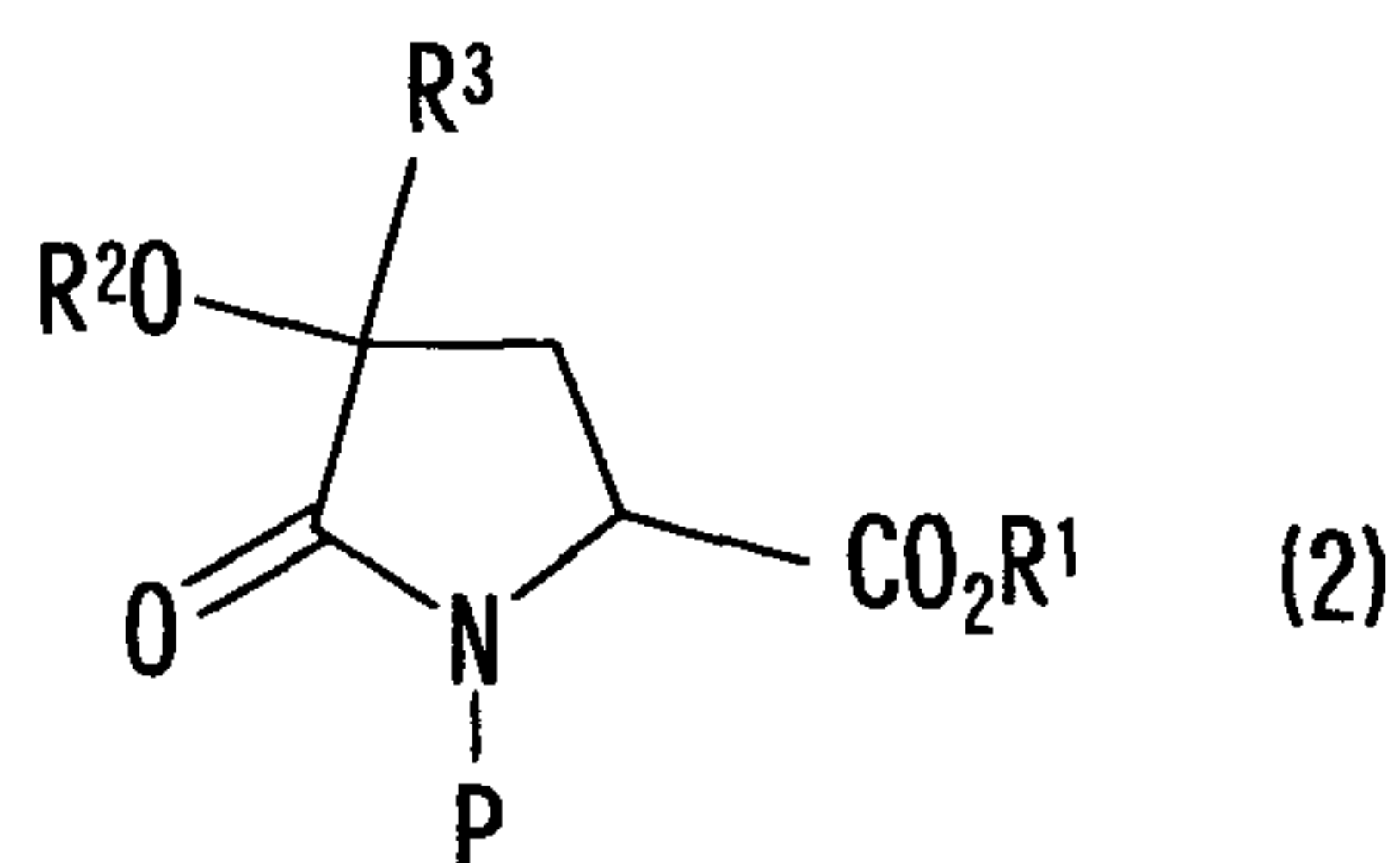
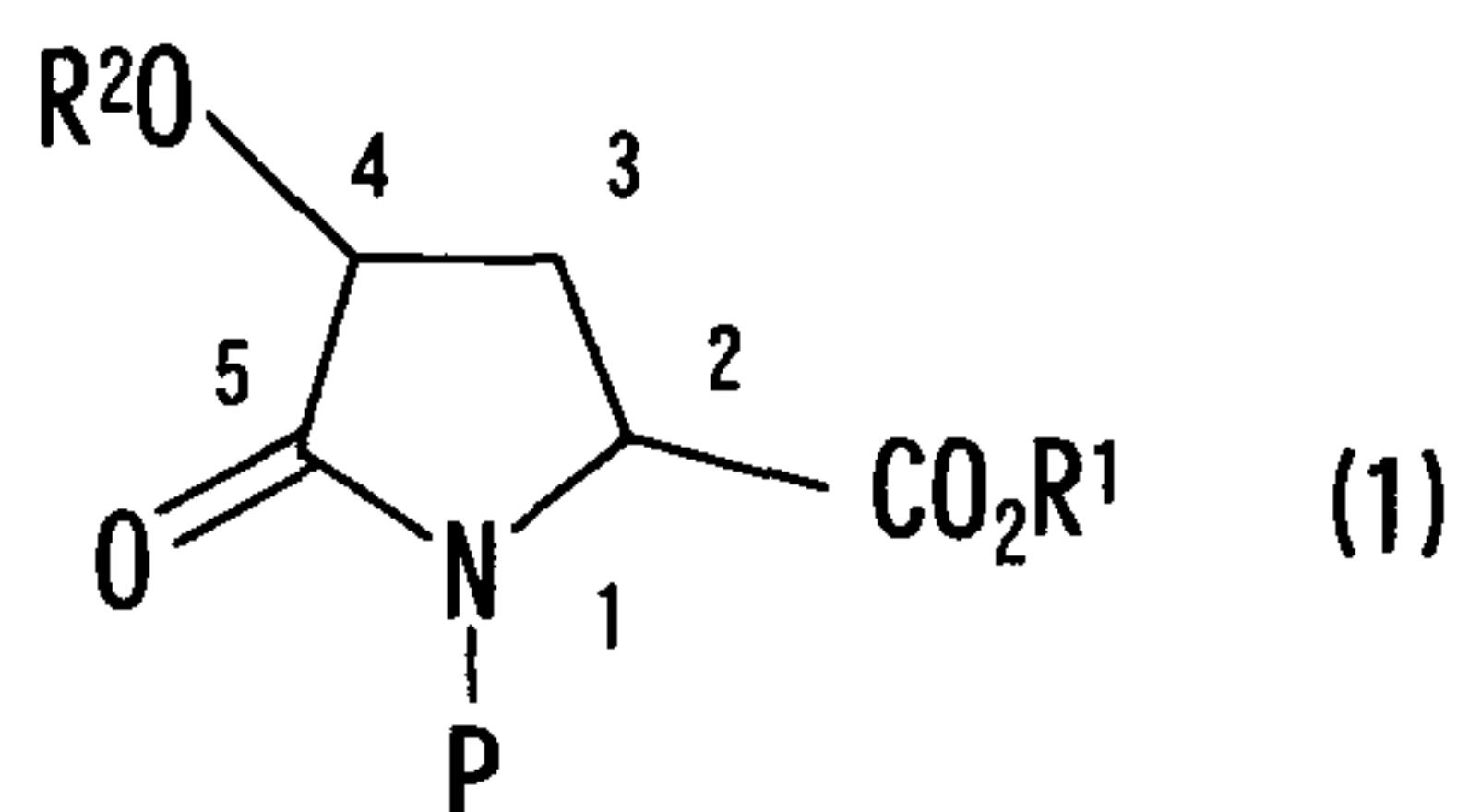
We have completed this invention based on our findings. Thus, this invention covers the following:

[1] A method of manufacturing a glutamic acid derivative represented by formula (3) below (including one in the form of a salt), characterized by subjecting a 4-protected hydroxy-pyroglutamic acid derivative represented by formula (1) below (including one in the form of a salt) to an alkylation reaction to prepare a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2) below (including one in the form of a salt) and subjecting the derivative to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent and P stands for a protecting group for an imino group.

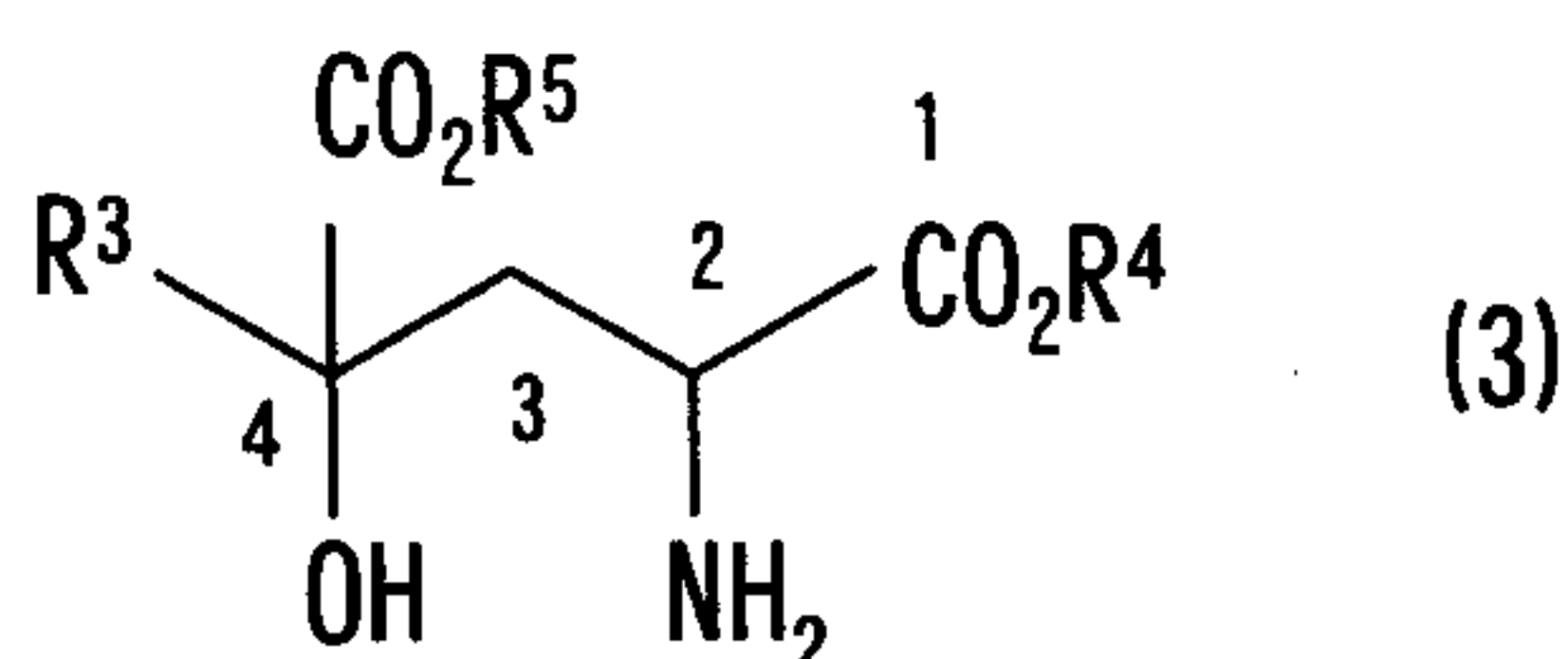
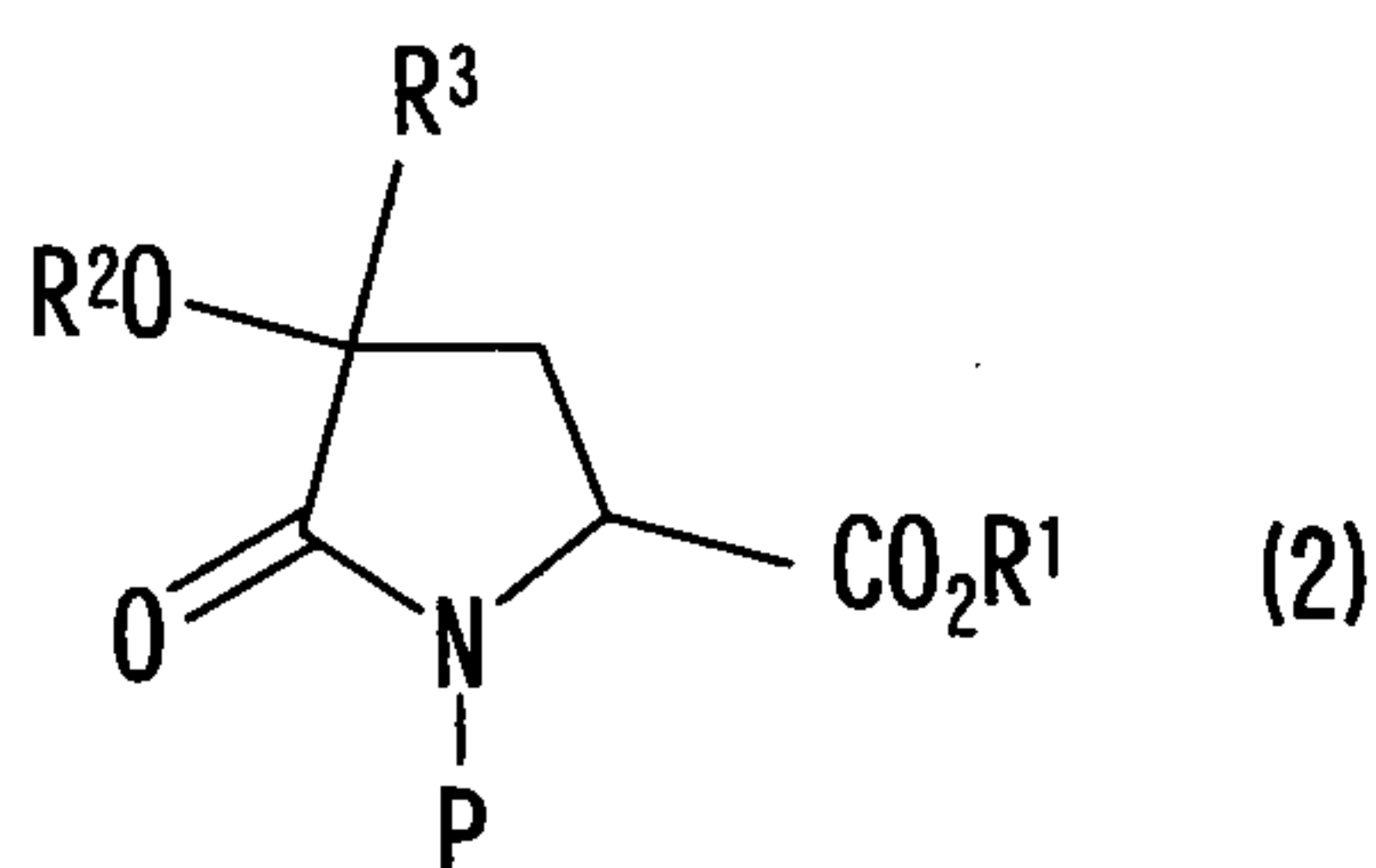
[2] A method of manufacturing a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2) below (including one in the form of a salt), characterized by subjecting a 4-protected hydroxypyroglutamic acid derivative represented by formula (1) below (including one in the form of a salt) to an alkylation reaction:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, R^3 stands for a group selected from a

hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group and P stands for a protecting group for an imino group.

[3] A method of manufacturing a glutamic acid derivative represented by formula (3) below (including one in the form of a salt), characterized by subjecting a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2) below (including one in the form of a salt) to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent and P stands for a protecting group for an imino group.

[4] A method as set forth at [1] or [3] above, wherein R^1 stands for a group selected from an alkyl group having 1 to

5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, R^3 stands for a group selected from an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to 20 carbon atoms, an aralkyl group having 1 to 20 carbon atoms and a heterocyclic hydrocarbon group having 1 to 20 carbon atoms and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[5] A method as set forth at [2] above, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, R^3 stands for a group selected from an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to 20 carbon atoms, an aralkyl group having 1 to 20 carbon atoms and a heterocyclic hydrocarbon group having 1 to 20 carbon atoms and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[6] A method as set forth at any of [1] to [3] above, wherein R^3 is a benzyl group or an N-protected-3-indolylmethyl group.

[7] A method as set forth at [1] or [2] above, wherein the alkylation reaction is performed in the presence of an alkylating agent represented by formula (4) below:



where R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent and X stands for a halogen atom.

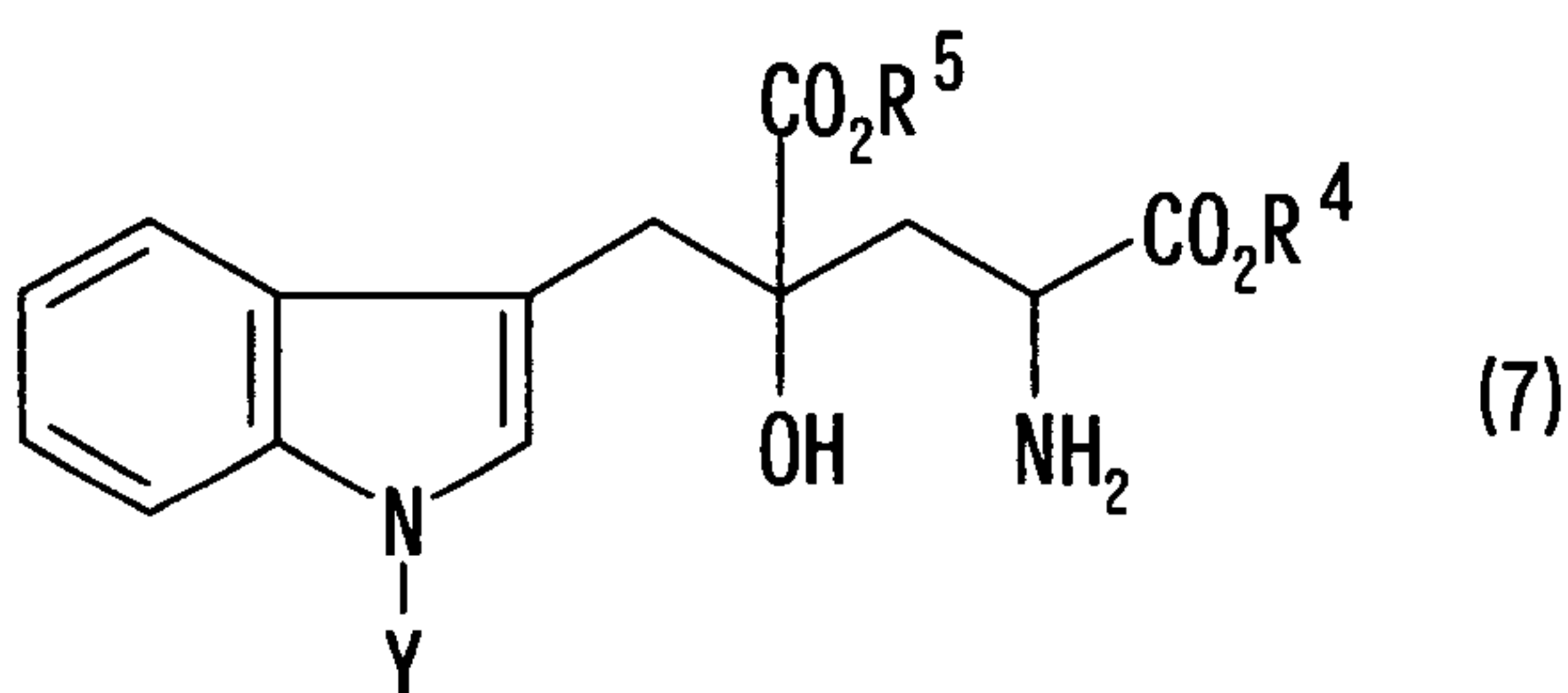
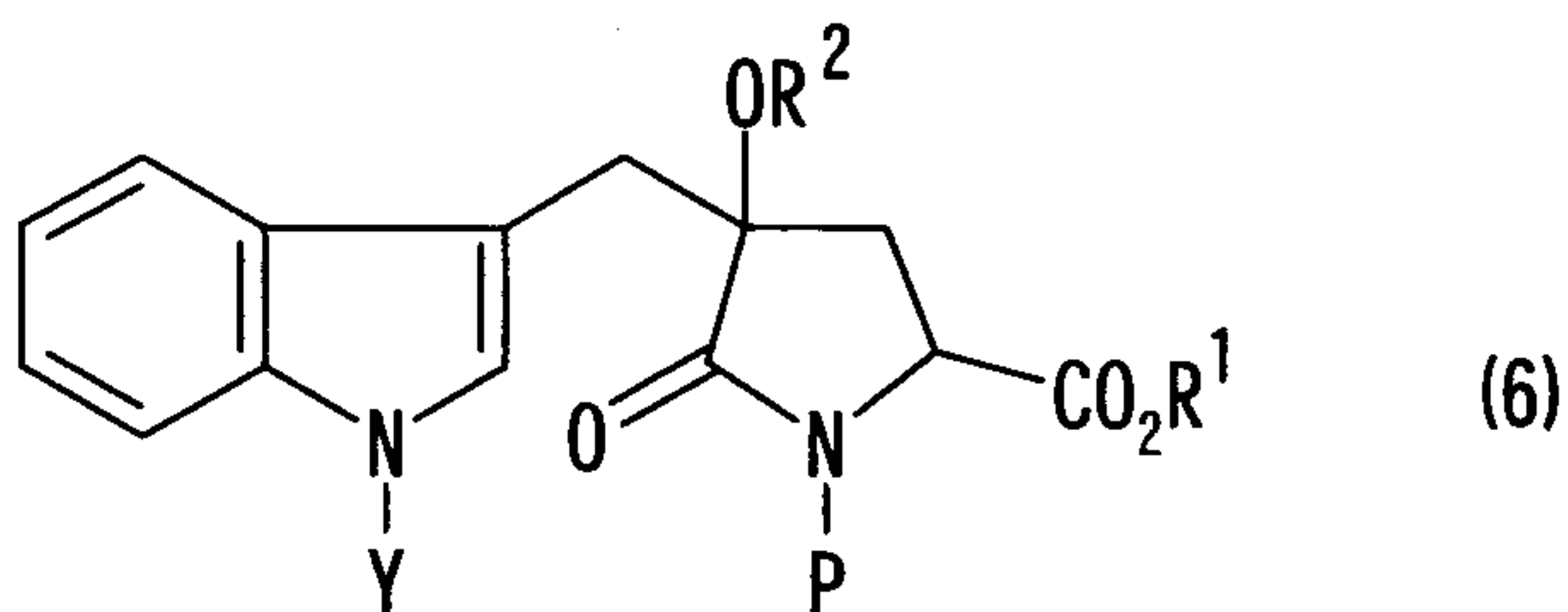
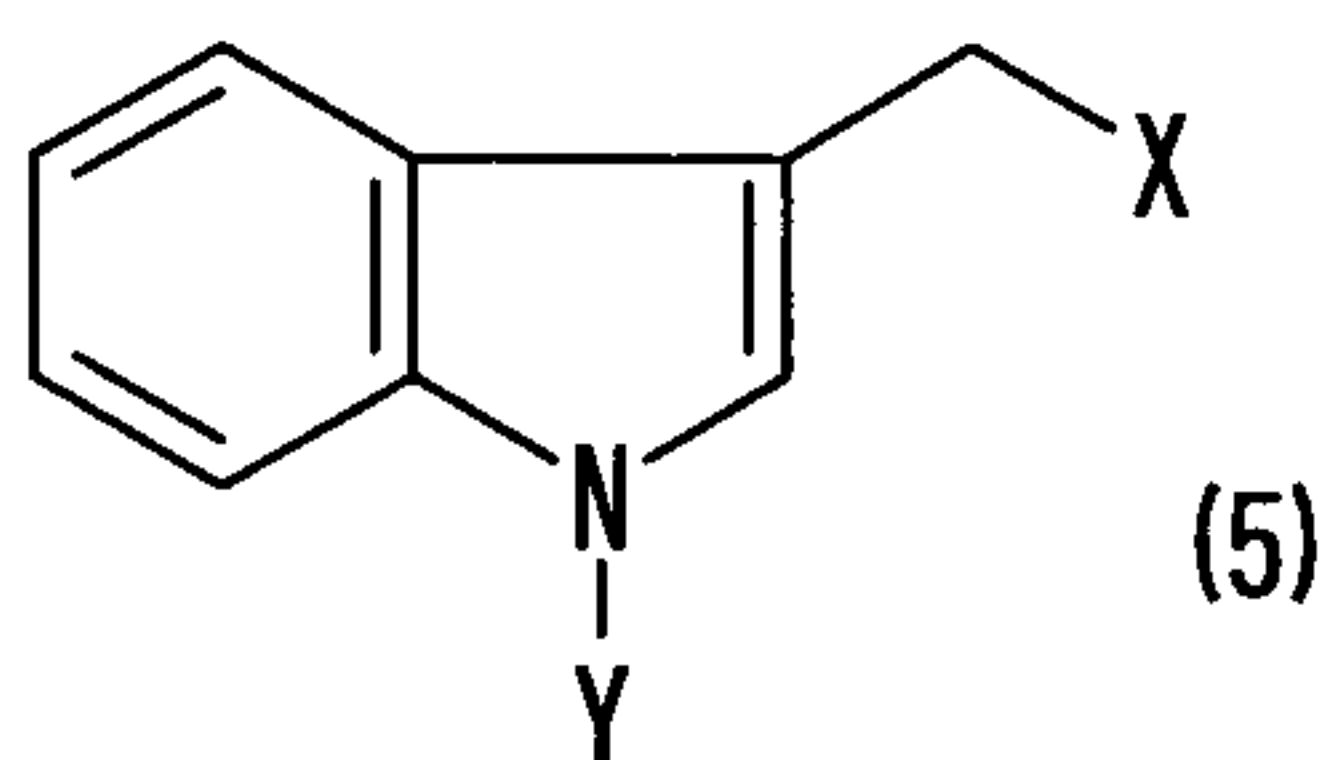
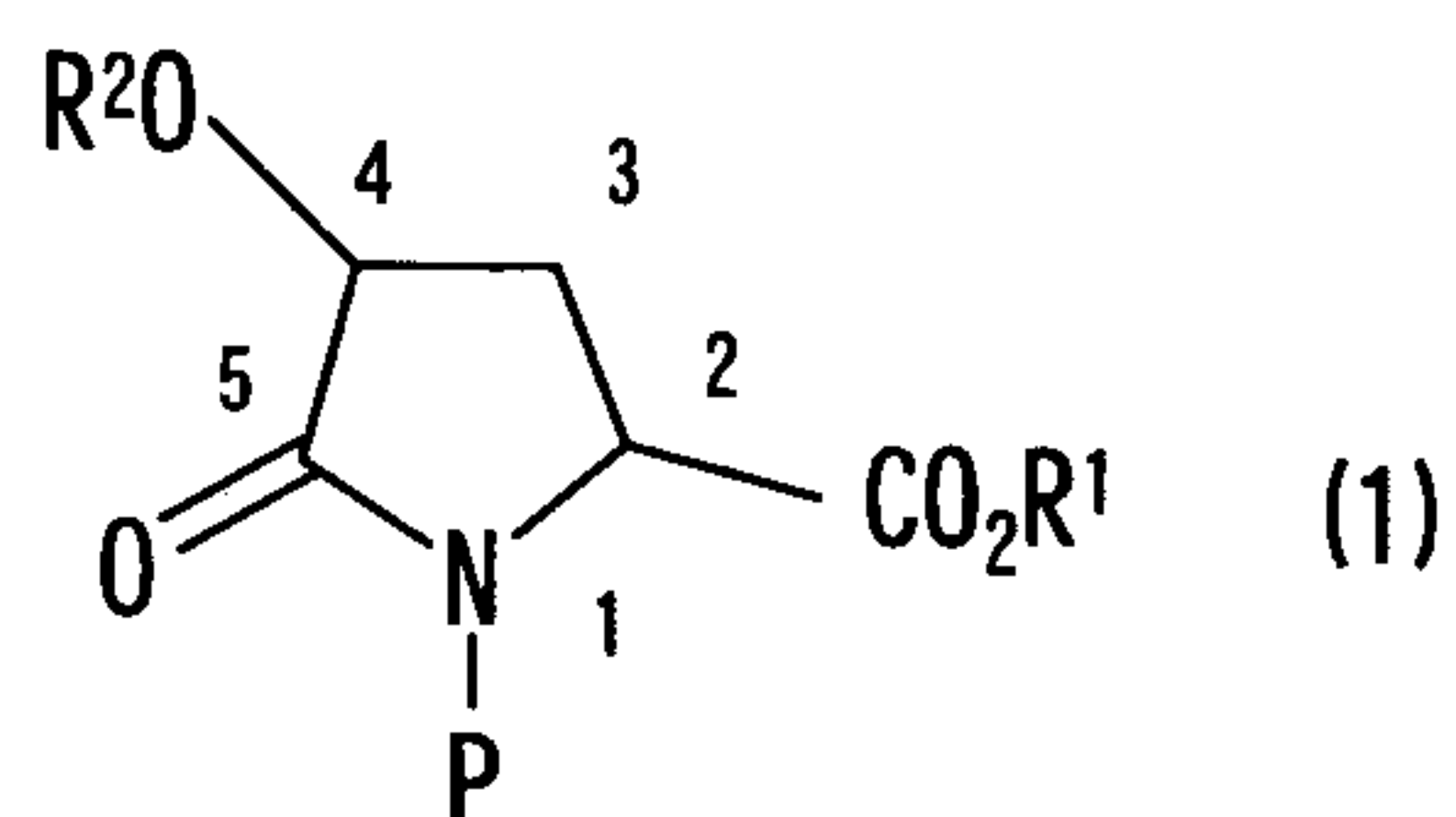
[8] A method as set forth at [7] above, wherein the alkylation reaction is performed in the presence of a base.

[9] A method as set forth at [7] above, wherein the base is one or more kinds of base selected from a lithium salt of hexamethyldisilazane, lithium hexamethyldisilazanide, a potassium salt of hexamethyldisilazane, potassium hexamethyl-disilazanide, a sodium salt of hexamethyldisilazane, sodium hexamethyldisilazanide, lithium diisopropylamide and normal-butyl lithium.

[10] A method as set forth at [7] above, wherein the base is used in a molar ratio of between 1.0 and 2.0 to 1 relative to the 4-protected hydroxyglutamic acid derivative.

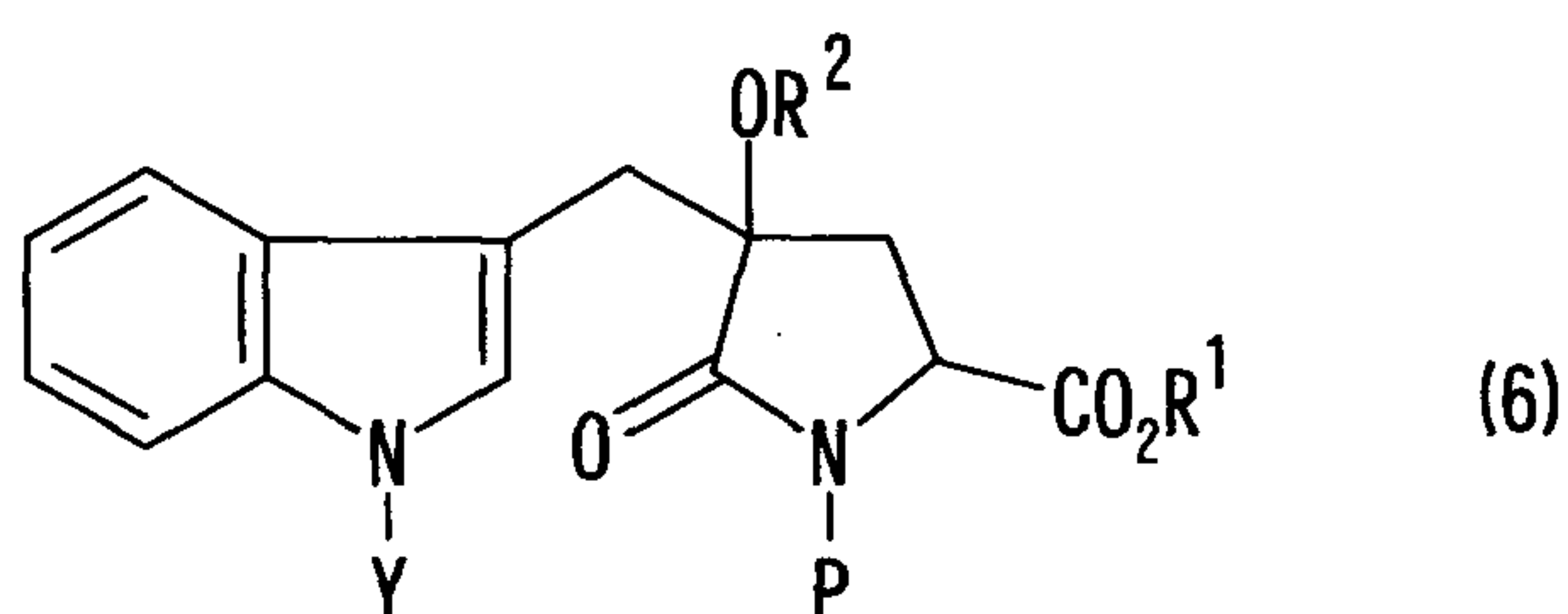
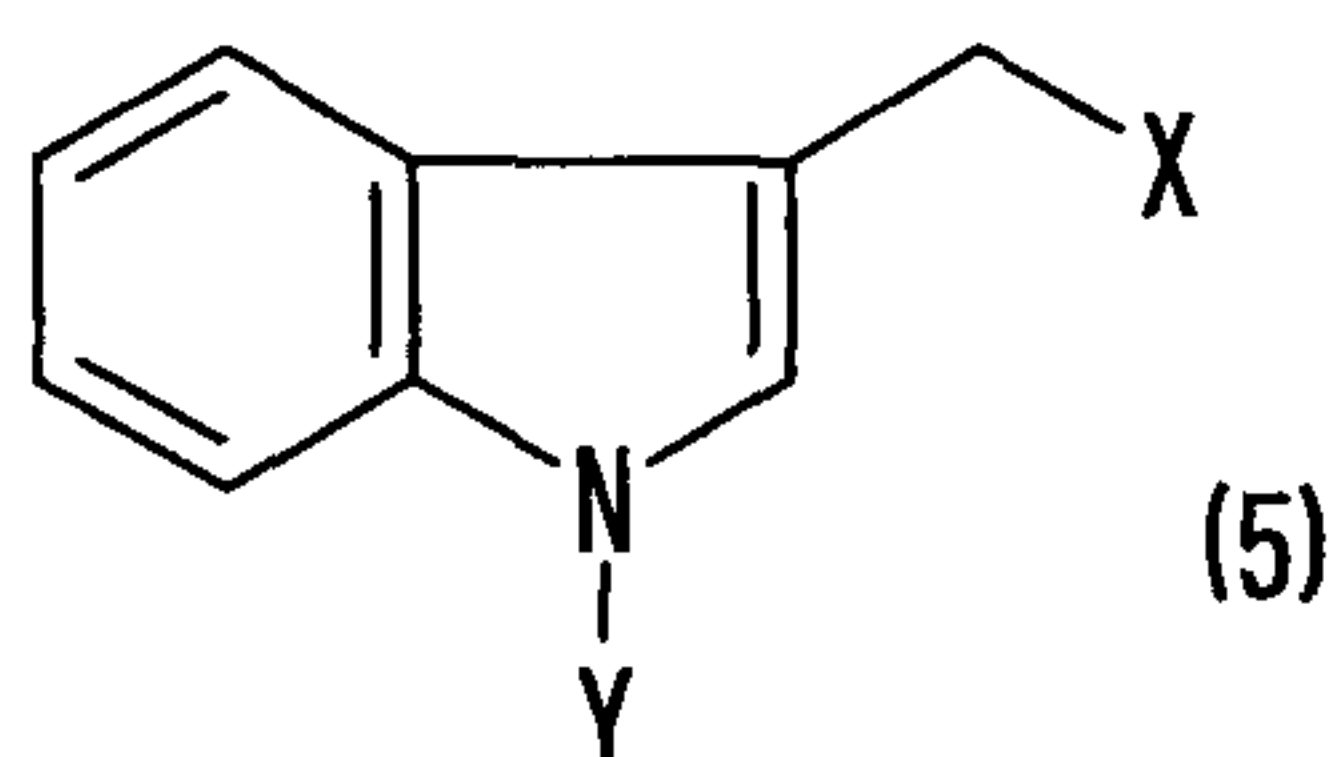
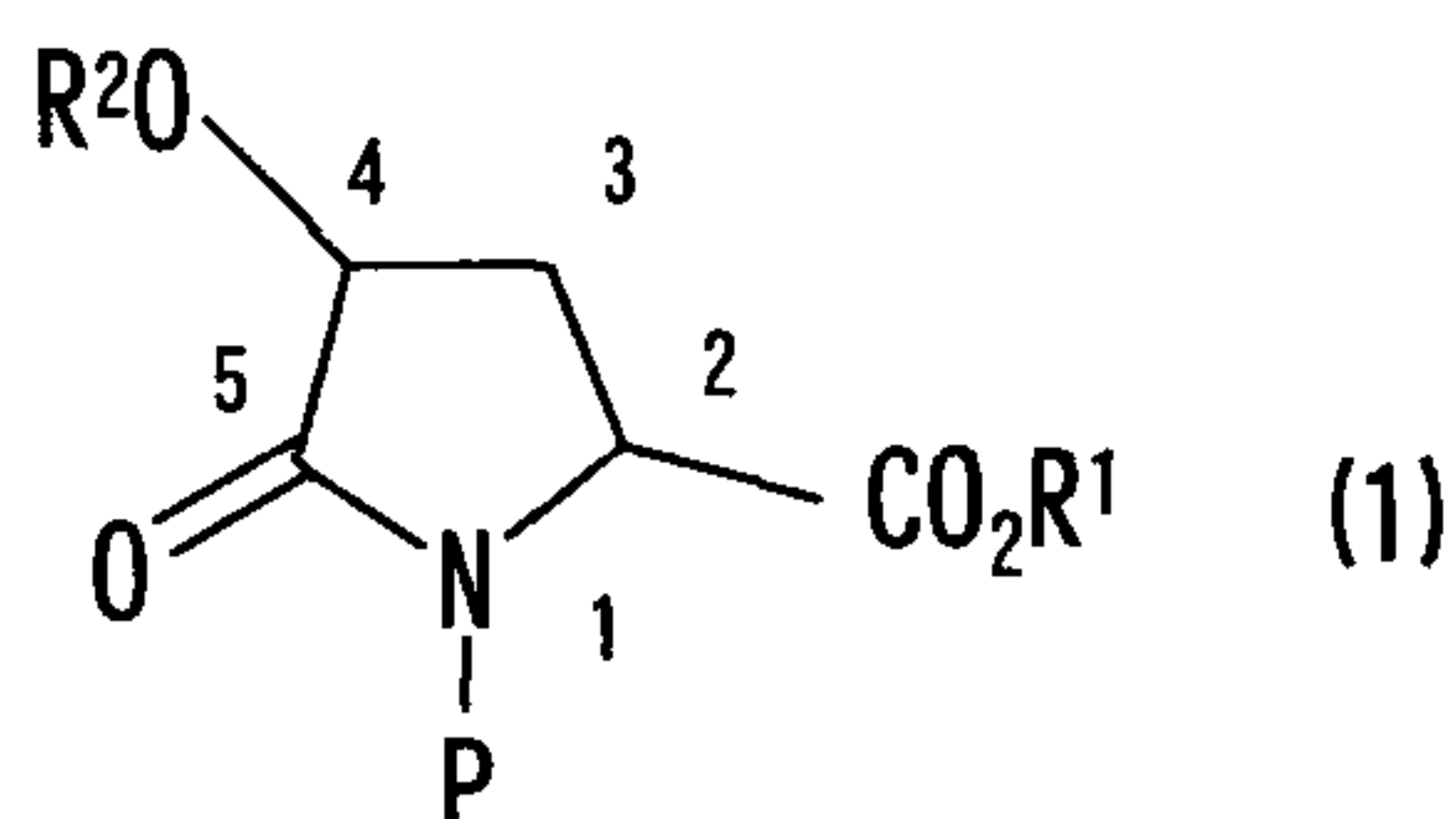
[11] A method of manufacturing a monatin derivative represented by formula (7) below (including one in the form of a salt), characterized by reacting a 4-protected hydroxy-pyroglutamic acid derivative represented by formula (1) below (including one in the form of a salt) with

N-protected-3-halogenomethylindole represented by formula (5) below to prepare a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) below (including one in the form of a salt) and subjecting the derivative to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group and Y stands for a protecting group for an indolyl group.

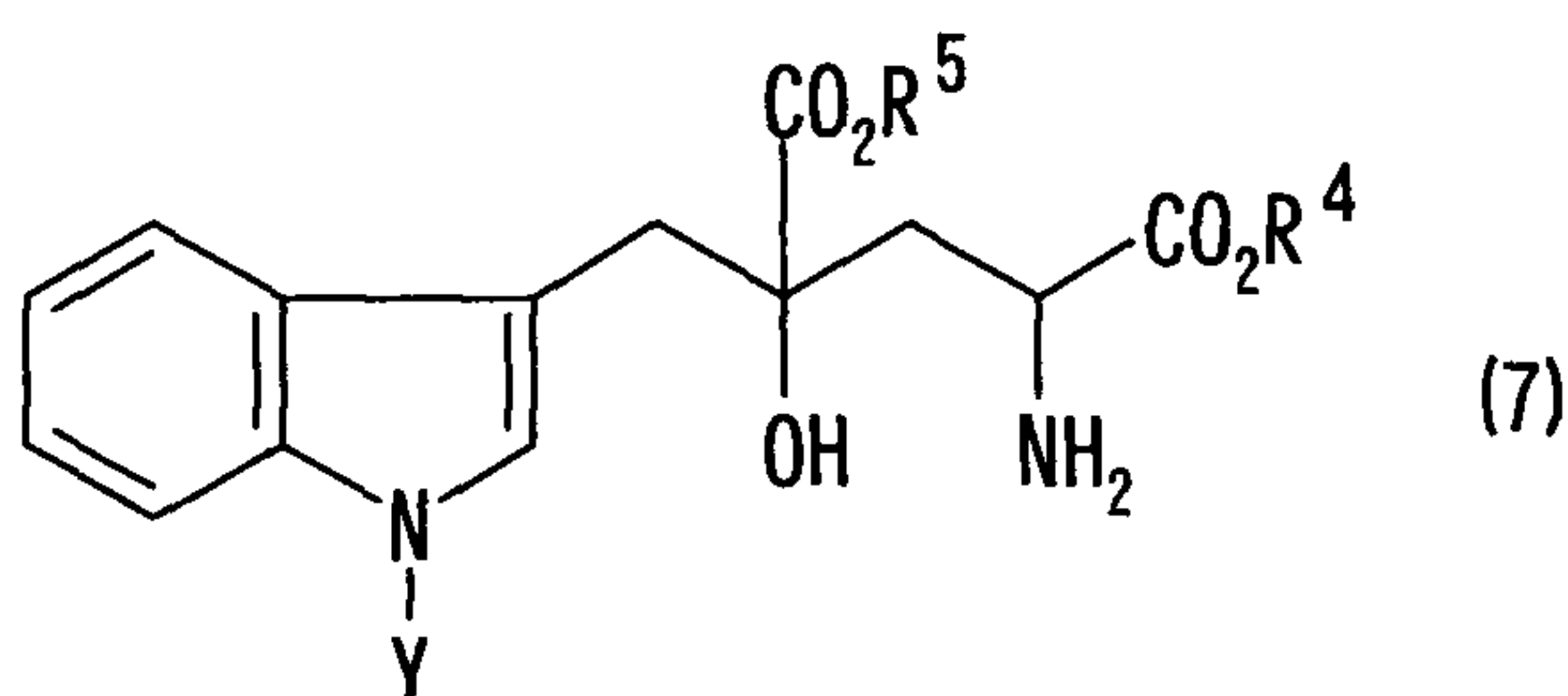
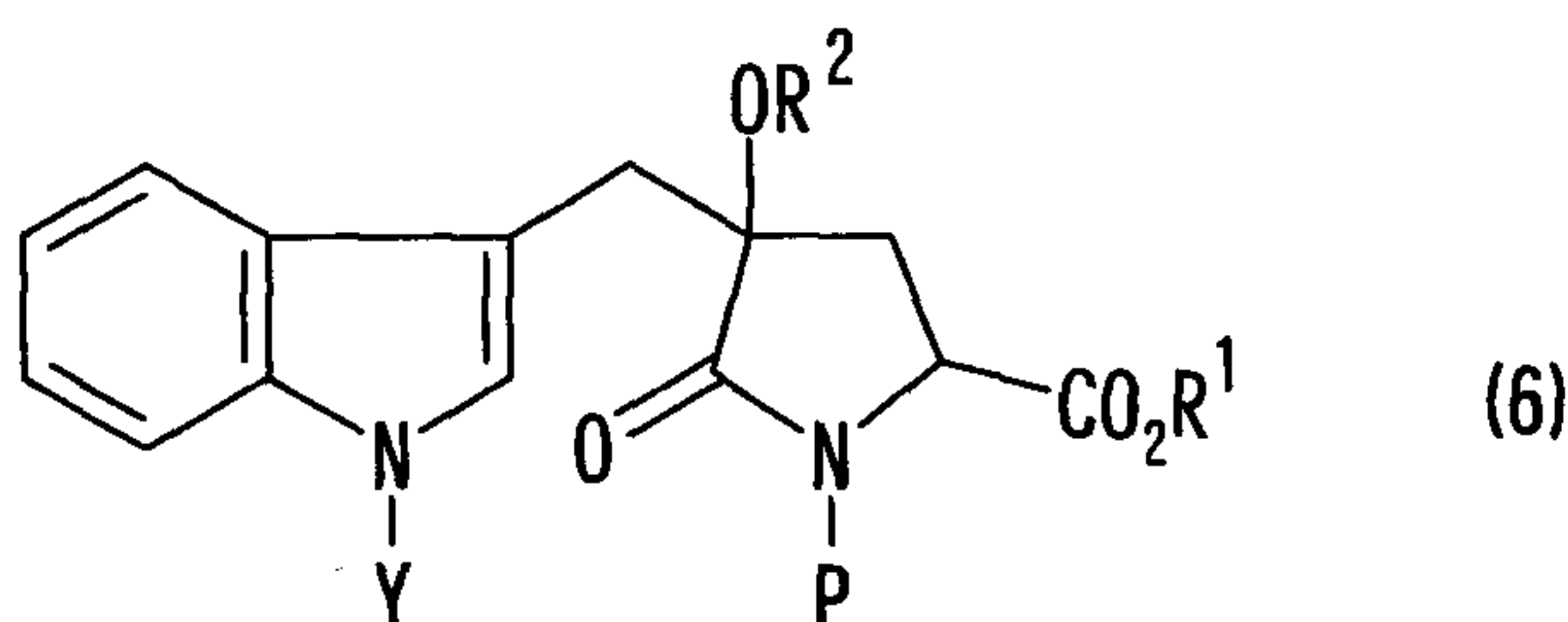
[12] A method of manufacturing a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) below (including one in the form of a salt), characterized by reacting a 4-protected hydroxypyroglutamic acid derivative represented by formula (1) below (including one in the form of a salt) with N-protected-3-halogeno-methylindole represented by formula (5) below:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group and Y stands for a protecting group for an indolyl group.

[13] A method of manufacturing a monatin derivative

represented by formula (7) below (including one in the form of a salt), characterized by subjecting a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) below (including one in the form of a salt) to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group and Y stands for a protecting group for an indolyl group.

[14] A method as set forth at [11] above, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from

a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[15] A method as set forth at [12] above, wherein R^1 stands for a group selected from a hydrogen atom, an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

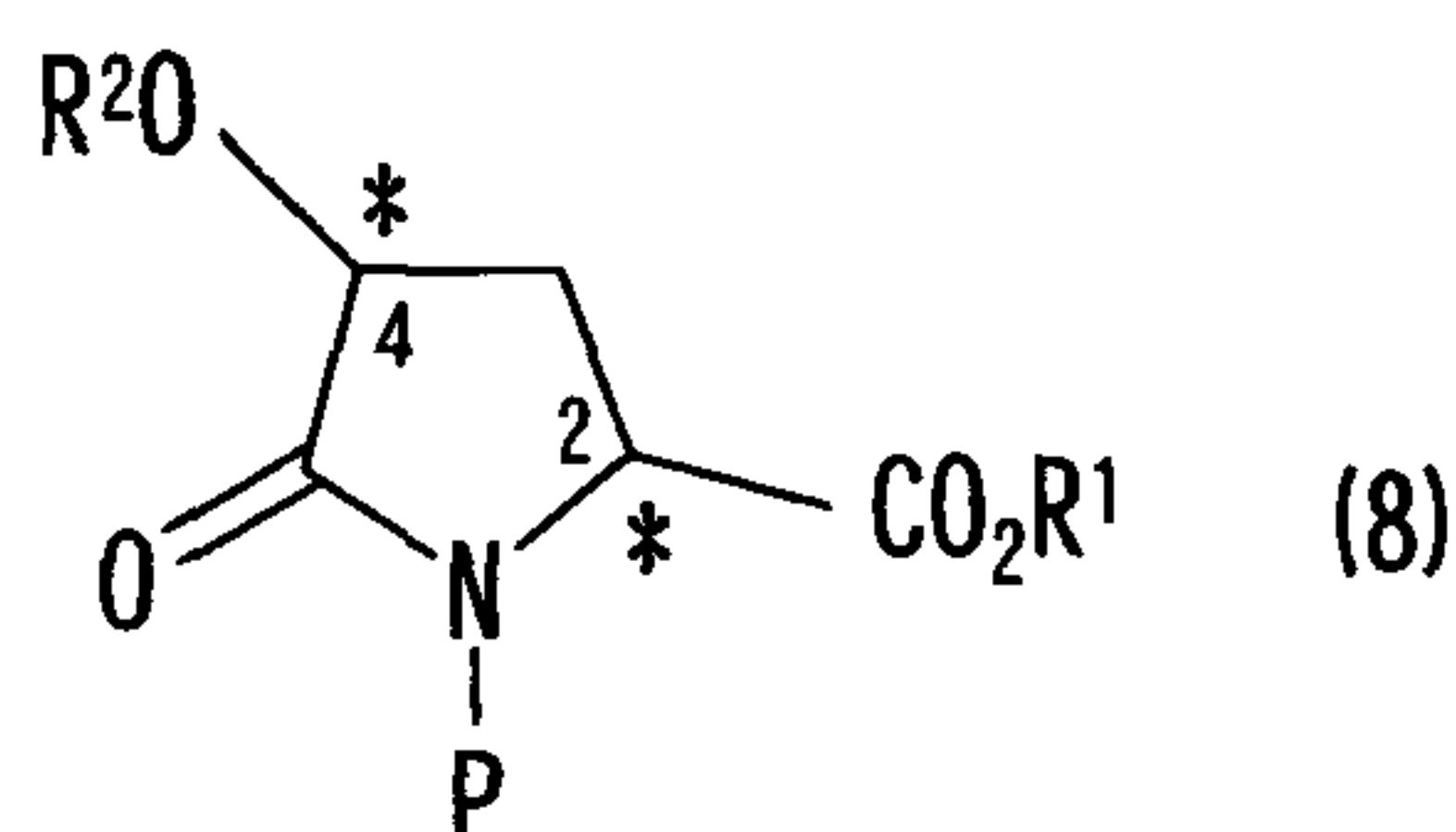
[16] A method as set forth at [13] above, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

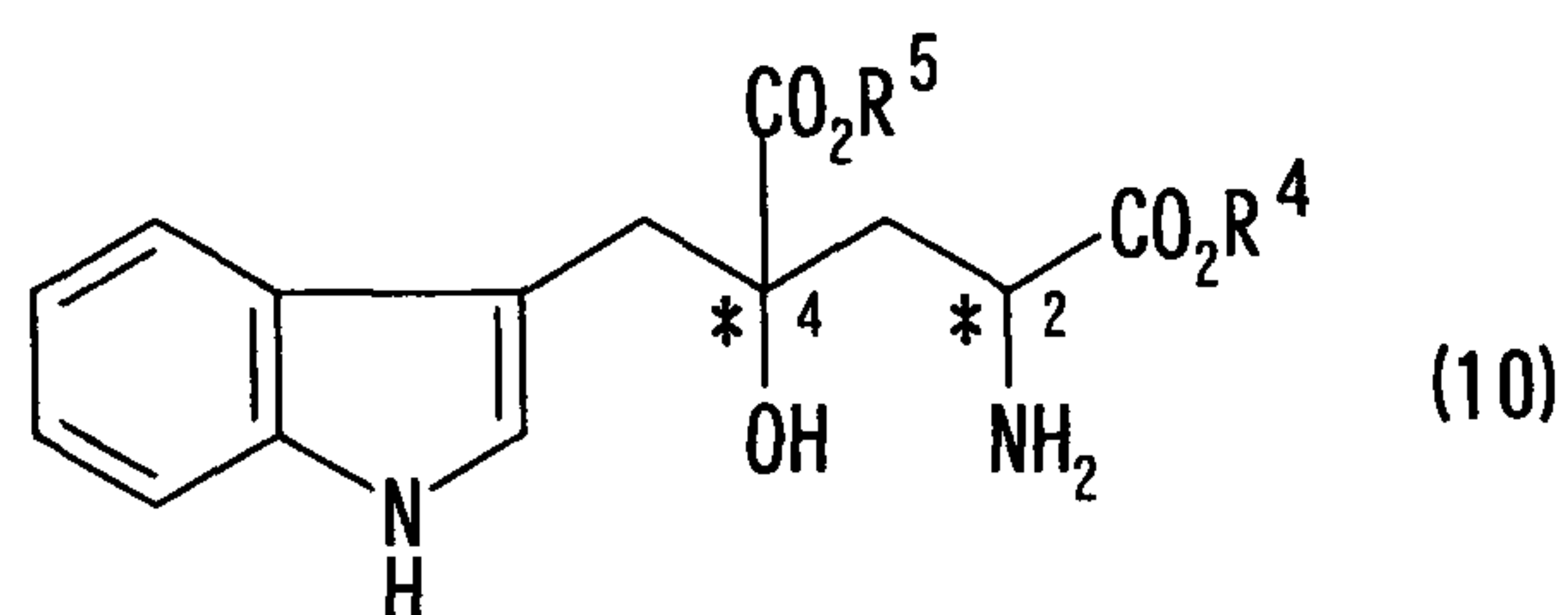
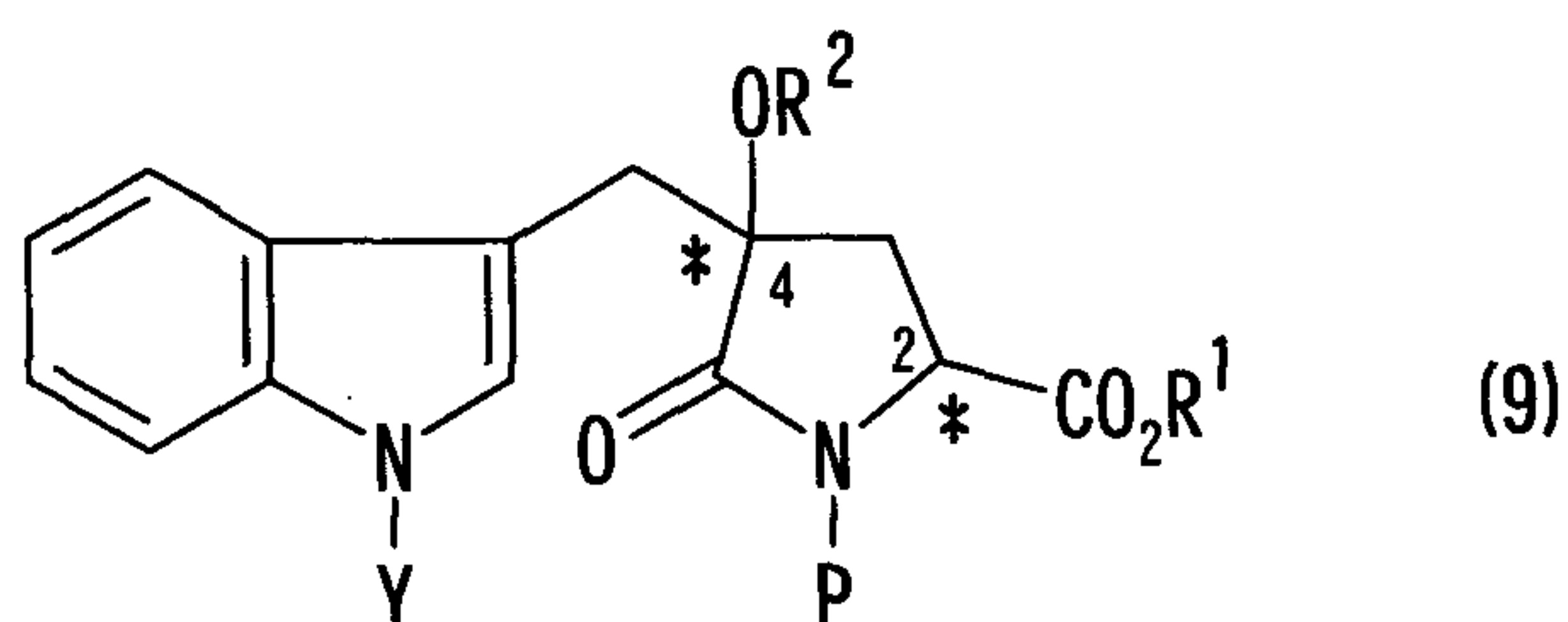
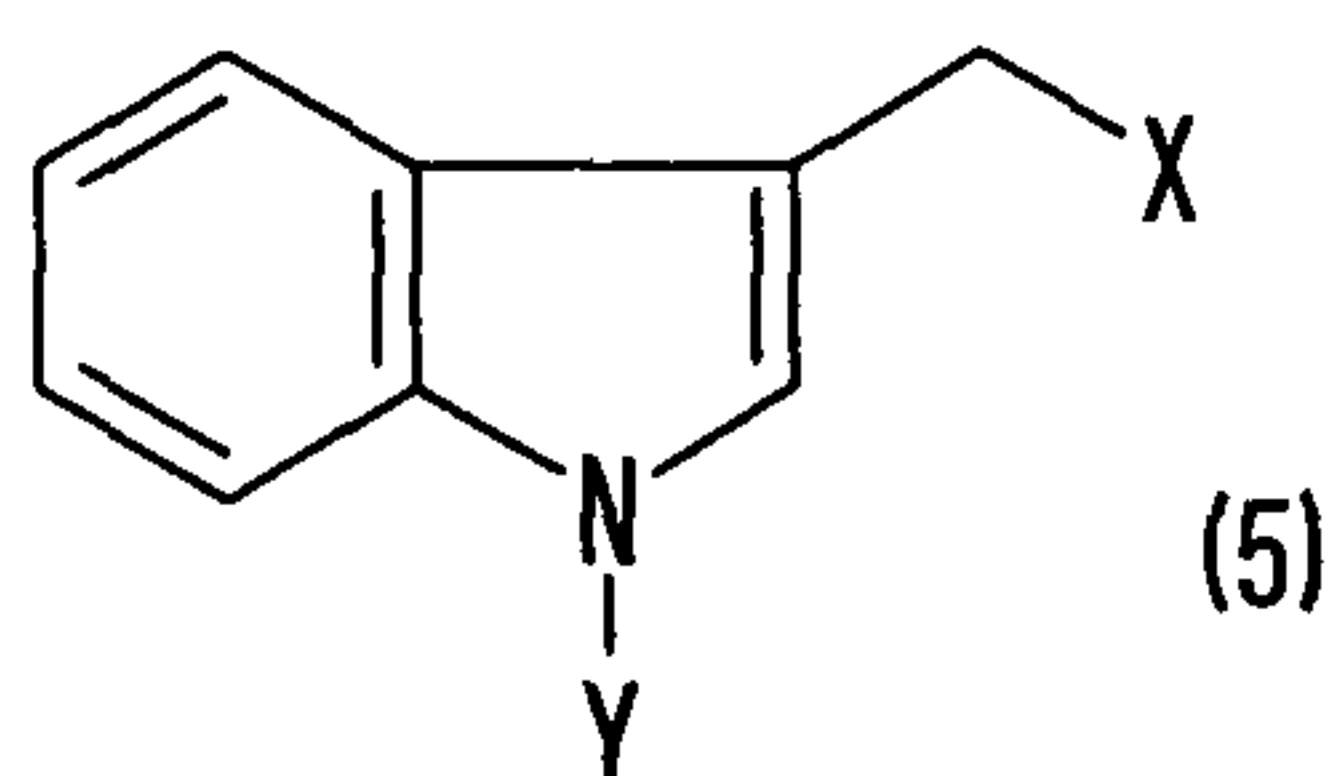
[17] A method as set forth at [11] or [12] above, wherein the alkylation reaction is performed in the presence of a base.

[18] A method as set forth at [17] above, wherein the base is one or more kinds of base selected from a lithium salt of hexamethyldisilazane, lithium hexamethyldisilazane, a potassium salt of hexamethyldisilazane, potassium hexamethyl-disilazane, a sodium salt of hexamethyldisilazane, sodium hexamethyldisilazane, lithium diisopropylamide and normal butyl lithium.

[19] A method as set forth at [17] above, wherein the base is used in a molar ratio of between 1.0 and 2.0 to 1 relative to the 4-protected hydroxyglutamic acid derivative.

[20] A method of manufacturing an optically active monatin derivative represented by formula (10) below (including one in the form of a salt), characterized by reacting an optically active 4-protected hydroxy-pyroglutamic acid derivative represented by formula (8) below (including one in the form of a salt) with N-protected-3-halogenomethylindole represented by formula (5) below to prepare an optically active 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (9) below (including one in the form of a salt) and subjecting the derivative to hydrolysis and deprotection steps:

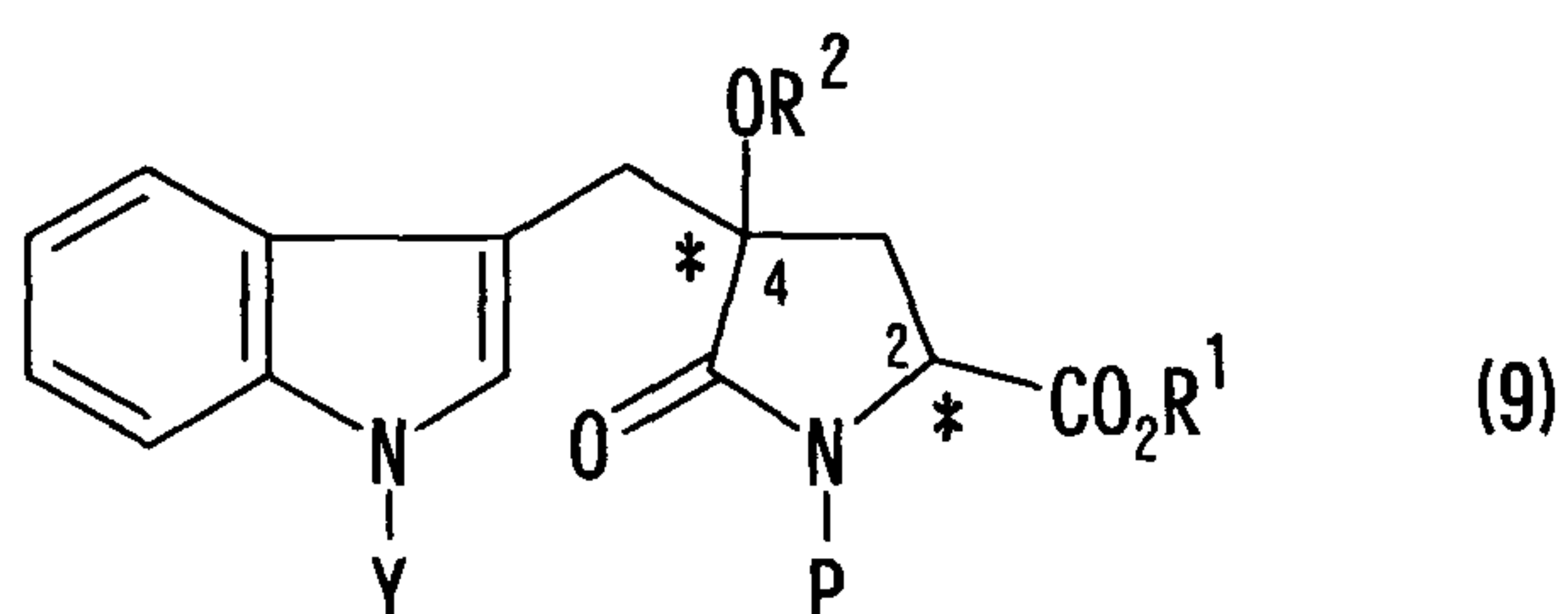
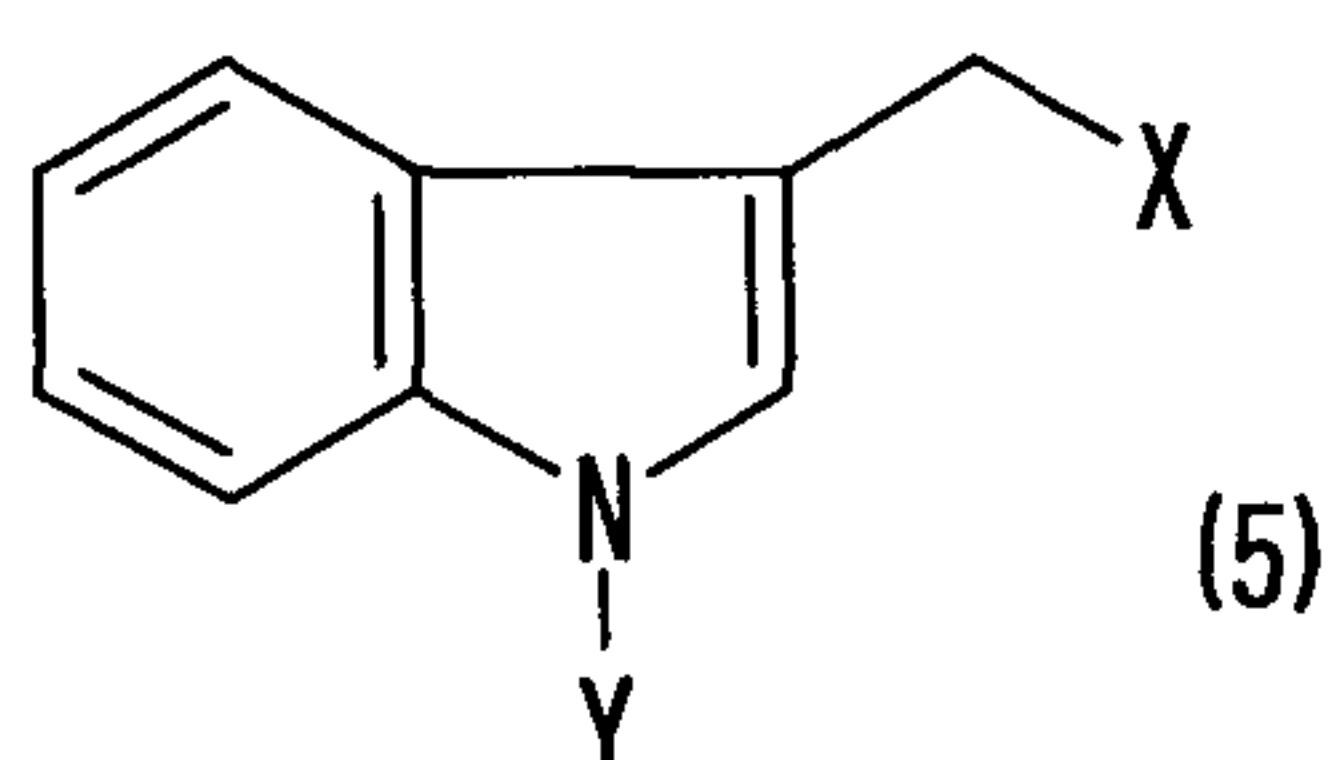
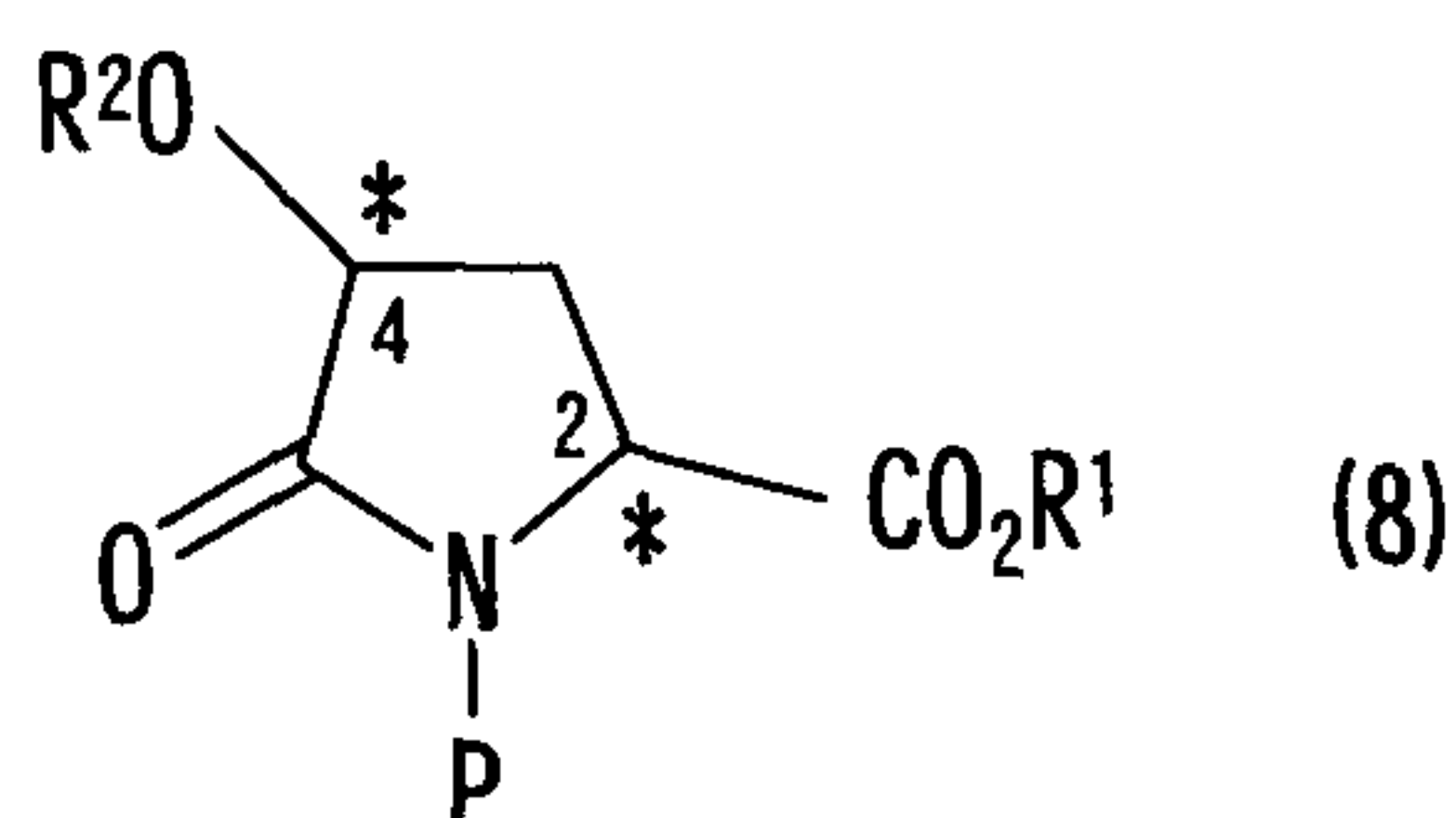




where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group, $*$ stands for an asymmetric carbon atom, the configuration at the 2-position in formula (8) is R or S, the configuration at the 4-position is R, S or RS, so that when the configuration at the 2-position in formula (8) is R, the configurations in formulas (9) and (10) are (2R, 4R), respectively, and when the configuration at the 2-position in formula (8) is S, the configurations in formulas (9) and (10) are (2S, 4S), respectively.

[21] A method of manufacturing an optically active

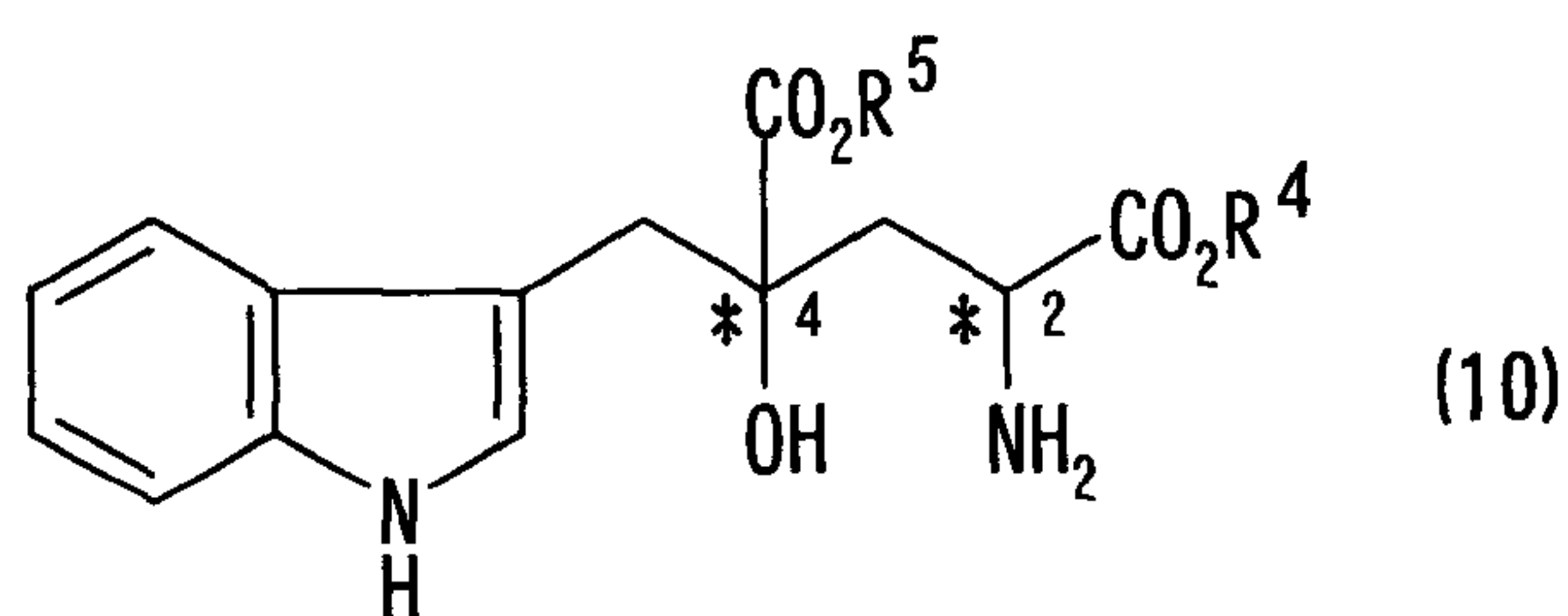
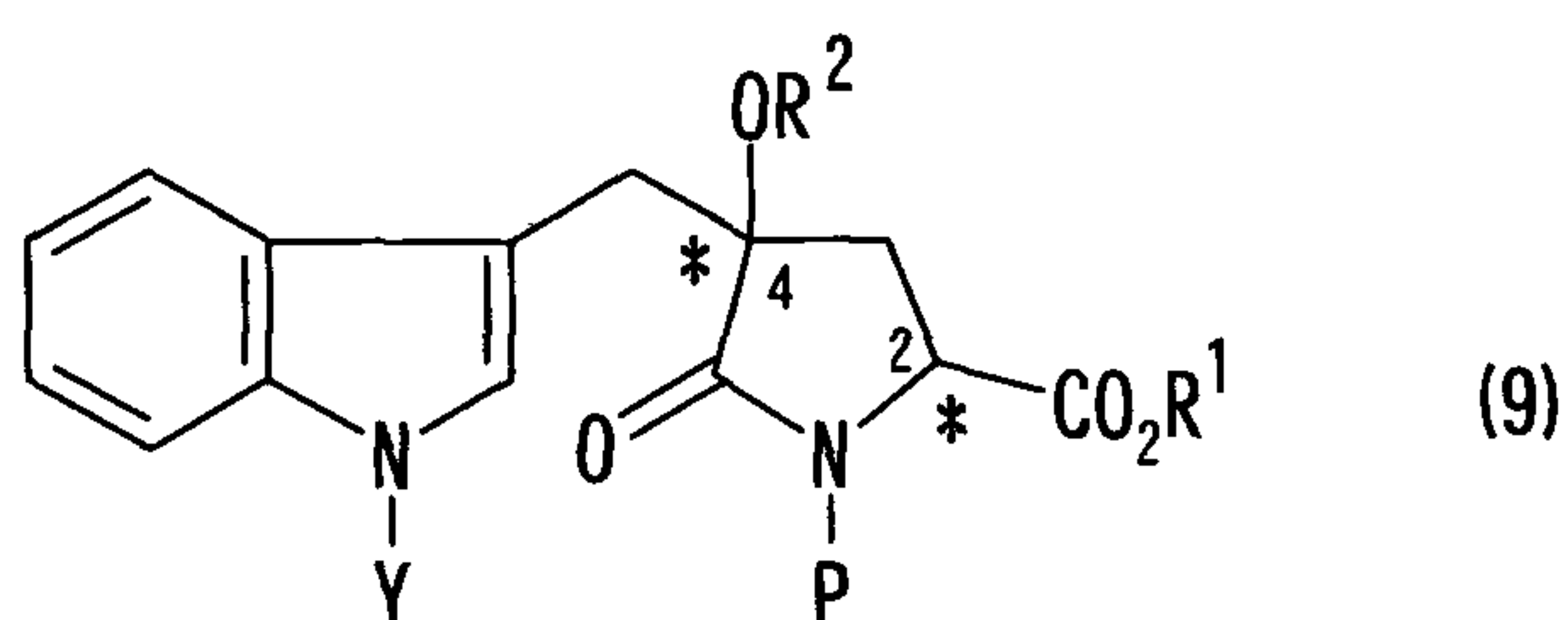
4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (9) below (including one in the form of a salt), characterized by reacting an optically active 4-protected hydroxy-pyroglutamic acid derivative represented by formula (8) below (including one in the form of a salt) with N-protected-3-halogenomethylindole represented by formula (5) below:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group, * stands for an asymmetric carbon atom, the configuration at the 2-position in formula (8) is R or S, the configuration at the 4-position is R, S or RS, so

that when the configuration at the 2-position in formula (8) is R, the configurations in formula (9) are (2R, 4R), respectively, and when the configuration at the 2-position in formula (8) is S, the configurations in formula (9) are (2S, 4S), respectively.

[22] A method of manufacturing an optically active monatin derivative represented by formula (10) below (including one in the form of a salt), characterized by subjecting an optically active 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (9) below (including one in the form of a salt) to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group, * stands for an asymmetric carbon atom, and when the configuration in formula

(9) is (2R, 4R), the configuration in formula (10) is (2R, 4R), and when the configuration in formula (9) is (2S, 4S), the configuration in formula (10) is (2S, 4S).

[23] A method as set forth at [20] above, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[24] A method as set forth at [21] above, wherein R^1 stands for a group selected from a hydrogen atom, an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[25] A method as set forth at [22] above, wherein R^1 stands

for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

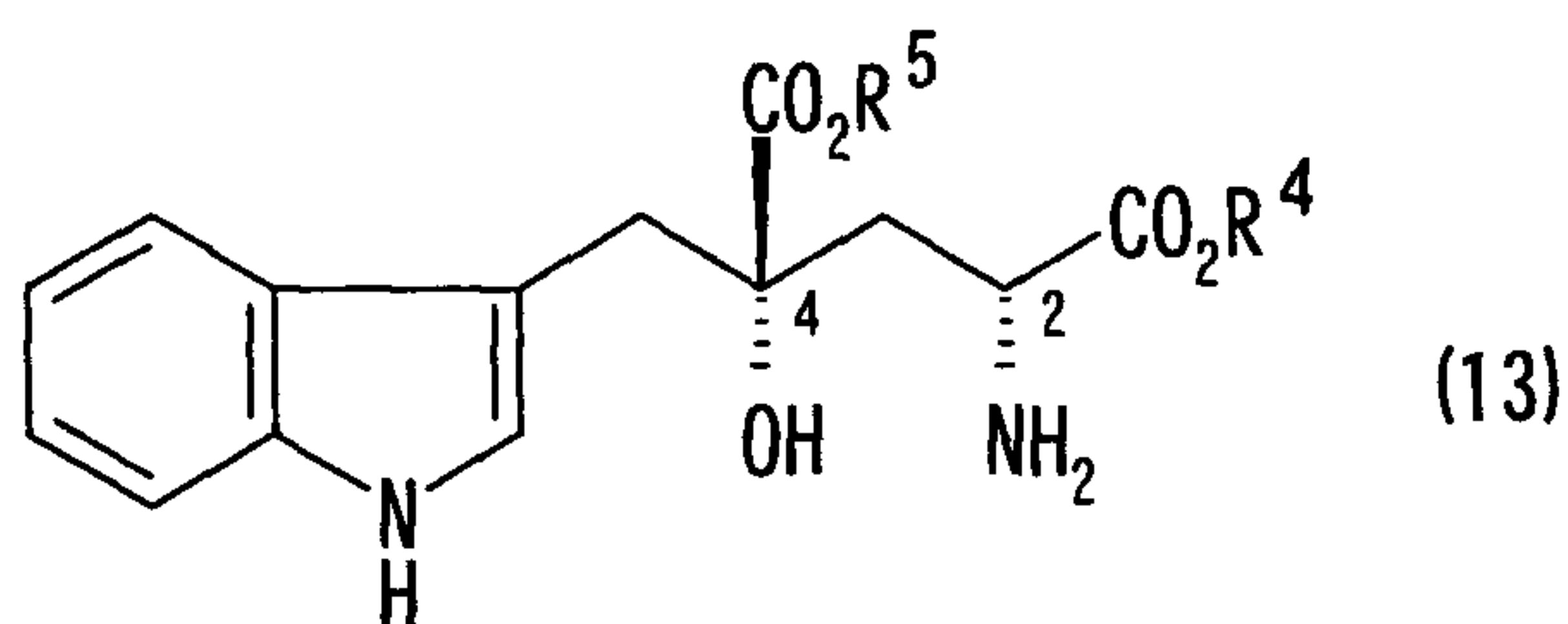
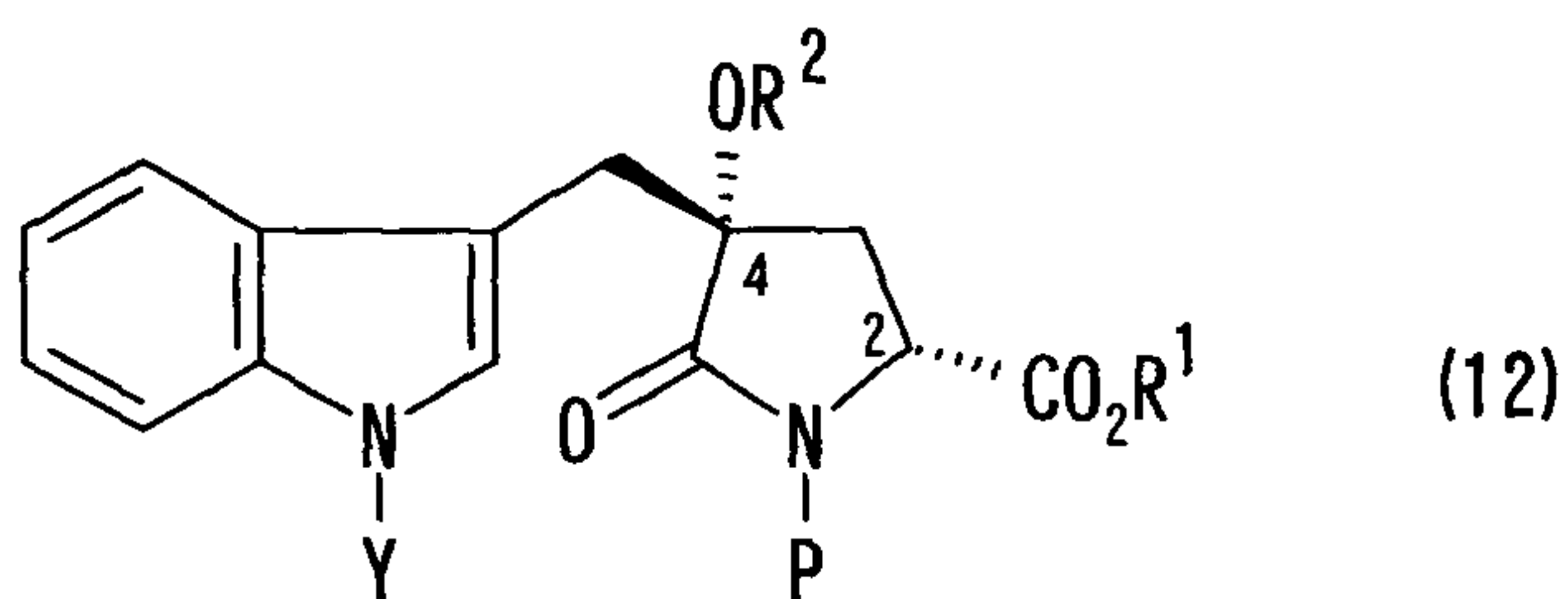
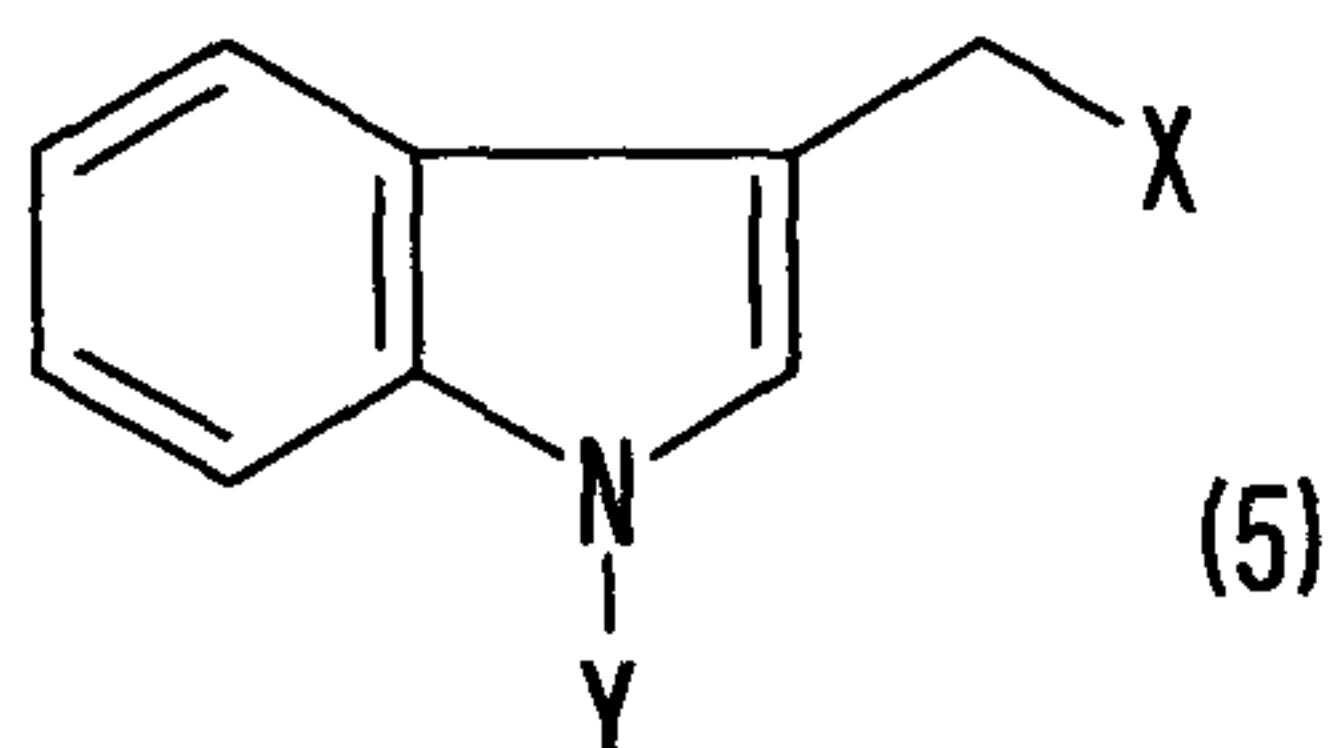
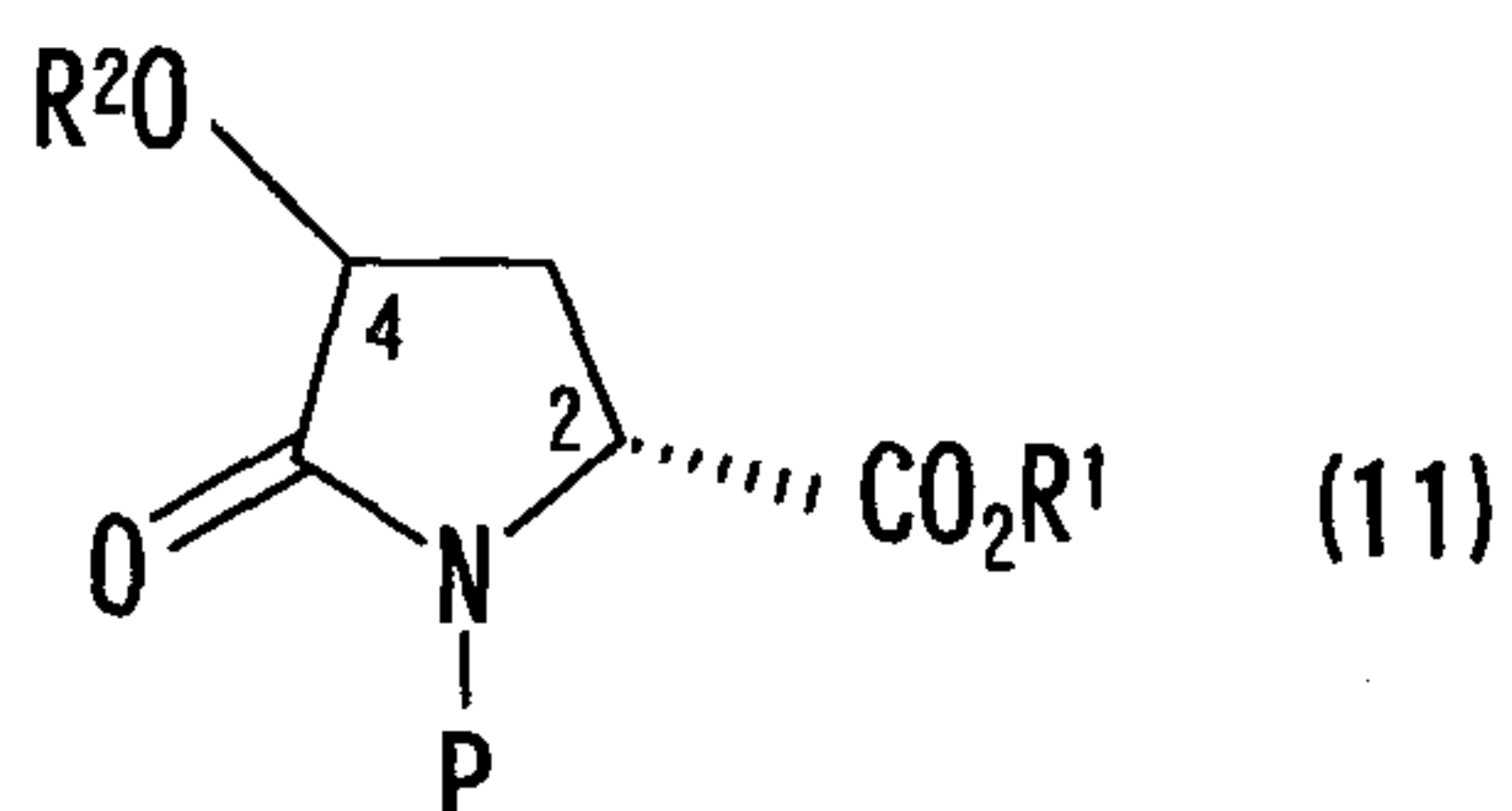
[26] A method as set forth at [20] or [21] above, wherein the reaction of an optically active 4-protected hydroxypyroglutamic acid derivative represented by formula (8) with N-protected-3-halogenomethylindole represented by formula (5) is performed in the presence of a base.

[27] A method as set forth at [26] above, wherein the base is one or more kinds of base selected from a lithium salt of hexamethyldisilazane, lithium hexamethyldisilazane, a potassium salt of hexamethyldisilazane, potassium hexamethyl-disilazane, a sodium salt of hexamethyldisilazane, sodium hexamethyldisilazane, lithium diisopropylamide and normal butyl lithium.

[28] A method as set forth at [26] above, wherein the base is used in a molar ratio of between 1.0 and 2.0 to 1 relative to the 4-protected hydroxyglutamic acid derivative.

[29] A method of manufacturing a (2R, 4R)-monatin derivative represented by formula (13) below (including one in the form

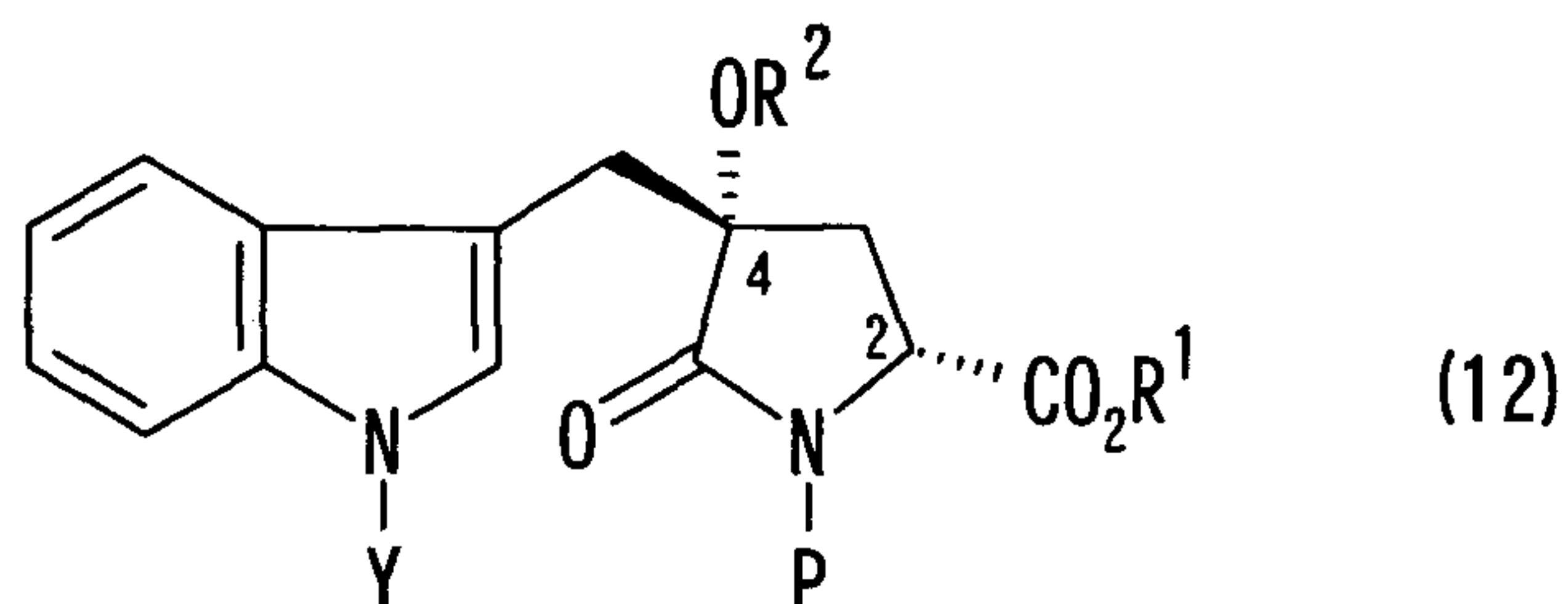
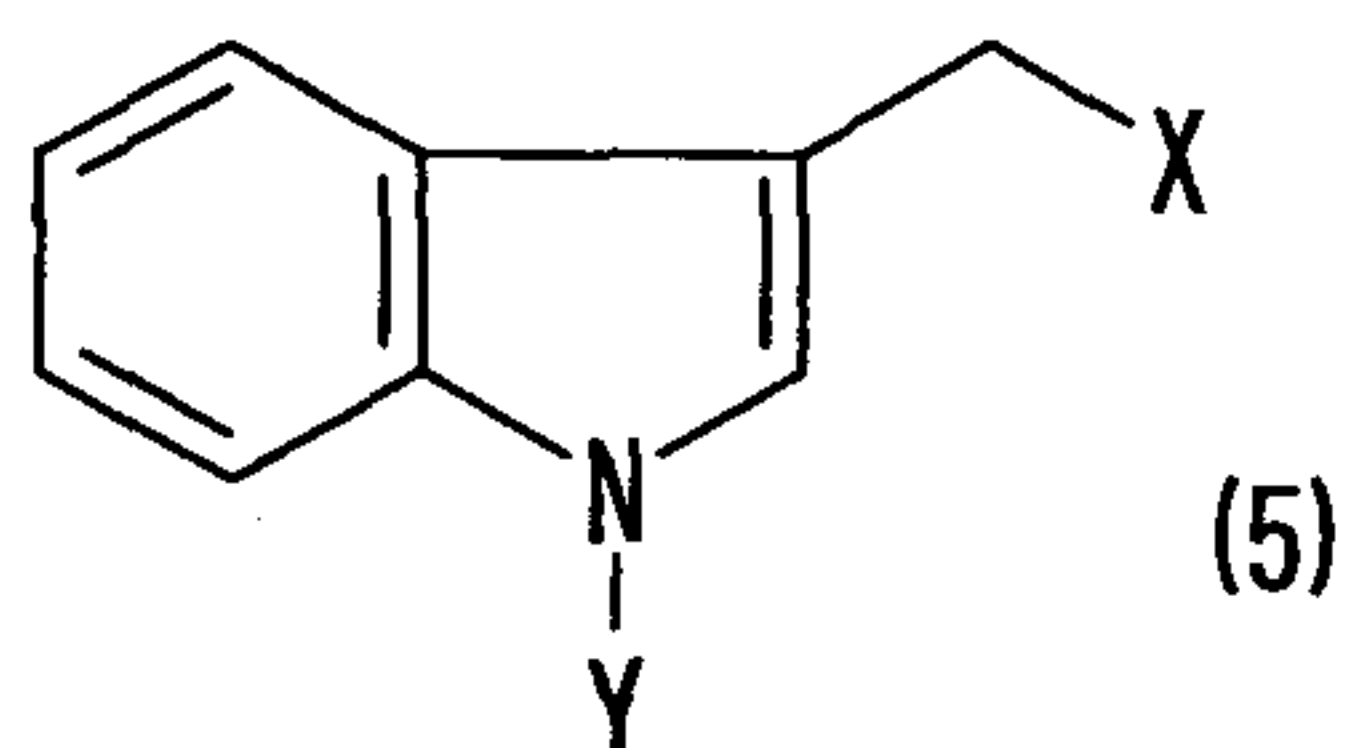
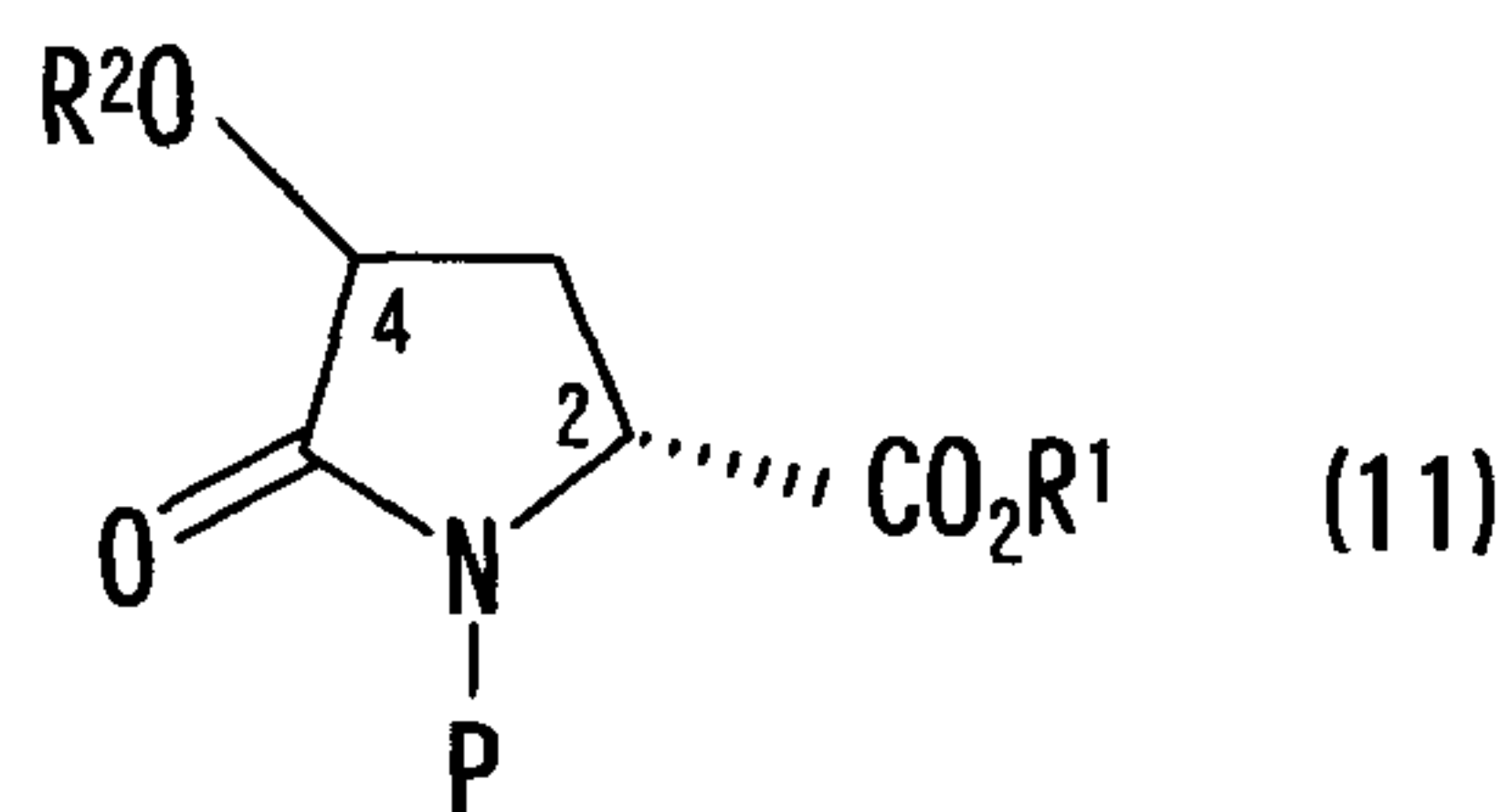
of a salt), characterized by reacting a (2R)-4-protected hydroxy-pyroglutamic acid derivative represented by formula (11) below (including one in the form of a salt) with N-protected-3-halogenomethylindole represented by formula (15) below to prepare a (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (12) below (including one in the form of a salt) and subjecting the derivative to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another

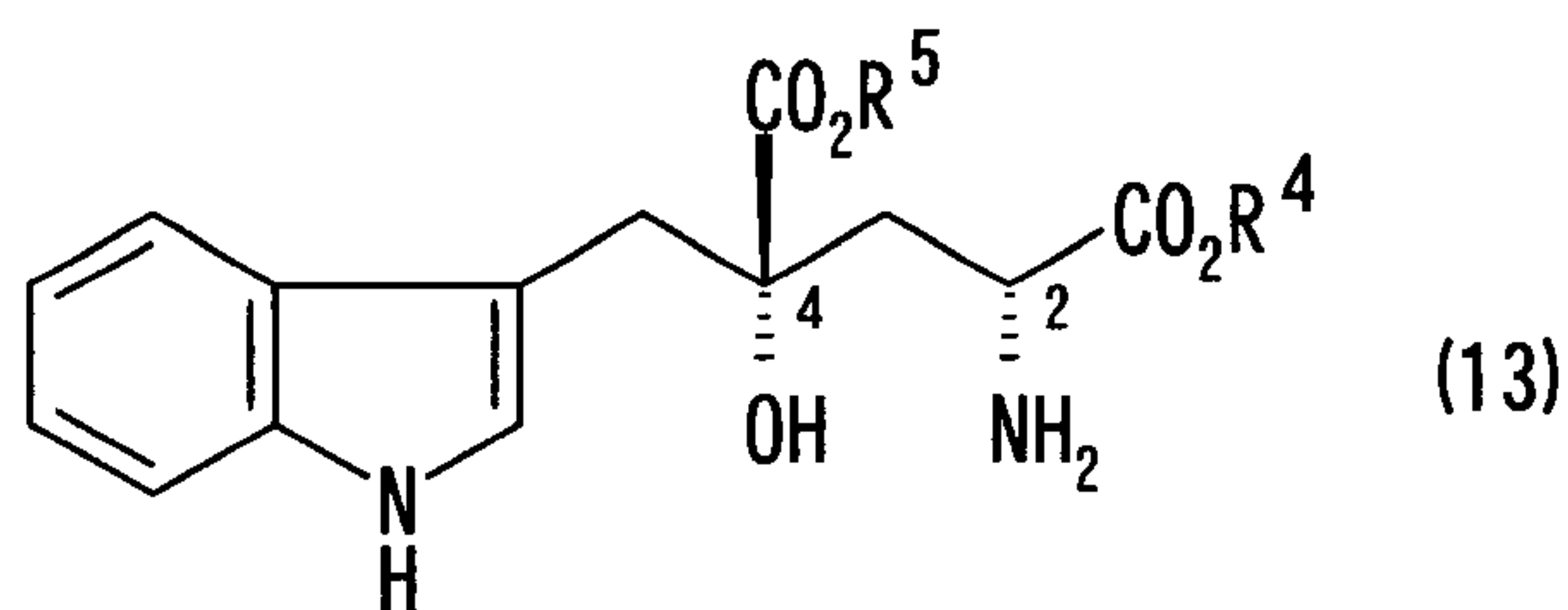
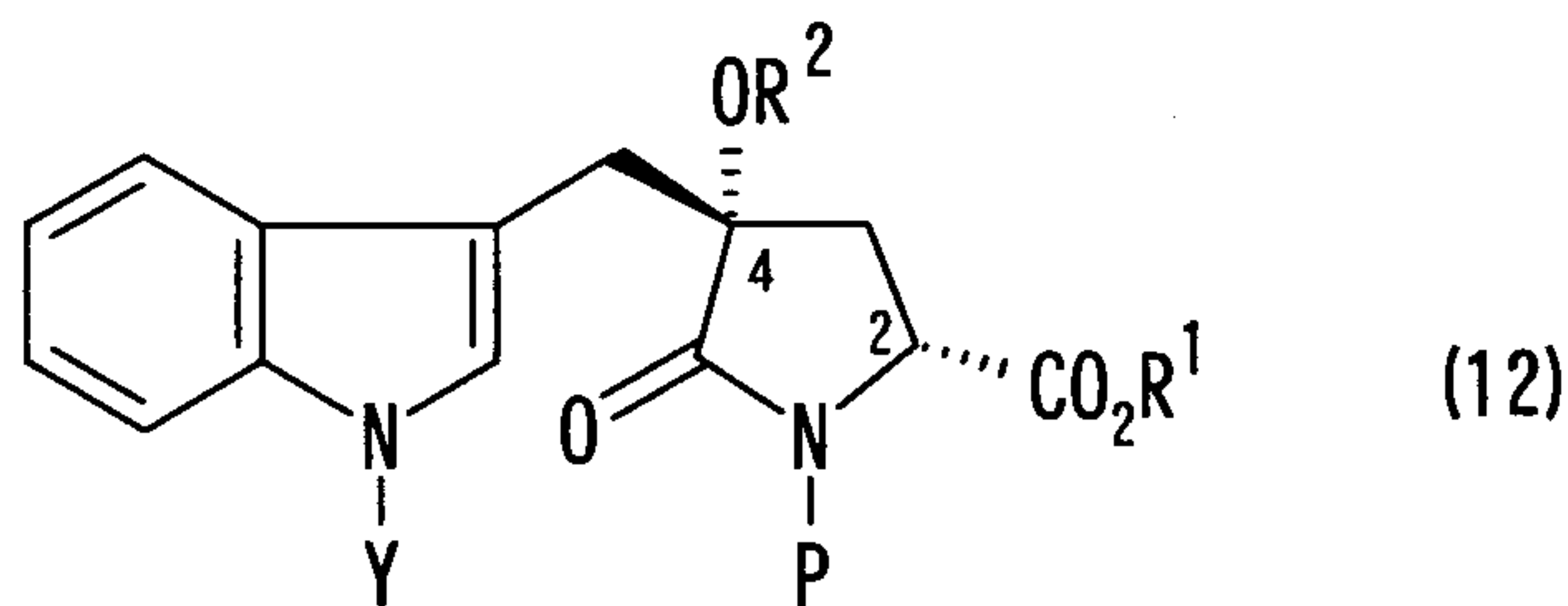
for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group and the configuration at the 4-position in formula (11) is R, S or RS.

[30] A method of manufacturing a (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (12) below (including one in the form of a salt), characterized by reacting a (2R)-4-protected hydroxypyroglutamic acid derivative represented by formula (11) below (including one in the form of a salt) with N-protected-3-halogenomethylindole represented by formula (5) below:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group and the configuration at the 4-position in formula (11) is R, S or RS.

[31] A method of manufacturing a (2R, 4R)-monatin derivative represented by formula (13) below (including one in the form of a salt), characterized by subjecting a (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (12) below (including one in the form of a salt) to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group.

[32] A method as set forth at [29] above, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[33] A method as set forth at [30] above, wherein R^1 stands for a group selected from a hydrogen atom, an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[34] A method as set forth at [31] above, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl

group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[35] A method as set forth at [29] or [30] above, wherein the reaction of a (2R)-4-protected hydroxypyroglutamic acid derivative represented by formula (11) with N-protected-3-halogenomethylindole represented by formula (5) is performed in the presence of a base.

[36] A method as set forth at [26] above, wherein the base is one or more kinds of base selected from a lithium salt of hexamethyldisilazane, lithium hexamethyldisilazane, a potassium salt of hexamethyldisilazane, potassium hexamethyl-disilazane, a sodium salt of hexamethyldisilazane, sodium hexamethyldisilazane, lithium diisopropylamide and normal butyl lithium.

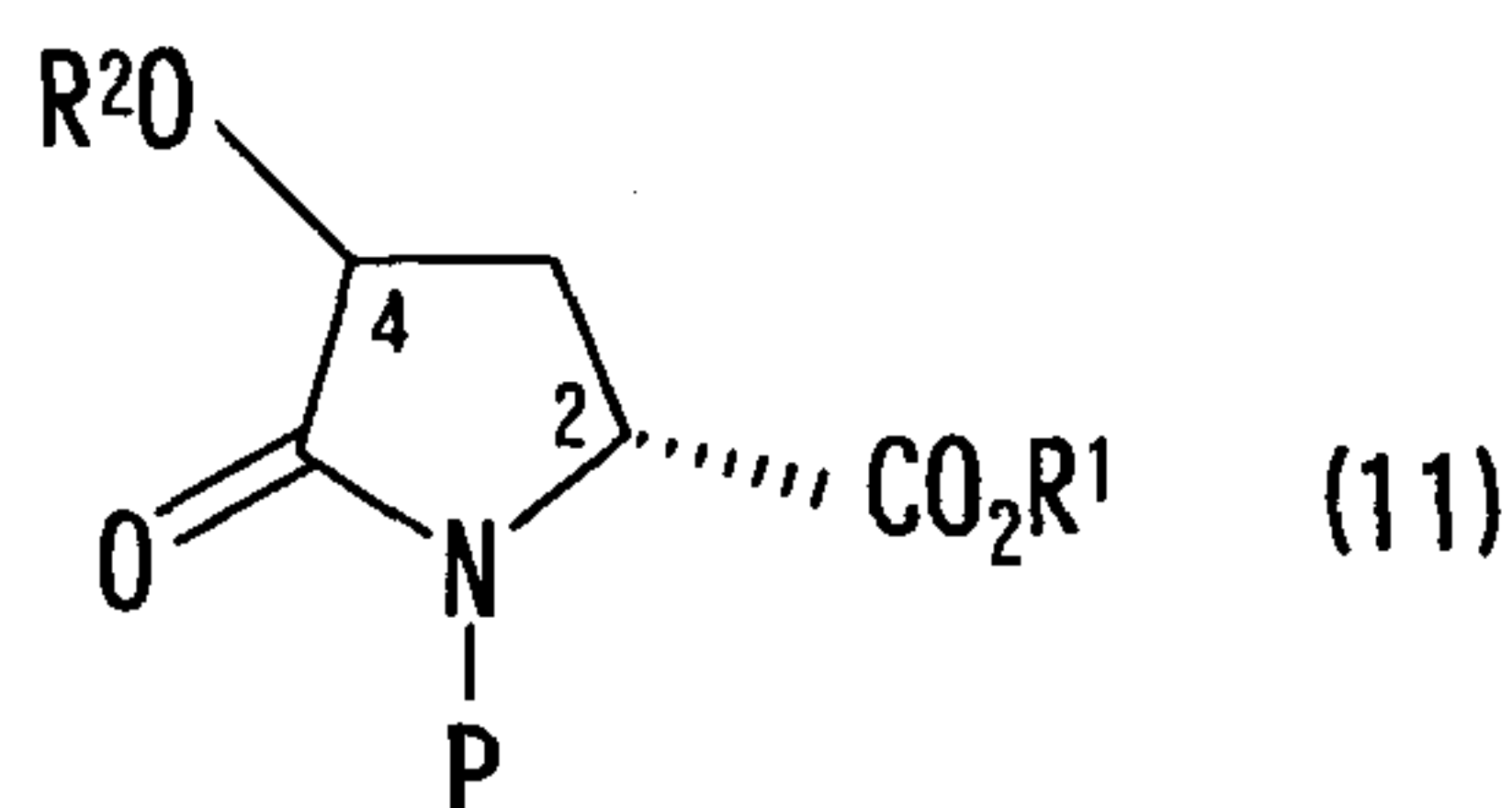
[37] A method as set forth at [26] above, wherein the base is used in a molar ratio of between 1.0 and 2.0 to 1 relative to the 4-protected hydroxyglutamic acid derivative.

[38] A method as set forth at [29] above, wherein R¹ stands for a methyl group, R⁴ and R⁵ stand for a hydrogen atom each, R² stands for a t-butyldimethylsilyl group, X stands for a bromine atom and P and Y stand for a t-butoxycarbonyl group each.

[39] A method as set forth at [30] above, wherein R^1 stands for a methyl group, R^2 stands for a t-butyldimethylsilyl group, X stands for a bromine atom and P and Y stand for a t-butoxycarbonyl group each.

[40] A method as set forth at [31] above, wherein R^1 stands for a methyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a t-butyldimethylsilyl group and P and Y stand for a t-butoxycarbonyl group each.

[41] A (2R)-4-hydroxypyroglutamic acid derivative represented by formula (11) below (including one in the form of a salt):



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group and the configuration at the 4-position in formula (11) is R, S or RS.

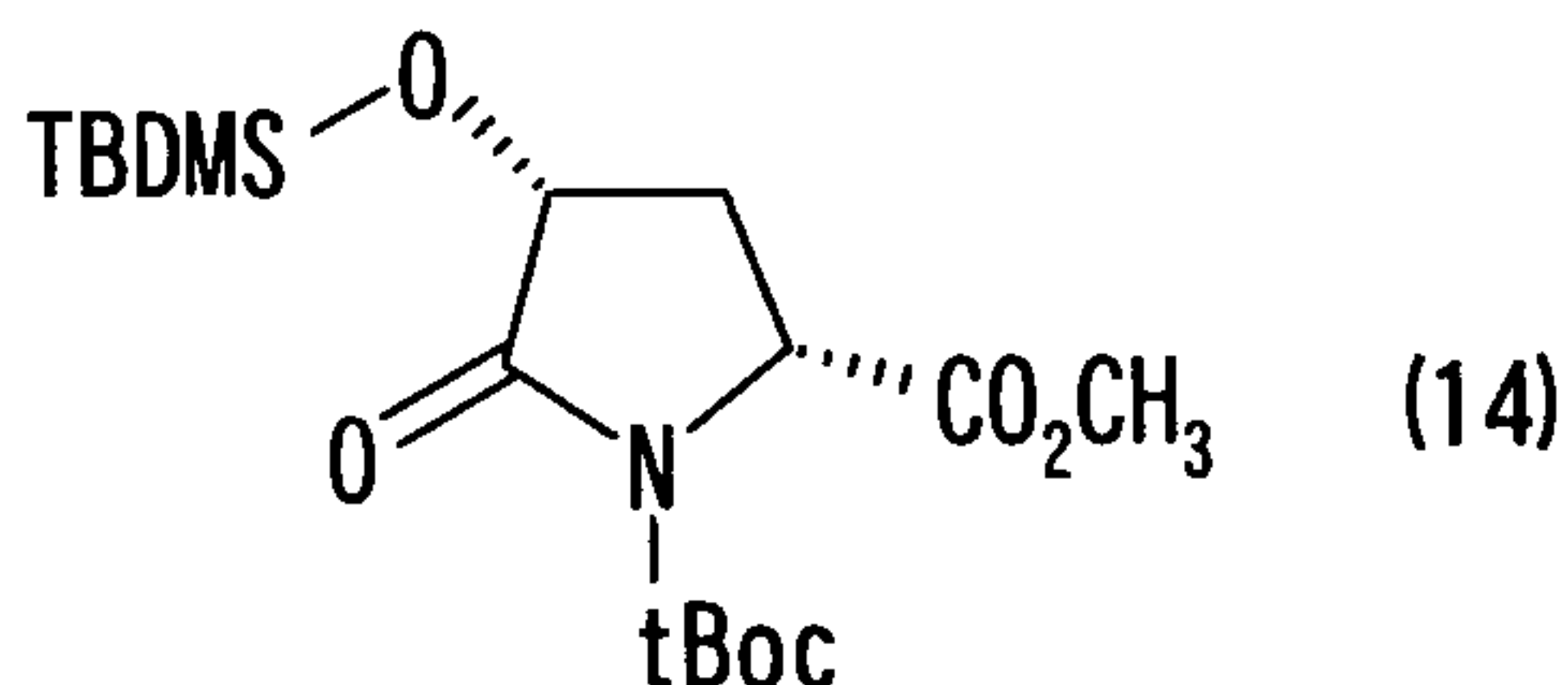
[42] A (2R)-4-hydroxypyroglutamic acid derivative as set forth at [41] above, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl

group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[43] A (2R)-4-hydroxypyroglutamic acid derivative as set forth at [41] above, wherein R^1 stands for a methyl group, R^2 stands for a t-butyldimethylsilyl group and P stands for a t-butoxycarbonyl group.

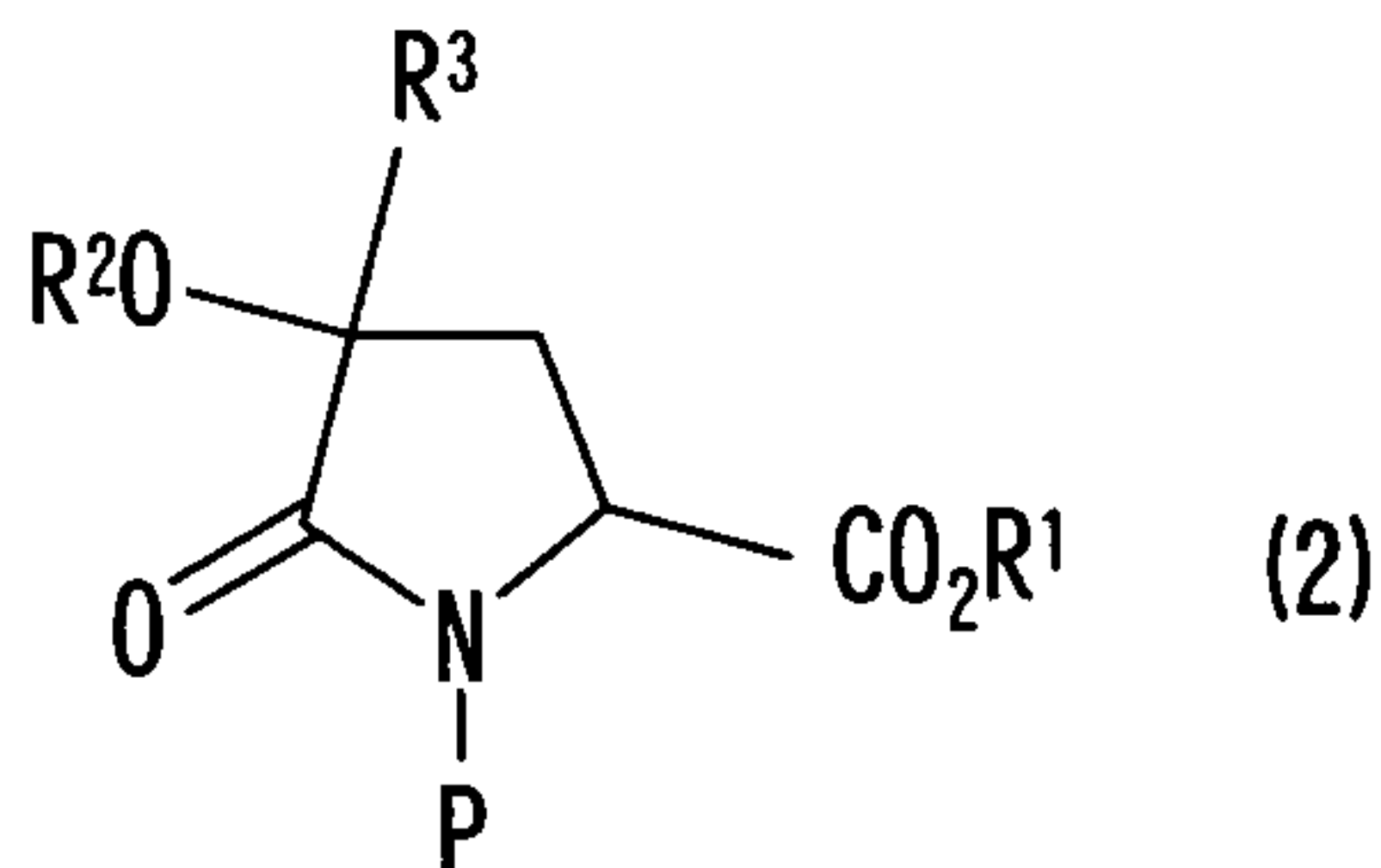
[44] An

N-t-butoxycarbonyl-4-t-butyldimethylsilyloxy-D-pyroglutamic acid methyl ester represented by formula (14) below:



where tBoc stands for a t-butoxycarbonyl group and TBDMS stands for a t-butyldimethylsilyloxy group.

[45] A 4-protected hydroxyl-4-substituted pyroglutamic acid derivative represented by formula (2) (including one in the form of a salt):

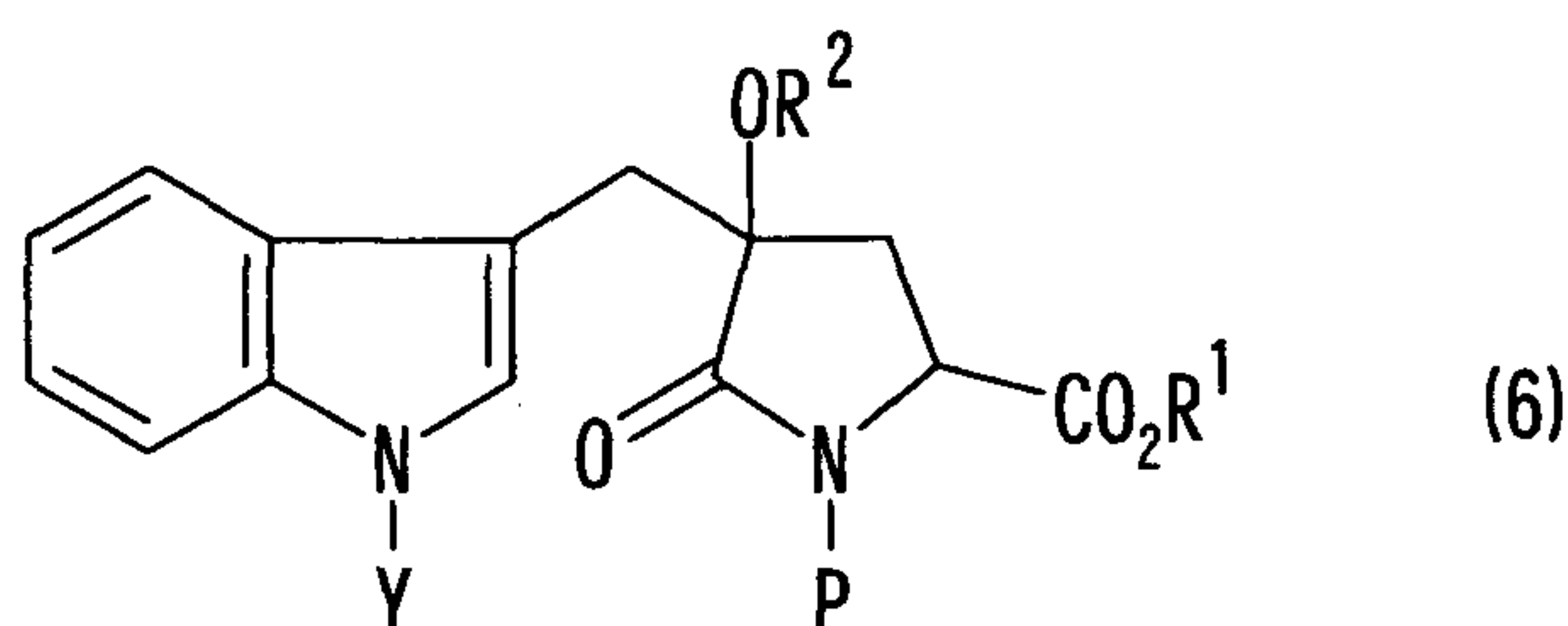


where R^1 stands for a group selected from a hydrogen atom

and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group and P stands for a protecting group for an imino group.

[46] A 4-protected hydroxyl-4-substituted pyroglutamic acid derivative as set forth at [45] above, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, R^3 stands for a group selected from an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to 20 carbon atoms, an aralkyl group having 1 to 20 carbon atoms and a heterocyclic hydrocarbon group having 1 to 20 carbon atoms and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

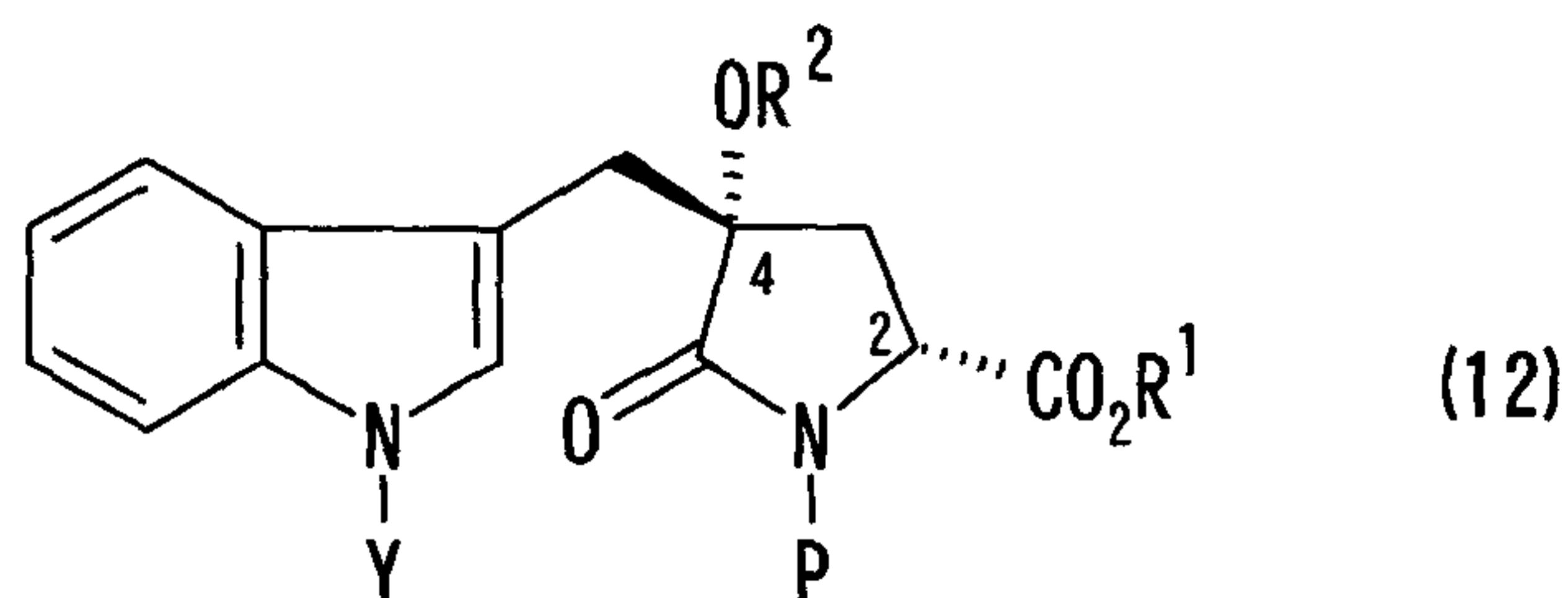
[47] A 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) (including one in the form of a salt):



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group and Y stands for a protecting group for an indolyl group.

[48] A 4-protected hydroxy-4-substituted pyroglutamic acid derivative as set forth at [47] above, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[49] A (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (12) (including one in the form of a salt):



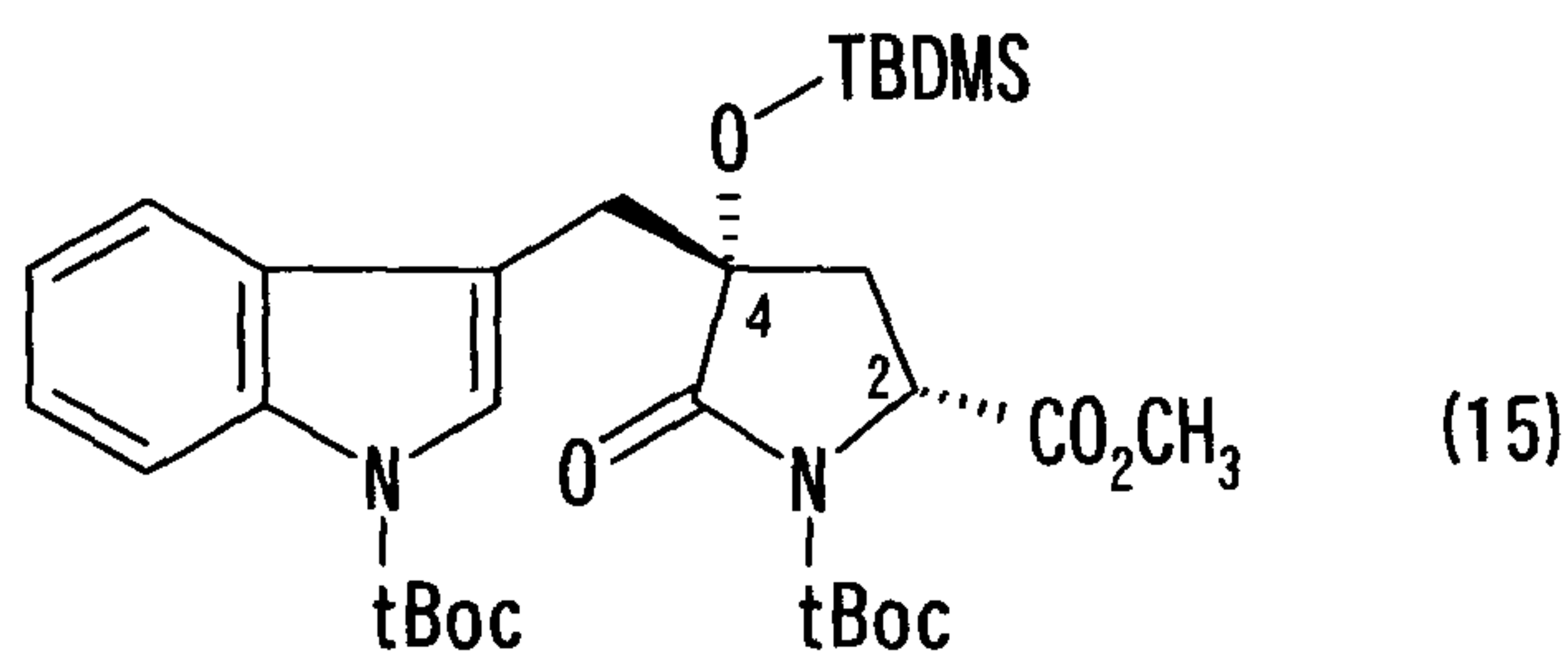
where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group and Y stands for a protecting group for an indolyl group.

[50] A (2R, 4R)-4-protected hydroxy-4-substituted

pyroglutamic acid derivative as set forth at [49] above, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

[51] An

N-t-butoxycarbonyl- (4R) -4-t-butyldimethylsilyloxy-4-benzyl
-D-pyroglutamic acid methyl ester represented by formula (15)
below:

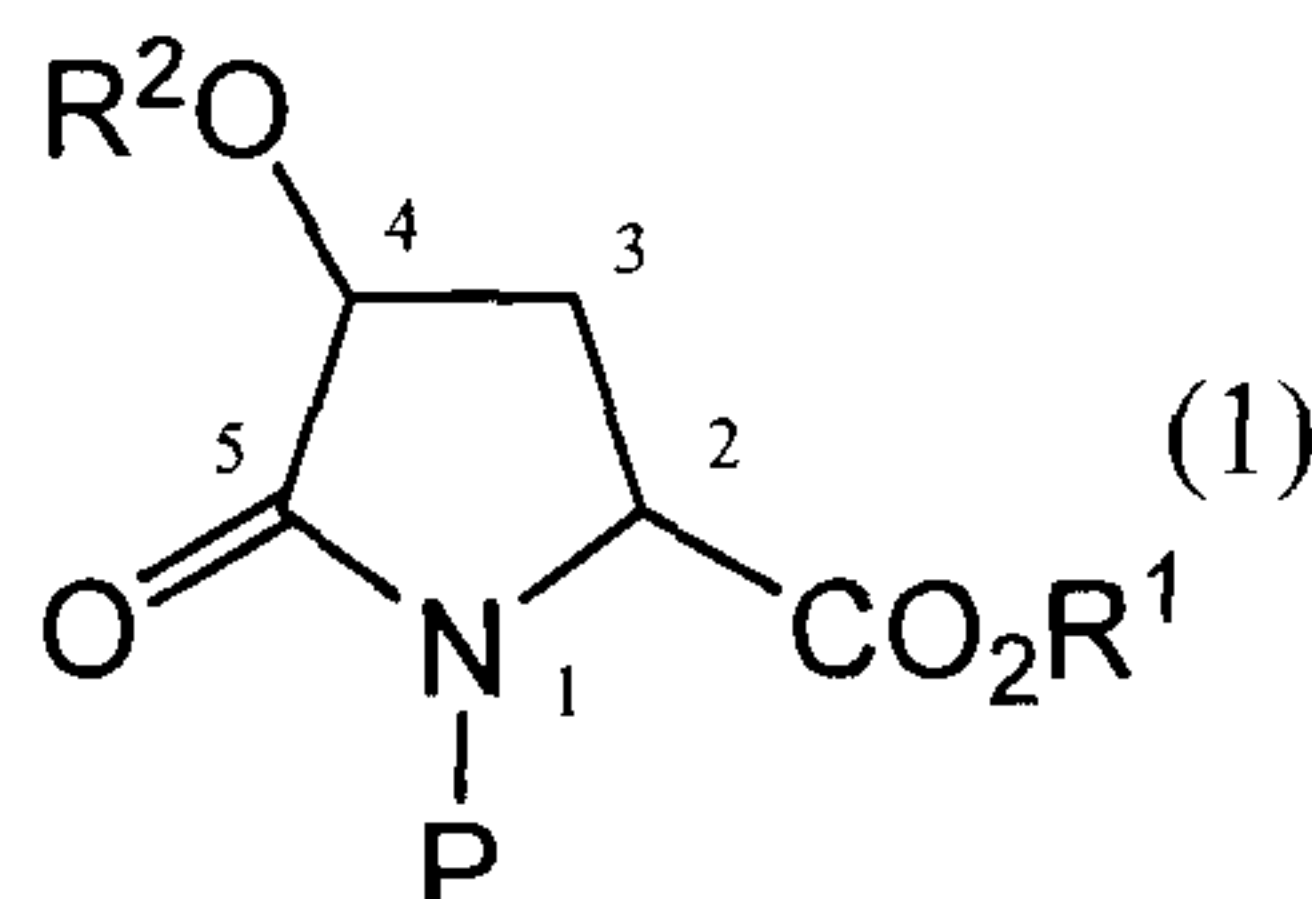


where tBoc stands for a t-butoxycarbonyl group and TBDMS stands for a t-butyldimethylsilyloxy group.

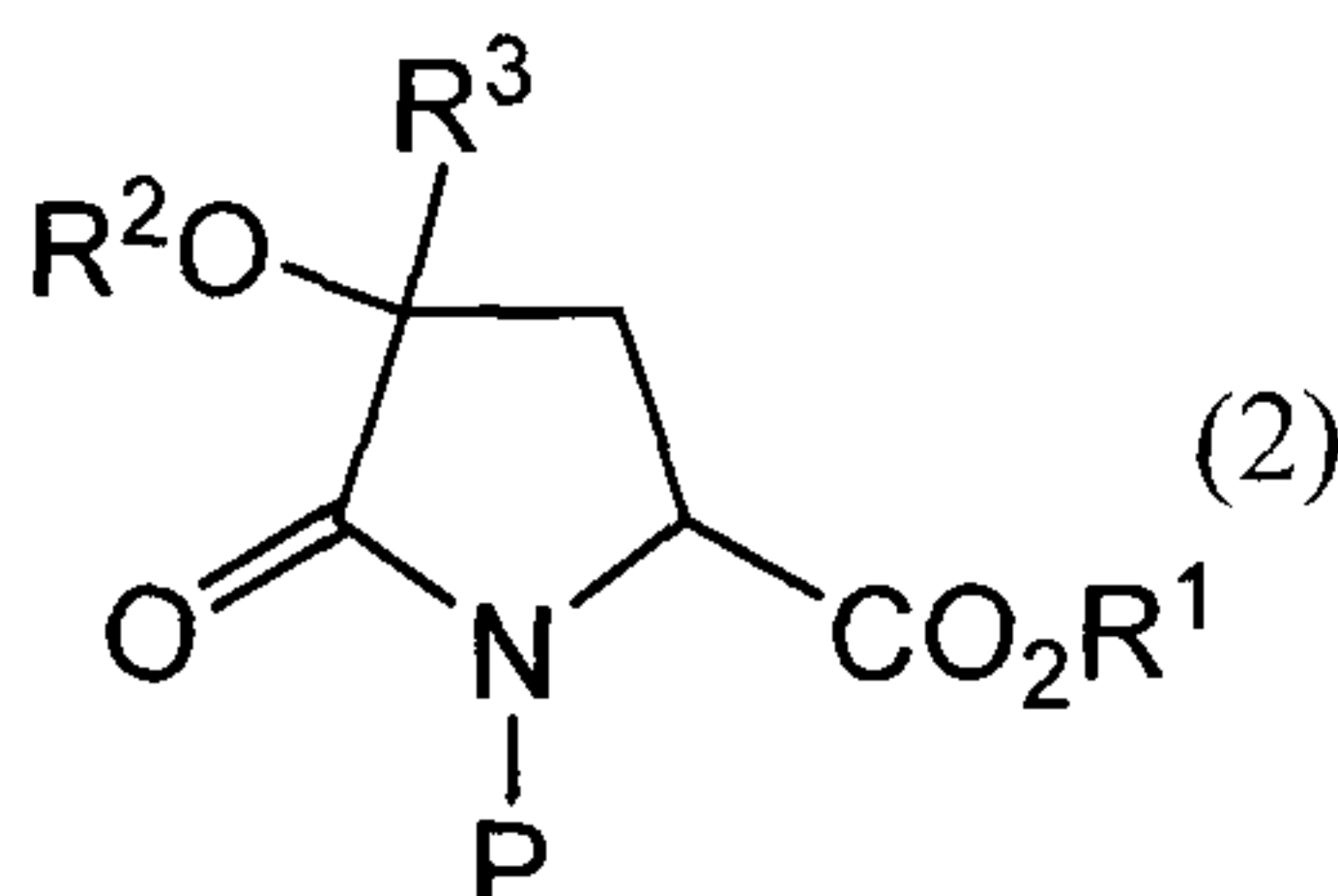
While it is known that naturally occurring monatin presents the (2S, 4S) form in its stereostructure, the term "monatin" as herein used covers all the compounds having the same structural formula, but differing in configuration. The individual stereoisomers may be called by designations indicating their stereoisomerism like "(2S, 4S)-monatin" and

"(2R, 4R)-monatin".

In accordance with one aspect of the present invention, there is provided a method comprising subjecting a 4-protected hydroxypyroglutamic acid derivative represented by formula (1) below or a salt thereof:



to an alkylation reaction to produce a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2) below, or a salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group and P stands for a protecting group for an imino group.

In accordance with another aspect of the present invention, there is provided a method as described herein, wherein R^3 is a benzyl group or an N-protected-3-indolylmethyl group.

In accordance with yet another aspect of the present invention, there is provided a method as described herein, wherein the alkylation reaction is performed in the presence of an alkylating agent represented by formula (4) below:



where R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent and X stands for a halogen atom.

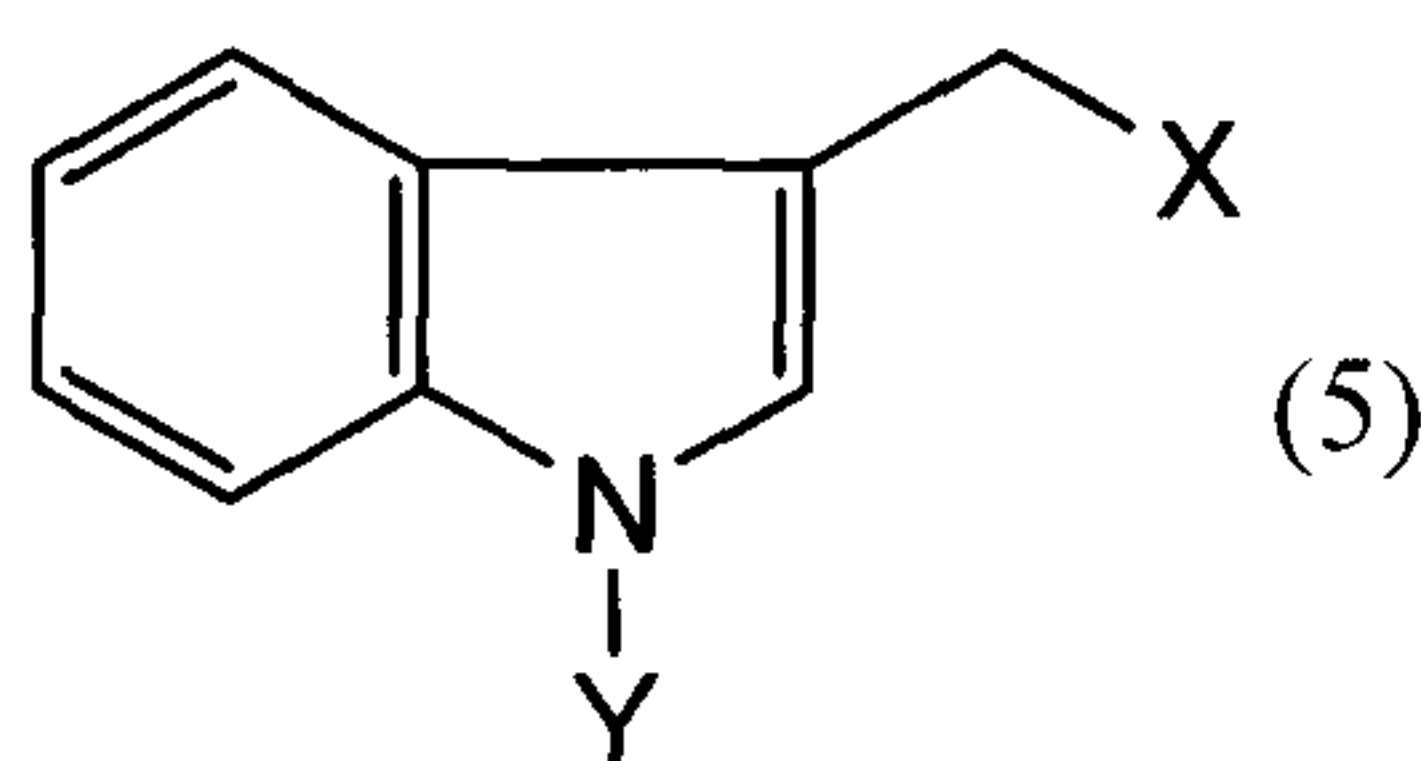
In accordance with still another aspect of the present invention, there is provided a method as described herein, wherein alkylation reaction is performed in the presence of a base.

In accordance with yet still another aspect of the present invention, there is provided a method as described herein, wherein the base is one or more kinds of base selected from a lithium salt of hexamethyldisilazane, lithium hexamethyldisilazanide, a potassium salt of hexamethyldisilazane, potassium hexamethyldisilazanide, a sodium salt of hexamethyldisilazane, sodium hexamethyldisilazanide, lithium diisopropylamide and normal butyl lithium.

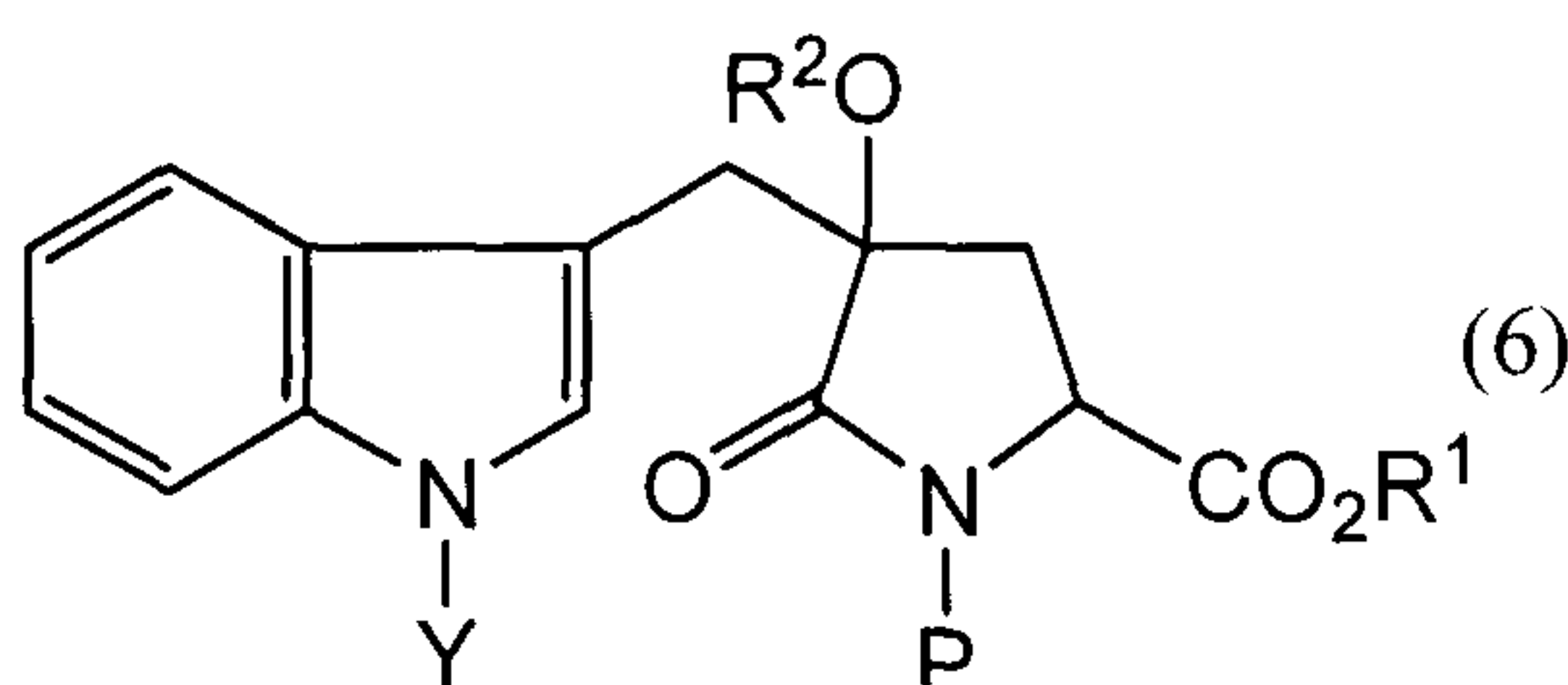
In accordance with a further aspect of the present invention, there is provided a method as described herein, wherein the base is used in a molar ratio of between 1.0 and 2.0 to 1 relative to the 4-protected hydroxyglutamic acid derivative.

In accordance with yet a further aspect of the present invention, there is provided a method as described herein, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, R^3 stands for a group selected from an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to 20 carbon atoms, an aralkyl group having 1 to 20 carbon atoms and a heterocyclic hydrocarbon group having 1 to 20 carbon atoms, and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

In accordance with still a further aspect of the present invention, there is provided a described herein, wherein the 4-protected hydroxypyroglutamic acid derivative represented by formula (1) as set out in claim 48, or a salt thereof, is subjected to alkylation with N-protected-3-halogeno-methylindole represented by formula (5) below:

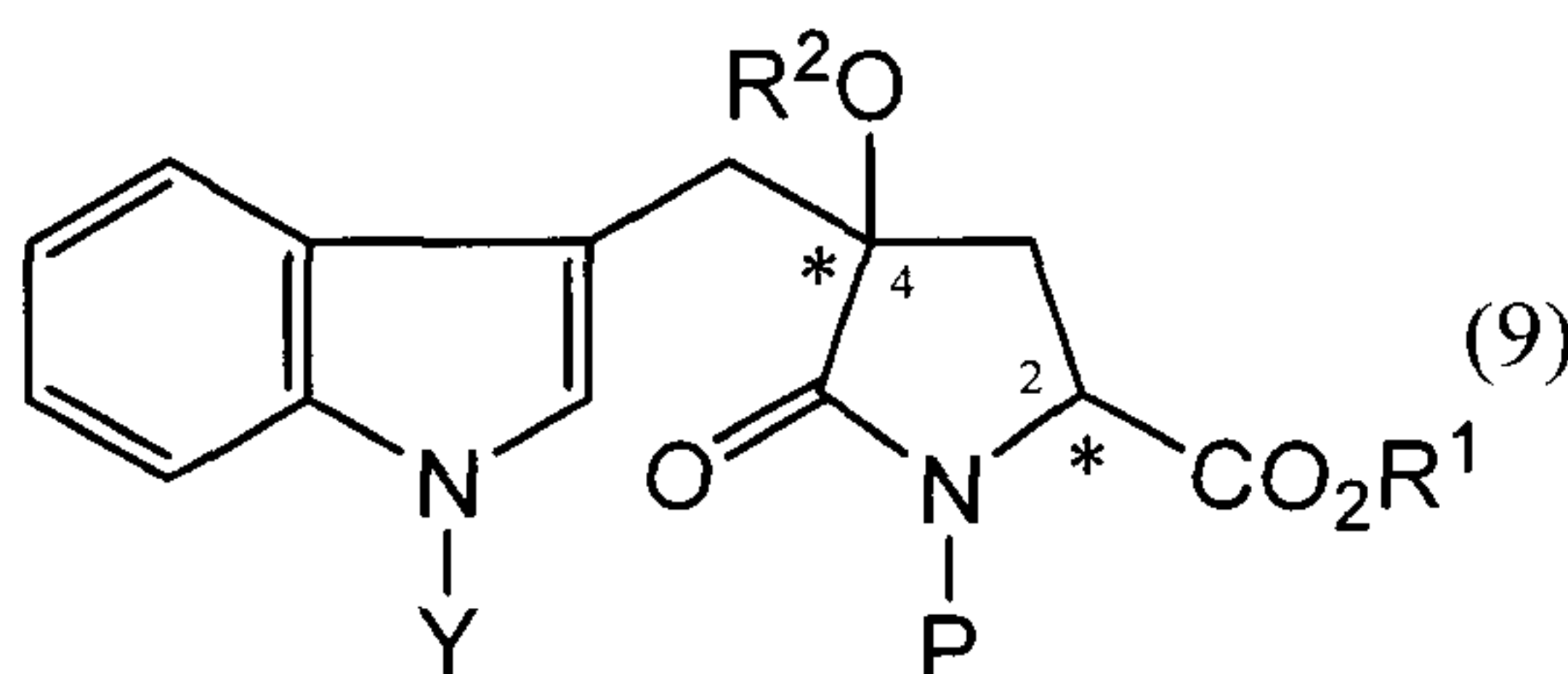
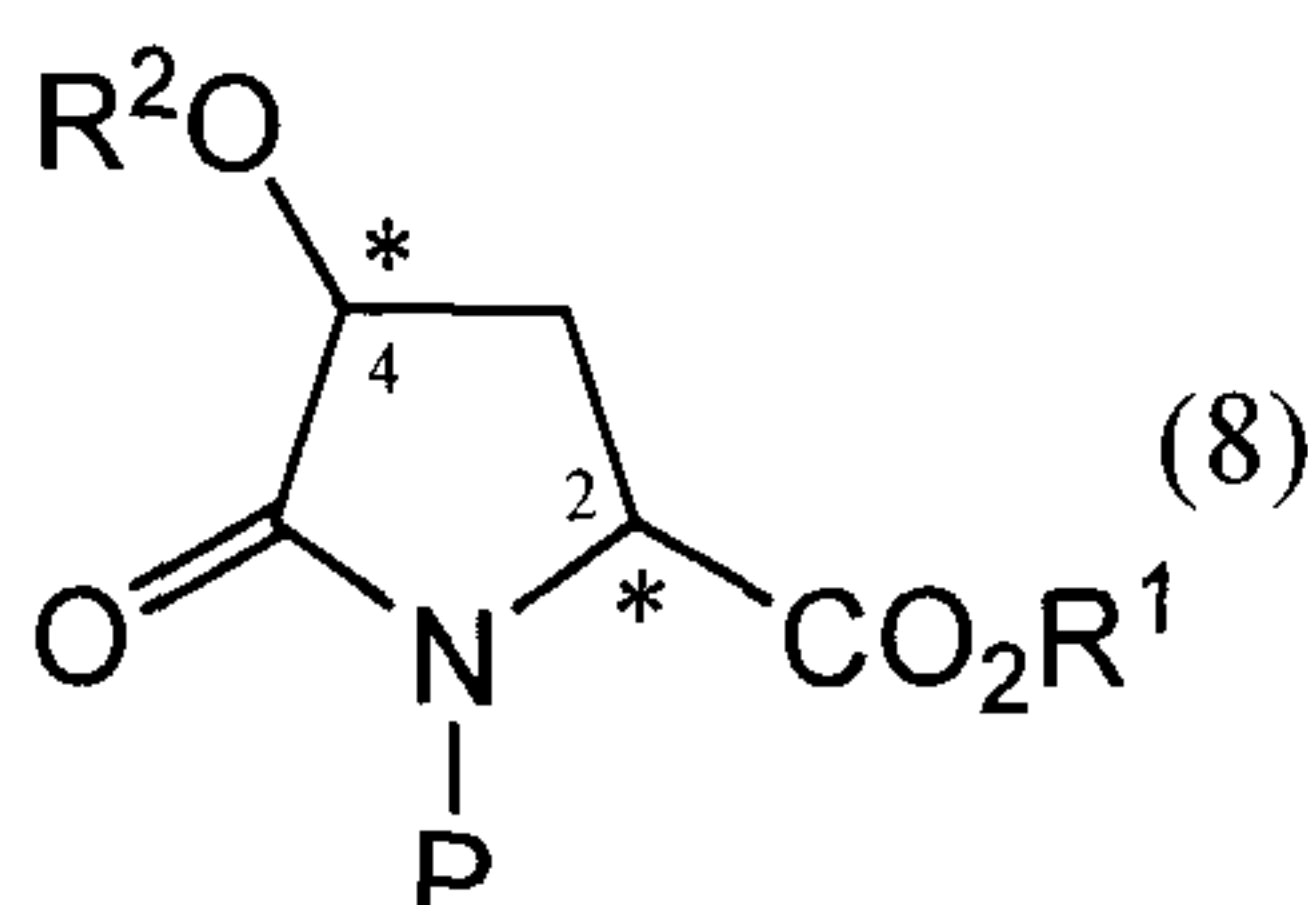


thereby to produce a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) below, or a salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group and Y stands for a protecting group for an indolyl group.

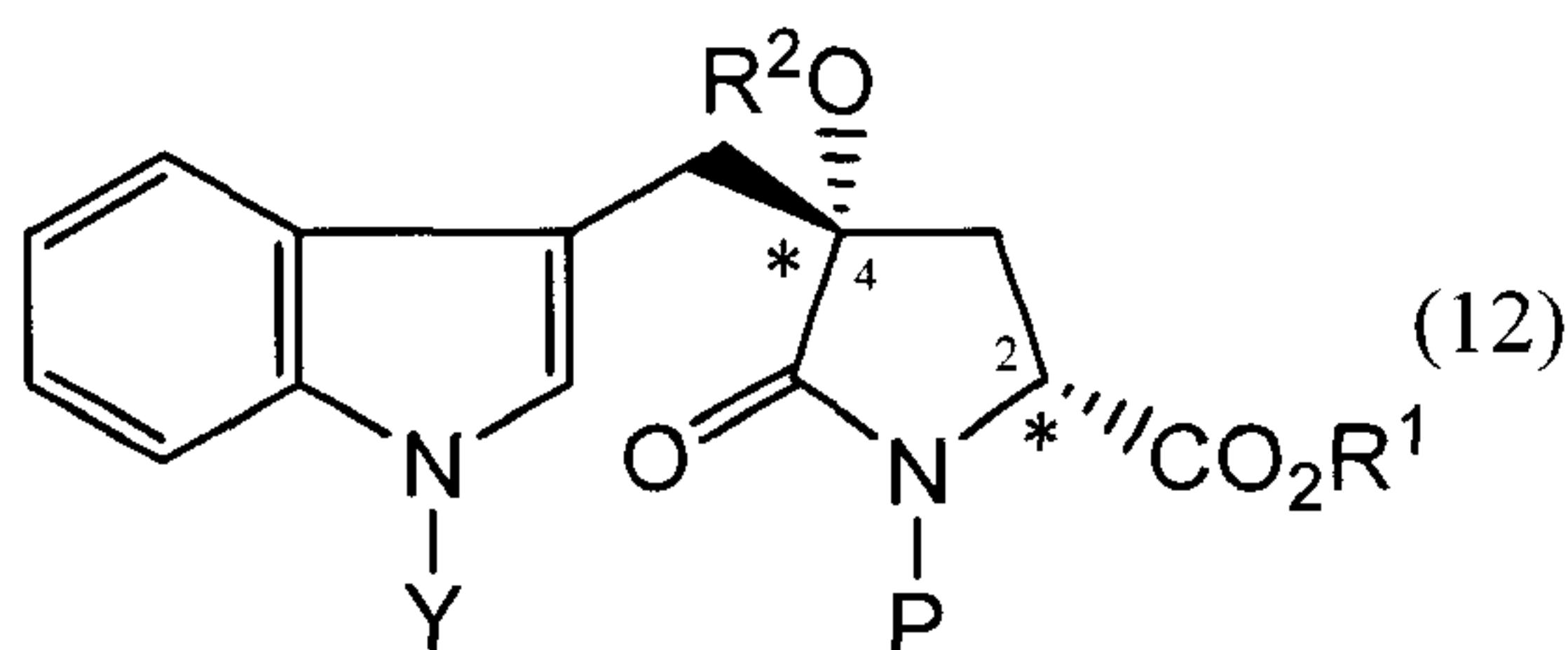
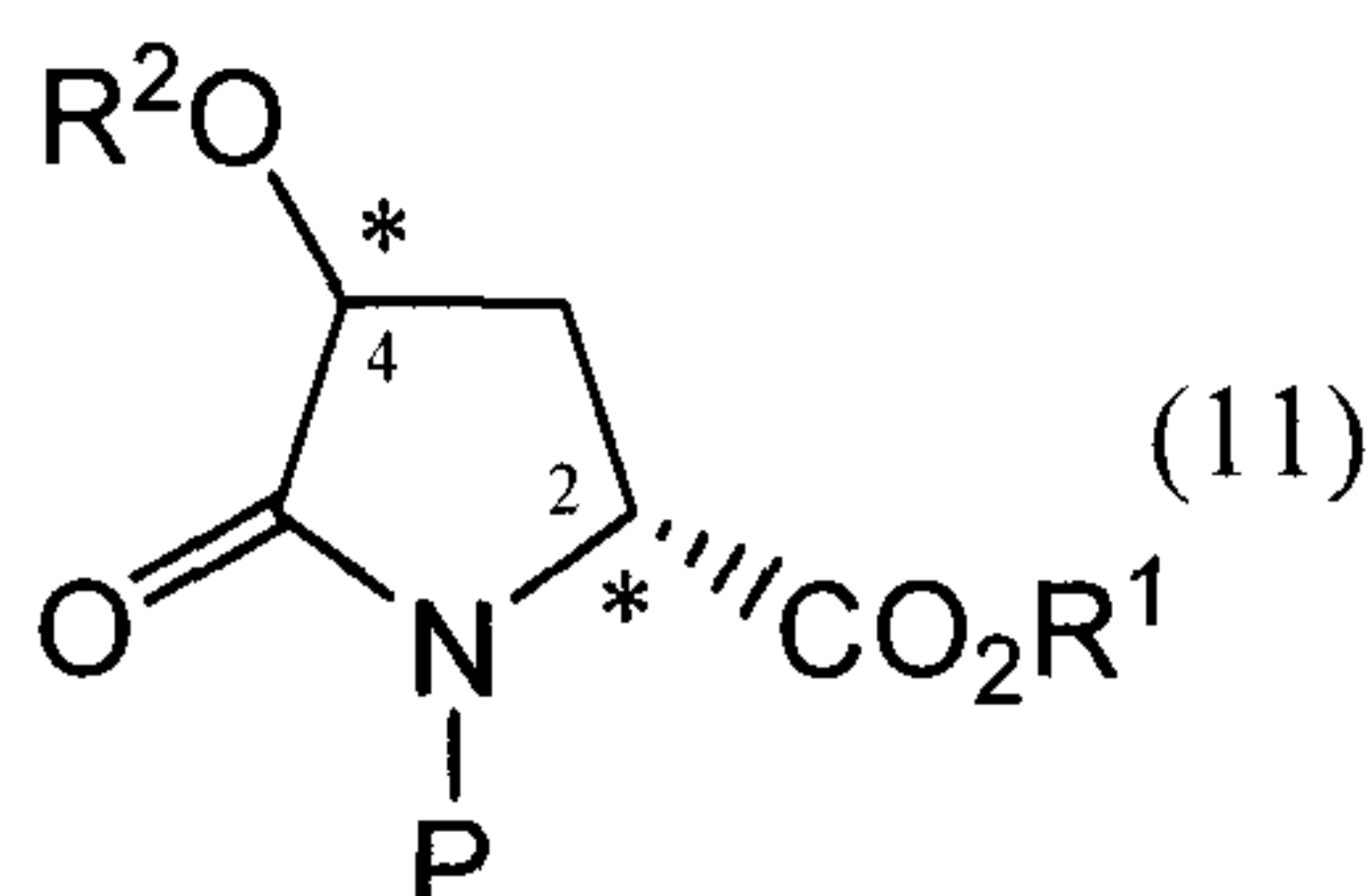
In accordance with yet still a further aspect of the present invention, there is provided a method described herein, wherein the 4-protected hydroxypyroglutamic acid derivative of formula (1) or salt thereof is an optically active 4-protected hydroxypyroglutamic acid derivative represented by formula (8) below or a salt thereof, and alkylation with the N-protected-3-halogenomethylindole represented by formula (5) results in production of an optically active 4-protected hydroxy-4-substituted pyroglutamic acid derivative of formula (9) below, or a salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group, * stands for an asymmetric carbon atom, the configuration at the 2-position in formula (8) is R or S,

the configuration at the 4-position is R, S or RS, so that when the configuration at the 2-position in formula (8) is R, the configurations in formula (9) are (2R, 4R), respectively, and when the configuration at the 2-position in formula (8) is S, the configurations in formula (9) are (2S, 4S), respectively.

In accordance with one embodiment of the present invention, there is provided a method described herein, wherein the 4-protected hydroxypyroglutamic acid derivative of formula (1) or salt thereof is a (2R)-4-protected hydroxypyroglutamic acid derivative represented by formula (11) below, or a salt thereof, and alkylation with N-protected-3-halogenomethylindole represented by formula (5) results in production of a (2R,4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative of formula (12) or a salt thereof:

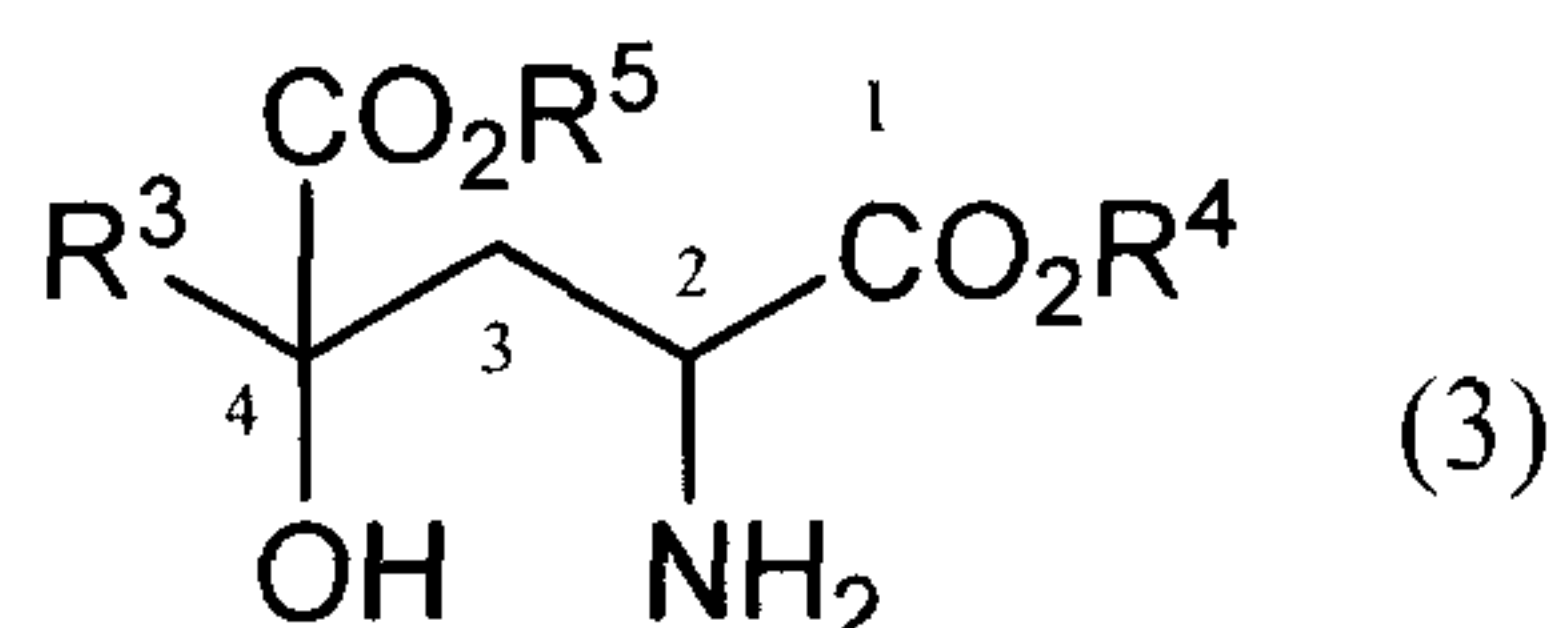


where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group and the configuration at the 4-position in formula (11) is R, S or RS.

In accordance with another embodiment of the present invention, there is provided a method described herein, wherein R^1 stands for a group selected from a hydrogen atom, an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

In accordance with yet another embodiment of the present invention, there is provided a method as described herein, wherein R^1 stands for a methyl group, R^2 stands for a t-butyldimethylsilyl group, X stands for a bromine atom and P and Y stand for a t-butoxycarbonyl group each.

In accordance with still another embodiment of the present invention, there is provided a method described herein, further comprising subjecting the derivative of formula (2) or a salt thereof to hydrolysis and deprotection steps thereby to produce a glutamic acid derivative represented by formula (3) below or a salt thereof:

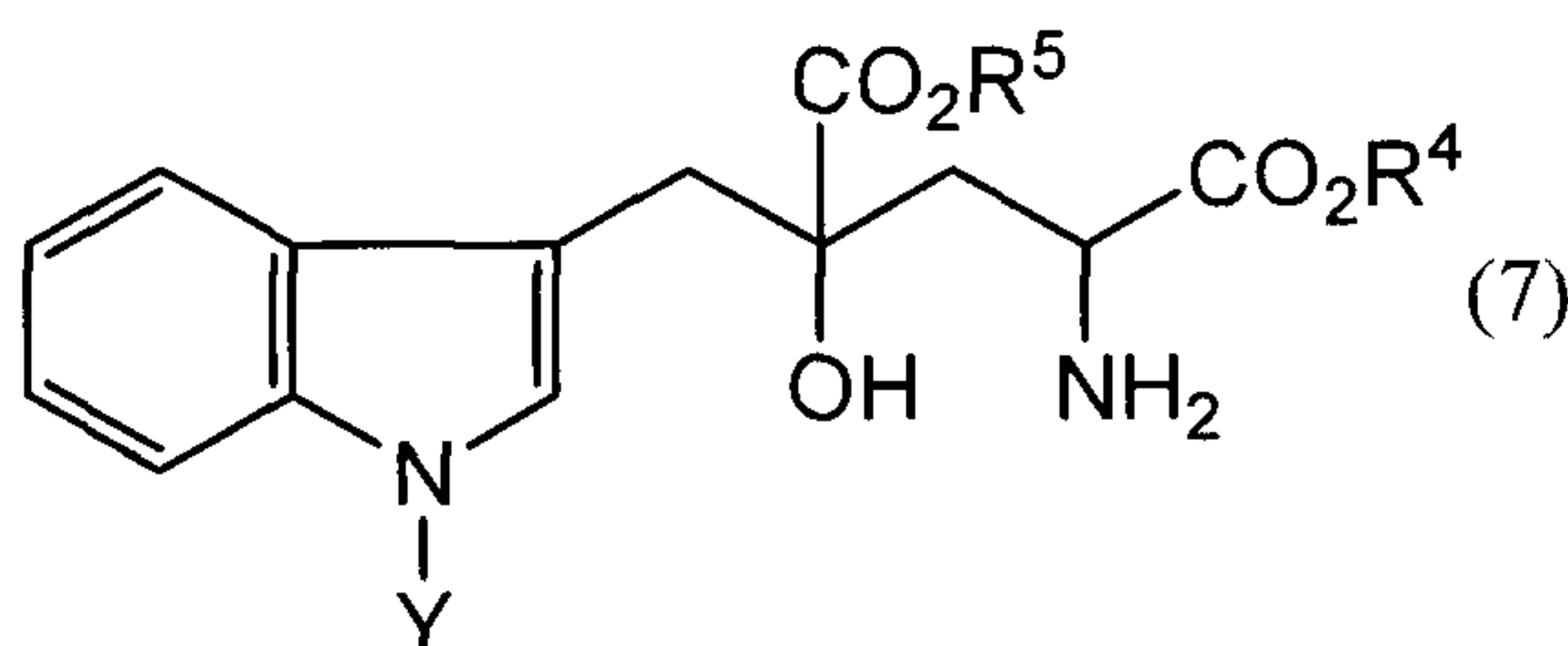


where R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, and R^3 stands for a group selected from a hydrocarbon

group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent.

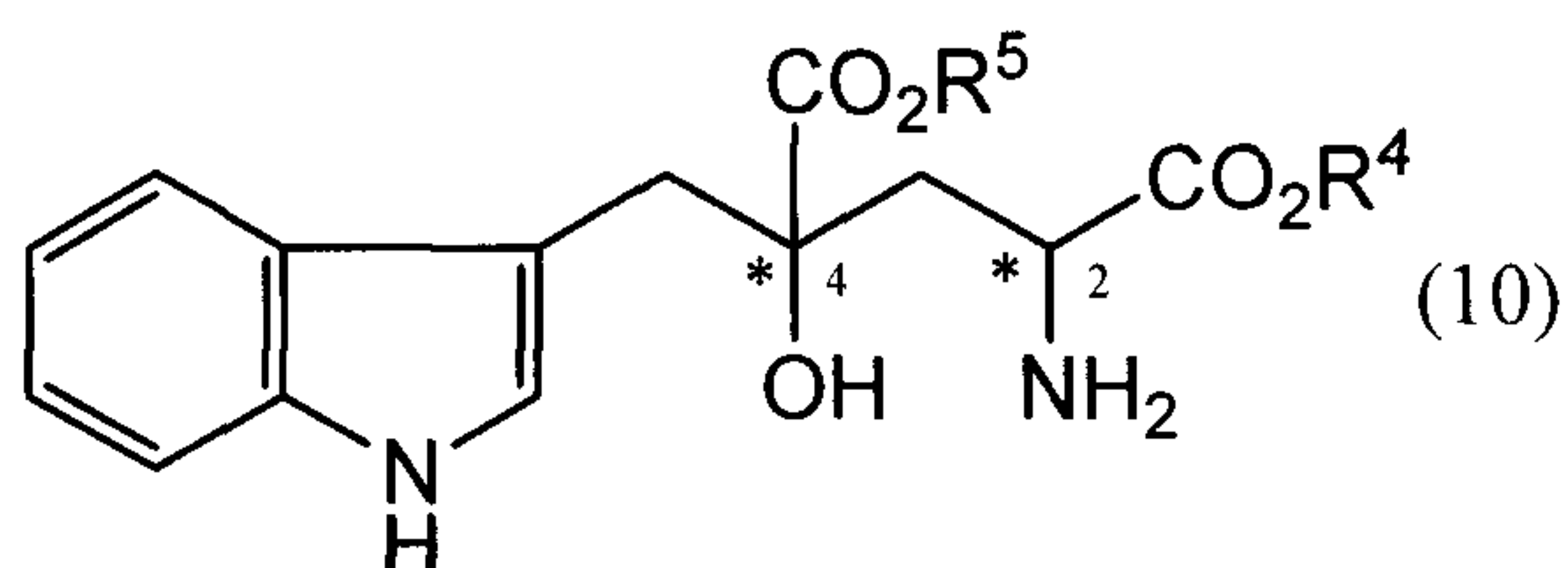
In accordance with yet still another embodiment of the present invention, there is provided a method as described herein, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, R^3 stands for a group selected from an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to 20 carbon atoms, an aralkyl group having 1 to 20 carbon atoms and a heterocyclic hydrocarbon group having 1 to 20 carbon atoms and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

In accordance with a further embodiment of the present invention, there is provided a method described herein, further comprising subjecting the derivative of formula (6), or a salt thereof to hydrolysis and deprotection steps thereby to produce a monatin acid derivative represented by formula (7) below, or a salt thereof:



where R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, and Y stands for a protecting group for an indolyl group.

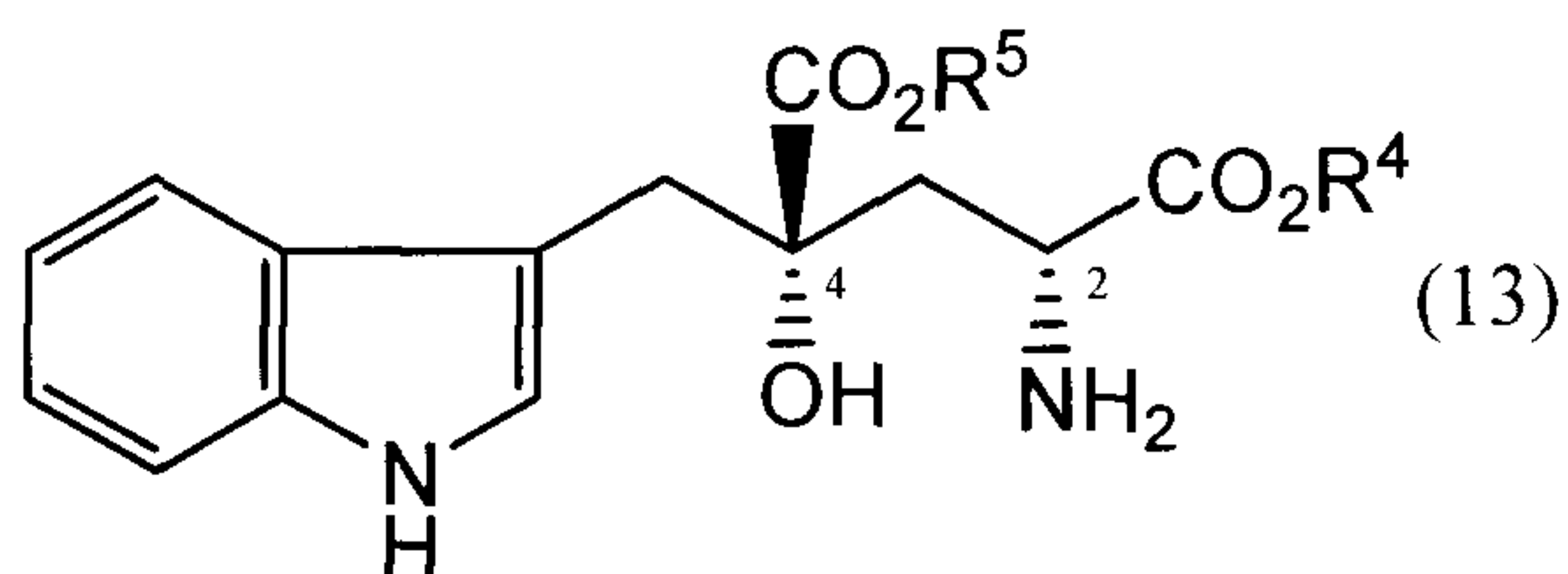
In accordance with yet a further embodiment of the present invention, there is provided a method described herein, further comprising subjecting the derivative of formula (9), or a salt thereof to hydrolysis and deprotection steps thereby to produce an optically active monatin derivative represented by formula (10) below, or a salt thereof:



where R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, * stands for an asymmetric carbon atom, the configuration at the 2-position in formula (8) as set out in claim 56 is R or S, the configuration at the 4-position is R, S or RS, so that when the configuration at the 2-position in formula (8) is R, the configurations in formulas (9) and (10) are (2R, 4R), respectively, and when the configuration at the 2-position in formula (8) is S, the configurations in formulas (9) as set out in claim 56 and (10) are (2S, 4S), respectively.

In accordance with still a further embodiment of the present invention, there is provided a method described herein, further comprising subjecting the derivative of formula (12), or a salt thereof to hydrolysis and deprotection steps thereby to produce a (2R,4R)-monatin

derivative represented by formula (13) below, or a salt thereof:

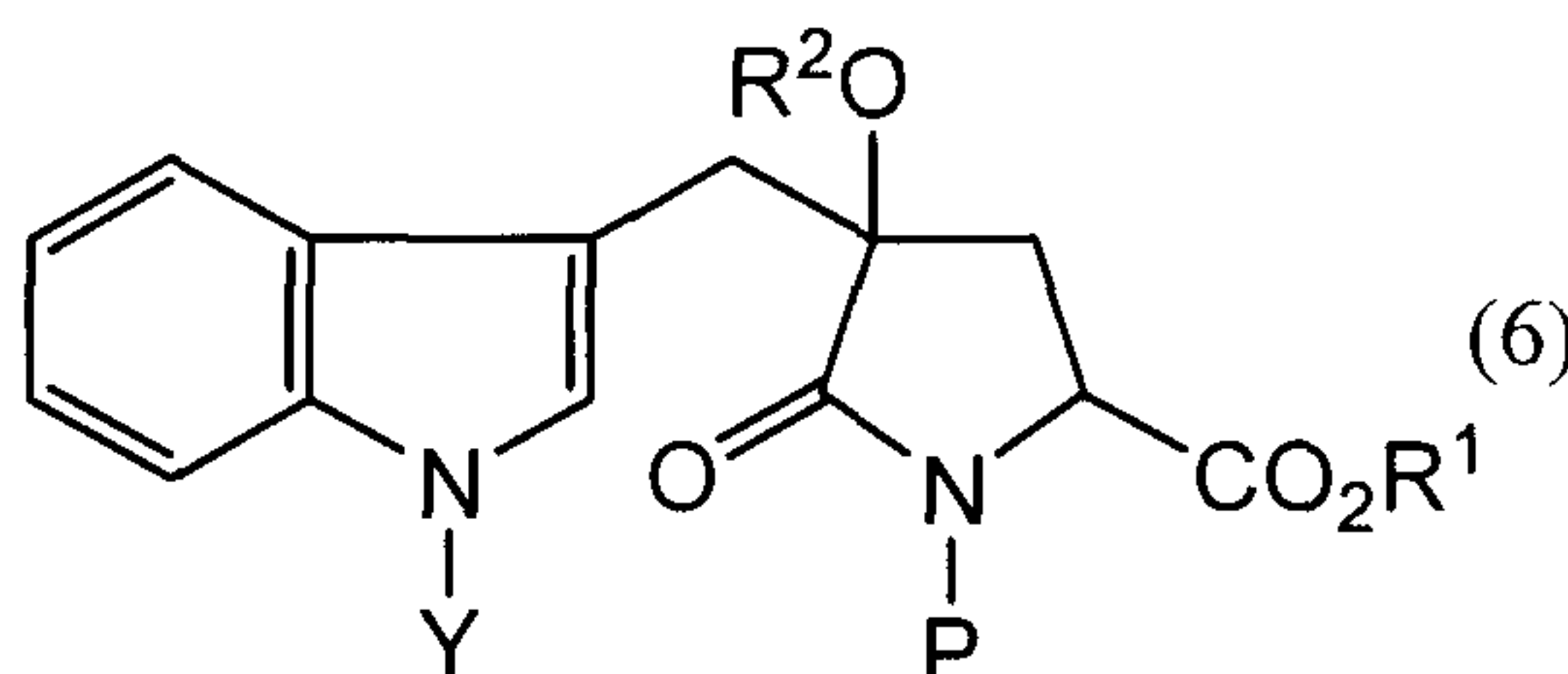


where R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group.

In accordance with yet still a further embodiment of the present invention, there is provided a method described herein, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

In another aspect of the present invention, there is provided a method as described herein, wherein R^1 stands for a methyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a t-butyldimethylsilyl group, X stands for a bromine atom and P and Y stand for a t-butoxycarbonyl group each.

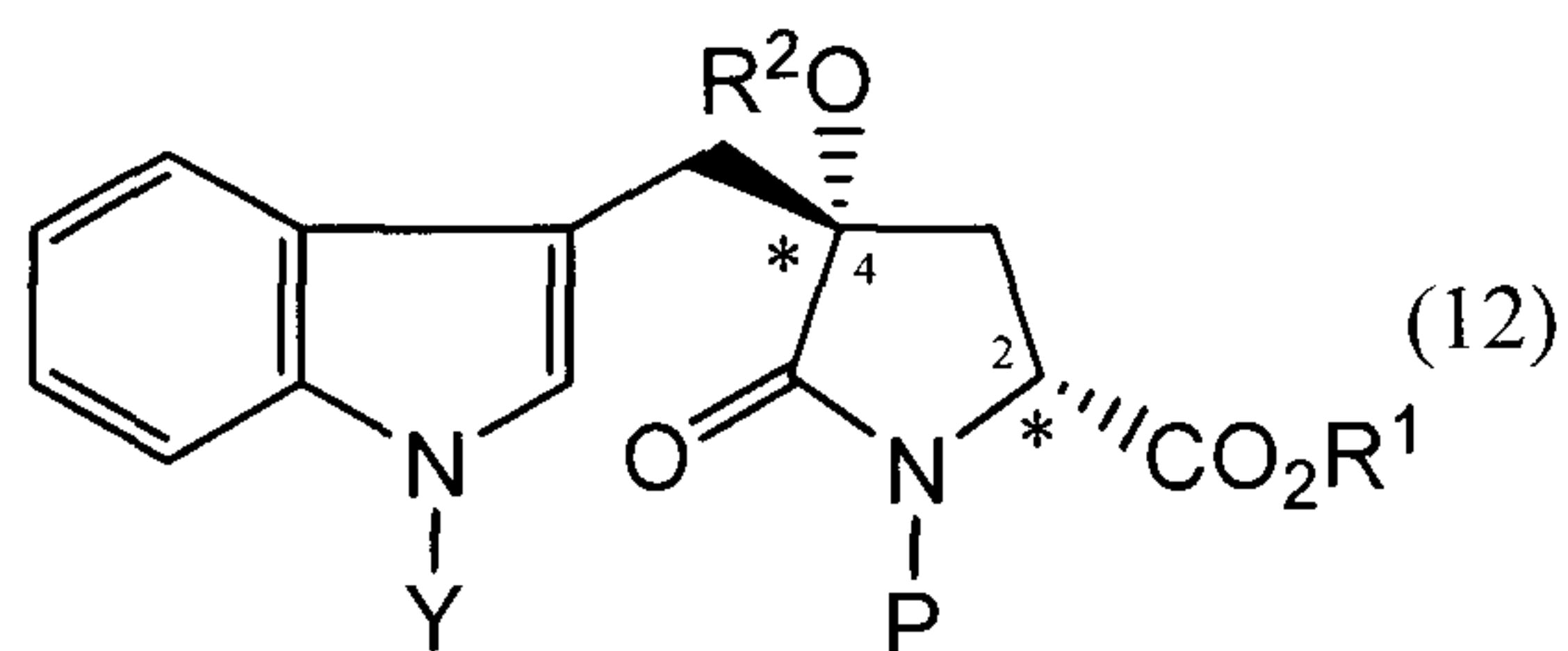
In yet another aspect of the present invention, there is provided a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) or a salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, P stands for a protecting group for an imino group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group and Y stands for a protecting group for an indolyl group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

In still another aspect of the present invention, there is provided a 4-protected hydroxy-4-substituted pyroglutamic acid derivative as described herein, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group.

In yet still another aspect of the present invention, there is provided a (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (12) or a salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, P stands for a protecting group for an imino group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group, and Y stands for a protecting group for an indolyl group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

In still a further aspect of the present invention, there is provided a (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative as described herein, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group.

According to this invention, a glutamic acid derivative represented by formula (3) is manufactured by subjecting a 4-protected hydroxy-pyroglutamic acid derivative represented by formula (1) to an alkylation reaction to prepare a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2) and subjecting the derivative to hydrolysis and deprotection steps.

The compounds represented by formulas (1), (2) and (3) may each be in the form of a salt. Any reference made herein to any of those compounds covers its salts unless otherwise noted. For example, in the event that at least one of R^1 , R^4 and R^5 is a hydrogen atom, i.e. in the event that the compound has a carboxyl group, the 4-protected hydroxypyroglutamic acid derivative as represented by formula (1), the 4-protected hydroxyl-4-substituted pyroglutamic acid derivative as represented by formula (2) and the 4-protected hydroxyl-4-substituted glutamic acid derivative (glutamic acid derivative) as represented by formula (3) may be in the form of their salts. The salt may, for example, be a salt formed by reacting any such compound with a base, such as sodium hydroxide, potassium hydroxide or ammonia, or a salt formed by adding thereto an inorganic acid, such as hydrochloric acid, or an organic acid, such as acetic acid.

In formulas (1) to (3), R^1 , R^4 and R^5 stand independently

of one another for a group selected from a hydrogen atom and a hydrocarbon group. A group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group is preferably selected as R^1 . A hydrogen atom is preferably selected as R^4 and R^5 .

In formulas (1) and (2), R^2 stands for a protecting group for a hydroxyl group. Groups which are usually employed in the art may be used as protecting groups for hydroxyl groups, and are, for example, a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group.

In formulas (1) and (2), P stands for a protecting group for an imino group. Groups which are usually employed in the art as protecting groups for amino and imino groups may be used as protecting groups for imino groups, and are, for example, a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

In formulas (2) and (3), R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent.

The hydrocarbon group may, for example, be a hydrocarbon group having 1 to 20 carbon atoms and is preferably an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to

20 carbon atoms, an aralkyl group having 1 to 20 carbon atoms or a heterocyclic hydrocarbon group having 1 to 20 carbon atoms. The heterocyclic hydrocarbon group may, for example, be a heterocyclic hydrocarbon group having 1 to 20 carbon atoms. The hydrocarbon group (or heterocyclic hydrocarbon group) may have any of a chain structure, a cyclic structure, or both. In the event that it has a chain structure, it may be a straight or branched chain.

The substituent which it may optionally have may, for example, be a halogen atom (an iodine, bromine, chlorine or fluorine atom, etc.), a hydroxyl group, an alkyl group having 1 to 3 carbon atoms, an alkoxy group having 1 to 3 carbon atoms or an amino group. In the event that the group represented by R^3 has a substituent, such as an amino, imino or hydroxyl group, the substituent may be protected by a protecting group for an amino, imino or hydroxyl group, etc. as mentioned above. In the event that the group represented by R^3 has an indolyl group in its skeleton as an indolylmethyl group does, the indolyl group may be protected by a protecting group for an imino group as mentioned above.

Preferred groups represented by R^3 are, for example, a benzyl group and an N-protected-3-indolylmethyl group.

In the event that an N-protected-3-indolylmethyl group is used as R^3 , this invention is suitable for use as a method of manufacturing monatin. The protecting group for an imino

group as mentioned above can be mentioned as a protecting group for the indolyl group in the N-protected-3-indolylmethyl group.

The 4-protected hydroxypyroglutamic acid derivative used according to this invention and represented by formula (1) can be prepared easily from 4-hydroxyproline by using the same method as described by X. Zhang et al (See Tetrahedron Letters 42, 5335-5338 (2001)), or a method similar thereto, or a method for synthesis used commonly in peptide chemistry if required. The intended 4-protected hydroxypyroglutamic acid derivative can be obtained, for example, by introducing a protecting group (for example, a t-butoxycarbonyl group) into the imino group in 4-hydroxyproline and a protecting group (for example, a t-butyldimethylsilyl group) into its hydroxyl group preferably after its esterification (for example, methyl esterification), and subjecting it to an oxidizing reaction with ruthenium oxide and sodium periodate.

As 4-hydroxyproline, it is possible to use each of its optical isomers, i.e. cis-4-hydroxy-L-proline, trans-4-hydroxy-L-proline, cis-4-hydroxy-D-proline and trans-4-hydroxy-D-proline, depending on the intended compound. For the manufacture of (2S, 4S)-monatin, for example, cis- or trans-4-hydroxy-L-proline is used to prepare a (2S)-4-hydroxypyroglutamic acid derivative as the starting material for the manufacturing method of this invention, and

for the manufacture of (2R, 4R)-monatin, cis- or trans-4-hydroxy-D-proline is used to prepare a (2R)-4-hydroxypyroglutamic acid derivative as the starting material for the manufacturing method of this invention.

As the 4-protected hydroxypyroglutamic acid derivative represented by formula (1), it is possible to mention as a preferred example a compound having a methyl group as R^1 , a t-butyldimethylsilyl group as R^2 and a t-butoxycarbonyl group as P. As the 4-protected hydroxyl-4-substituted pyroglutamic acid derivative represented by formula (2), it is possible to mention as a preferred example a compound having a methyl group as R^1 , a t-butyldimethylsilyl group as R^2 , an N-t-butoxycarbonyl-3-indolylmethyl group as R^3 and a t-butoxycarbonyl group as P.

The (2R)-4-protected hydroxypyroglutamic acid derivative represented by formula (11) in which the stereochemistry at the 2-position is (R) (including one in the form of a salt) is a novel substance.

The alkylation reaction of the 4-protected hydroxypyroglutamic acid derivative represented by formula (1) can be performed in the presence of an alkylating agent. In the context of this invention, "alkylation" does not mean the introduction of an alkyl group alone in the narrow sense of the word, such as a methyl, ethyl or butyl group, but includes, for example, the introduction of a residual hydrocarbon group

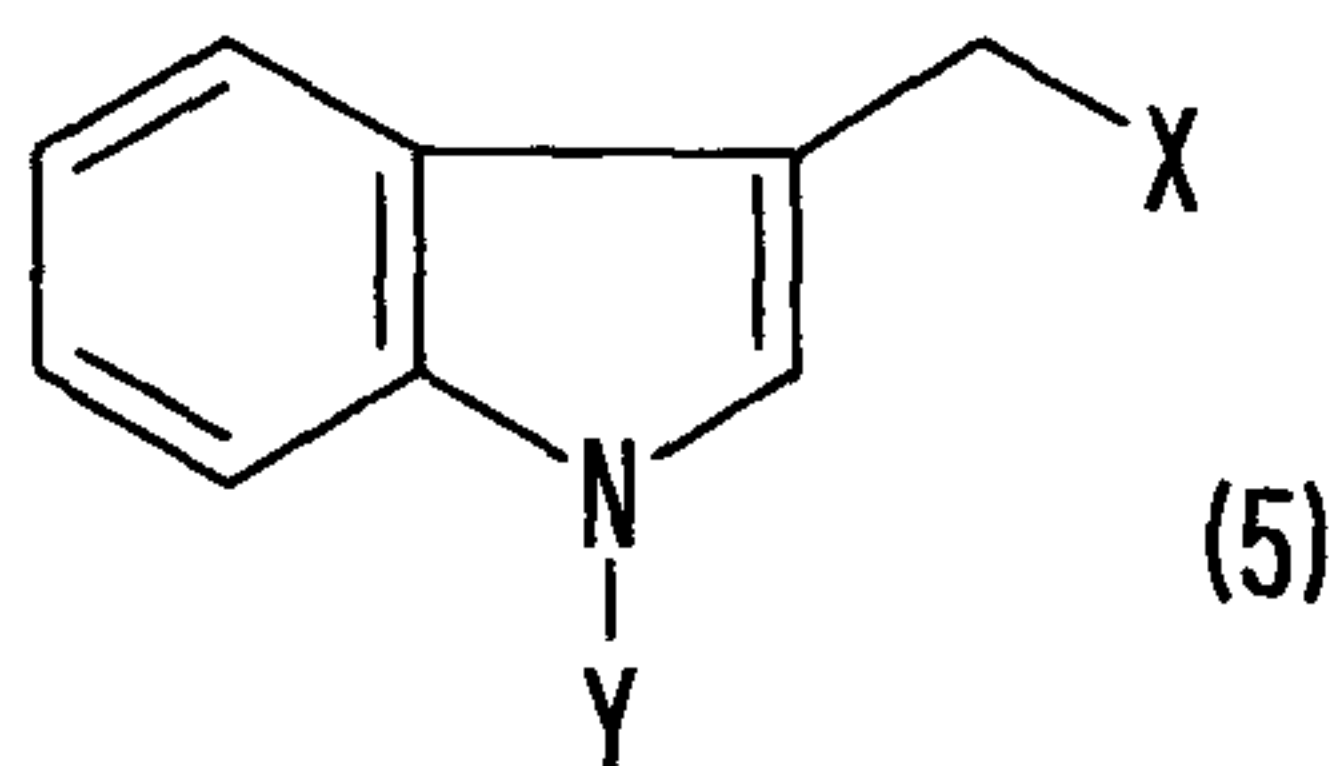
optionally having a substituent, and more specifically, means the introduction of a group represented by R^3 into the 4-protected hydroxypyroglutamic acid derivative represented by formula (1). The "alkylating agent" means a reagent used in the alkylation. As the alkylating agent, it is possible to mention an alkyl halide (alkyl chloride, alkyl bromide, alkyl iodide, etc.), and more specifically, a compound represented by formula (4) below:



[where R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent and X stands for a halogen atom.]

A more detailed description has been made of R^3 before. As a preferred halogen atom represented by X, it is possible to mention a chlorine, bromine or iodine atom.

For the manufacture of monatin according to this invention, it is possible to use an N-protected-3-halogeno-methylindole represented by formula (5) below as the alkylating agent:



[where Y stands for a protecting group for an indolyl group and X stands for a halogen atom.]

Groups which are usually employed in the art as protecting groups for amino and imino groups may be used as protecting groups for indolyl groups represented by Y, and are, for example, a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group. The halogen atom represented by X is as mentioned above. N-t-butoxycarbonyl-3-bromomethylindole having a t-butoxycarbonyl group as Y and a bromine atom as X is preferred as the N-protected-3-halogenomethylindole represented by formula (5).

It is preferable to use a base in the alkylation reaction according to this invention. In the event that any base is used, it is possible to mention as examples a lithium salt of hexamethyldisilazane [lithium hexamethyldisilazanide], a potassium salt of hexamethyldisilazane [potassium hexamethyl-disilazanide], a sodium salt of hexamethyldisilazane [sodium hexamethyldisilazanide], lithium diisopropylamide and n-butyl lithium.

The amount of the base to be used can be selected in a molar ratio of preferably, say, between 1.0 and 2.0 and more preferably, say, between 1.0 and 1.3 to 1 of the 4-protected hydroxypyroglutamic acid derivative as the starting substance. In the event that the starting substance is in the form of its salt or contains its salt, the molar ratio can be appropriately selected from the range stated above by considering the molar

amount of the 4-protected hydroxypyroglutamic acid derivative in its free form.

The alkylation reaction according to this invention is preferably performed in the presence of a solvent. Any solvent can be used without any particular limitation if it is inert in the reaction. It is possible to mention tetrahydrofuran, ether, dimethoxyethane, toluene and any mixture thereof as preferred solvents.

In the alkylation reaction according to this invention, it is possible to add HMPA (hexamethylphosphoramide) or DMPU (1,3-dimethyl-3,4,5,6-tetrahydro-2(1H)-pyrimidinone).

In the alkylation reaction according to this invention, it is desirable to use any solvent or additive after removing water therefrom as much as possible in order to have the reaction promoted. It is also desirable to have it performed in the atmosphere of an inert gas, such as nitrogen or argon.

While the reaction time for the alkylation reaction according to this invention is not specifically limited, it is possible to select preferably, say, about 0.5 to 24 hours and more preferably, say, about 1 to 5 hours. While the reaction temperature is not specifically limited, either, it is possible to select preferably, say, about -80°C to 50°C and more preferably about -78°C to 30°C.

After the reaction is over, it is possible to apply appropriate methods known in the art, such as extraction,

chromatography and crystallization, to isolate and refine the intended object. The 4-protected hydroxyl-4-substituted pyroglutamic acid derivative represented by formula (2) is a novel substance.

The 4-protected hydroxyl-4-substituted pyroglutamic acid derivative represented by formula (2) and obtained as described can be led through hydrolysis and deprotection steps to form the glutamic acid derivative represented by formula (3).

The "hydrolysis and deprotection steps" according to this invention means more specifically the steps of performing a hydrolysis reaction and a deprotection reaction for the protecting groups to thereby lead the 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2) to the glutamic acid derivative represented by formula (3).

The hydrolysis in the hydrolysis and deprotection steps is defined principally as a reaction for decomposing the bond forming a lactum ring. The deprotection in the hydrolysis and deprotection steps is defined principally as a reaction for deprotecting the protecting group for the hydroxyl group as represented by R^2 and the protecting group for the imino group as represented by P.

There is no particular limitation in the order of the hydrolysis and deprotection reactions. It is likely that

hydrolysis serves as a deprotection reaction, too (or that the deprotection reaction serves as a hydrolysis reaction, too), and the "hydrolysis and deprotection steps" according to this invention includes such cases where the hydrolysis and deprotection reactions cannot be distinguished clearly from each other.

The ring-opening reaction of the lactum ring by hydrolysis usually produces a carboxyl group at the 4-position having a hydrogen atom as R^5 in formula (3), but the carboxyl group at the 4-position may form an ester with alcohol in the event, for example, that hydrolysis is performed in the presence of an alcoholic solvent. In the event that such an ester is not converted to a carboxyl group by hydrolysis and deprotection steps, R^5 in formula (3) will be an alcohol-derived hydrocarbon group.

When R^1 in formula (2) stands for a hydrocarbon group, i.e. when $-COOR^1$ is an alkoxycarbonyl group, the alkoxycarbonyl group may be converted to a carboxyl group after hydrolysis and deprotection steps. In such a case, R^4 in formula (3) will be a hydrogen atom even when R^1 in formula (2) is a hydrocarbon group. It is possible to include the step of converting the alkoxycarbonyl group to a carboxyl group before the hydrolysis and deprotection steps. When $-COOR^1$ is a benzyloxycarbonyl group (R^1 is a benzyl group), for example, it can be led to a carboxyl group (R^1 is a hydrogen atom) by a catalytic

hydrogenation reaction prior to the hydrolysis and deprotection steps.

A compound having a hydrocarbon group as R^2 and/or R^3 in formula (3), i.e. a compound having an alkoxycarbonyl group in formula (3) can be led to a compound having a hydrogen atom as R^2 and/or R^3 by having its alkoxycarbonyl group converted to a carboxyl group by a method known in the art, such as hydrolysis with an acid or base.

When the group represented by R^3 in formula (2) has a protected imino group, a protected amino group, a protected indolyl group, a protected hydroxyl group, etc. in its structure, it is likely that the protecting group for any such imino, amino, indolyl or hydroxyl group, etc. may undergo deprotection through the hydrolysis and deprotection steps. It is, therefore, likely that R^3 in formula (3) and R^2 in formula (2) may not stand for the same group.

The hydrolysis reaction can be performed by a reaction with a base, a reaction with an acid, a catalytic hydrogenation reaction, a reaction with a fluoride, etc. The deprotection reaction can also be performed by any such reaction.

A hydrolysis reaction with a base is preferably employed for the hydrolysis reaction of the lactum ring. It is preferable to use lithium hydroxide, sodium hydroxide, potassium hydroxide, etc. as the base.

When a base is used, its amount can be selected in a molar

ratio of preferably, say, about 1 to 50 and more preferably, say, about 5 to 20 of base to 1 of the compound (in its free form). In the event that the 4-protected hydroxy-4-substituted pyro-glutamic acid derivative is in the form of its salt or contains its salt, the molar ratio can be appropriately selected from the range stated above by considering the molar amount of the 4-protected hydroxy-4-substituted pyroglutamic acid derivative in its free form.

As the solvent to be used in the hydrolysis reaction, it is possible to use a mixed solvent of water and an organic solvent miscible with water, as a reaction solvent, such as methanol, ethanol, isopropanol or other alcohol, tetrahydrofuran or acetonitrile.

The hydrolysis reaction usually causes the hydrolysis of the ester bond, as well as the lactum ring, and converts the alkoxycarbonyl group existing in the compound to a carboxyl group.

The reaction time for hydrolysis may be selected from preferably, say, about 1 to 48 hours and more preferably, say, about 3 to 15 hours. The reaction temperature for hydrolysis may be selected from preferably, say, about 0°C to 100°C and more preferably, say, about 20°C to 50°C.

Any method of deprotection that is usually employed in peptide chemistry, etc. may be followed for the deprotection

of the protecting groups in the 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2), for example, for the removal of the protecting groups for the imino group, amino group, indolyl group, hydroxyl group, etc. For example, it can be performed in the same way with the hydrolysis reaction as described above. For example, the t-butoxycarbonyl and t-butyldimethylsilyl groups can be removed with an acid, and the benzyloxycarbonyl group by a catalytic hydrogenation reaction. A fluoride can be used for the deprotection of only the t-butyldimethylsilyl group, for example.

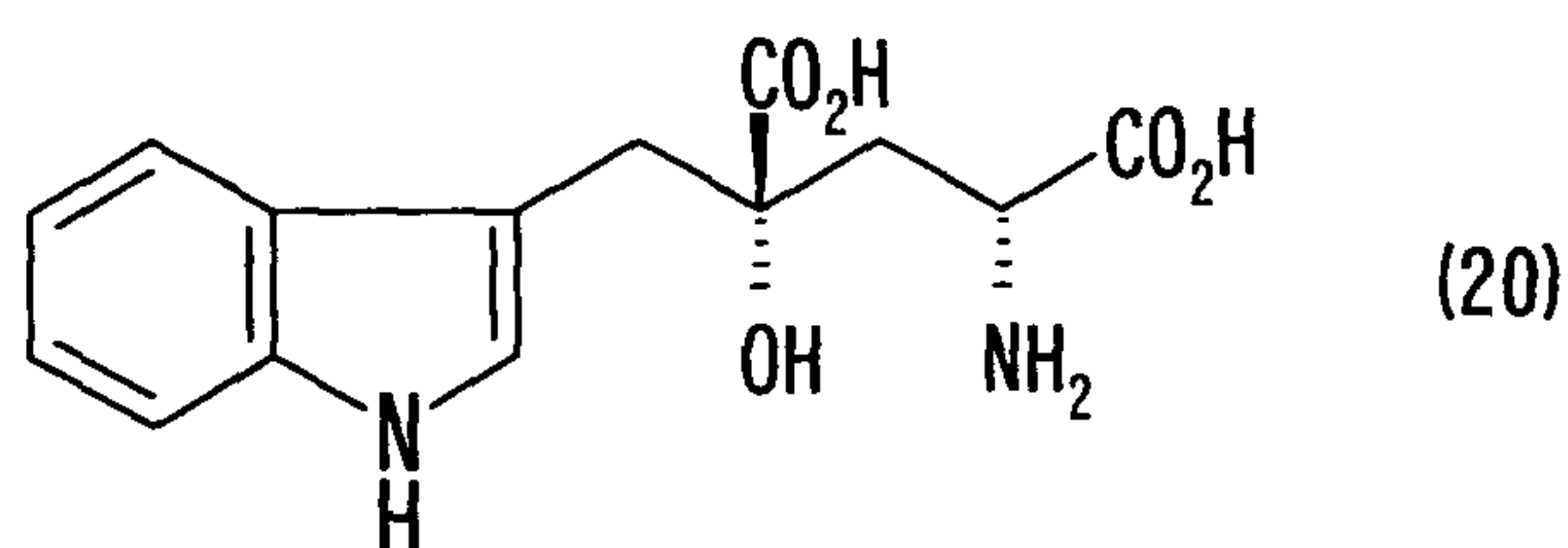
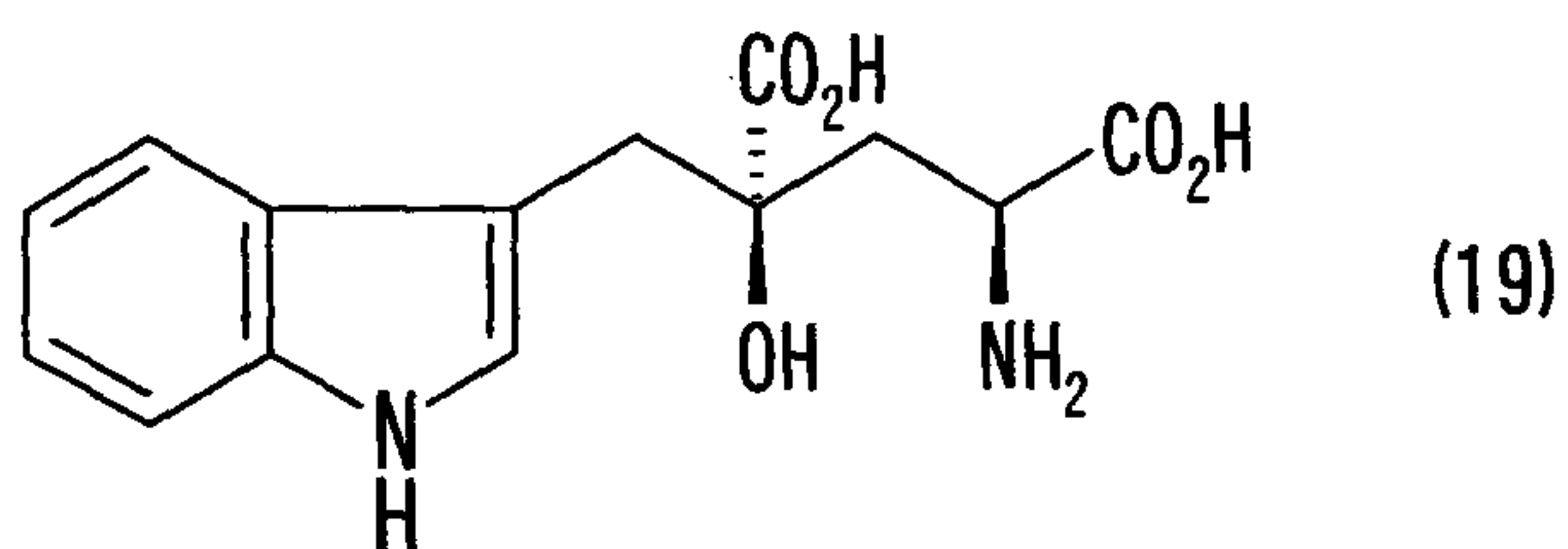
After the reaction is over, it is possible to apply appropriate methods known in the art, such as extraction, chromatography and crystallization, to isolate and refine the glutamic acid derivative manufactured by the method of this invention and represented by formula (3). It is preferably obtained as a crystal by crystallizing the product from water, alcohol or a mixed solvent thereof in the form of its salt with an acid, such as hydrochloric acid, its salt with a base, such as ammonia, or its salt with a metal, such as sodium, or in its free form.

When the glutamic acid derivative has been obtained in the form of a salt, it is possible to convert its salt to its free form or change it to another salt, or when it has been obtained in its free form, it is possible to convert it to a

salt, by employing any appropriate reaction known in the art, such as a free body forming reaction, a reaction for forming another salt or a salt changing reaction.

The alkylation reaction in the method of this invention makes it possible to have an intended group react selectively with the 4-position of the 4-protected hydroxypyroglutamic acid derivative represented by formula (1) and this reaction proceeds stereoselectively. Its configuration is retained until after the hydrolysis and deprotection steps. Accordingly, the method of this invention is very useful as a method of manufacturing a 4-protected hydroxyl-4-substituted pyroglutamic acid derivative having optical activity, a glutamic acid derivative having optical activity and particularly optically active monatin.

For example, the use of a (2S)-4-protected hydroxy pyroglutamic acid derivative as a 4-protected hydroxyl pyroglutamic acid derivative represented by formula (1) permits the selective manufacture of (2S, 4S)-monatin represented by formula (19) below and the use of a (2R)-4-protected hydroxyl pyroglutamic acid derivative permits the selective manufacture of (2R, 4R)-monatin represented by formula (20) below:



BEST MODE OF CARRYING OUT THE INVENTION

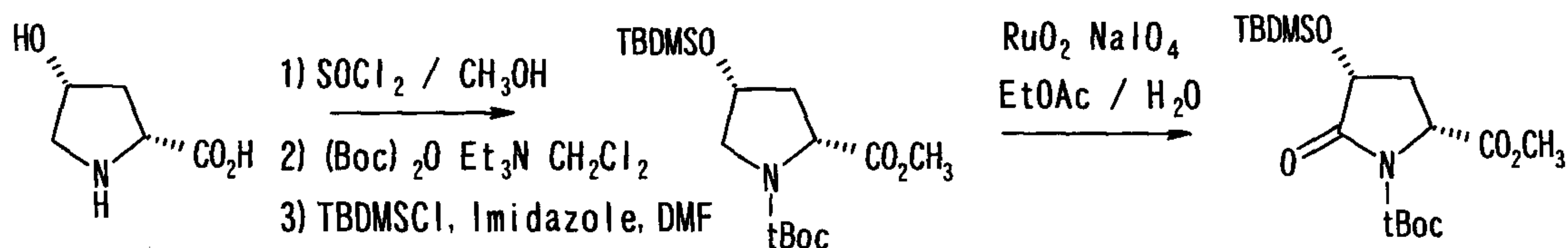
The invention will now be described in detail by examples of carrying it out, though these examples are not intended to limit this invention in any way.

¹H-NMR spectra were determined by Bruker AVANCE400 (400 MHz) and MS spectra by Thermo Quest TSQ700.

(Example 1)

Synthesis of

N-t-butoxycarbonyl-4-t-butyldimethylsilyloxy-D-pyroglutamic acid methyl ester



N-t-butoxycarbonyl-4-t-butyldimethylsilyloxy-D-pyroglutamic acid methyl ester was obtained as a colorless oily substance at a total yield of 66% from cis-4-hydroxy-D-proline

as a starting material in accordance with the method of X. Zhang et al (See Tetrahedron Letters, 42, 5335-5338 (2001)).

(MS spectrum)

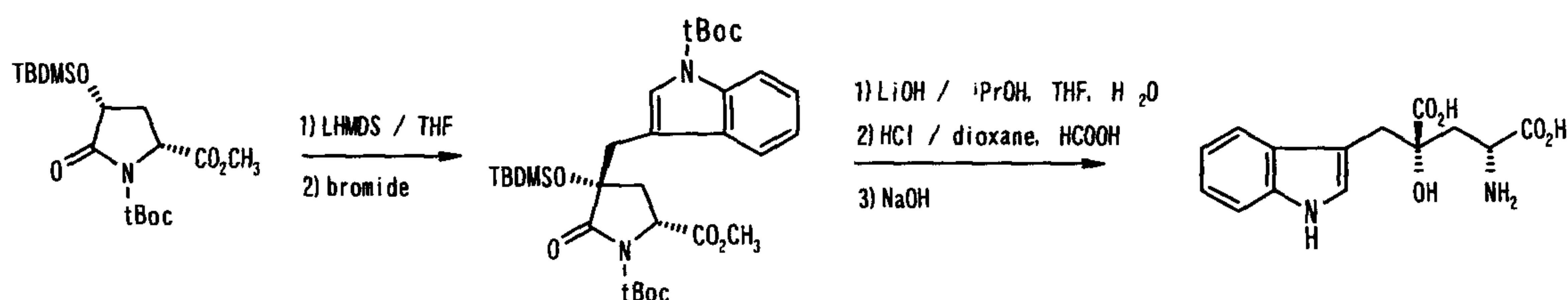
ESI-MS: 374.6 (M+H)⁺, 396.59 (M+Na)⁺.

(NMR spectrum)

¹H-NMR (CDCl₃, 400 MHz) δ ppm: 0.11 (s, 3H), 0.16 (s, 3H), 0.89 (s, 9H), 1.50 (s, 9H), 1.99 (m, 1H), 2.57 (m, 1H), 3.76 (s, 3H), 4.28 (t, 1H), 4.46 (t, 1H).

(Example 2)

Synthesis of (2R, 4R)-monatin



1.45 g (3.9 mmol) of the above N-t-butoxycarbonyl-4-t-butyltrimethylsilyloxy-D-pyrroline-2-carboxylic acid methyl ester was dissolved in 15 ml of anhydrous THF (tetrahydrofuran) in an atmosphere of argon gas. The resulting solution was cooled to -78°C, 2.8 ml (4.8 mmol; 1.7 mM/ml) of LHMDS (lithium hexamethyldisilazane) were added to it and it was stirred for an hour. A solution obtained by dissolving 1.30 g (4.2 mmol) of N-t-butoxycarbonyl-3-bromomethylindole in 4 ml of THF was dropped into the reacted solution and it was stirred at -78°C for 25 minutes and at room temperature for two hours. An aqueous solution of ammonium chloride was added to the reacted

solution and two times of extraction were performed with 50 ml of ethyl acetate. An organic layer was washed with 50 ml of water and 50 ml of a saturated saline solution and was dried with anhydrous magnesium sulfate. Magnesium sulfate was removed by filtration and the filtrate was concentrated under reduced pressure. The residue was refined by PTLC (preparative thin-layer chromatography) to yield 1.21 g (2.01 mmol) of N-t-butoxycarbonyl-(4R)-4-t-butyldimethylsilyloxy-4-(N-t-butoxycarbonyl-3-indolylmethyl)-D-pyroglutamic acid methyl ester. Its ^1H -NMR spectrum showed a peak marked by a very small amount (several percent) of impurity beside the isomers of the compound.

(MS spectrum)

ESI-MS: 626.0 ($\text{M}+\text{Na}$) $^+$.

(NMR spectrum)

^1H -NMR (CDCl_3 , 400 MHz) δ ppm: 0.14 (s, 3H), 0.30 (s, 3H), 0.87 (s, 9H), 1.45 (s, 9H), 1.66 (s, 9H), 2.09 (dd, 1H), 2.42 (dd, 1H), 3.02 (d, 1H), 3.19 (d, 1H), 3.71 (s, 3H), 4.16 (m, 1H), 7.22-7.32 (m, 2H), 7.49 (m, 2H), 8.17 (brd, 1H).

544 mg (0.90 mmol) of the above compound were dissolved in a mixed solvent prepared from 6 ml of isopropanol, 3 ml of THF and 8 ml of water and the solution was kept at 0°C. 605 mg (14.43 mmol) of lithium hydroxide monohydrate were added to the reacted solution and it was stirred at room temperature for five hours. The reacted solution was concentrated under

reduced pressure, 15 ml of water were added to the residue and the solution had its pH adjusted to 3 with a 2N solution of hydrochloric acid. Two times of extraction were performed with 50 ml of ethyl acetate and an organic layer was washed with a saturated saline solution and was dried with anhydrous magnesium sulfate. Magnesium sulfate was removed by filtration and the filtrate was concentrated under reduced pressure.

The residue was dissolved in 4 ml of formic acid and the reacted solution was kept at 0°C. 4 ml of a 4N HCl/dioxane solution were added to it and it was stirred at room temperature for 30 minutes. The reacted solution was concentrated under reduced pressure and the residue was dissolved in 10 ml of water and washed with 20 ml of ether and 20 ml of ethyl acetate. The aqueous solution was neutralized with a 2N solution of NaOH and after it was concentrated to about one-fifth, 20 ml of ethanol were added to it. The resulting crystal was collected by filtration and dried under reduced pressure to yield 155 mg (0.49 mmol) of (2R, 4R)-monatin as a sodium salt. Its analysis for optical isomers was conducted by HPLC (high performance liquid chromatography) using a chiral column and revealed only (2R, 4R) and (2R, 4S) forms of isomers having an integrated peak ratio of 98:2.

(MS spectrum)

ESI-MS: 291 (M-H)⁻.

(NMR spectrum)

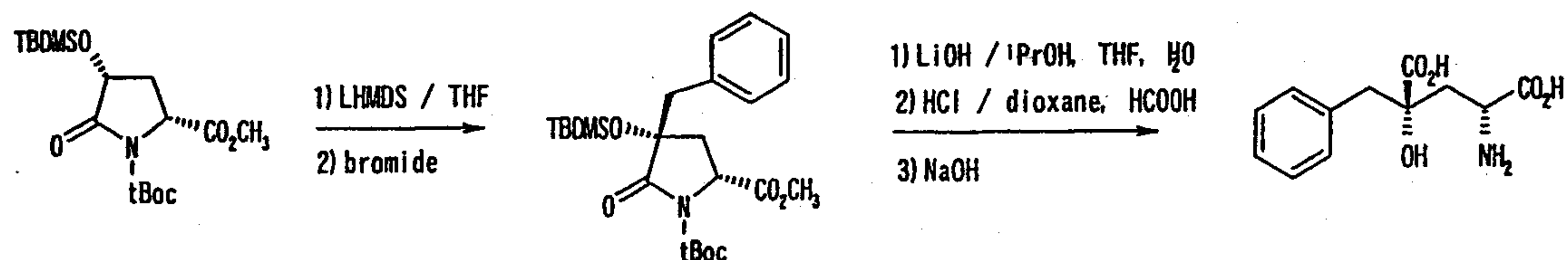
^1H -NMR (D_2O , 400 MHz) δ ppm:

<Sodium salt of (2R, 4R)-monatin>

1.99 (dd, 1H, $J=11.8$ Hz, $J=15.2$ Hz), 2.60 (dd, 1H, $J=1.9$ Hz, $J=15.2$ Hz), 3.02 (d, 1H, $J=14.6$ Hz), 3.22 (d, 1H, $J=14.6$ Hz), 3.57 (d, 1H, $J=10.2$ Hz), 7.08 (t, 1H, $J=7.2$ Hz), 7.15 (t, 1H, $J=7.2$ Hz), 7.16 (s, 1H), 7.42 (d, 1H, $J=8.0$ Hz), 7.66 (d, 1H, $J=8.0$ Hz).

(Example 3)

Synthesis of (2R, 4R)-4-hydroxy-4-benzylglutamic acid



N-t-butoxycarbonyl-(4R)-4-t-butyldimethylsilyloxy-4-benzyl-D-pyrroglutamic acid methyl ester was obtained as a solid at a yield of 46.0% by using benzyl bromide instead of N-t-butoxycarbonyl-3-bromomethylindole and otherwise repeating Example 2. Its ^1H -NMR spectrum showed a single stereoisomer.

(MS spectrum)

ESI-MS: 464.8 ($\text{M}+\text{H}$) $^+$, 486.8 ($\text{M}+\text{Na}$) $^+$.

(NMR spectrum)

^1H -NMR (CDCl_3 , 400 MHz) δ ppm: 0.13 (s, 3H), 0.29 (s, 3H), 0.86 (s, 9H), 1.46 (s, 9H), 1.96 (dd, 1H), 2.45 (dd, 1H), 2.88 (d, 1H), 3.16 (d, 1H), 3.71 (s, 3H), 3.80 (m, 1H), 7.20-7.31 (m,

5H).

A sodium salt of (2R, 4R)-4-hydroxy-4-benzylglutamic acid was obtained at a yield of 57.4% by using the above compound and otherwise repeating Example 2. Its analysis for optical isomers was conducted by HPLC using a chiral column and revealed only (2R, 4R) and (2R, 4S) forms of isomers having an integrated peak ratio of 99:1 or higher.

(MS spectrum)

ESI-MS: 252 (M-H)⁻.

(NMR spectrum)

¹H-NMR (400 MHz, D₂O) δ ppm:

<Sodium salt of (2R, 4R)-4-hydroxy-4-benzylglutamic acid>

1.95 (dd, 1H, J=11.8 Hz, J=15.3 Hz), 2.56 (d, 1H, J=15.2 Hz), 2.81 (d, 1H, J=13.6 Hz), 3.07 (d, 1H, J=13.6 Hz), 3.55 (d, 1H, J=11.8 Hz), 7.19-7.31 (m, 5H).

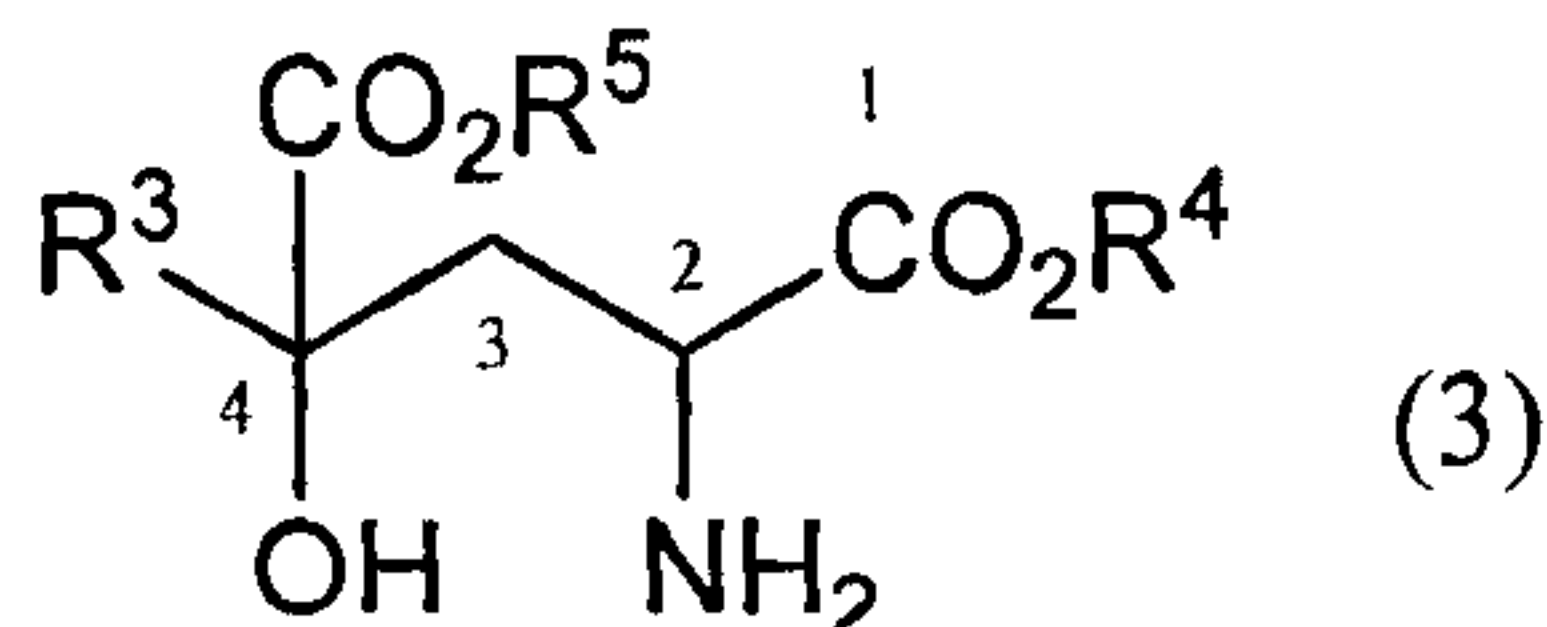
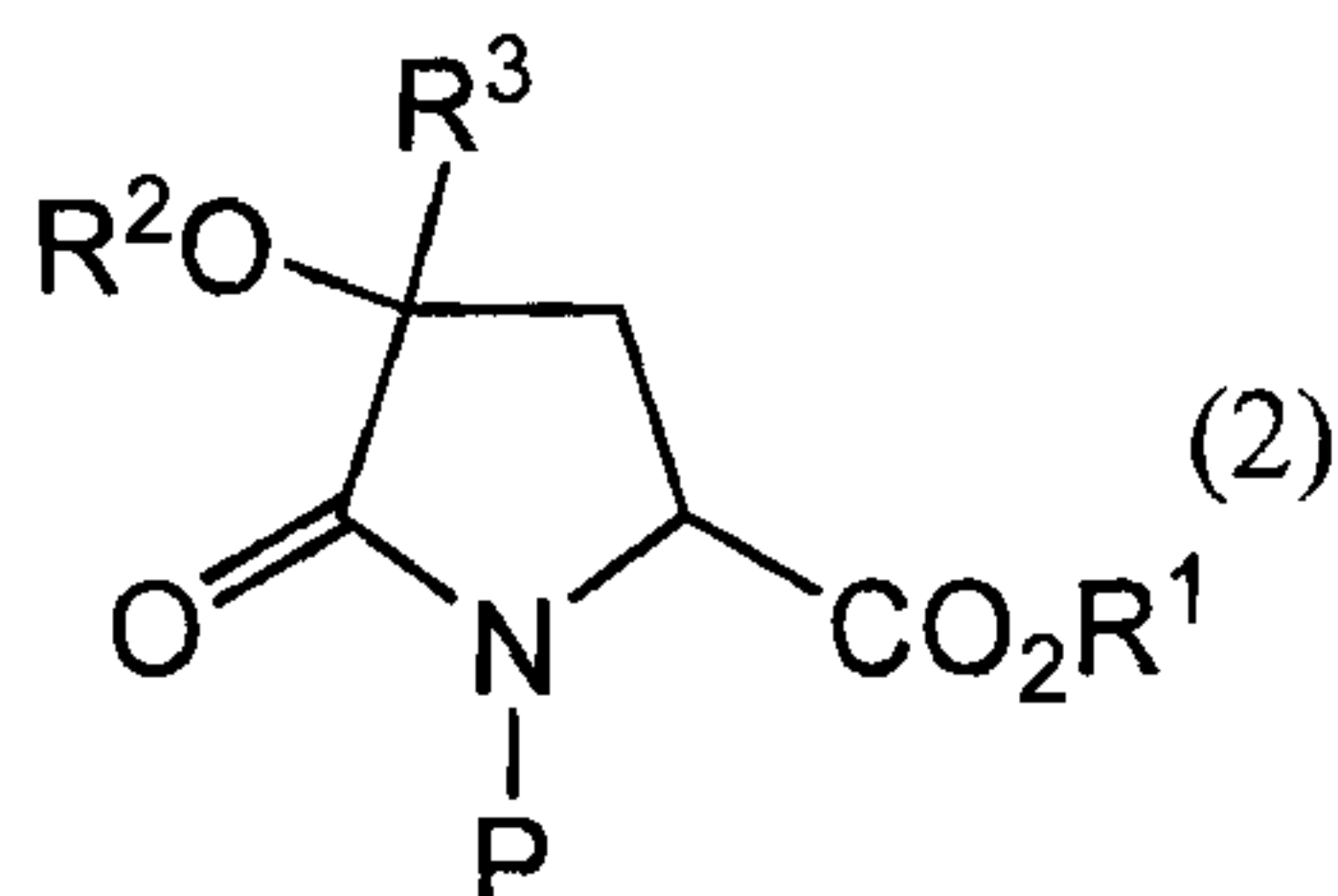
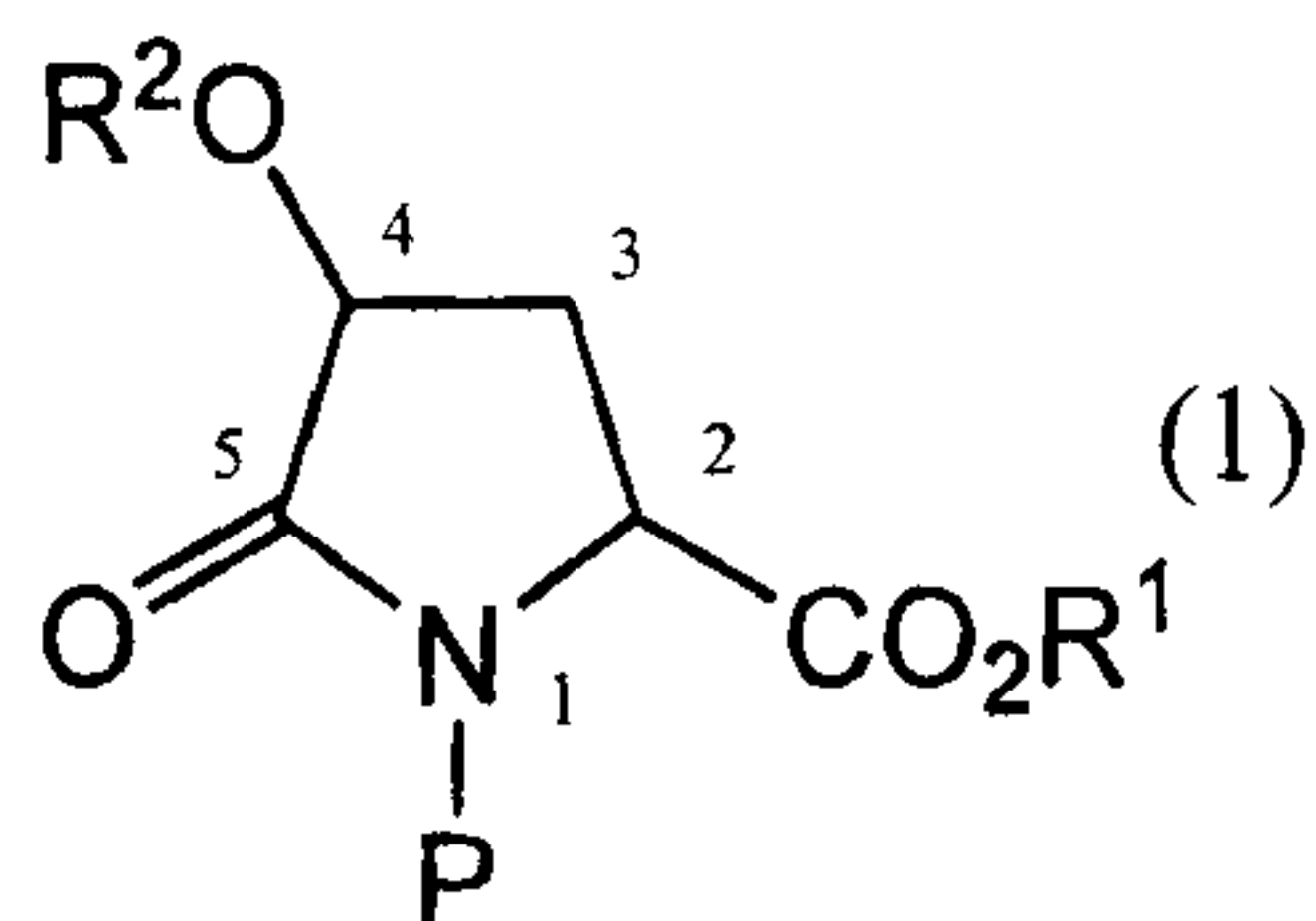
INDUSTRIAL APPLICABILITY

According to this invention, it is possible to manufacture efficiently and easily a glutamic acid derivative known as a sweetener, typically monatin, and a 4-protected hydroxyl pyroglutamic acid derivative as an intermediate in the manufacture thereof. The alkylation reaction of the 4-protected hydroxyl pyroglutamic acid derivative according to this invention is suitable for use as a method of manufacturing a glutamic acid derivative having optical

activity, particularly optically active monatin, since it can be carried out selectively at the 4-position and stereoselectively.

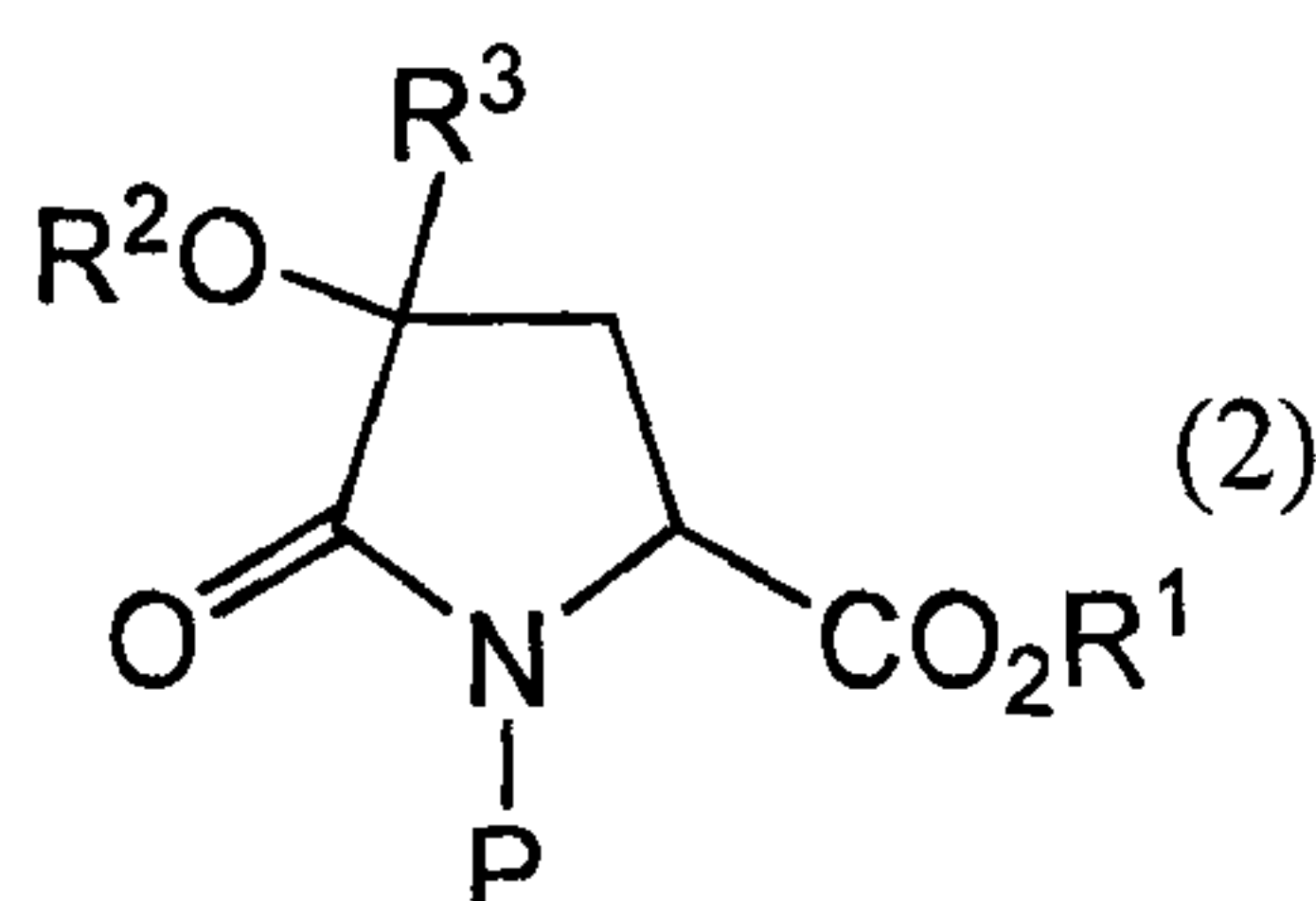
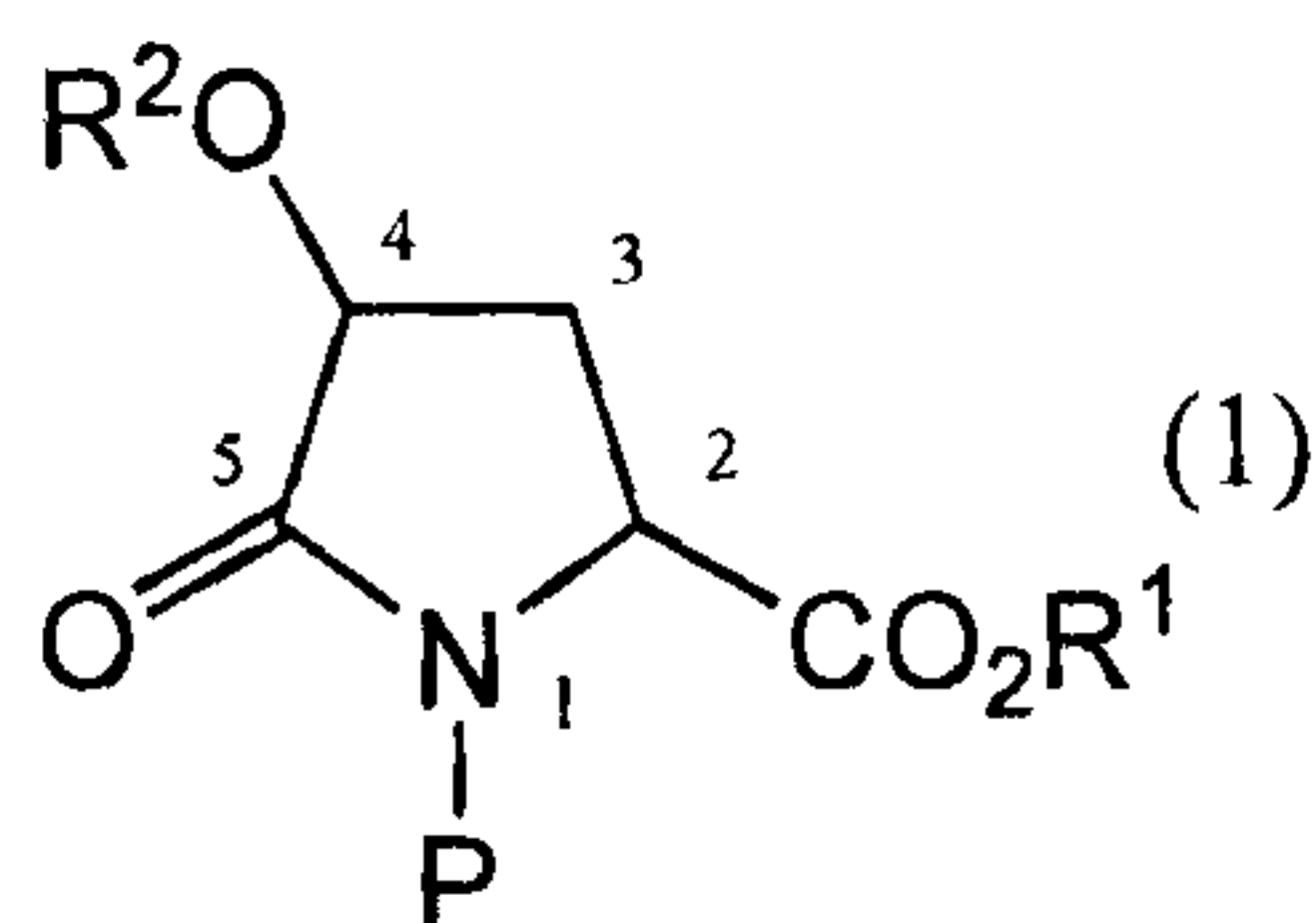
CLAIMS

1. A method of manufacturing a glutamic acid derivative represented by formula (3) below or salt thereof, characterized by subjecting a 4-protected hydroxy-pyroglutamic acid derivative represented by formula (1) below or salt thereof to an alkylation reaction to prepare a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2) below or salt thereof and subjecting the derivative to hydrolysis and deprotection steps:



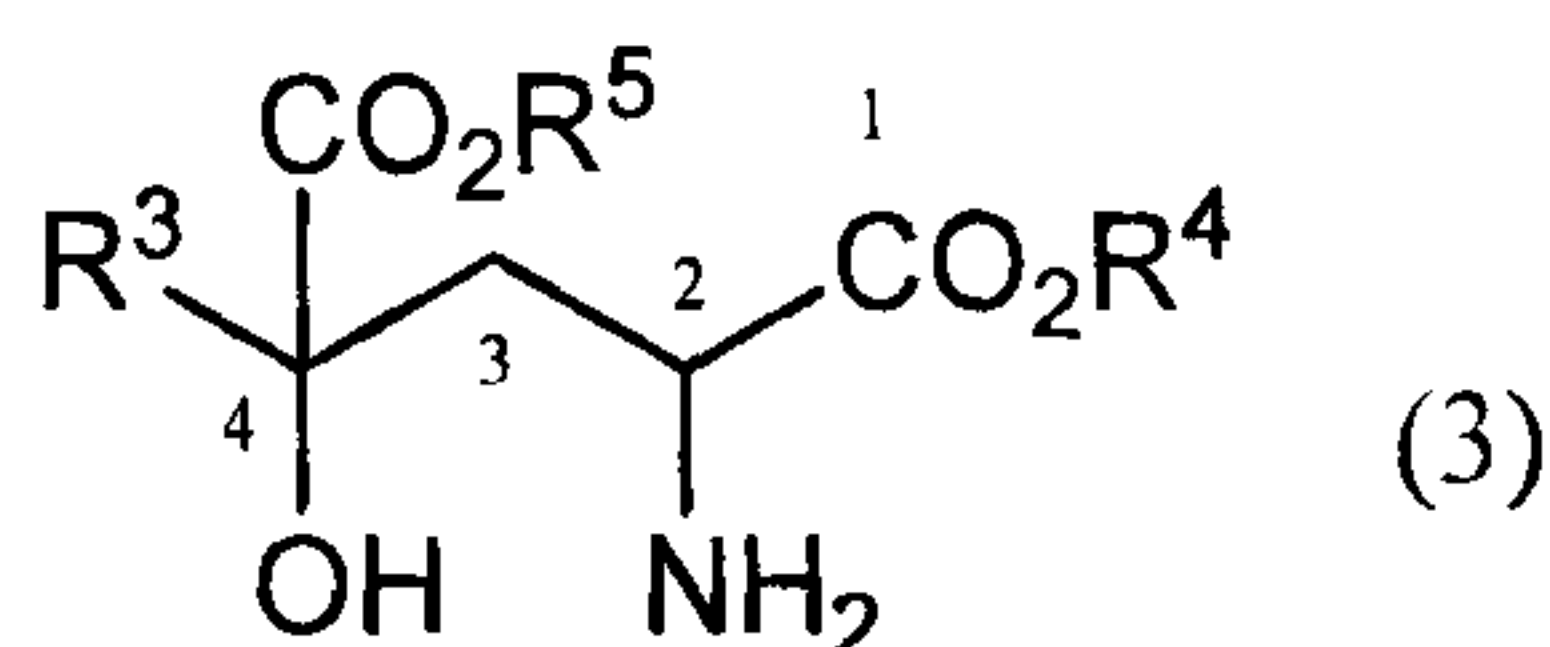
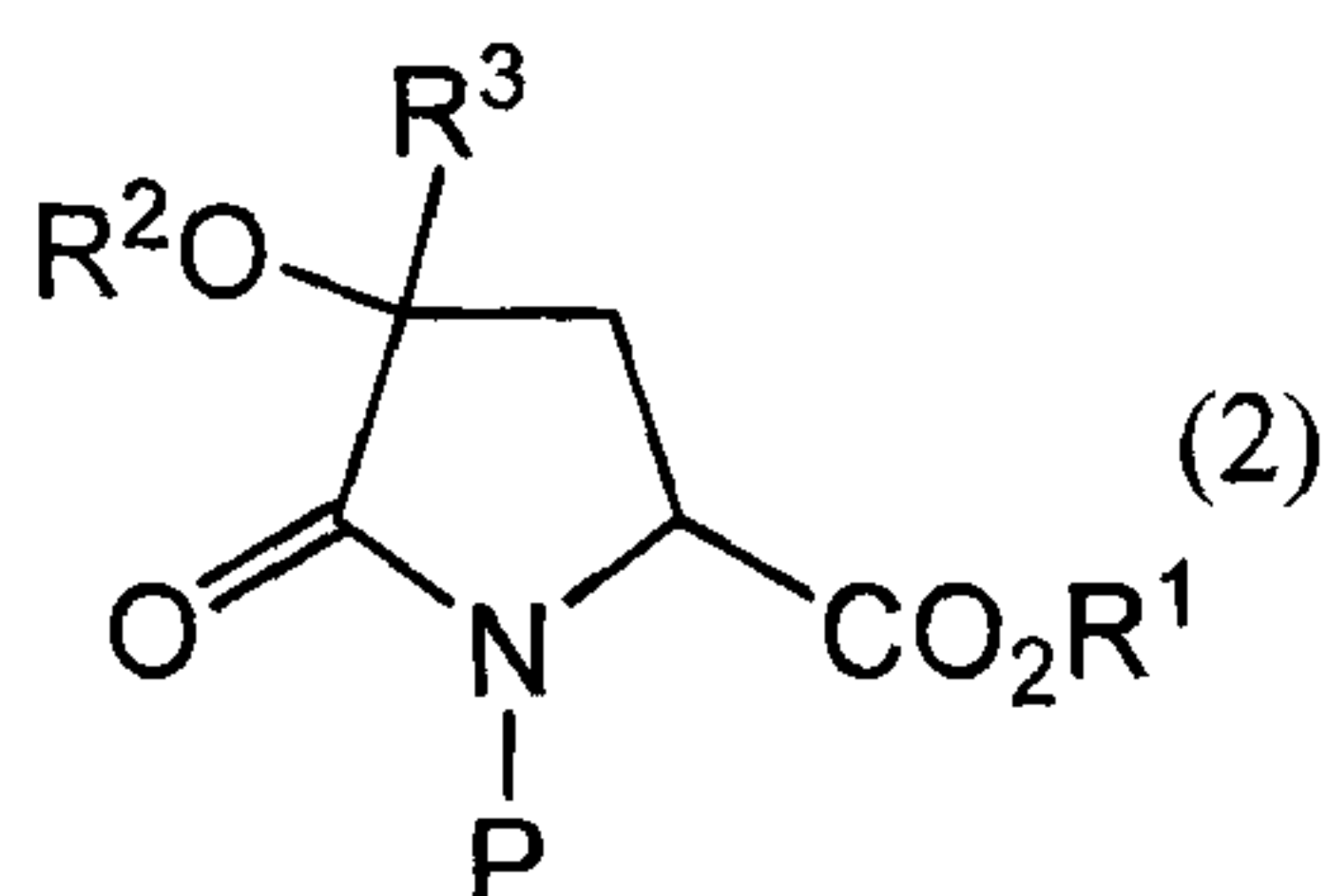
where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent and P stands for a protecting group for an imino group.

2. A method of manufacturing a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2) below or salt thereof, characterized by subjecting a 4-protected hydroxypyroglutamic acid derivative represented by formula (1) below or salt thereof to an alkylation reaction:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group and P stands for a protecting group for an imino group.

3. A method of manufacturing a glutamic acid derivative represented by formula (3) below or salt thereof, characterized by subjecting a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2) below or salt thereof to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent and P stands for a protecting group for an imino group.

4. A method as set forth in claim 1 or 3, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, R^3 stands for a group selected from an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to 20 carbon atoms, an aralkyl group having 1 to 20 carbon atoms and a heterocyclic hydrocarbon group having 1 to 20 carbon atoms and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

5. A method as set forth in claim 2, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected

from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, R^3 stands for a group selected from an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to 20 carbon atoms, an aralkyl group having 1 to 20 carbon atoms and a heterocyclic hydrocarbon group having 1 to 20 carbon atoms and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

6. A method as set forth in any one of claims 1 to 3, wherein R^3 is a benzyl group or an N-protected-3-indolylmethyl group.

7. A method as set forth in claim 1 or 2, wherein the alkylation reaction is performed in the presence of an alkylating agent represented by formula (4) below:



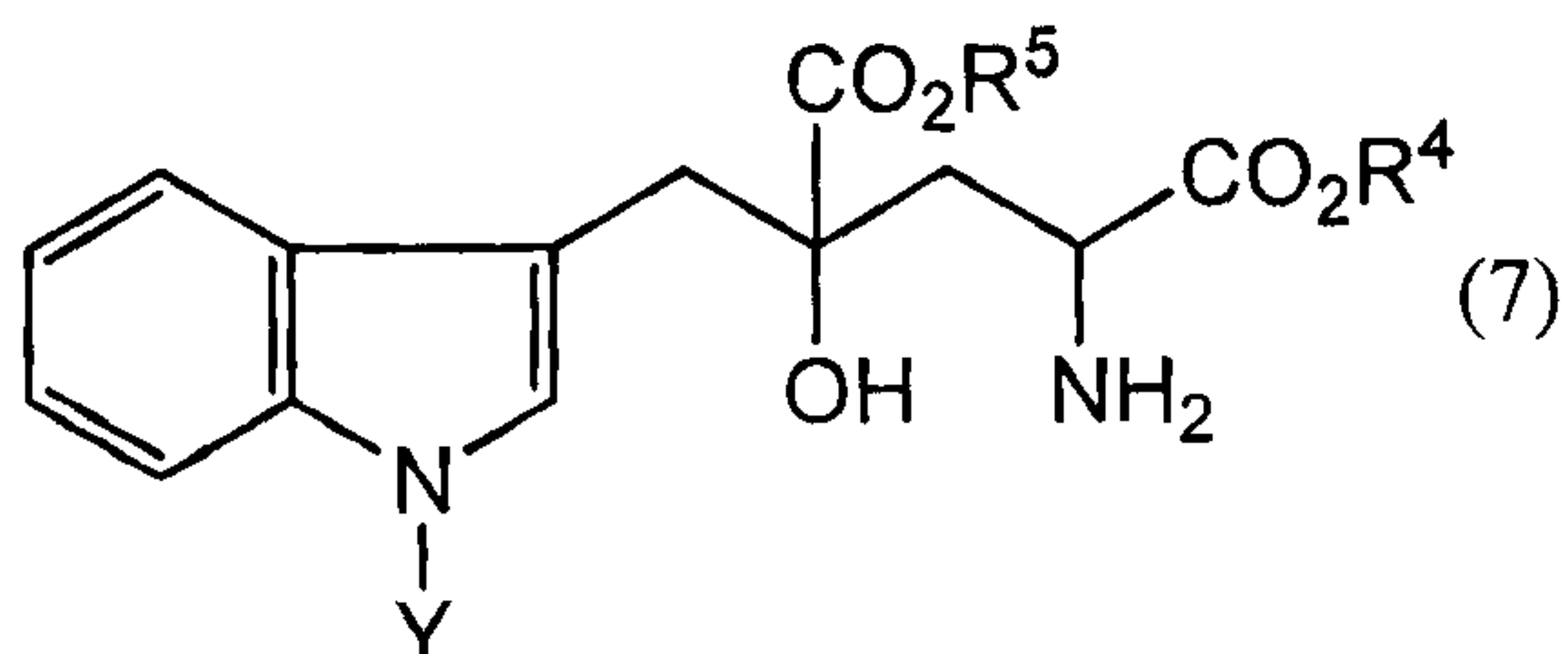
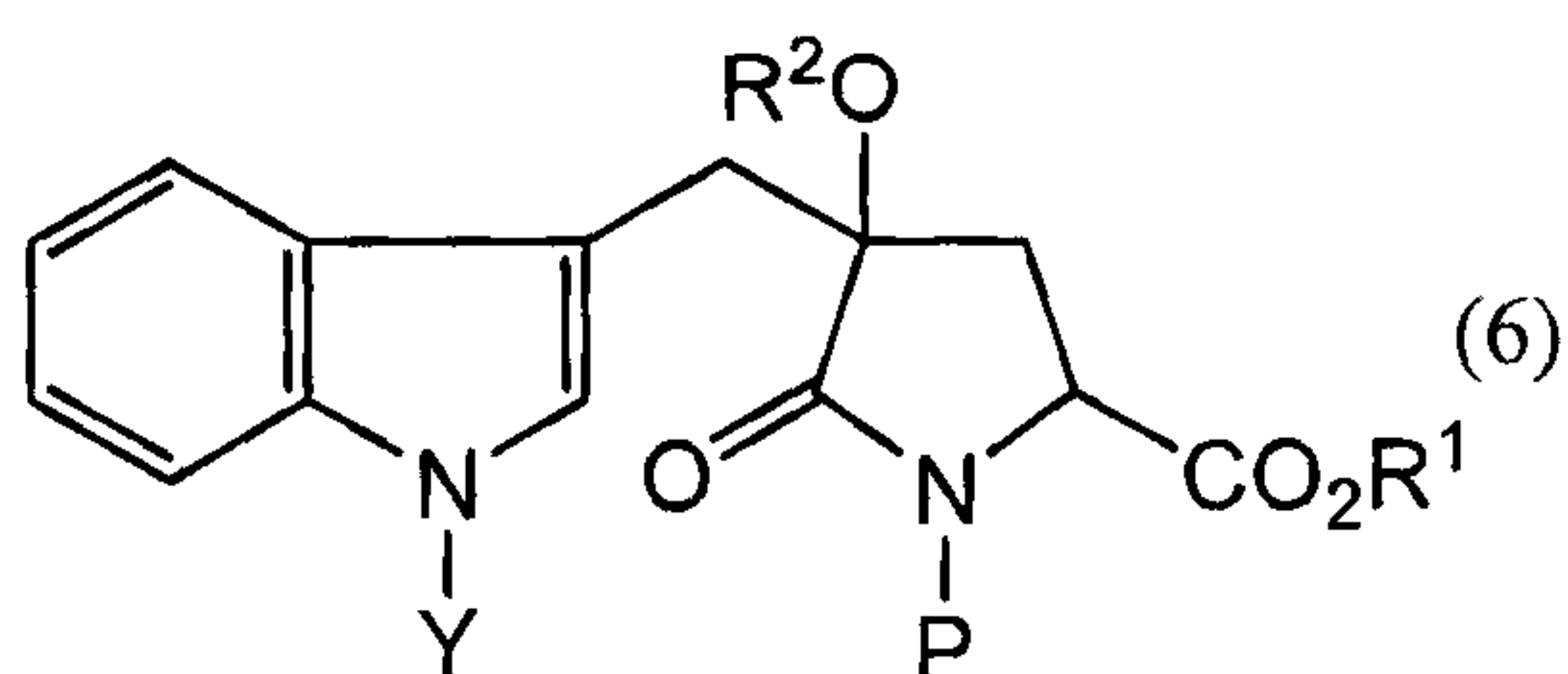
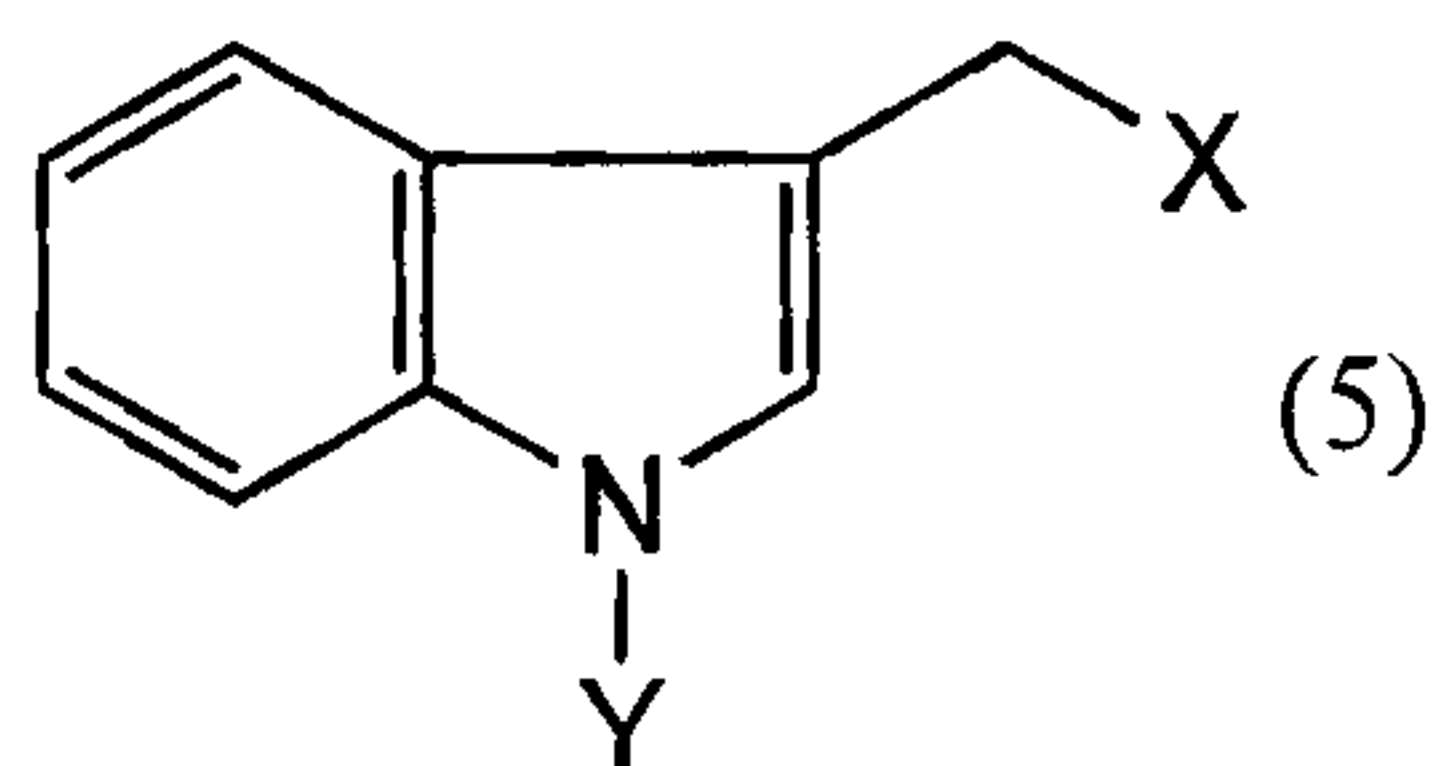
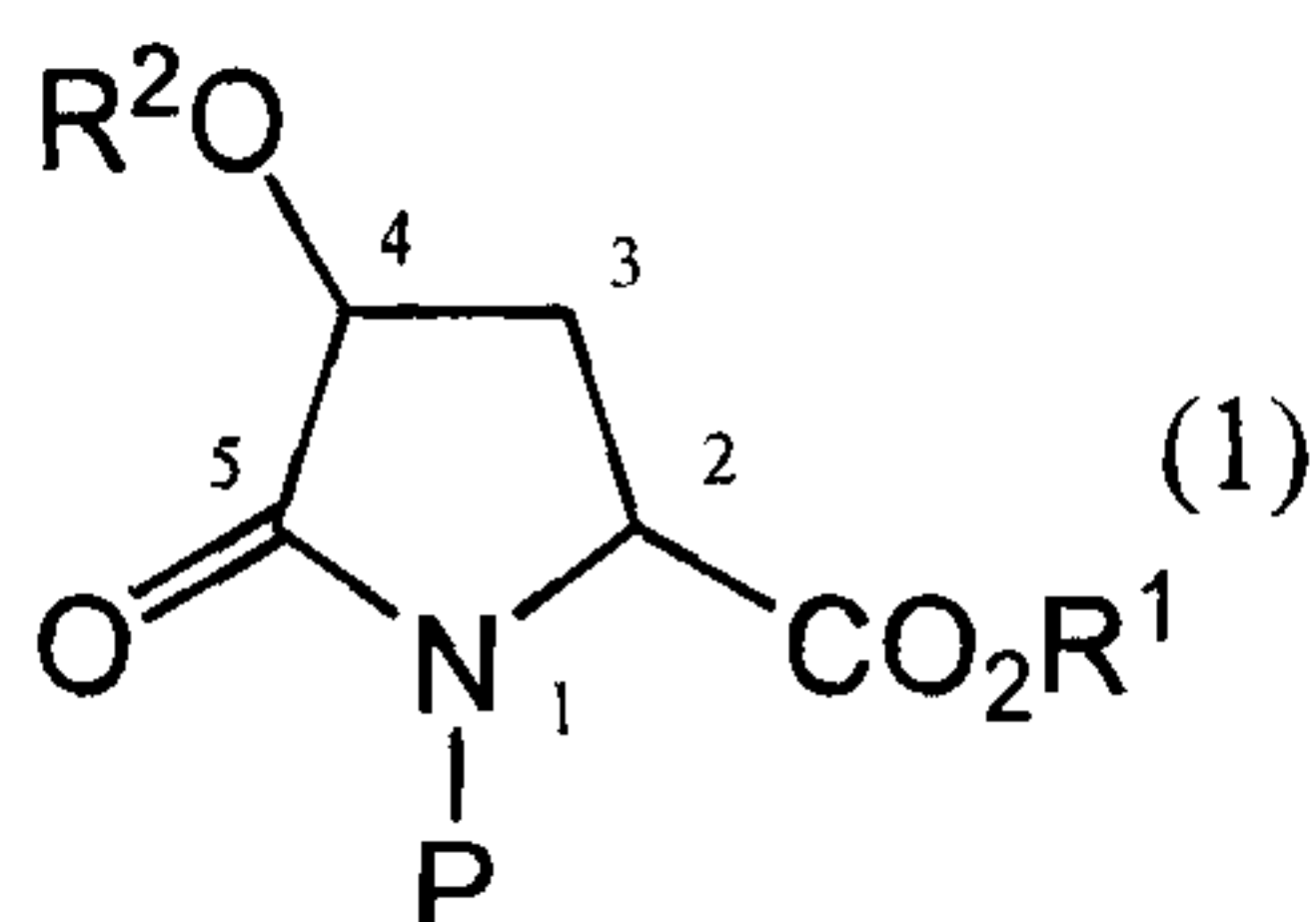
where R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent and X stands for a halogen atom.

8. A method as set forth in claim 7, wherein the alkylation reaction is performed in the presence of a base.

9. A method as set forth in claim 8, wherein the base is one or more kinds of base selected from lithium hexamethyldisilazanide, potassium hexamethyl-disilazanide, sodium hexamethyldisilazanide, lithium diisopropylamide and normal butyl lithium.

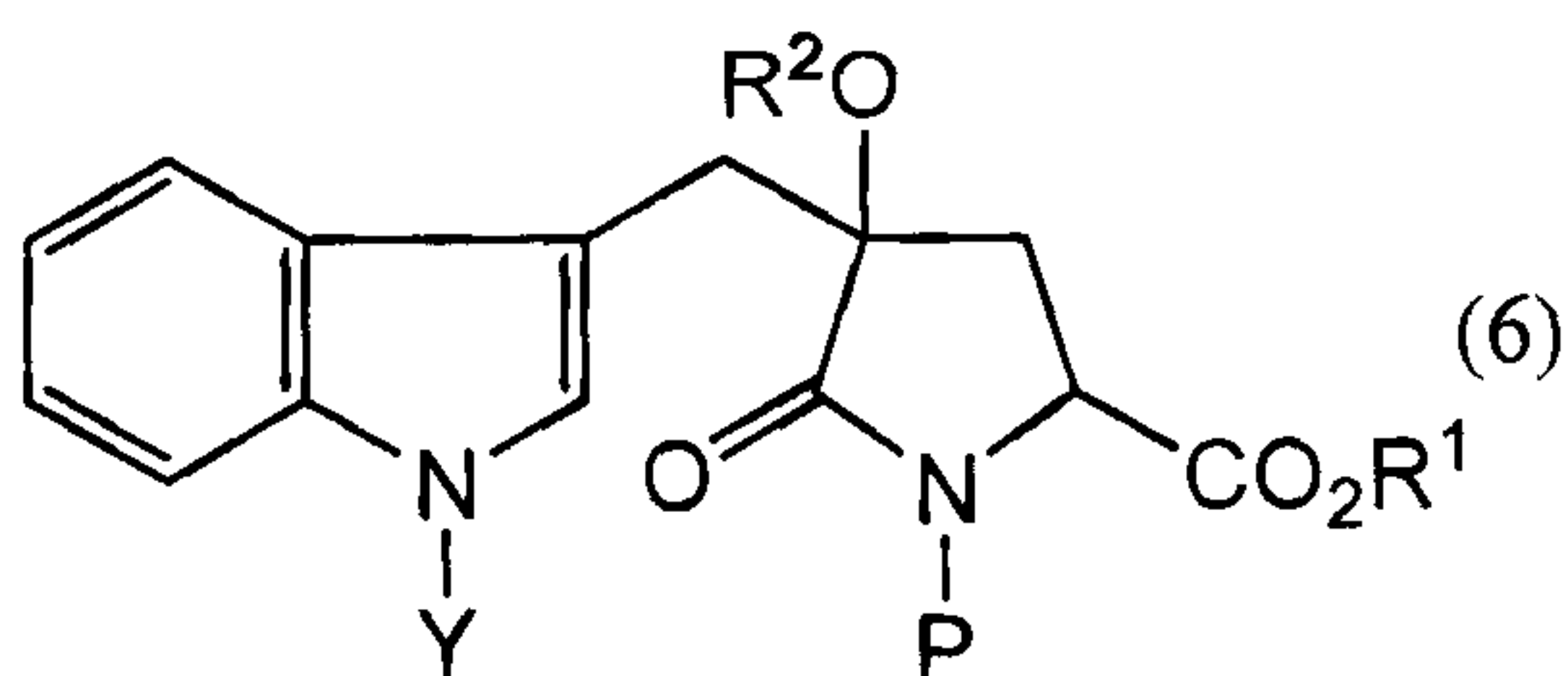
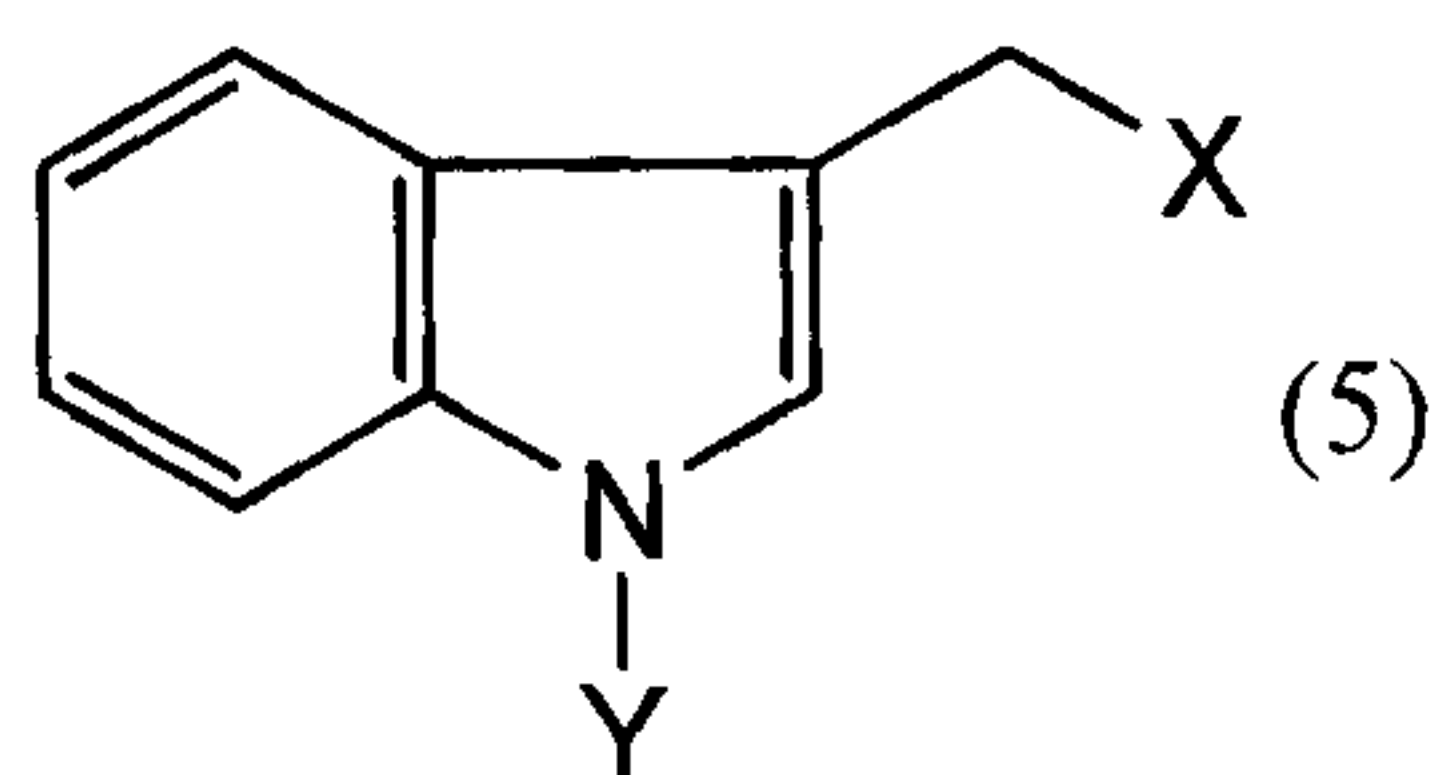
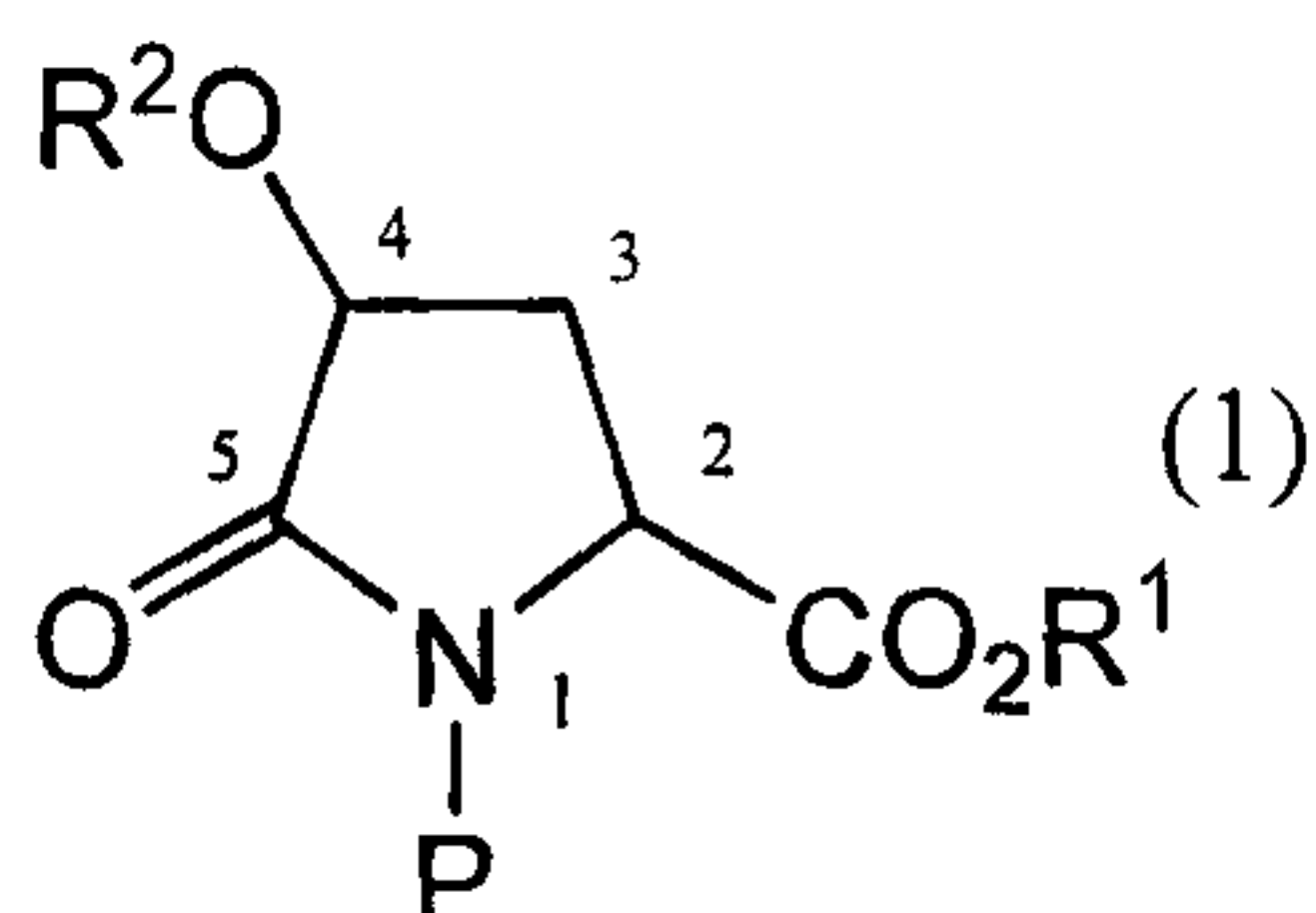
10. A method as set forth in claim 8, wherein the base is used in a molar ratio of between 1.0 and 2.0 to 1 relative to the 4-protected hydroxyglutamic acid derivative.

11. A method of manufacturing a monatin acid derivative represented by formula (7) below or salt thereof, characterized by reacting a 4-protected hydroxy-pyroglutamic acid derivative represented by formula (1) below or salt thereof with N-protected-3-halogenomethylindole represented by formula (5) below to prepare a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) below or salt thereof and subjecting the derivative to hydrolysis and deprotection steps:



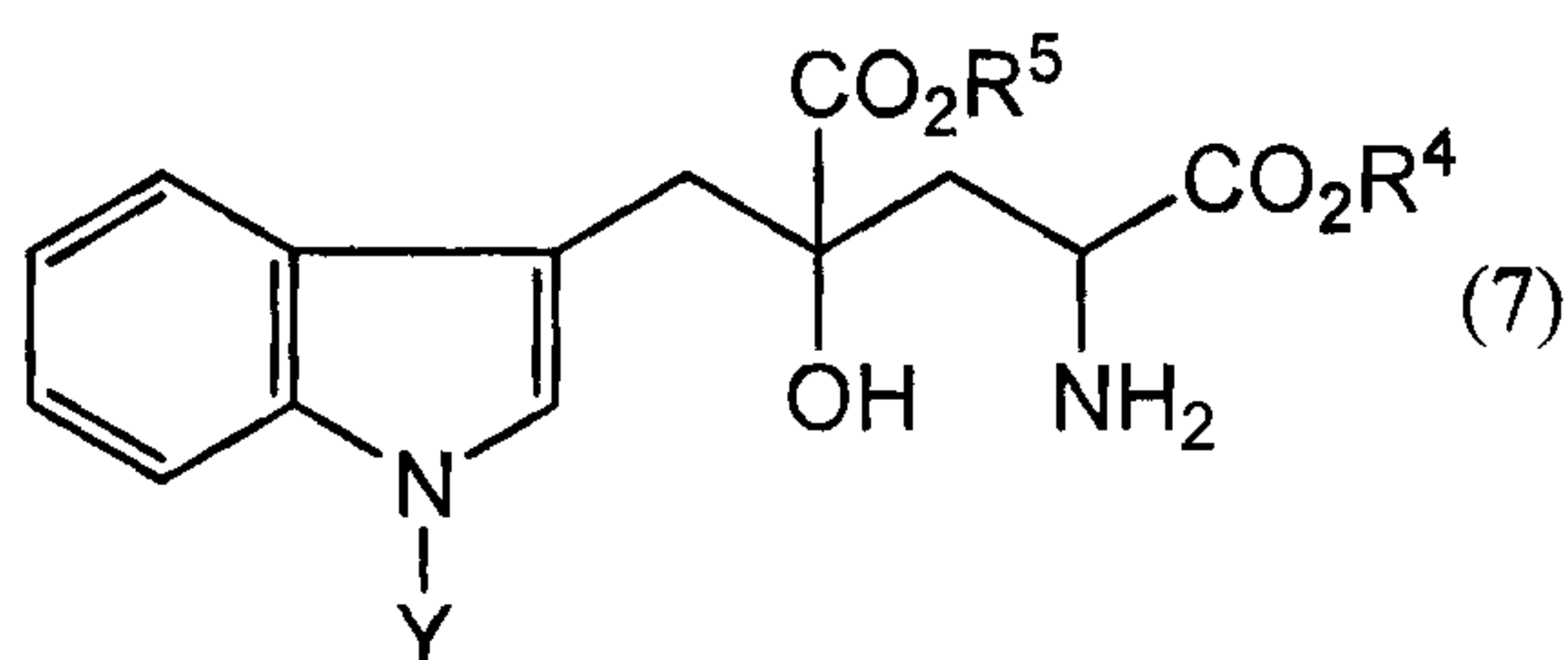
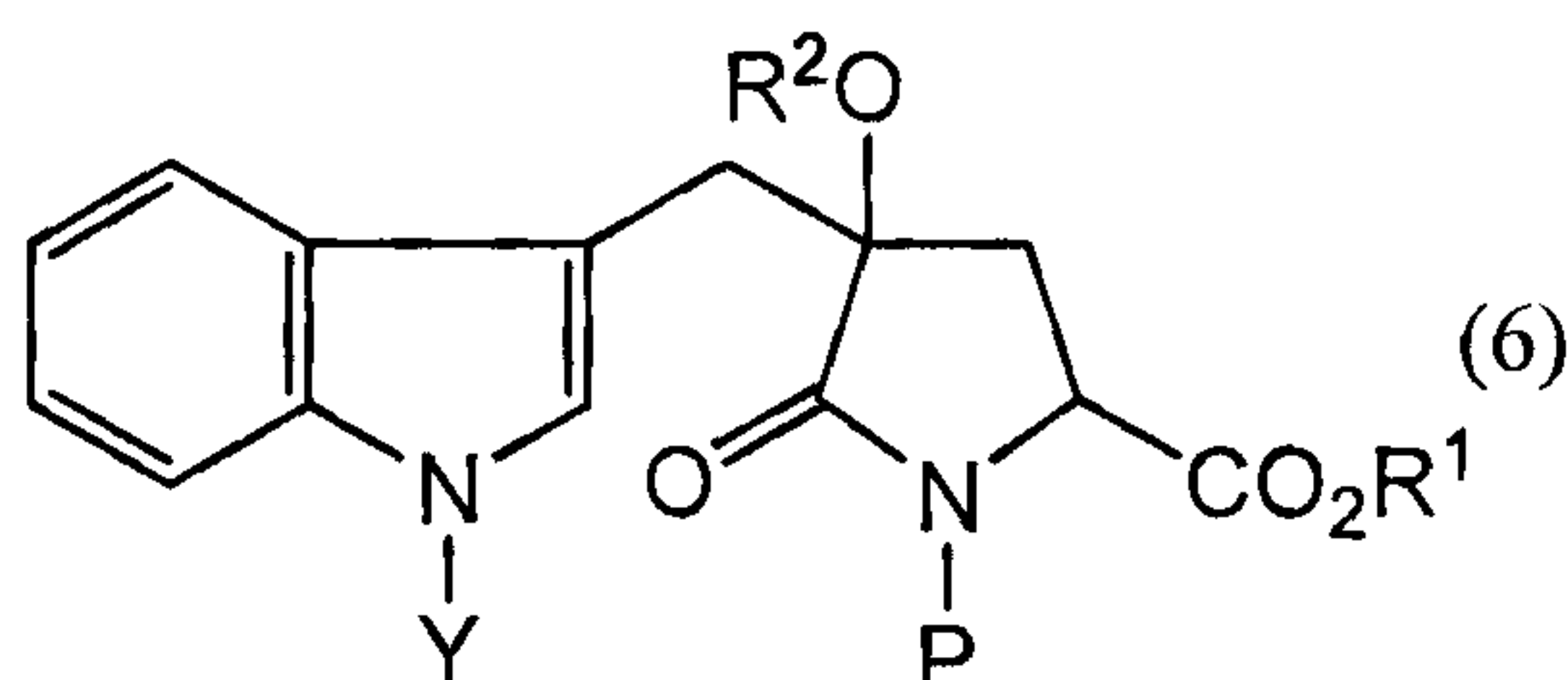
where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group and Y stands for a protecting group for an indolyl group.

12. A method of manufacturing a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) below or salt thereof, characterized by reacting a 4-protected hydroxypyroglutamic acid derivative represented by formula (1) below or salt thereof with N-protected-3-halogeno-methylindole represented by formula (5) below:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group and Y stands for a protecting group for an indolyl group.

13. A method of manufacturing a monatin derivative represented by formula (7) below or salt thereof, characterized by subjecting a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) below or salt thereof to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group and Y stands for a protecting group for an indolyl group.

14. A method as set forth in claim 11, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

15. A method as set forth in claim 12, wherein R^1 stands for a group selected from a hydrogen atom, an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

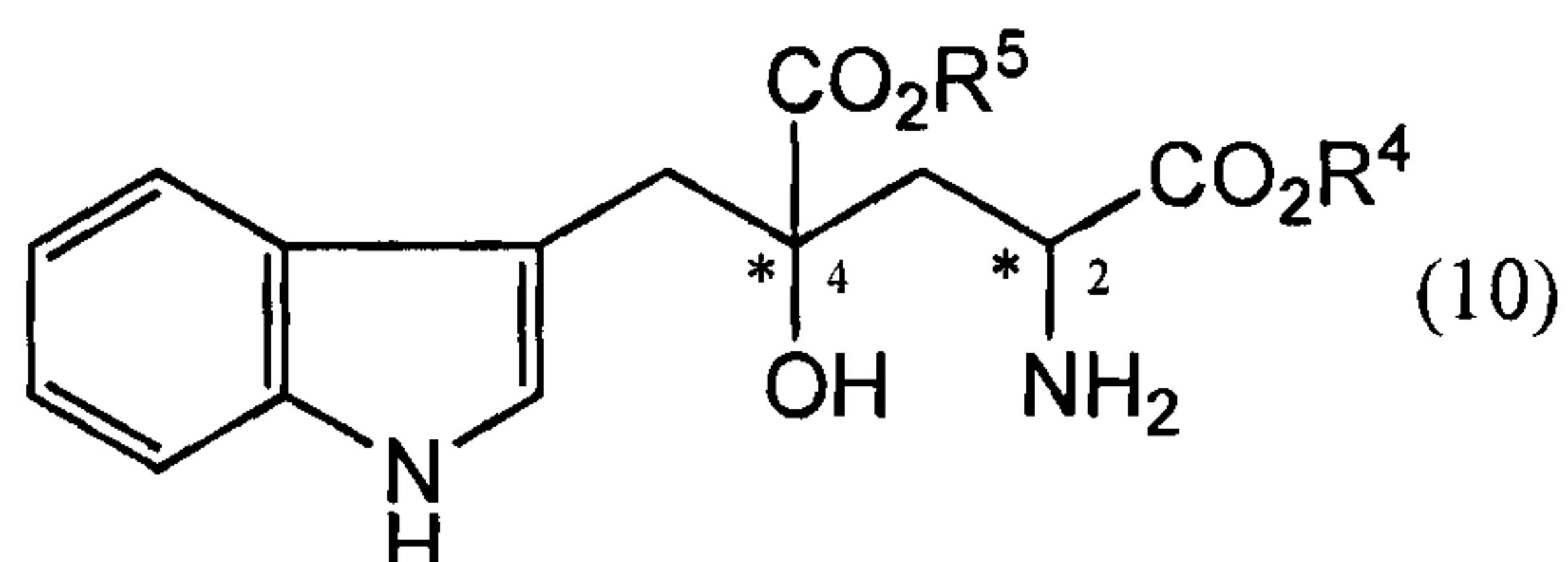
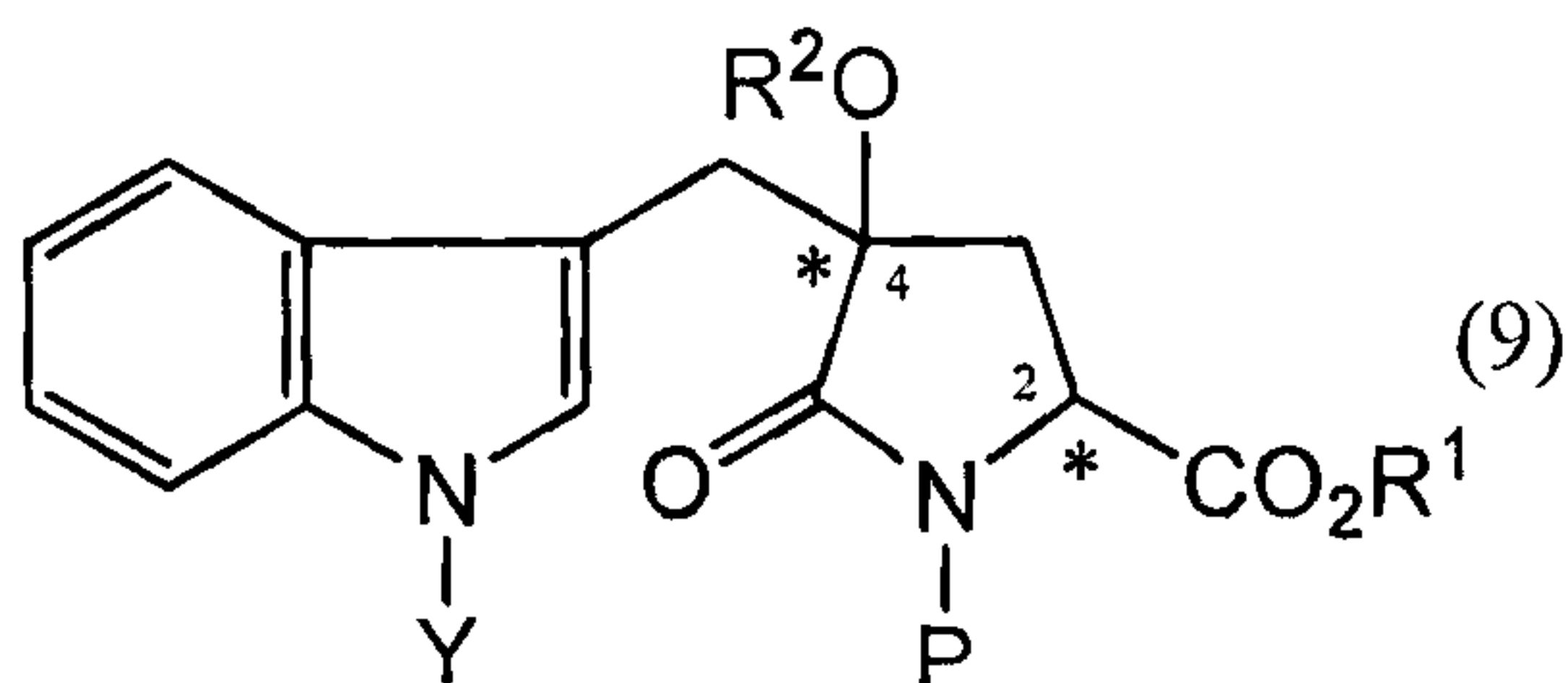
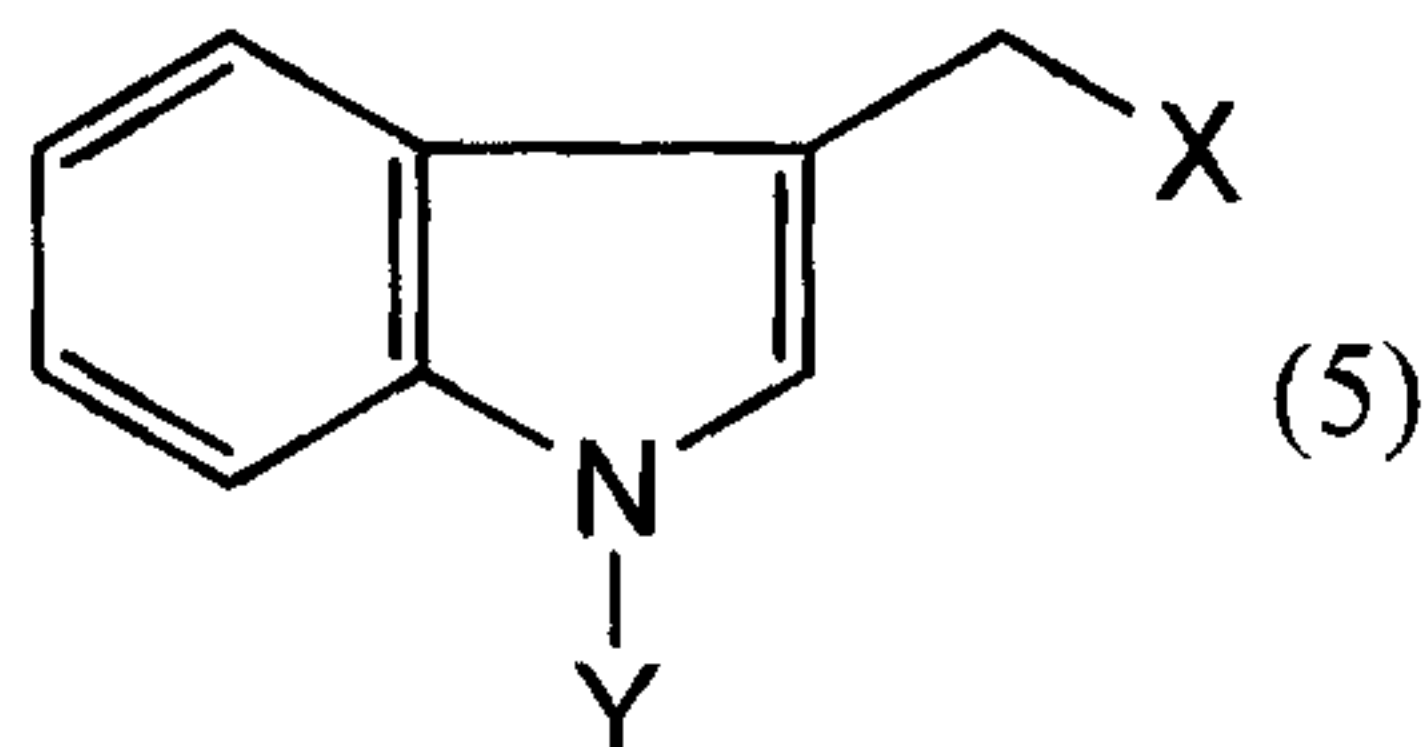
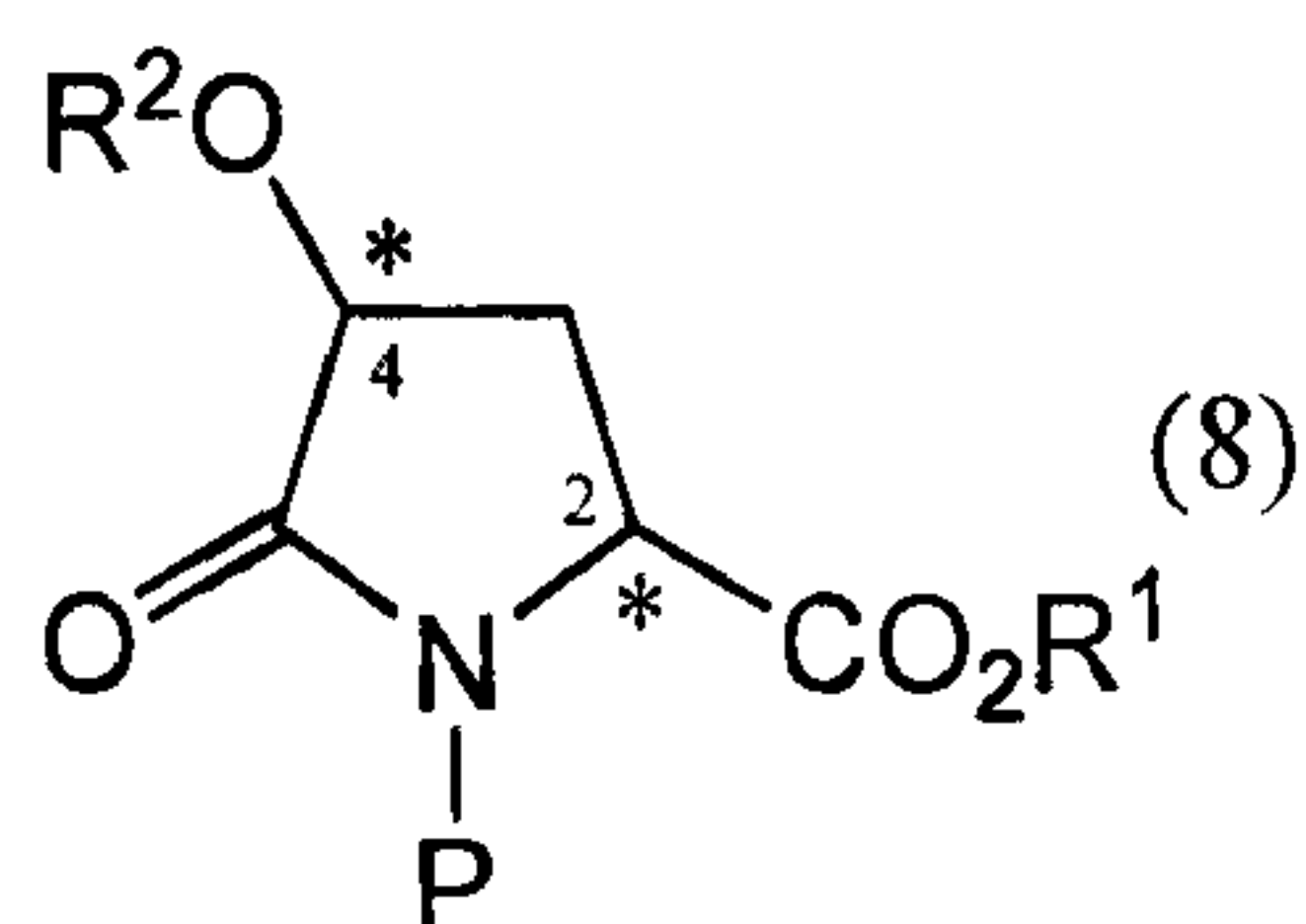
16. A method as set forth in claim 13, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

17. A method as set forth in claim 11 or 12, wherein the alkylation reaction is performed in the presence of a base.

18. A method as set forth in claim 17, wherein the base is one or more kinds of base selected from lithium hexamethyldisilazane, potassium hexamethyl-disilazane, sodium hexamethyldisilazane, lithium diisopropylamide and normal butyl lithium.

19. A method as set forth in claim 17, wherein the base is used in a molar ratio of between 1.0 and 2.0 to 1 relative to the 4-protected hydroxyglutamic acid derivative.

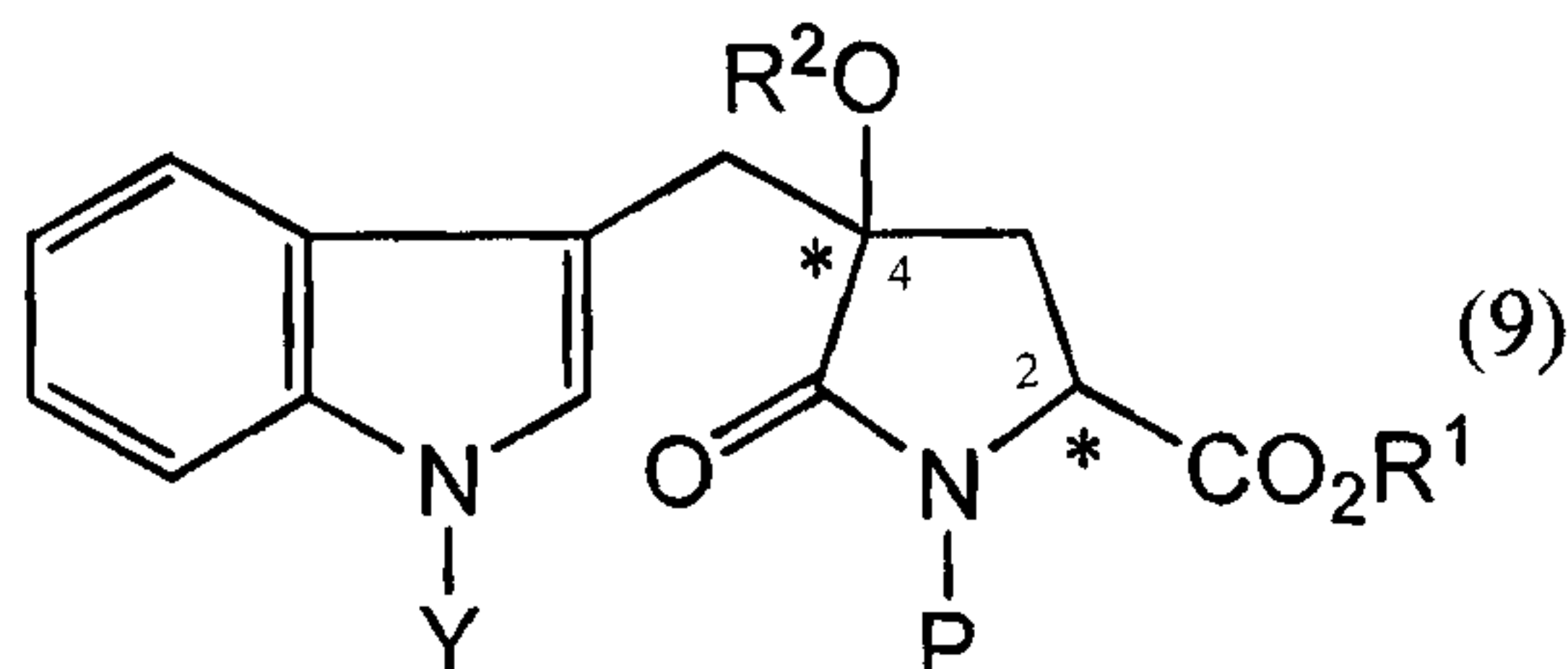
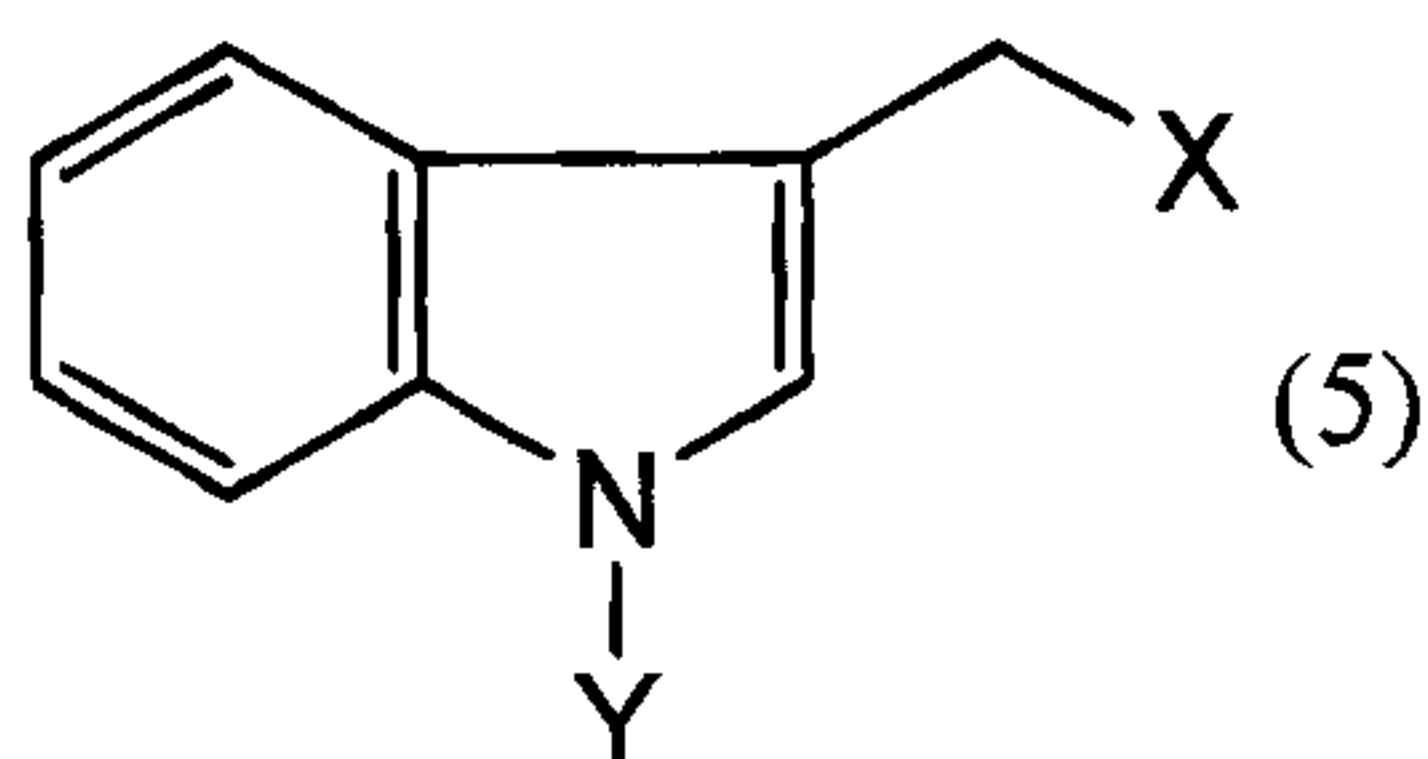
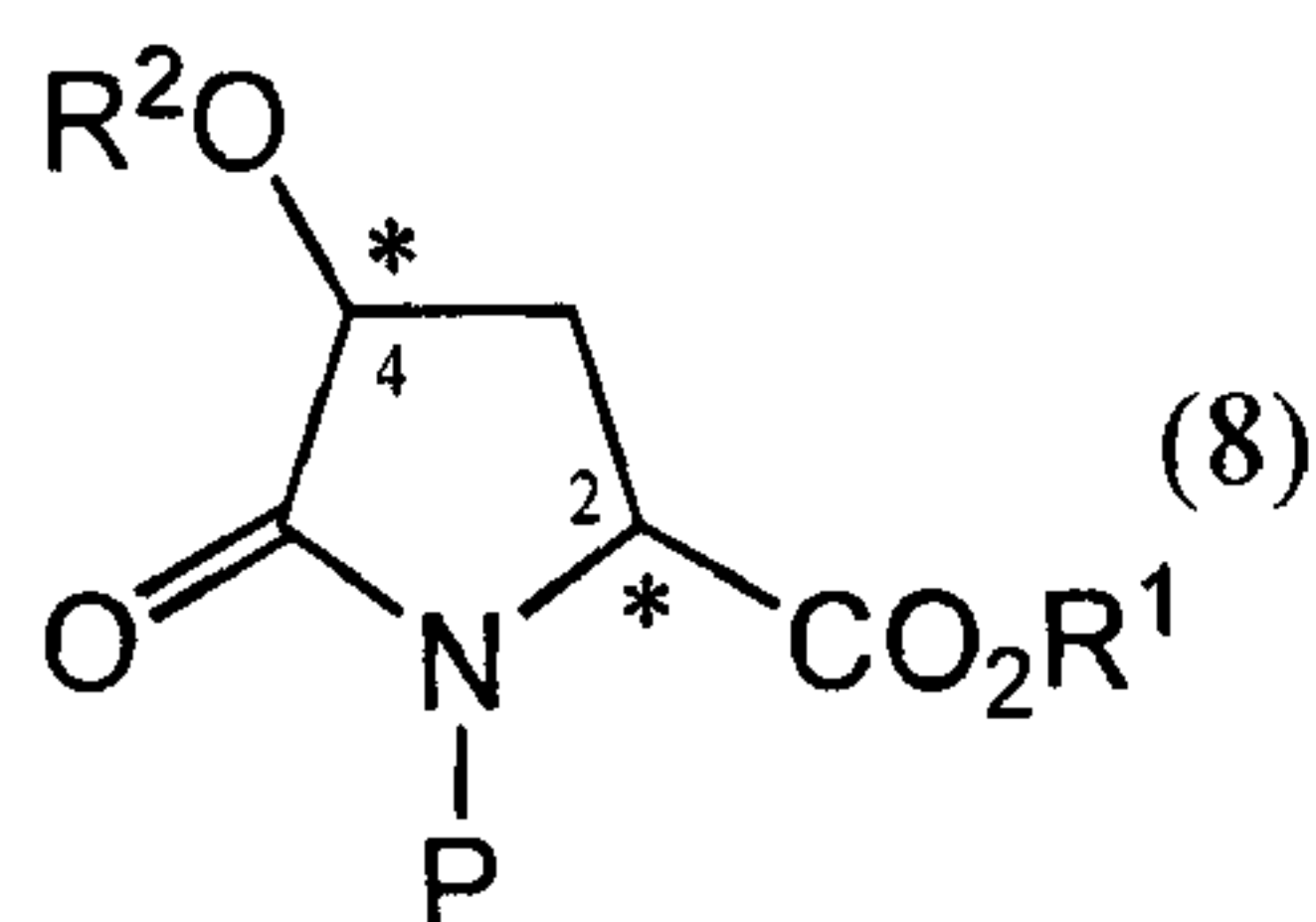
20. A method of manufacturing an optically active monatin derivative represented by formula (10) below or salt thereof, characterized by reacting an optically active 4-protected hydroxy-pyroglutamic acid derivative represented by formula (8) below or salt thereof with N-protected-3-halogenomethylindole represented by formula (5) below to prepare an optically active 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (9) below or salt thereof and subjecting the derivative to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting

group for an imino group, Y stands for a protecting group for an indolyl group, * stands for an asymmetric carbon atom, the configuration at the 2-position in formula (8) is R or S, the configuration at the 4-position is R, S or RS, so that when the configuration at the 2-position in formula (8) is R, the configurations in formulas (9) and (10) are (2R, 4R), respectively, and when the configuration at the 2-position in formula (8) is S, the configurations in formulas (9) and (10) are (2S, 4S), respectively.

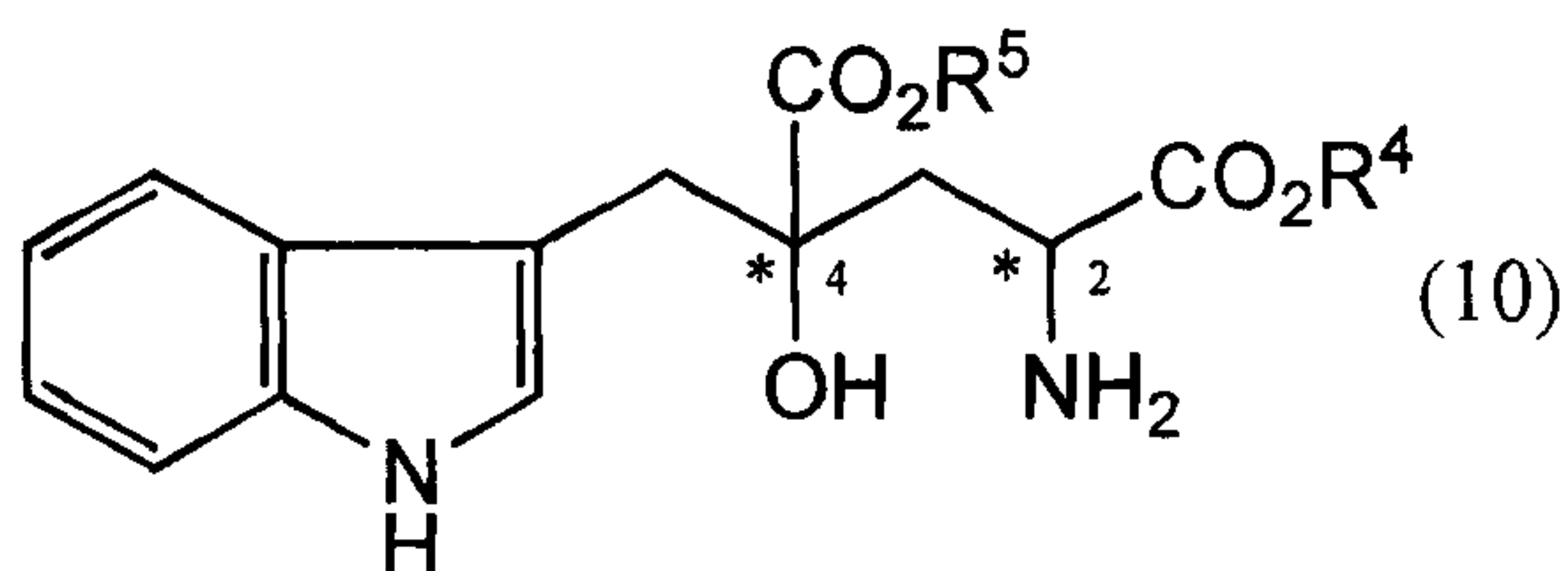
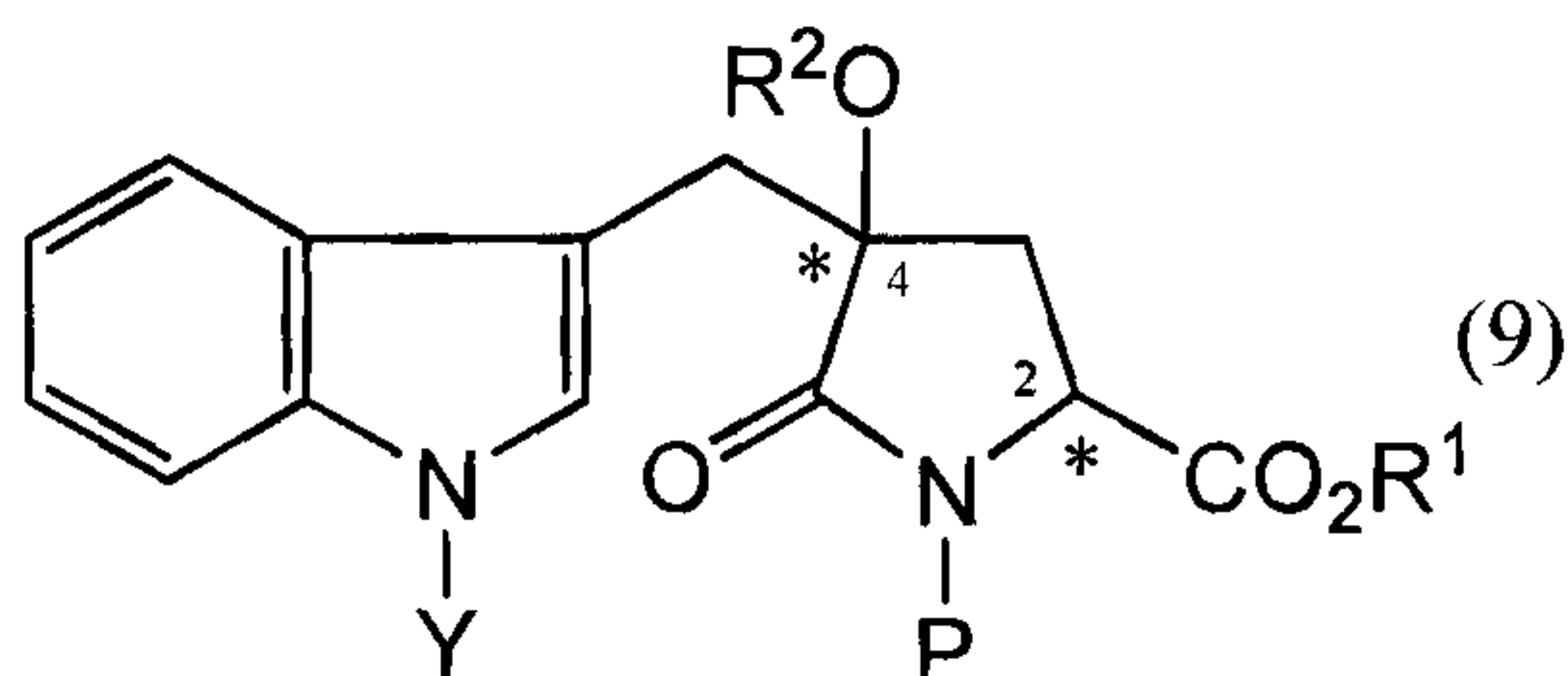
21. A method of manufacturing an optically active 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (9) below or salt thereof, characterized by reacting an optically active 4-protected hydroxy-pyroglutamic acid derivative represented by formula (8) below or salt thereof with N-protected-3-halogenomethylindole represented by formula (5) below:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting

group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group, * stands for an asymmetric carbon atom, the configuration at the 2-position in formula (8) is R or S, the configuration at the 4-position is R, S or RS, so that when the configuration at the 2-position in formula (8) is R, the configurations in formula (9) are (2R, 4R), respectively, and when the configuration at the 2-position in formula (8) is S, the configurations in formula (9) are (2S, 4S), respectively.

22. A method of manufacturing an optically active monatin derivative represented by formula (10) below or salt thereof, characterized by subjecting an optically active 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (9) below or salt thereof to hydrolysis and deprotection steps:



where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group, * stands for an asymmetric carbon atom, and when the

configuration in formula (9) is (2R, 4R) , the configuration in formula (10) is (2R, 4R) , and when the configuration in formula (9) is (2S, 4S), the configuration in formula (10) is (2S, 4S).

23. A method as set forth in claim 20, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

24. A method as set forth in claim 22, wherein R^1 stands for a group selected from a hydrogen atom, an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

25. A method as set forth in claim 22, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group,

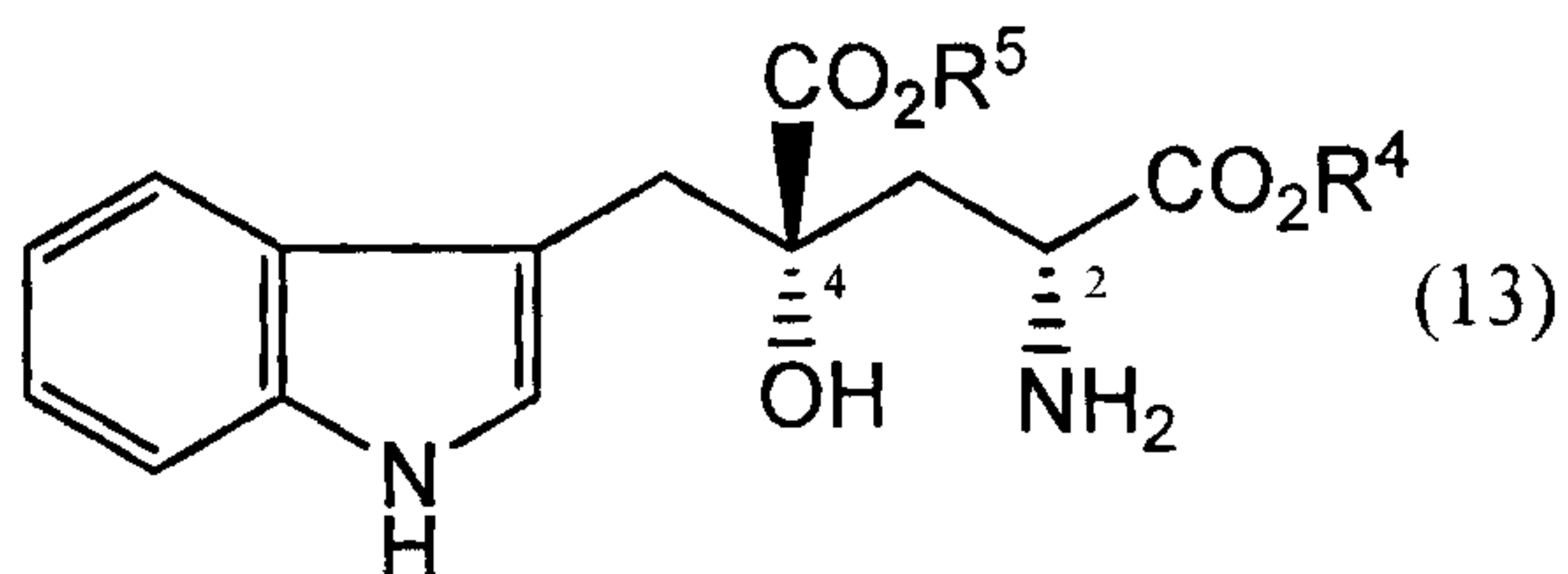
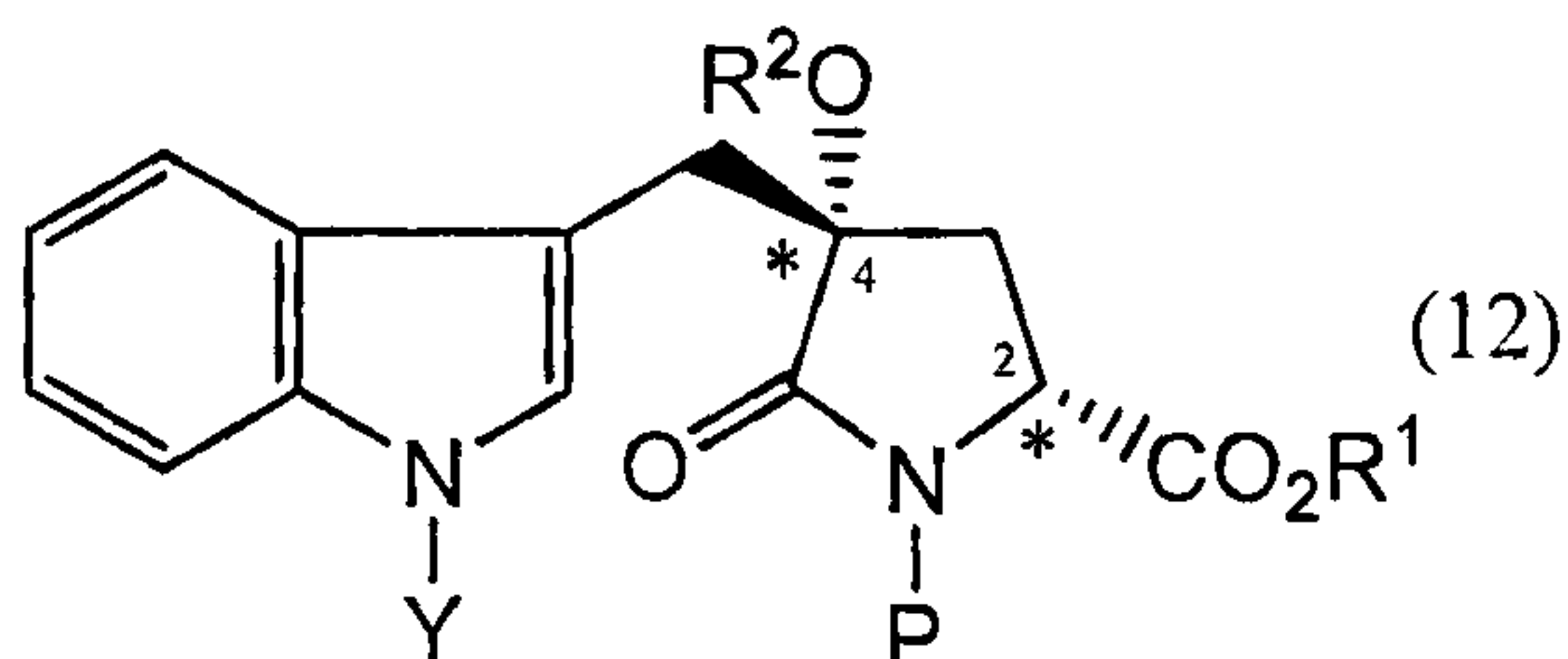
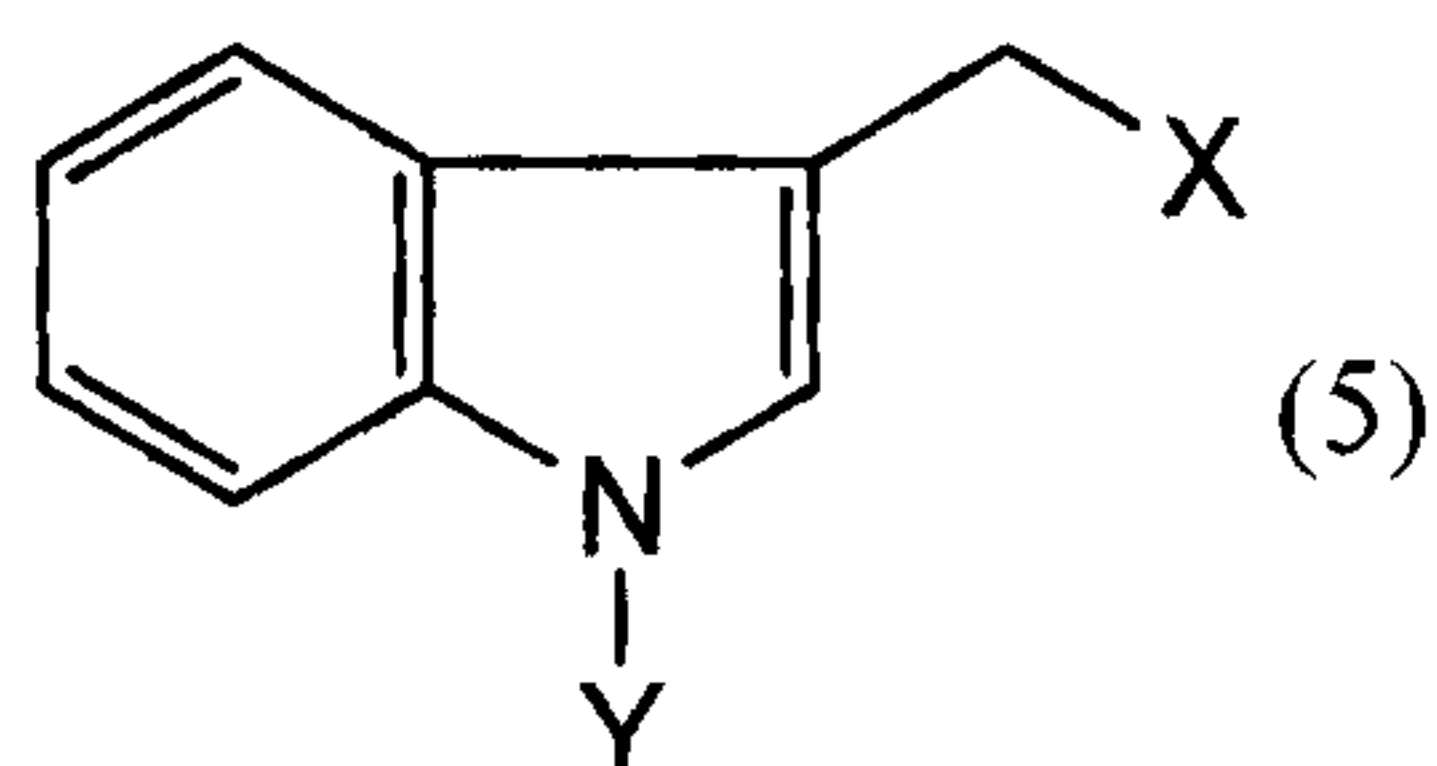
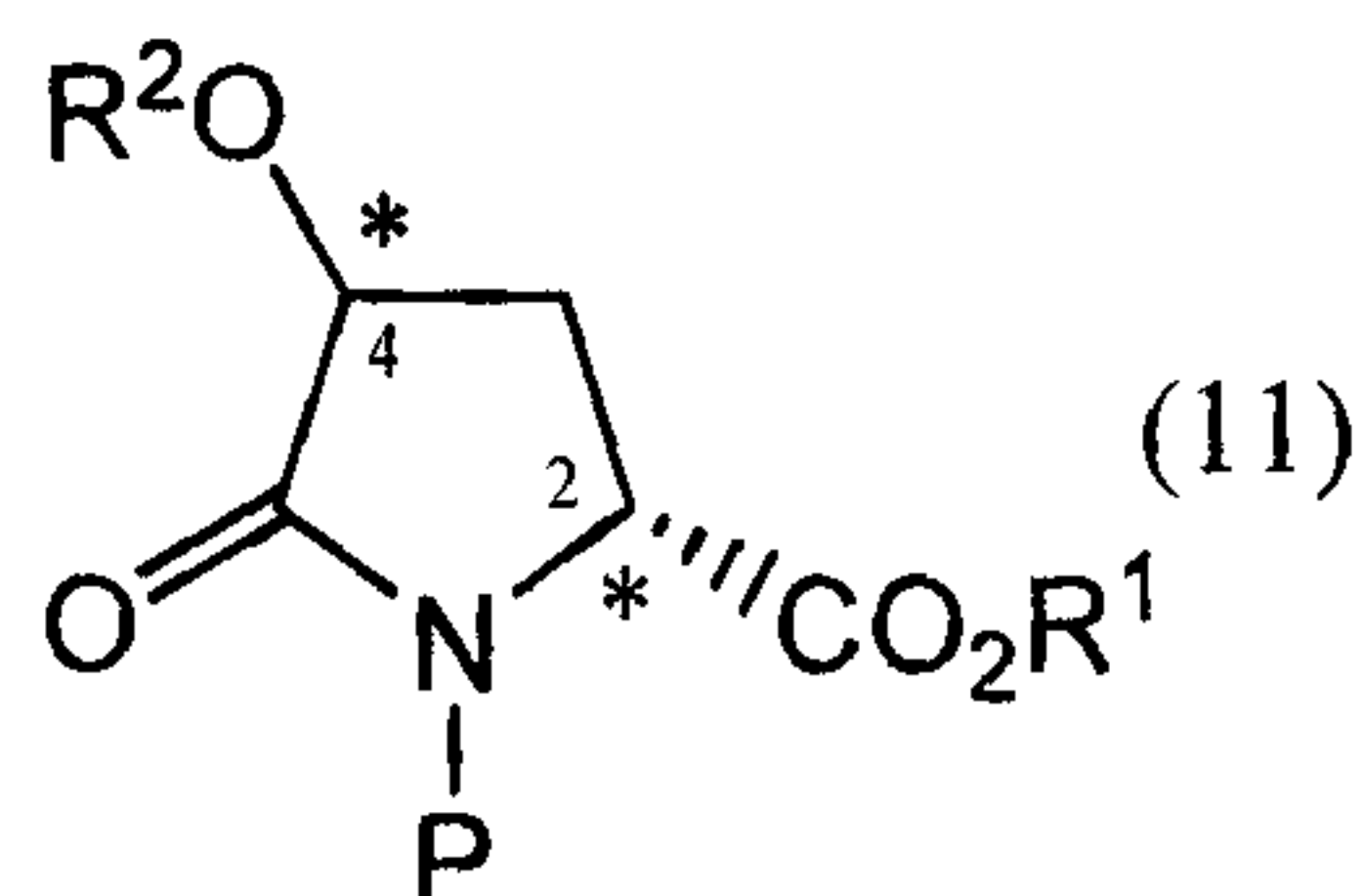
a benzyloxycarbonyl group and a t-butoxycarbonyl group and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

26. A method as set forth in claim 20 or 21, wherein the reaction of an optically active 4-protected hydroxypyroglutamic acid derivative represented by formula (8) with N-protected-3-halogenomethylindole represented by formula (5) is performed in the presence of a base.

27. A method as set forth in claim 26, wherein the base is one or more kinds of base selected from lithium hexamethyldisilazane, potassium hexamethyl-disilazane, sodium hexamethyldisilazane, lithium diisopropylamide and normal butyl lithium.

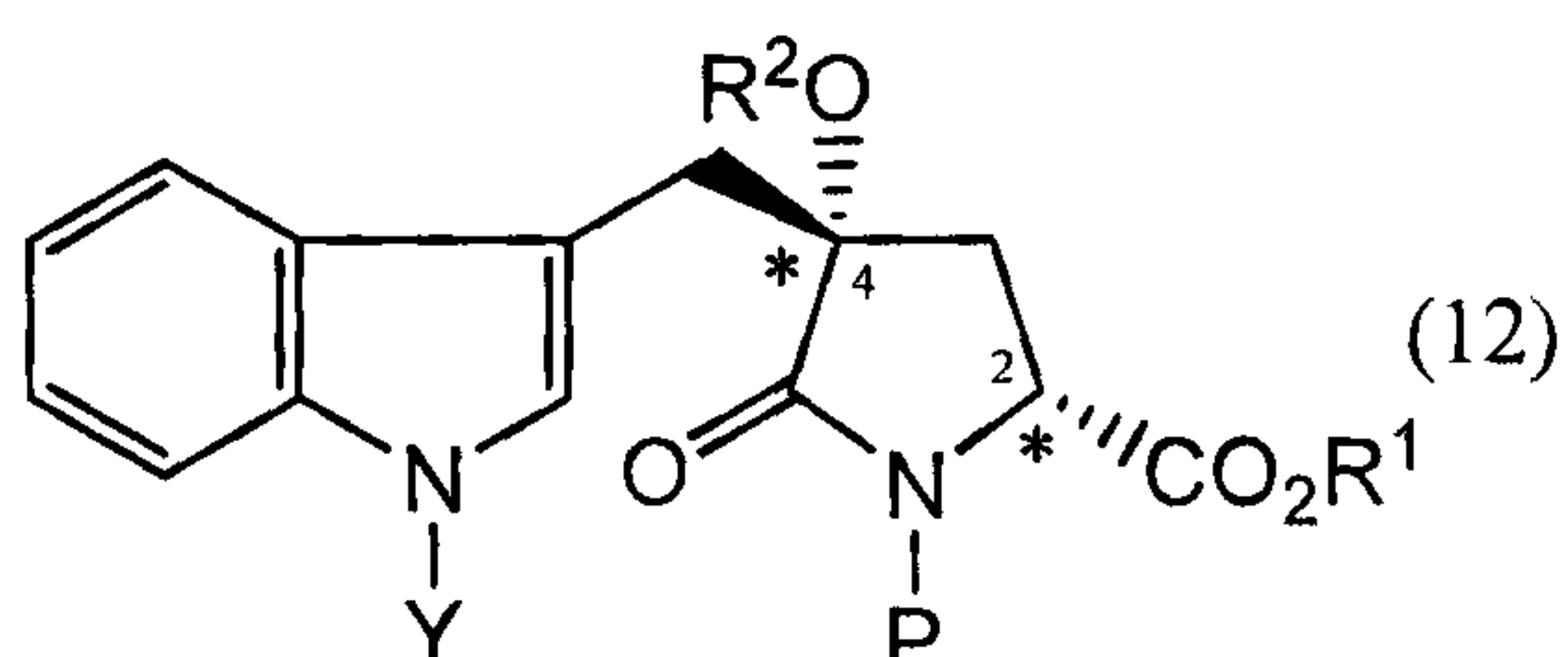
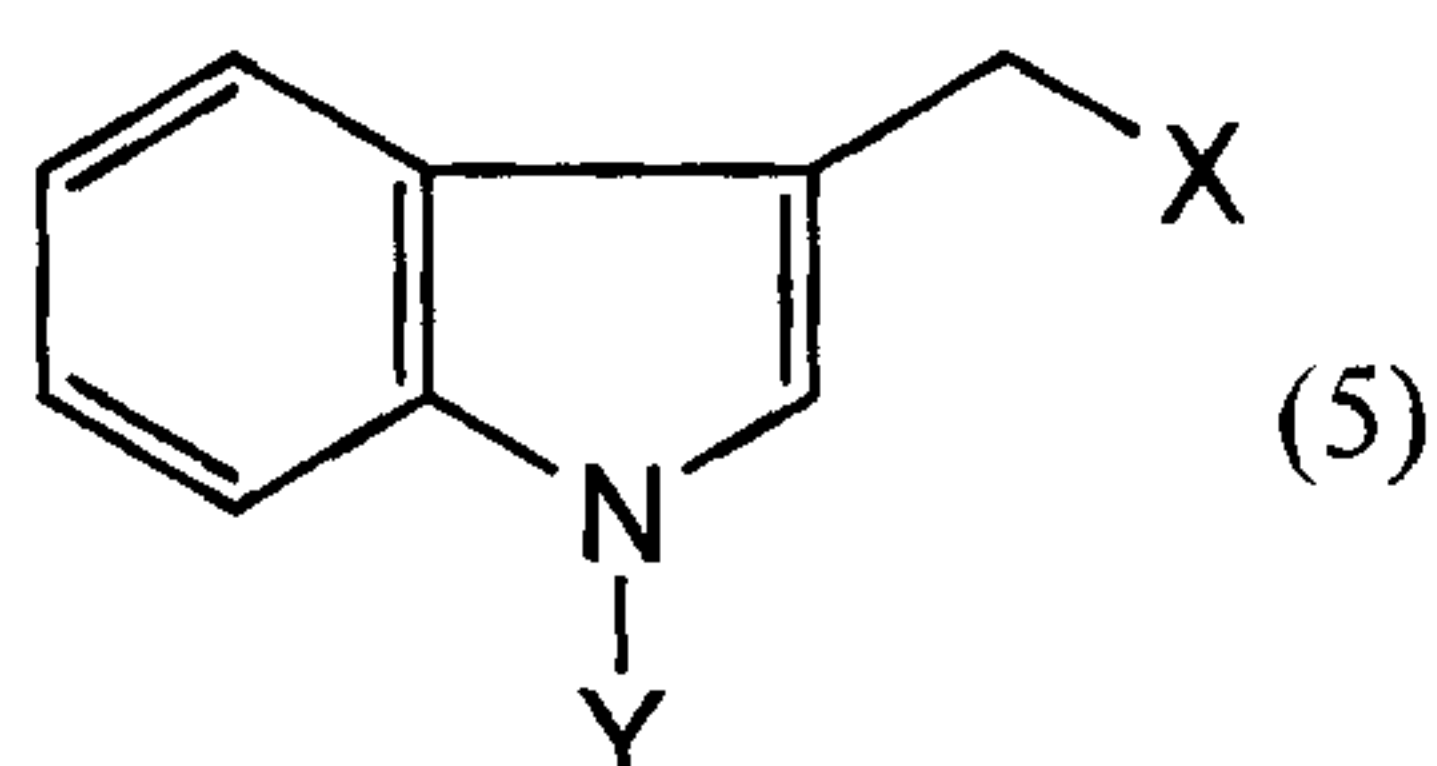
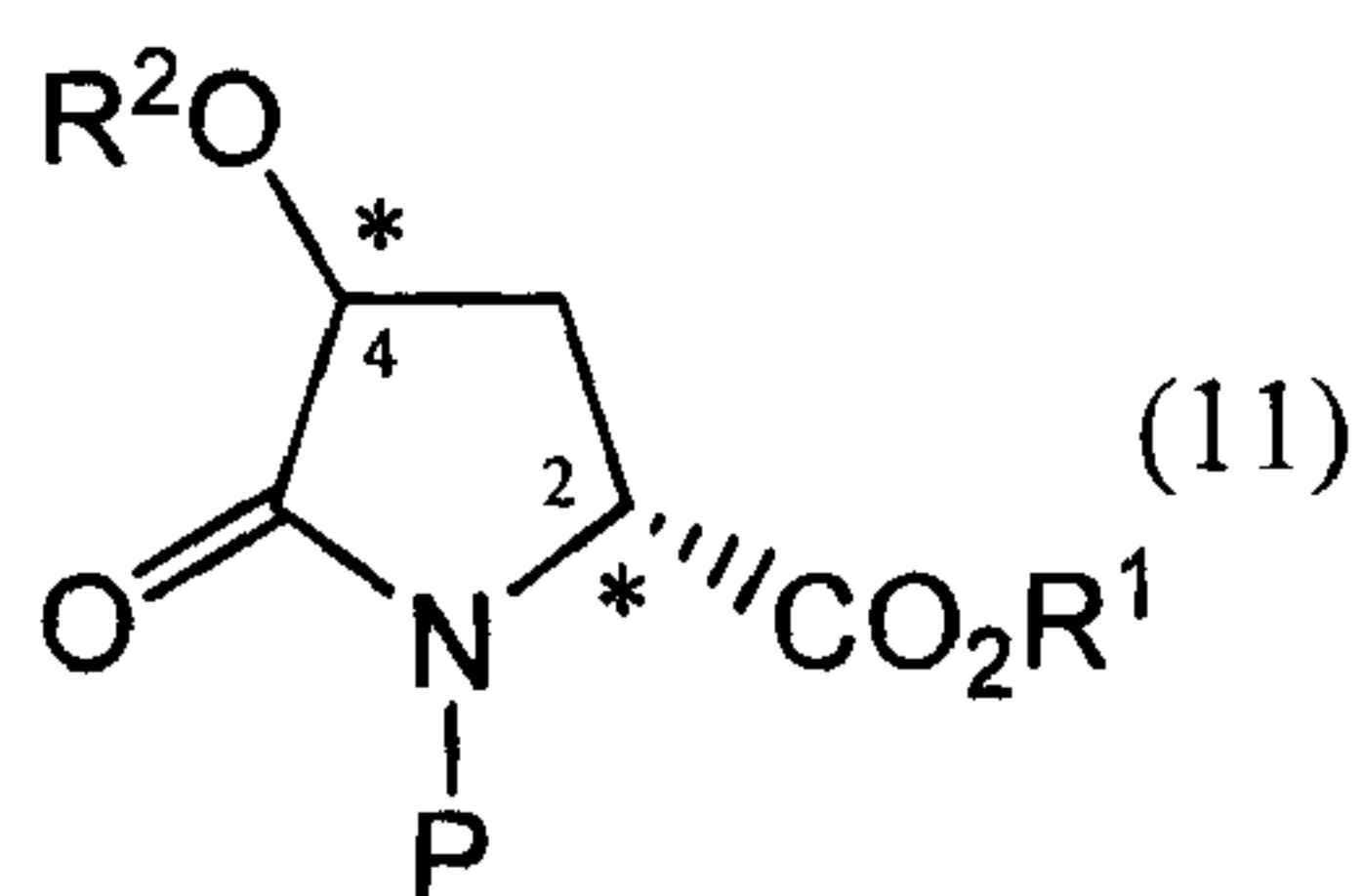
28. A method as set forth in claim 26, wherein the base is used in a molar ratio of between 1.0 and 2.0 to 1 relative to the 4-protected hydroxyglutamic acid derivative.

29. A method of manufacturing a (2R, 4R)-monatin derivative represented by formula (13) below or salt thereof, characterized by reacting a (2R)-4-protected hydroxy-pyroglutamic acid derivative represented by formula (11) below or salt thereof with N-protected-3-halogenomethylindole represented by formula (5) below to prepare a (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (12) below or salt thereof and subjecting the derivative to hydrolysis and deprotection steps:



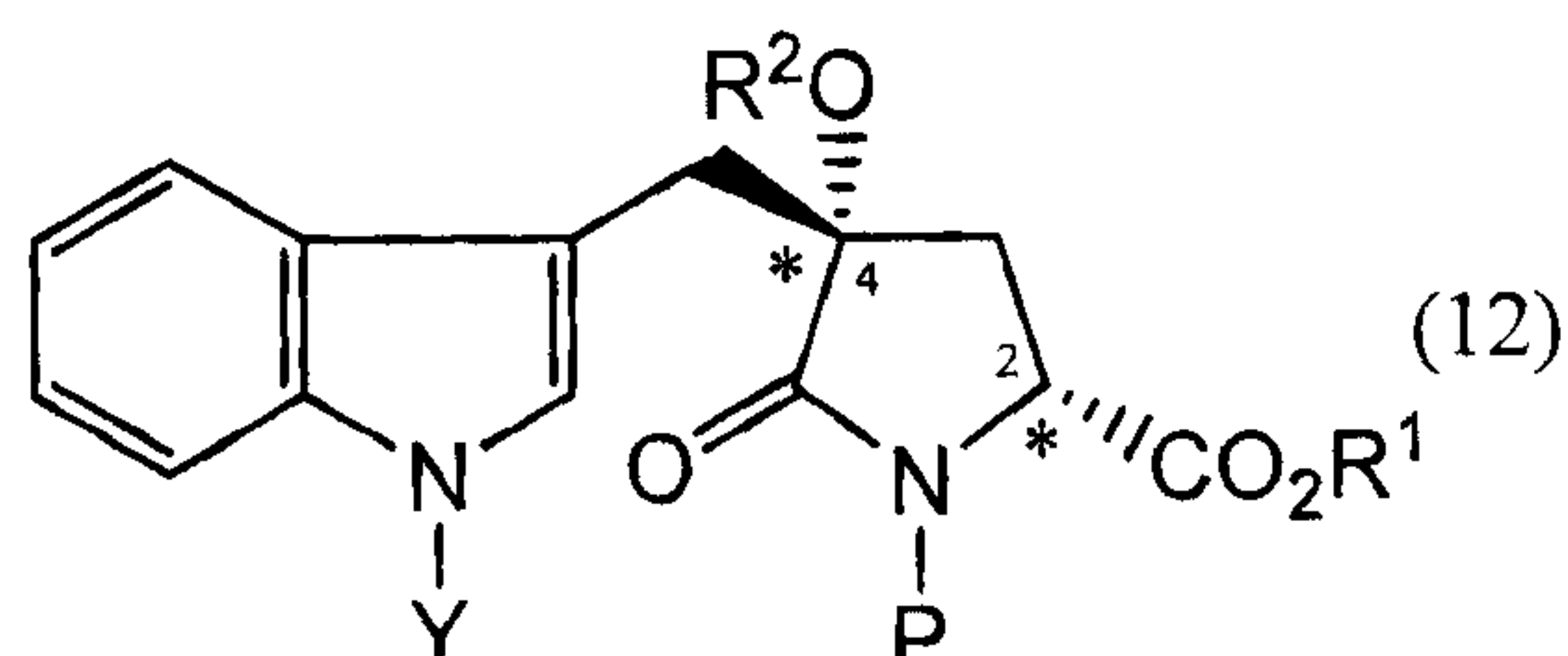
where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group and the configuration at the 4-position in formula (11) is R, S or RS.

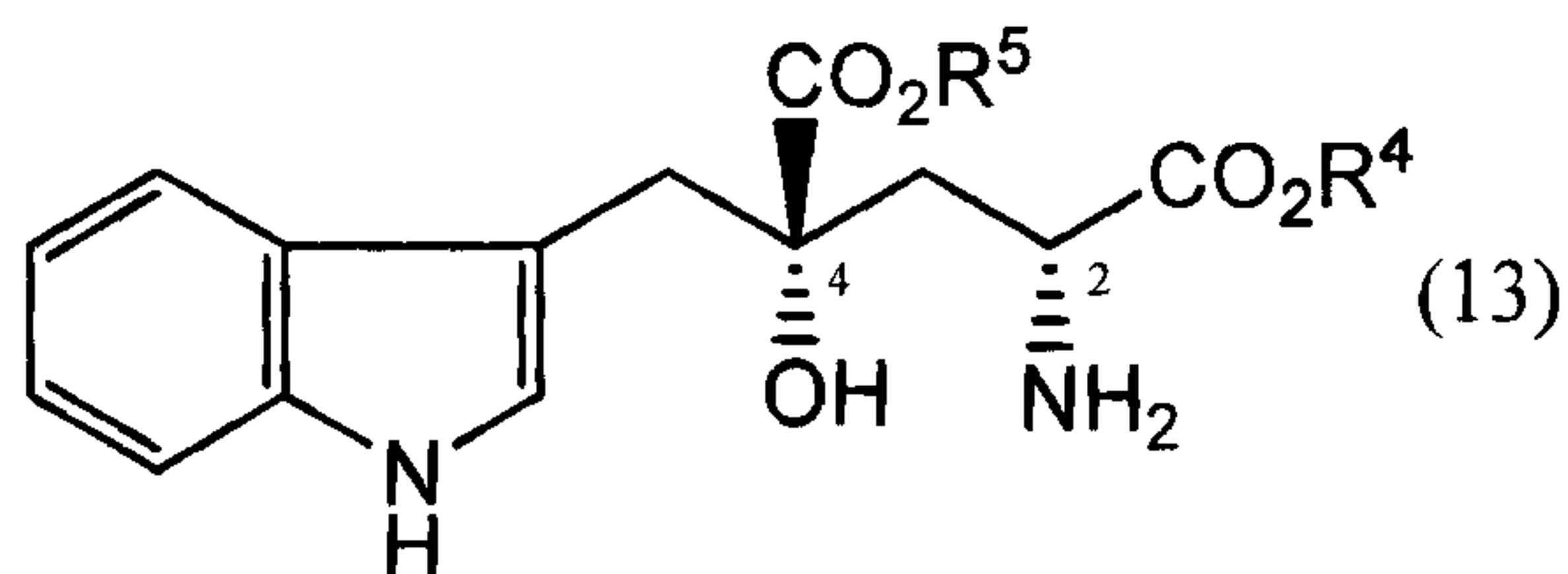
30. A method of manufacturing a (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (12) below or salt thereof, characterized by reacting a (2R)-4-protected hydroxypyroglutamic acid derivative represented by formula (11) below or salt thereof with N-protected-3-halogenomethylindole represented by formula (5) below:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group and the configuration at the 4-position in formula (11) is R, S or RS.

31. A method of manufacturing a (2R, 4R)-monatin derivative represented by formula (13) below or salt thereof, characterized by subjecting a (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (12) below or salt thereof to hydrolysis and deprotection steps:





where R^1 , R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group.

32. A method as set forth in claim 29, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

33. A method as set forth in claim 30, wherein R^1 stands for a group selected from a hydrogen atom, an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

34. A method as set forth in claim 31, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

35. A method as set forth in claim 29 or 30, wherein the reaction of a (2R)-4-protected hydroxypyroglutamic acid derivative represented by formula (11) with N-protected-3-halogenomethylindole represented by formula (5) is performed in the presence of a base.

36. A method as set forth in claim 26, wherein the base is one or more kinds of base selected from lithium hexamethyldisilazane, potassium hexamethyl-disilazane, sodium hexamethyldisilazane, lithium diisopropylamide and normal butyl lithium.

37. A method as set forth in claim 36, wherein the base is used in a molar ratio of between 1.0 and 2.0 to 1 relative to the 4-protected hydroxyglutamic acid derivative.

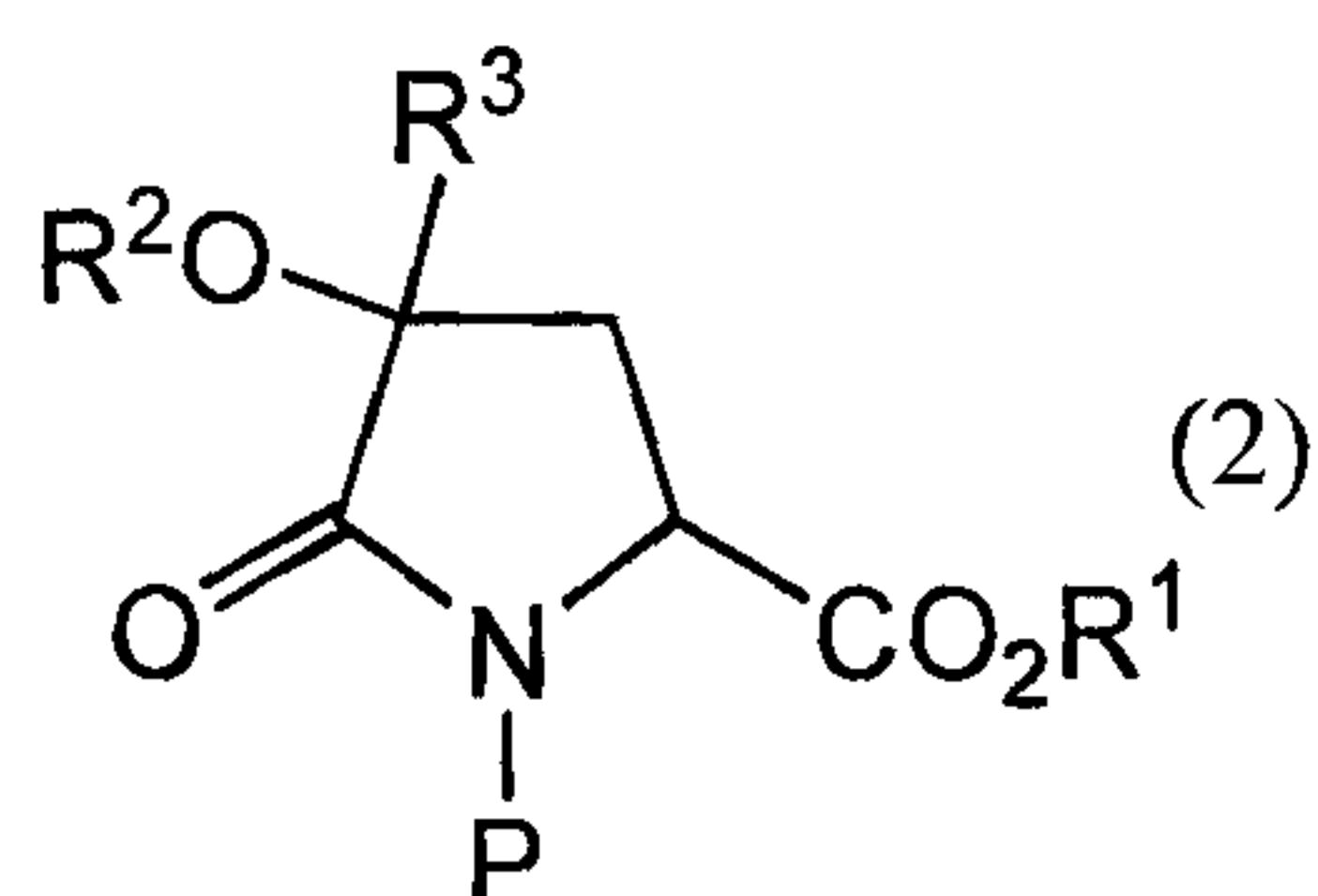
38. A method as set forth in claim 29, wherein R^1 stands for a methyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a t-butyldimethylsilyl group, X stands for a bromine atom and P and Y stand for a t-butoxycarbonyl group each.

39. A method as set forth in claim 30, wherein R^1 stands for a methyl group, R^2 stands for a t-butyldimethylsilyl

group, X stands for a bromine atom and P and Y stand for a t-butoxycarbonyl group each.

40. A method as set forth in claim 31, wherein R^1 stands for a methyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a t-butyldimethylsilyl group and P and Y stand for a t-butoxycarbonyl group each.

41. A 4-protected hydroxyl-4-substituted pyroglutamic acid derivative represented by formula (2) or salt thereof:

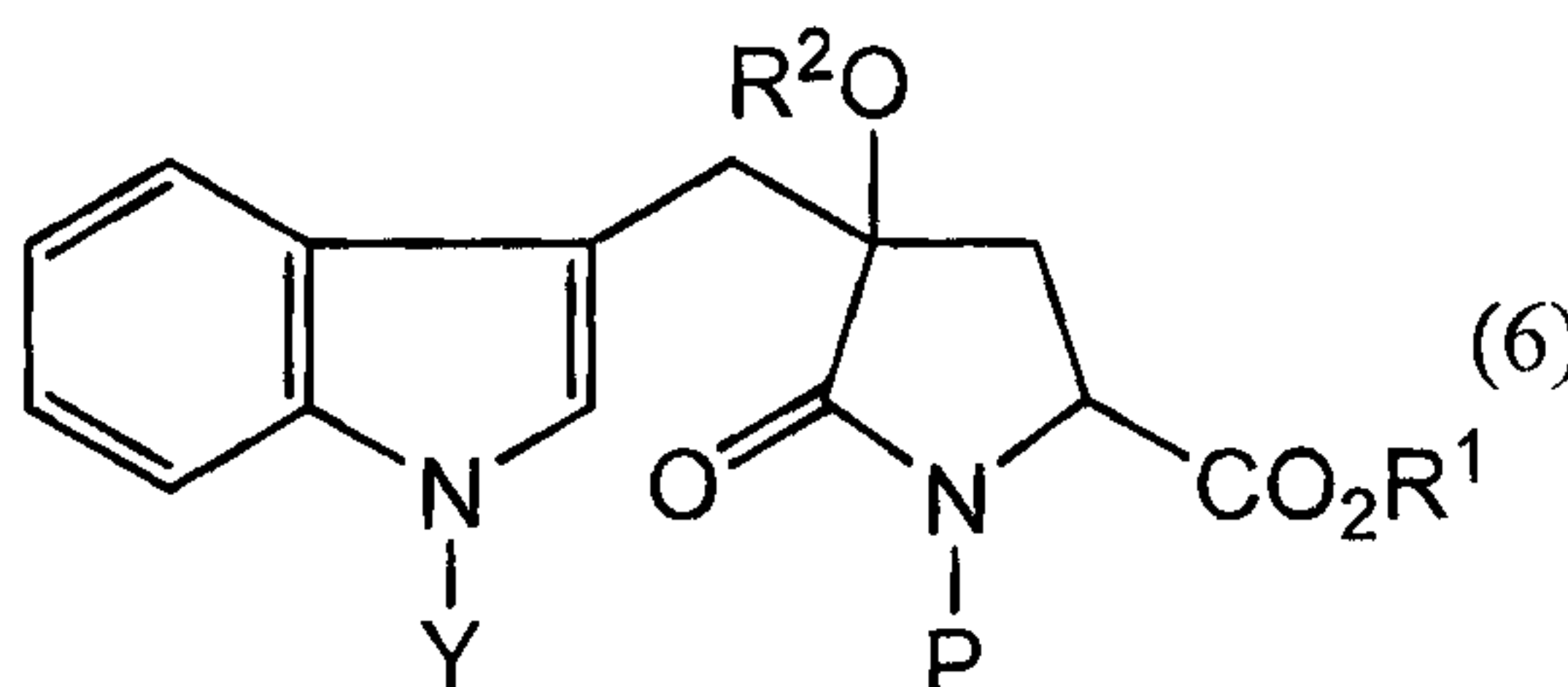


where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group and P stands for a protecting group for an imino group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

42. A 4-protected hydroxyl-4-substituted pyroglutamic acid derivative as set forth in claim 41, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, and R^3 stands for a group selected from an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to 20 carbon atoms, an aralkyl group having

1 to 20 carbon atoms and a heterocyclic hydrocarbon group having 1 to 20 carbon atoms.

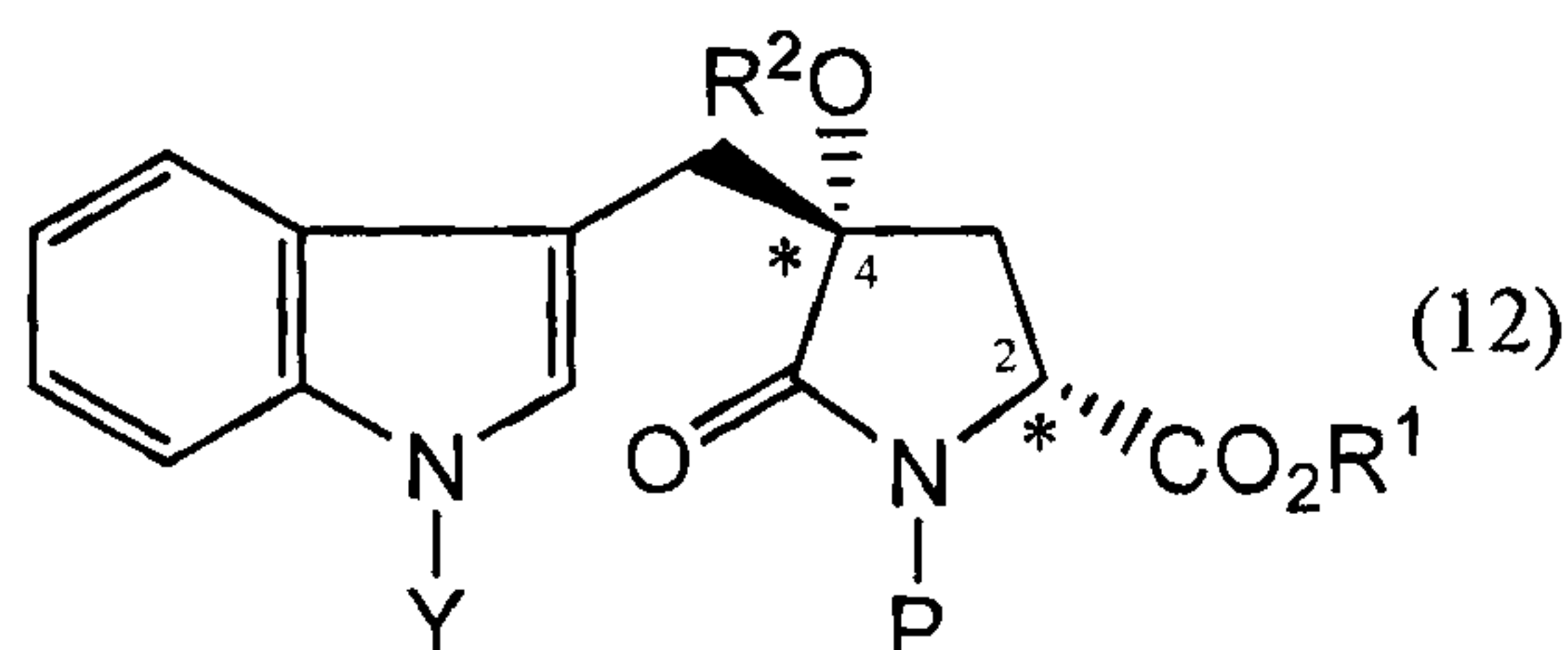
43. A 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) or salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, P stands for a protecting group for an imino group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group and Y stands for a protecting group for an indolyl group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

44. A 4-protected hydroxy-4-substituted pyroglutamic acid derivative as set forth in claim 43, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group.

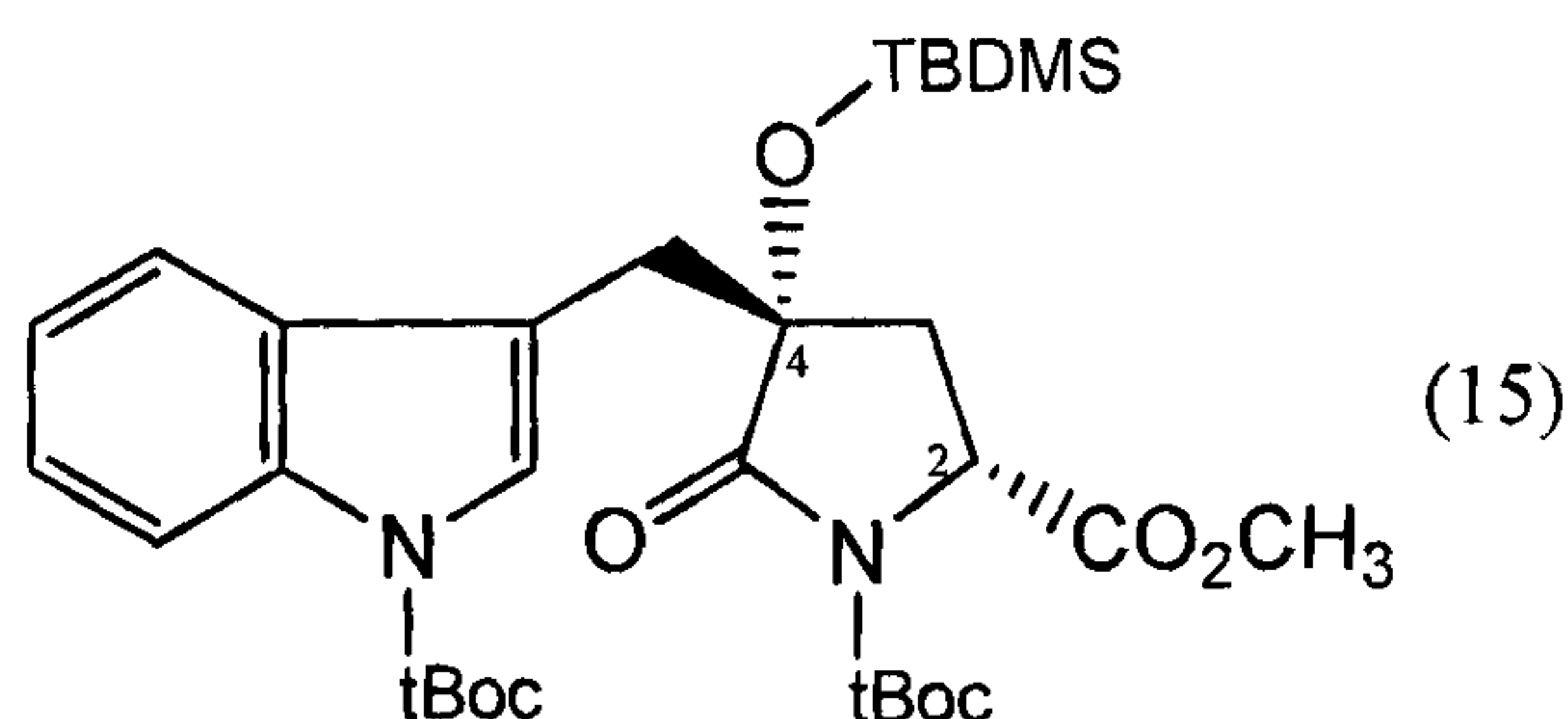
45. A (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (12) or salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, P stands for a protecting group for an imino group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group, and Y stands for a protecting group for an indolyl group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

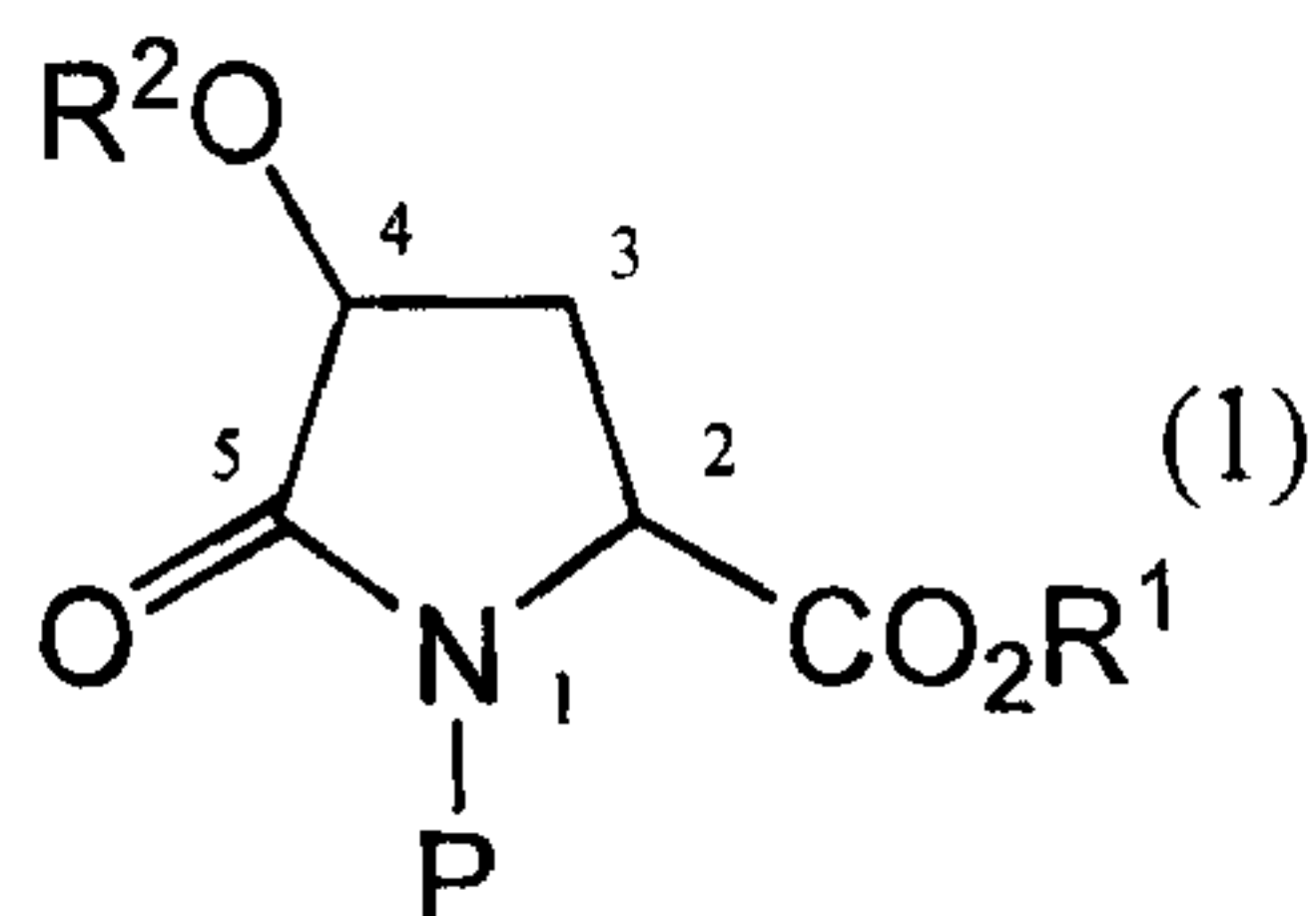
46. A (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative as set forth in claim 45, wherein R^1 stands for a group selected from an alkyl group having 1 to carbon atoms and a benzyl group.

47. An N-t-butoxycarbonyl-(4R)-4-t-butyldimethylsilyloxy-4-benzyl -D-pyroglutamic acid methyl ester represented by formula (15) below:

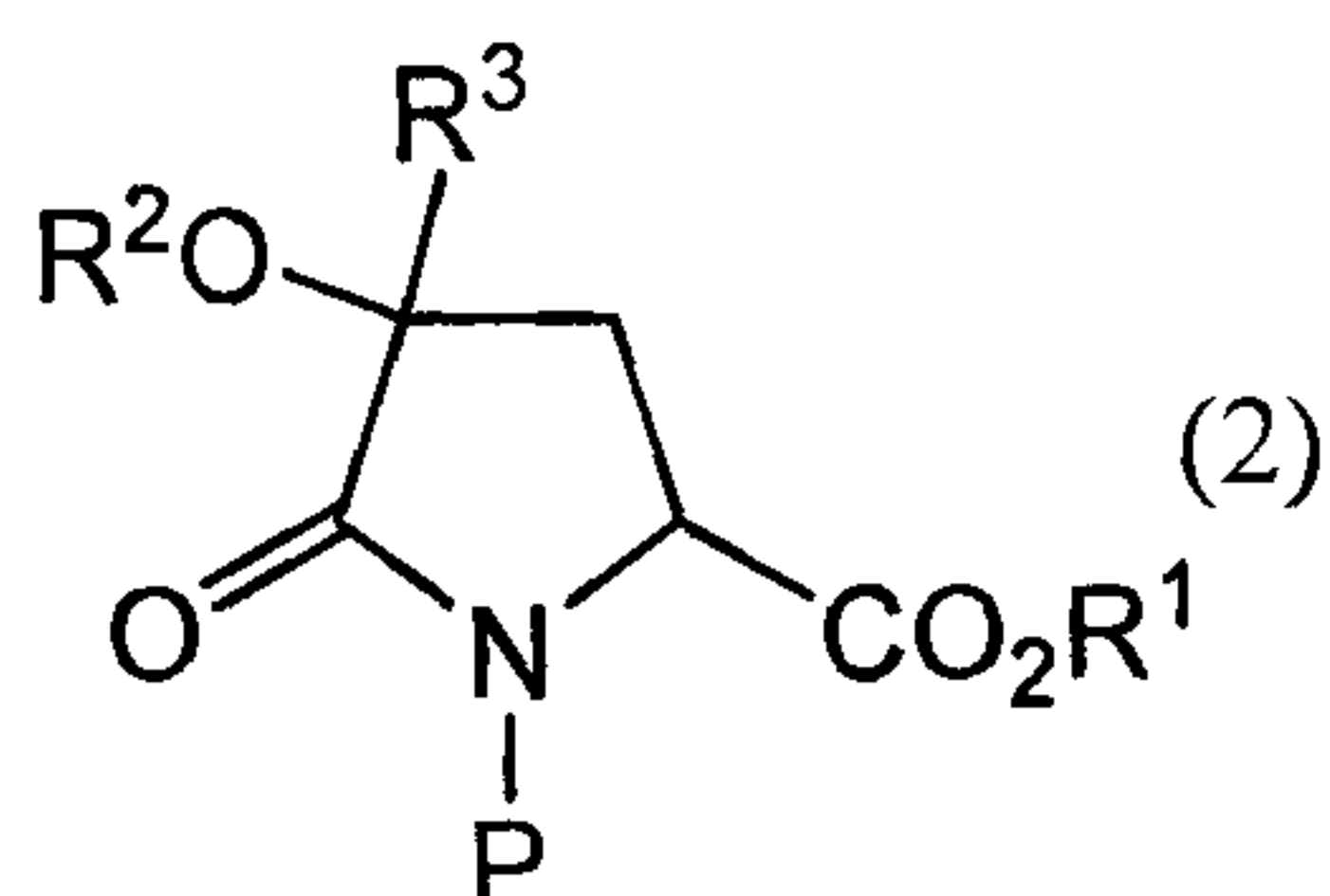


where tBoc stands for a t-butoxycarbonyl group and TBDMS stands for a t-butyldimethylsilyl group.

48. A method comprising subjecting a 4-protected hydroxypyroglutamic acid derivative represented by formula (1) below or a salt thereof:



to an alkylation reaction to produce a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (2) below, or a salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group and P stands for a protecting group for an imino group.

49. A method as set forth in claim 48, wherein R^3 is a benzyl group or an N-protected-3-indolylmethyl group.

50. A method as set forth in claim 48, wherein the alkylation reaction is performed in the presence of an alkylating agent represented by formula (4) below:



where R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic

hydrocarbon group optionally having a substituent and X stands for a halogen atom.

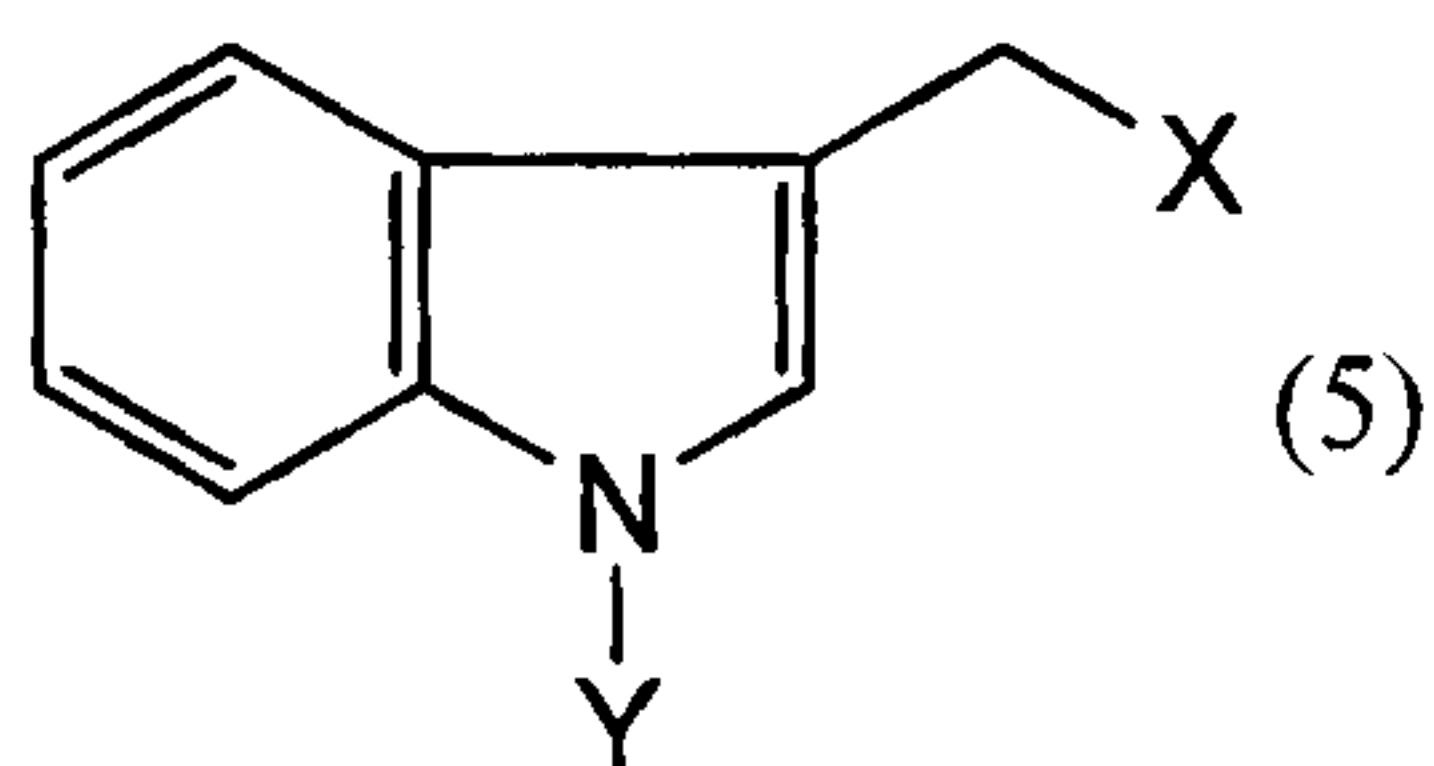
51. A method as set forth in claim 50, wherein alkylation reaction is performed in the presence of a base.

52. A method as set forth in claim 50, wherein the base is one or more kinds of base selected from lithium hexamethyldisilazanide, potassium hexamethyldisilazanide, sodium hexamethyldisilazanide, lithium diisopropylamide and normal butyl lithium.

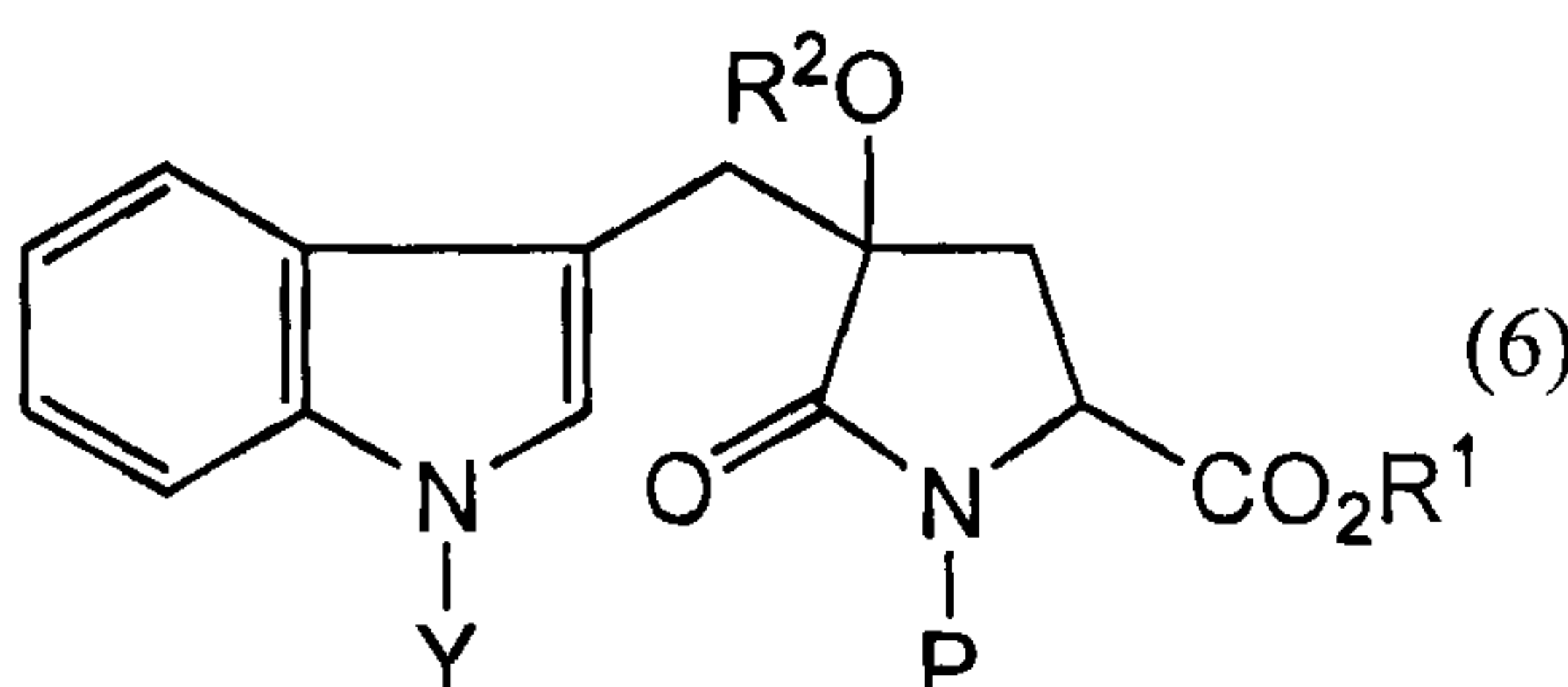
53. A method as set forth in claim 50, wherein the base is used in a molar ratio of between 1.0 and 2.0 to 1 relative to the 4-protected hydroxyglutamic acid derivative.

54. A method as set forth in claim 48, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, R^3 stands for a group selected from an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to 20 carbon atoms, an aralkyl group having 1 to 20 carbon atoms and a heterocyclic hydrocarbon group having 1 to 20 carbon atoms, and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

55. A method according to any one of claims 48 to 54, wherein the 4-protected hydroxypyroglutamic acid derivative represented by formula (1) as set out in claim 48, or a salt thereof, is subjected to alkylation with N-protected-3-halogeno-methylindole represented by formula (5) below:

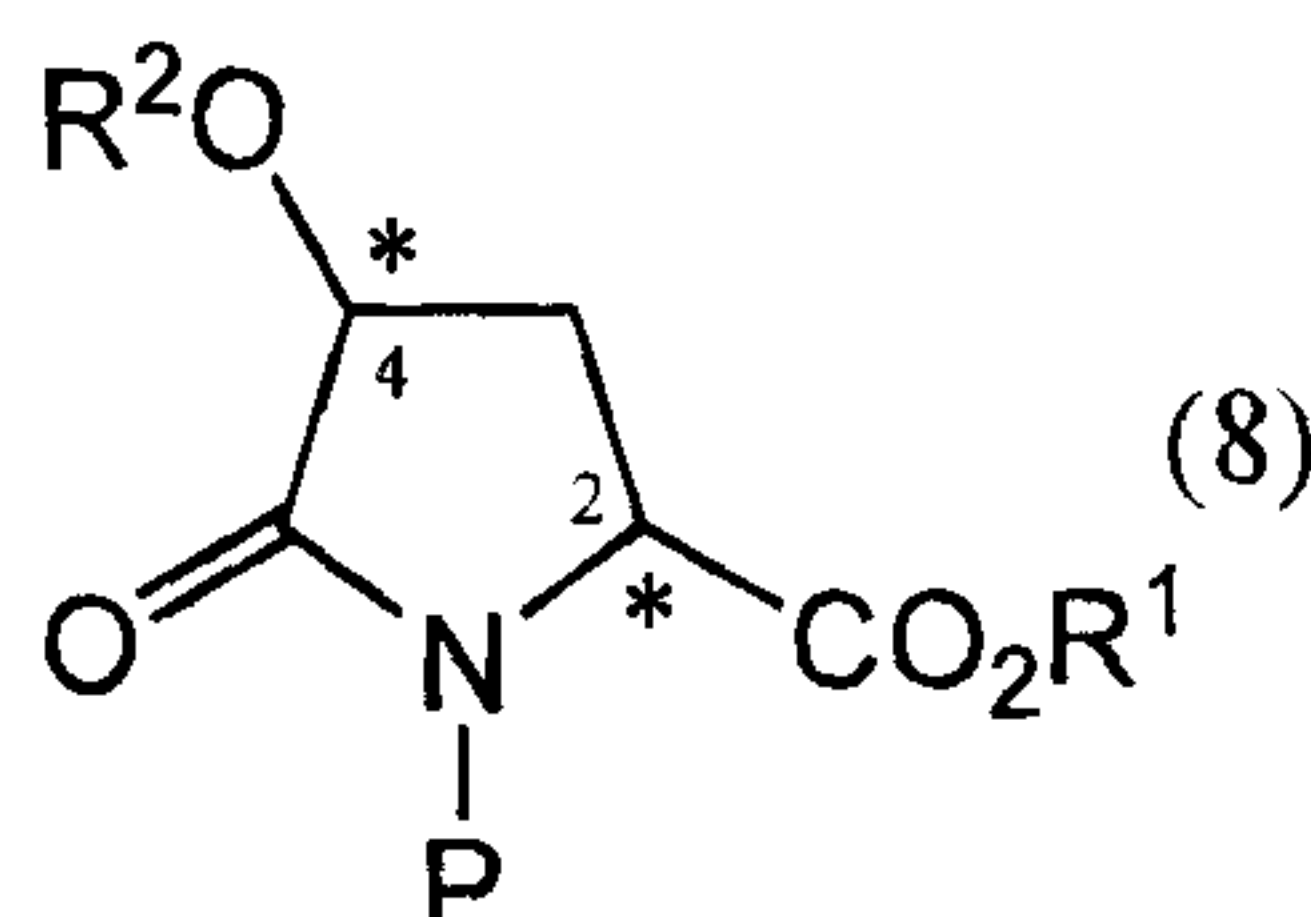


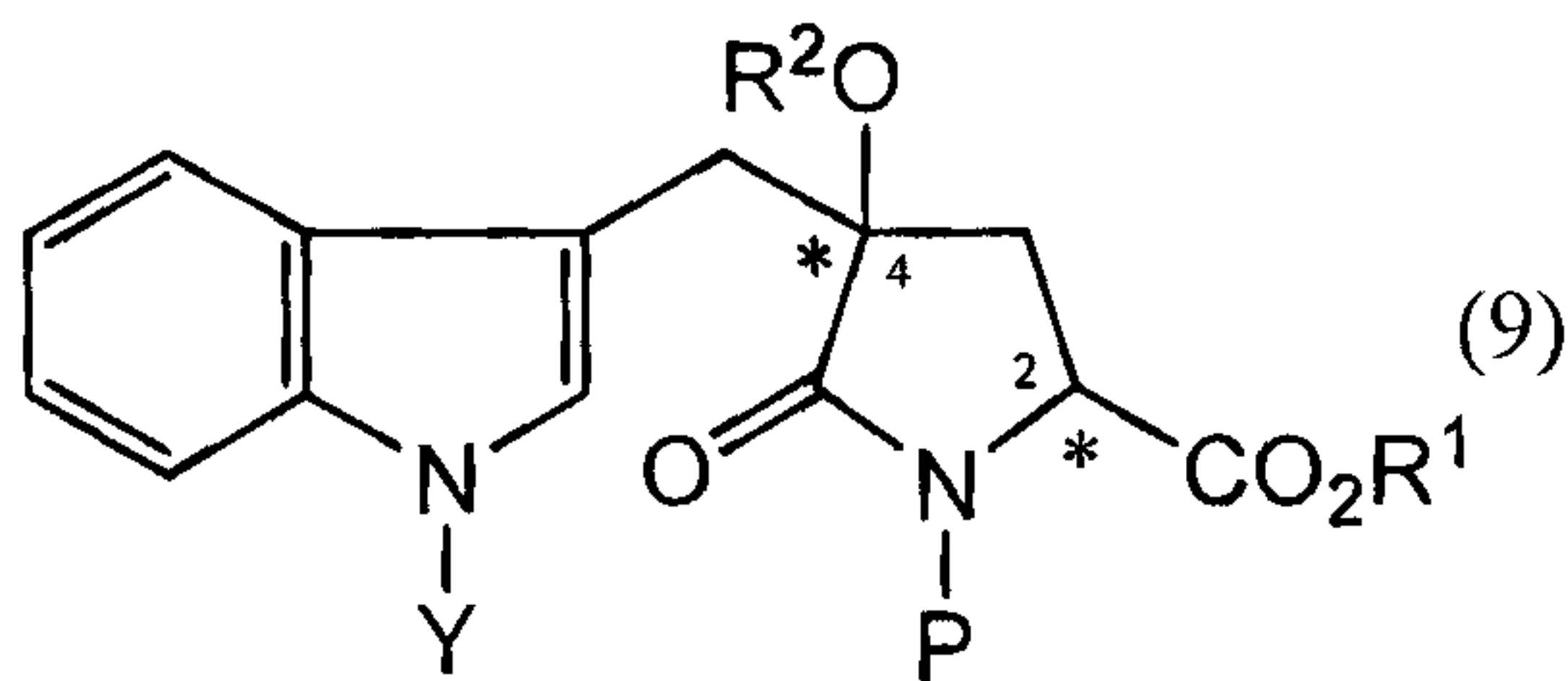
thereby to produce a 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) below, or a salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, X stands for a halogen atom, P stands for a protecting group for an imino group and Y stands for a protecting group for an indolyl group.

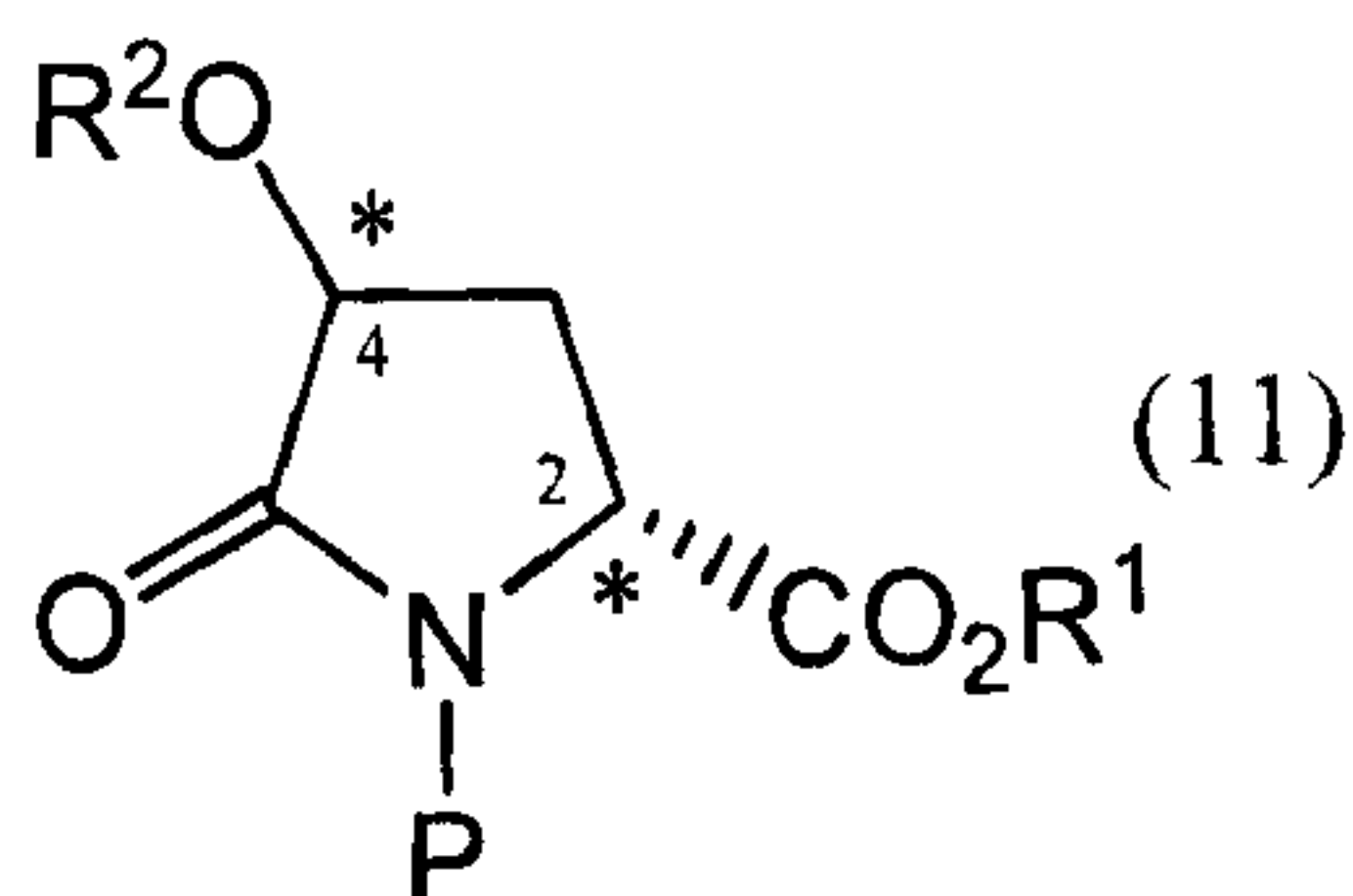
56. A method according to claim 55, wherein the 4-protected hydroxypyroglutamic acid derivative of formula (1) or salt thereof is an optically active 4-protected hydroxypyroglutamic acid derivative represented by formula (8) below or a salt thereof, and alkylation with the N-protected-3-halogenomethylindole represented by formula (5) results in production of an optically active 4-protected hydroxy-4-substituted pyroglutamic acid derivative of formula (9) below, or a salt thereof:

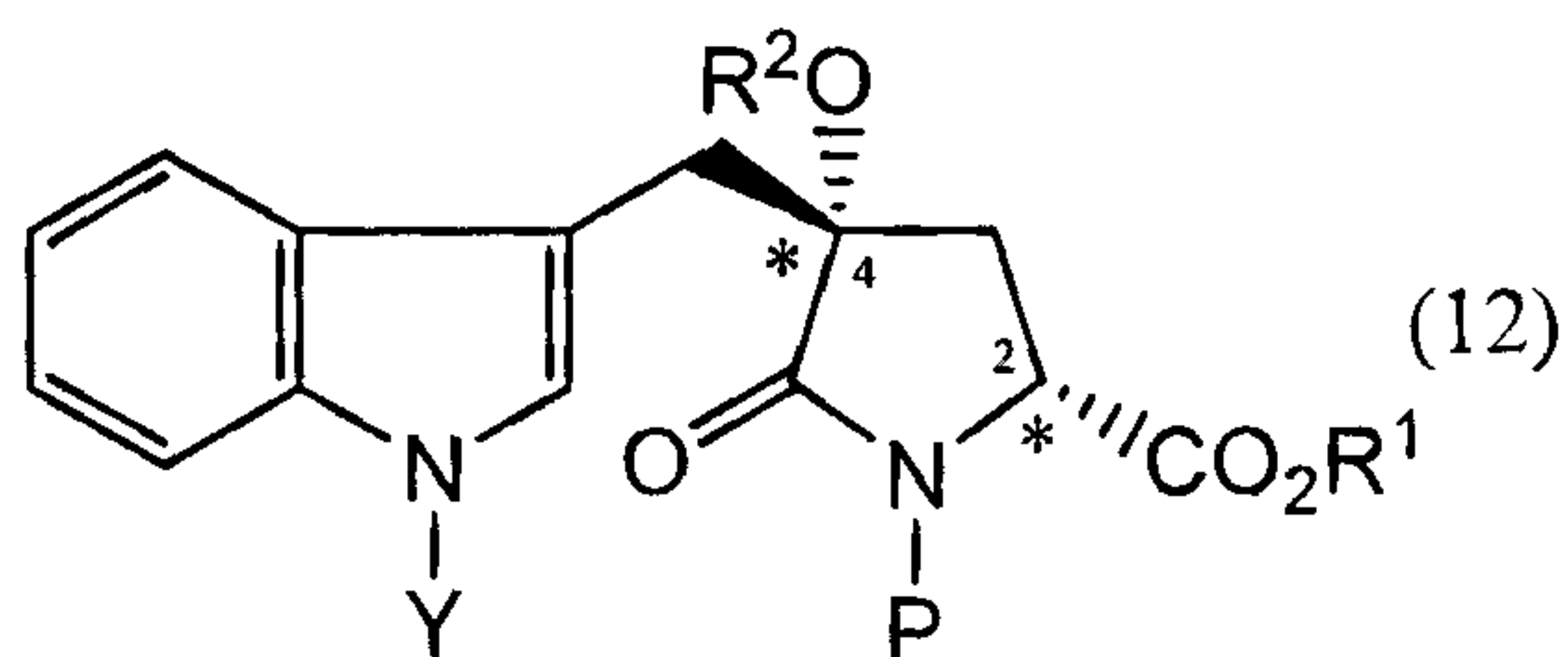




where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group, * stands for an asymmetric carbon atom, the configuration at the 2-position in formula (8) is R or S, the configuration at the 4-position is R, S or RS, so that when the configuration at the 2-position in formula (8) is R, the configurations in formula (9) are (2R, 4R), respectively, and when the configuration at the 2-position in formula (8) is S, the configurations in formula (9) are (2S, 4S), respectively.

57. A method according to claim 56, wherein the 4-protected hydroxypyroglutamic acid derivative of formula (1) or salt thereof is a (2R)-4-protected hydroxypyroglutamic acid derivative represented by formula (11) below, or a salt thereof, and alkylation with N-protected-3-halogenomethylindole represented by formula (5) results in production of a (2R,4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative of formula (12) or a salt thereof:





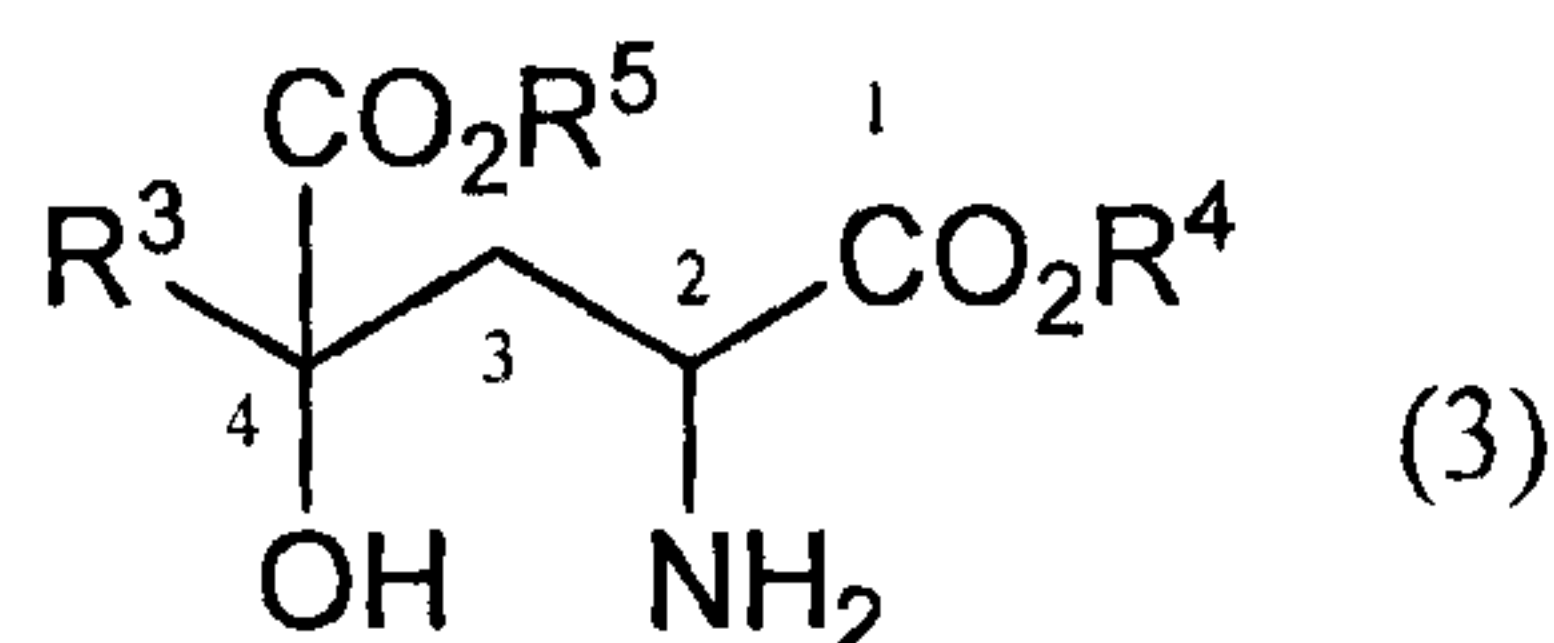
where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group, P stands for a protecting group for an imino group, Y stands for a protecting group for an indolyl group and the configuration at the 4-position in formula (11) is R, S or RS.

58. A method as set forth in any one of claims 55 to 57, wherein R^1 stands for a group selected from a hydrogen atom, an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

59. A method as set forth in claim 57, wherein R^1 stands for a methyl group, R^2 stands for a t-butyldimethylsilyl group, X stands for a bromine atom and P and Y stand for a t-butoxycarbonyl group each.

60. A method according to any one of claims 48 to 53, further comprising subjecting the derivative of formula (2) or a salt thereof to hydrolysis and deprotection steps

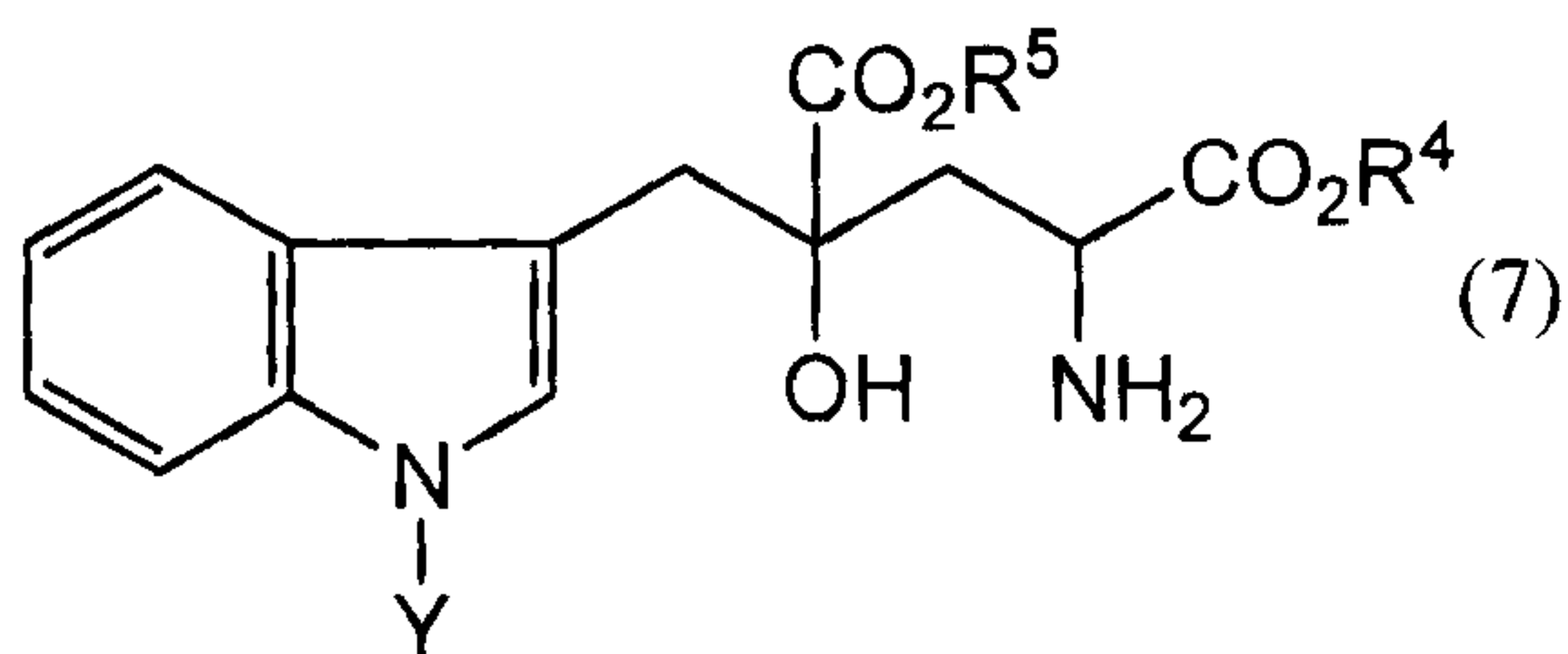
thereby to produce a glutamic acid derivative represented by formula (3) below or a salt thereof:



where R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, and R^3 stands for a group selected from a hydrocarbon group optionally having a substituent and a heterocyclic hydrocarbon group optionally having a substituent.

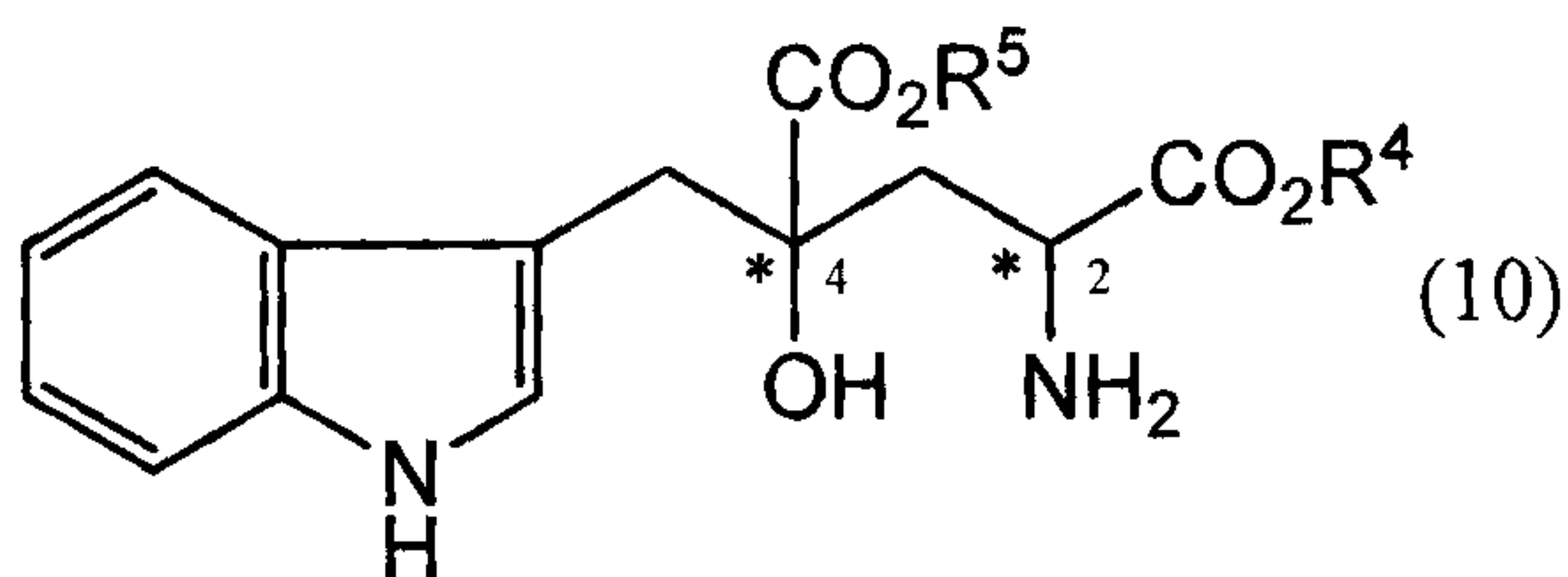
61. A method as set forth in claim 60, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, R^3 stands for a group selected from an alkyl group having 1 to 20 carbon atoms, an aryl group having 1 to 20 carbon atoms, an aralkyl group having 1 to 20 carbon atoms and a heterocyclic hydrocarbon group having 1 to 20 carbon atoms and P stands for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

62. A method according to claim 55, further comprising subjecting the derivative of formula (6), or a salt thereof to hydrolysis and deprotection steps thereby to produce a monatin acid derivative represented by formula (7) below, or a salt thereof:



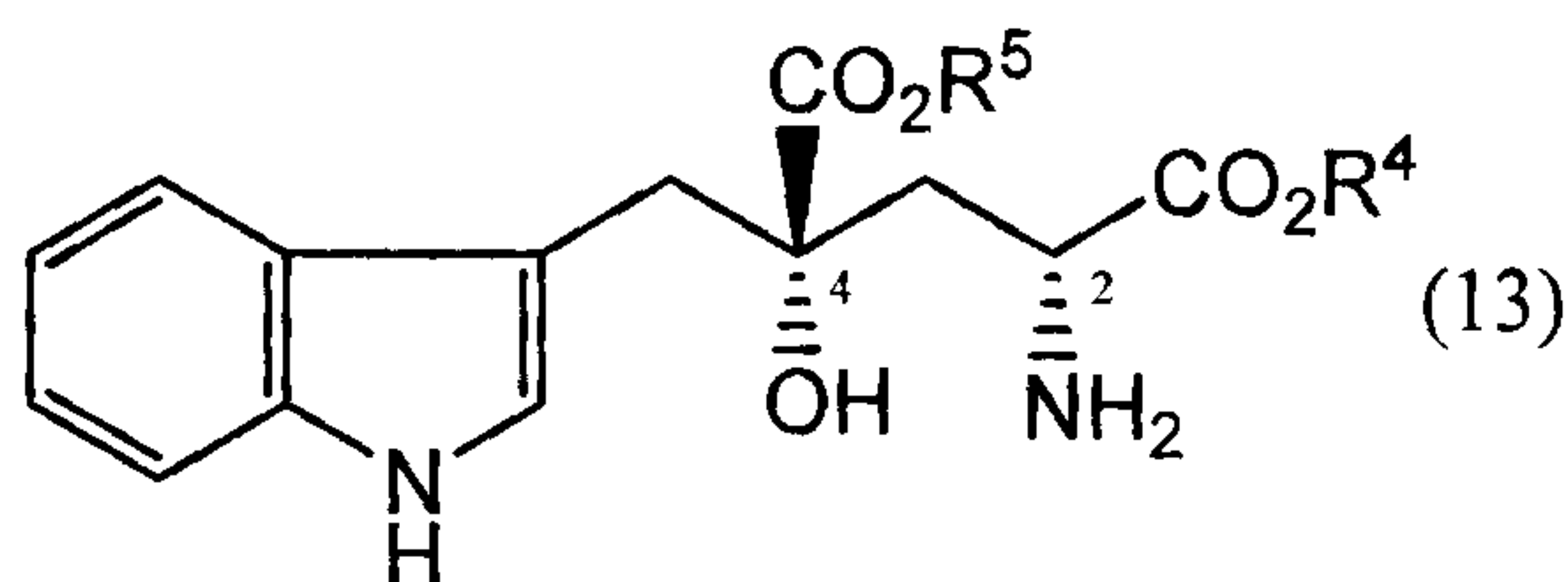
where R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, and Y stands for a protecting group for an indolyl group.

63. A method according to claim 56, further comprising subjecting the derivative of formula (9), or a salt thereof to hydrolysis and deprotection steps thereby to produce an optically active monatin derivative represented by formula (10) below, or a salt thereof:



where R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group, * stands for an asymmetric carbon atom, the configuration at the 2-position in formula (8) as set out in claim 56 is R or S, the configuration at the 4-position is R, S or RS, so that when the configuration at the 2-position in formula (8) is R, the configurations in formulas (9) and (10) are (2R, 4R), respectively, and when the configuration at the 2-position in formula (8) is S, the configurations in formulas (9) as set out in claim 56 and (10) are (2S, 4S), respectively.

64. A method according to claim 57, further comprising subjecting the derivative of formula (12), or a salt thereof to hydrolysis and deprotection steps thereby to produce a (2R,4R)-monatin derivative represented by formula (13) below, or a salt thereof:

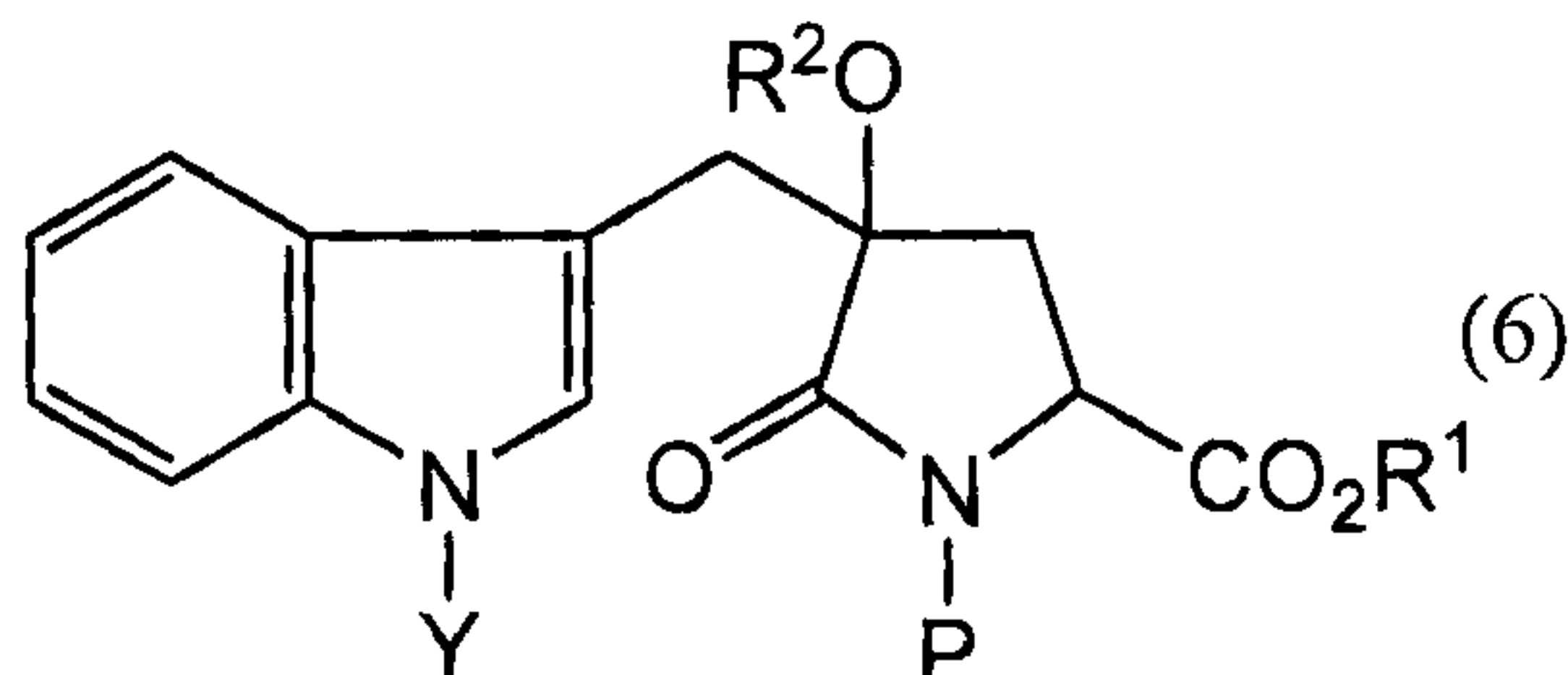


where R^4 and R^5 stand independently of one another for a group selected from a hydrogen atom and a hydrocarbon group.

65. A method according to any one of claims 62 to 64, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, X stands for a group selected from a chlorine atom, a bromine atom and an iodine atom and P and Y stand independently of each other for a group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

66. A method as set forth in claim 64, wherein R^1 stands for a methyl group, R^4 and R^5 stand for a hydrogen atom each, R^2 stands for a t-butyldimethylsilyl group, X stands for a bromine atom and P and Y stand for a t-butoxycarbonyl group each.

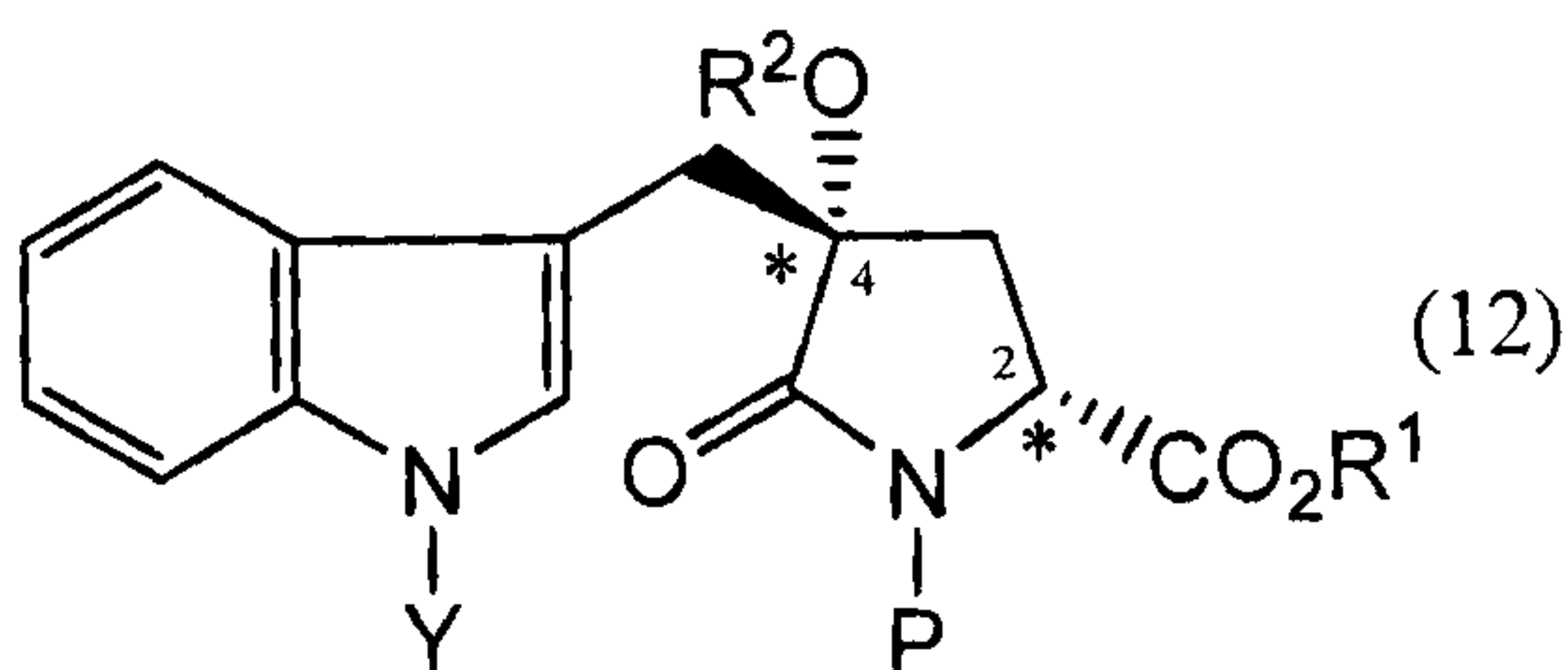
67. A 4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (6) or a salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, P stands for a protecting group for an imino group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group and Y stands for a protecting group for an indolyl group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

68. A 4-protected hydroxy-4-substituted pyroglutamic acid derivative as set forth in claim 67, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group.

69. A (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative represented by formula (12) or a salt thereof:



where R^1 stands for a group selected from a hydrogen atom and a hydrocarbon group, R^2 stands for a protecting group for a hydroxyl group selected from a t-butyldimethylsilyl group, a trimethylsilyl group, a t-butyldiphenylsilyl group, a benzyl group, a t-butyl group, a benzyloxycarbonyl group and a t-butoxycarbonyl group, P stands for a protecting group for an imino group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group, and Y stands for a protecting group for an indolyl group selected from a t-butoxycarbonyl group, a benzyloxycarbonyl group and a benzyl group.

70. A (2R, 4R)-4-protected hydroxy-4-substituted pyroglutamic acid derivative as set forth in claim 69, wherein R^1 stands for a group selected from an alkyl group having 1 to 5 carbon atoms and a benzyl group.