The invention relates to a dihydrospiro-[cycloalkyl]-pyrimidone derivative represented by formula (I) or a salt thereof: wherein: X represents two hydrogen atoms, a sulfur atom, an oxygen atom or a C₁₋₂ alkyl group and a hydrogen atom; Y represents a bond, a carbonyl group, a methylene group optionally substituted; R₁ represents a 2, 3 or 4-pyridine ring or a 2, 4 or 5-pyrimidine ring, the ring being optionally substituted; R₂ represents a benzene ring or a naphthalene ring; the rings being optionally substituted; R₃ represents a hydrogen atom, a C₁₋₂ alkyl group or a halogen atom; m represents 1 to 4 n represents 0 to 3 p represents 0 to 2 q represents 0 to 2; p+ q being inferior to 4. The invention relates also to a medicament comprising the said derivative or a salt thereof as an active ingredient which is used for preventive and/or therapeutic treatment of a neurodegenerative disease caused by abnormal activity of GSK3β, such as Alzheimer disease.
Title: SUBSTITUTED 8'-PYRIDINYL-DIHYDROSPiro[CYCLOALKYL]-PYRIMIDO[1,2-a] PYRIMIDIN-6-ONE AND 8'-PYRIMIDINYL-DIHYDROSPiro[CYCLOALKYL]-PYRIMIDO[1,2-a] PYRIMIDIN-6-ONE DERIVATIVES AND THEIR USE AGAINST NEUROGENERATIVE DISEASES

Abstract: The invention relates to a dihydrospiro-[cycloalkyl]-pyrimidone derivative represented by formula (I) or a salt thereof:

wherein: X represents two hydrogen atoms, a sulfur atom, an oxygen atom or a C1-2 alkyl group and a hydrogen atom; Y represents a bond, a carbonyl group, a methylene group optionally substituted; R1 represents a 2, 3 or 4-pyridine ring or a 2, 4 or 5-pyrimidine ring, the ring being optionally substituted; R2 represents a benzene ring or a naphthalene ring; the rings being optionally substituted; R3 represents a hydrogen atom, a C1-4 alkyl group or a halogen atom; m represents 1 to 4 n represent 0 to 3 p represents 0 to 2 q represents 0 to 2, p+q being inferior to 4. The invention relates also to a medicament comprising the said derivative or a salt thereof as an active ingredient which is used for preventive and/or therapeutic treatment of a neurodegenerative disease caused by abnormal activity of GSK3β, such as Alzheimer disease.
SPECIFICATION

SUBSTITUTED 8'-PYRIDINYL-DIHYDROSPIRO-[CYCLOALKYL] -PYRIMIDO[1,2-A]PYRIMIDIN-6-ONE AND 8'-PYRIDINYL-DIHYDROSPIRO-[CYCLOALKYL] -PYRIMIDO[1,2-A]PYRIMIDIN-6-ONE DERIVATIVES AND THEIR USE AGAINST NEUROGENERATIVE DISEASES

Technical Field

The present invention relates to compounds that are useful as an active ingredient of a medicament for preventive and/or therapeutic treatment of neurodegenerative diseases caused by abnormal activity of GSK3β.

Background Art

GSK3β (glycogen synthase kinase 3β) is a proline directed serine, threonine kinase that plays an important role in the control of metabolism, differentiation and survival. It was initially identified as an enzyme able to phosphorylate and hence inhibit glycogen synthase. It was later recognized that GSK3β was identical to tau protein kinase 1 (TPK1), an enzyme that phosphorylates tau protein in epitopes that are also found to be hyperphosphorylated in Alzheimer’s disease and in several tauopathies.

Interestingly, protein kinase B (AKT) phosphorylation of GSK3β results in a loss of its kinase activity, and it has been hypothesized that this inhibition may mediate some of the effects of neurotrophic factors. Moreover, phosphorylation by GSK3β of β-catenin, a protein involved in cell survival, results in its degradation by an ubiquitinilation dependent proteasome pathway.

Thus, it appears that inhibition of GSK3β activity may result in neurotrophic activity. Indeed there is evidence that lithium, an uncompetitive inhibitor of GSK3β, enhances neuritogenesis in some models and also increases neuronal survival, through the induction of survival factors such as Bcl-2 and the inhibition of the expression of proapoptotic factors such as P53 and Bax.

Recent studies have demonstrated that β-amyloid increases the GSK3β activity and tau protein phosphorylation. Moreover, this hyperphosphorylation as well as the neurotoxic effects of β-amyloid are blocked by lithium chloride and by a GSK3β antisense mRNA. These observations strongly suggest that GSK3β may be the link between the two major pathological processes in Alzheimer’s disease:

abnormal APP (Amyloid Precursor Protein) processing and tau protein hyperphosphorylation.
Although tau hyperphosphorylation results in a destabilization of the neuronal cytoskeleton, the pathological consequences of abnormal GSK3β activity are, most likely, not only due to a pathological phosphorylation of tau protein because, as mentioned above, an excessive activity of this kinase may affect survival through the modulation of the expression of apoptotic and antiapoptotic factors. Moreover, it has been shown that β-amyloid-induced increase in GSK3β activity results in the phosphorylation and, hence the inhibition of pyruvate dehydrogenase, a pivotal enzyme in energy production and acetylcholine synthesis.

Altogether these experimental observations indicate that GSK3β may find application in the treatment of the neuropathological consequences and the cognitive and attention deficits associated with Alzheimer’s disease, as well as other acute and chronic neurodegenerative diseases. These include, in a non-limiting manner, Parkinson’s disease, tauopathies (e.g. frontotemporalparietal dementia, corticobasal degeneration, Pick’s disease, progressive supranuclear palsy) and other dementia including vascular dementia; acute stroke and others traumatic injuries; cerebrovascular accidents (e.g. age related macular degeneration); brain and spinal cord trauma; peripheral neuropathies; retinopathies and glaucoma.

In addition GSK3β may find application in the treatment of other diseases such as: Non-insulin dependent diabetes (such as diabetes type II) and obesity; manic depressive illness; schizophrenia; alopecia;cancers such as breast cancer, non-small cell lung carcinoma, thyroid cancer, T or B-cell leukemia and several virus-induced tumors.

Disclosure of the Invention

An object of the present invention is to provide compounds useful as an active ingredient of a medicament for preventive and/or therapeutic treatment of a disease caused by abnormal GSK3β activity, more particularly of neurodegenerative diseases. More specifically, the object is to provide novel compounds useful as an active ingredient of a medicament that enables prevention and/or treatment of neurodegenerative diseases such as Alzheimer’s disease.

Thus, the inventors of the present invention have identified compounds possessing inhibitory activity against GSK3β. As a result, they found that compounds represented by the following formula (I) had the desired activity and
were useful as an active ingredient of a medicament for preventive and/or therapeutic treatment of the aforementioned diseases.

The present invention thus provides dihydrospiro-[cycloalkyl]-pyrimidone derivatives represented by formula (I) or salts thereof, solvates thereof or hydrates thereof:

\[
\begin{array}{c}
R_2^N \quad \text{Y} \quad \text{X} \quad \text{N} \quad \text{R}_1 \\
\quad \text{R}_2 \quad \text{N} \quad \text{N} \quad \text{R}_3 \\
\quad \text{m} \quad \text{n} \quad \text{p}
\end{array}
\]

wherein:

- X represents two hydrogen atoms, a sulfur atom, an oxygen atom or a C\(_{1-2}\) alkyl group and a hydrogen atom;
- Y represents a bond, a carbonyl group, a methylene group optionally substituted by one or two groups chosen from a C\(_{1-6}\) alkyl group, a hydroxyl group, a C\(_{1-4}\) alkoxy group, a C\(_{1-2}\) perhalogenated alkyl group or an amino group;
- R\(_1\) represents a 2, 3 or 4-pyridine ring or a 2, 4 or 5-pyrimidine ring, the ring being optionally substituted by a C\(_{1-4}\) alkyl group, a C\(_{1-4}\) alkoxy group, or a halogen atom;
- R\(_2\) represents a benzene ring or a naphthalene ring; the rings being optionally substituted by 1 to 4 substituents selected from a C\(_{1-6}\) alkyl group, a methylenedioxy group, a halogen atom, a C\(_{1-2}\) perhalogenated alkyl group, a C\(_{1-3}\) halogenated alkyl group, a hydroxyl group, a C\(_{1-4}\) alkoxy group, a nitro, a cyano, an amino, a C\(_{1-5}\) monoalkylamino group or a C\(_{2-10}\) dialkylamino group;
- R\(_3\) represents a hydrogen atom, a C\(_{1-6}\) alkyl group or a halogen atom;
- m represents 1 to 4;
- n represent 0 to 3;
- p represents 0 to 2; and
- q represents 0 to 2, p + q being inferior to 4.
According to another aspect of the present invention, there is provided a medicament comprising as an active ingredient a substance selected from the group consisting of the pyrimidone derivatives represented by formula (I) and the physiologically acceptable salts thereof, and the solvates thereof and the hydrates thereof. As preferred embodiments of the medicament, there are provided the aforementioned medicament which is used for preventive and/or therapeutic treatment of diseases caused by abnormal GSK3β activity, and the aforementioned medicament which is used for preventive and/or therapeutic treatment of neurodegenerative diseases and in addition other diseases such as: Non-insulin dependent diabetes (such as diabetes type II) and obesity; manic depressive illness; schizophrenia; alopecia; cancers such as breast cancer, non-small cell lung carcinoma, thyroid cancer, T or B-cell leukemia and several virus-induced tumors.

As further preferred embodiments of the present invention, there are provided the aforementioned medicament wherein the diseases are neurodegenerative diseases and are selected from the group consisting of Alzheimer's disease, Parkinson's disease, tauopathies (e.g. frontotemporoparietal dementia, corticobasal degeneration, Pick's disease, progressive supranuclear palsy) and other dementia including vascular dementia; acute stroke and others traumatic injuries; cerebrovascular accidents (e.g. age related macular degeneration); brain and spinal cord trauma; peripheral neuropathies; retinopathies and glaucoma, and the aforementioned medicament in the form of pharmaceutical composition containing the above substance as an active ingredient together with one or more pharmaceutical additives.

The present invention further provides an inhibitor of GSK3β activity comprising as an active ingredient a substance selected from the group consisting of the dihydrospiro-[cycloalkyl]-pyrimidone derivatives of formula (I) and the salts thereof, and the solvates thereof and the hydrates thereof.

According to further aspects of the present invention, there is provided a method for preventive and/or therapeutic treatment of neurodegenerative diseases caused by abnormal GSK3β activity, which comprises the step of administering to a patient a preventively and/or therapeutically effective amount of a substance selected from the group consisting of dihydrospiro-[cycloalkyl]-pyrimidone derivatives of formula (I) and the physiologically acceptable salts thereof, and the solvates thereof and the hydrates thereof; and a use of a substance selected from
the group consisting of the dihydrospiro-[cycloalkyl]-pyrimidone derivatives of
formula (I) and the physiologically acceptable salts thereof, and the solvates
thereof and the hydrates thereof for the manufacture of the aforementioned
medicament.

As used herein, the C<sub>1</sub> to C<sub>6</sub> alkyl group represents a straight or branched alkyl
group having 1 to 6 carbon atoms, for example, methyl group, ethyl group, n-
propyl group, isopropyl group, n-butyl group, isobutyl group, sec-butyl group, tert-
butyl group, n-pentyl group, isopentyl group, neopentyl group, 1,1-dimethylpropyl

group, n-hexyl group, iso/hexyl group, and the like;

The C<sub>1</sub> to C<sub>4</sub> alkoxy group represents an alkyl/oxy group having 1 to 4 carbon
atoms for example, methoxy group, ethoxy group, propoxy group, isopropoxy
group, butoxy group, isobutoxy group, sec-butoxy group, tert-butoxy group, and the
like;

The halogen atom represents a fluorine, chlorine, bromine or iodine atom;
The C<sub>1</sub> to C<sub>2</sub> perhalogenated alkyl group represents an alkyl group wherein all
the hydrogen have been substituted by a halogeno, for example a CF<sub>3</sub> or C<sub>2</sub>F<sub>5</sub>;
The C<sub>1</sub> to C<sub>3</sub> halogenated alkyl group represents an alkyl group wherein at
least one hydrogen has not been substituted by an halogen atom;
The C<sub>1</sub> to C<sub>5</sub> monoalkylamino group represents an amino group substituted by
one C<sub>1</sub> to C<sub>6</sub> alkyl group, for example, methylamino group, ethylamino group,
propylamino group, isopropylamino group, butylamino group, isobutylamino group,
tert-butylamino group, pentylamino group and isopentylamino group;
The C<sub>2</sub> to C<sub>10</sub> dialkylamino group represents an amino group substituted by
two C<sub>1</sub> to C<sub>5</sub> alkyl groups, for example, dimethylamino group, ethylmethylamino group,
diethylamino group, methylpropylamino group and diisopropylamino group;

A leaving group L represents a group which could be easily cleaved and
substituted, such a group may be for example a tosyl, a mesyl, a bromide and the
like.

The compounds represented by the aforementioned formula (I) may form
a salt. Examples of the salt include, when an acidic group exists, salts of alkali
metals and alkaline earth metals such as lithium, sodium, potassium, magnesium,
and calcium; salts of ammonia and amines such as methylamine, dimethylamine,
trimethylamine, dicyclohexylamine, tris(hydroxymethyl)aminomethane, N,N-
bis(hydroxyethyl)piperazine, 2-amino-2-methyl-1-propanol, ethanolamine, N-
methylglucamine, and L-glucamine; or salts with basic amino acids such as lysine,
δ-hydroxylsine, and arginine. The base-addition salts of acidic compounds are
prepared by standard procedures well known in the art.

When a basic group exists, examples include salts with mineral acids such as hydrochloric acid, hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid; salts with organic acids such as methanesulfonic acid, benzenesulfonic acid, p-toluenesulfonic acid, acetic acid, propionic acid, tartaric acid, fumaric acid, maleic acid, malic acid, oxalic acid, succinic acid, citric acid, benzoic acid, mandelic acid, cinnamic acid, lactic acid, glycolic acid, glucuronic acid, ascorbic acid, nicotinic acid, and salicylic acid; or salts with acidic amino acids such as aspartic acid, and glutamic acid.

The acid-addition salts of the basic compounds are prepared by standard procedures well known in the art which include, but are not limited thereto, dissolving the free base in an aqueous alcohol solution containing the appropriate acid and isolating the salt by evaporating the solution, or by reacting the free base and an acid in an organic solvent, in which case the salt separates directly, or is precipitated with a second organic solvent, or can be obtained by concentration of the solution. The acids which can be used to prepare the acid-addition salts include preferably those which produce, when combined with the free base, pharmaceutically-acceptable salts, that is, salts whose anions are relatively innocuous to the animal organism in pharmaceutical doses of the salts, so that the beneficial properties inherent in the free base are not compromised by side effects ascribable to the anions. Although medicinally acceptable salts of the basic compounds are preferred, all acid-addition salts are within the scope of the present invention.

In addition to the dihydrospiro-[cycloalkyl]-pyrimidone derivatives represented by the aforementioned formula (I) and salts thereof, their solvates and hydrates also fall within the scope of the present invention.

The dihydrospiro-[cycloalkyl]-pyrimidone derivatives represented by the aforementioned formula (I) may have one or more asymmetric carbon atoms. As for the stereochemistry of such asymmetric carbon atoms, they may independently be in either (R) and (S) configuration, and the derivative may exist as stereoisomers such as optical isomers, or diastereoisomers. Any stereoisomers in pure form, any mixtures of stereoisomers, racemates and the like fall within the scope of the present invention.
Examples of compounds of the present invention are shown in table 1 hereinafter. However, the scope of the present invention is not limited by these compounds.

One of the embodiments of the present invention includes compounds of formula (I) wherein:

(1) R1 represents a 3- or 4-pyridine ring and more preferably a 4-pyridine ring; or a 4- or 5-pyrimidine ring and more preferably a 4-pyrimidine ring, the rings being optionally substituted by a C_{1-2} alkyl group, a C_{1-2} alkoxy group or a halogen atom; and/or

(2) R2 represents a benzene ring or a naphthalene ring, the ring being optionally substituted 1 to 4 substituents selected from a C_{1-3} alkyl group, a halogen atom, a hydroxyl group or a C_{1-2} alkoxy group; and/or

(3) R3 represents a hydrogen atom, a C_{1-3} alkyl group or a halogen atom; more preferably a hydrogen atom; and/or

(4) Y represents a bond, a carbonyl group or a methylene group optionally substituted by one or two groups chosen from a C_{1-3} alkyl group, a hydroxyl group, a C_{1-4} alkoxy group, a C_{1-2} perhalogenated alkyl group or an amino group;

(5) p + q equals 2 or 3, preferably 2; and more particularly wherein R1, R2, R3 and Y are as defined here-above.

Another embodiment of the present invention include compounds of formula (I) wherein:

(1) R1 represents an unsubstituted 4-pyridine ring or 4-pyrimidine ring; and/or

(2) R2 represents a benzene ring, the ring being optionally substituted 1 to 4 substituents selected from a C_{1-3} alkyl group, a halogen atom, a hydroxyl group or a C_{1-2} alkoxy group; and/or

(3) R3 represents a hydrogen atom; and/or

(4) X represents two hydrogen atoms; and/or

(5) Y represents a bond, a carbonyl group or a methylene group optionally substituted by a hydroxyl group; and/or

(6) p represents 2 and q represents 0; and more particularly wherein R1, R2, R3, X, Y, p and q are as defined here-above.
Particularly compounds of the present invention represented by formula (I) include compounds of table 1:

1. 1'-[(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

2. 1'-(2-Oxo-2-phenylethyl)-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

3. 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

4. 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

5. 1'-(2R)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

6. 1'-(2-Oxo-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

7. 1'-(2-Oxo-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

8. 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

9. 1'-(2-Oxo-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

10. 1'-(2-Oxo-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

11. 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

12. 1'-(2R)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
13. 1''-(2R)-2-Hydroxy-2-phenylethyl]-8''-pyridin-4-yl-3',4'-dihydrospiro-
[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

14. 1''-(phenylmethyl)- 8''-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-
pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

15. 1''-(2R)-2-Hydroxy-2-phenylethyl]- 8''-pyridin-4-yl-3',4'-dihydrospiro-
[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

16. 1''-(phenylmethyl)- 8''-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-
pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

17. 1''-(phenylmethyl)- 8''-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopropane-1,2'-
pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

18. 1''-(phenylmethyl)- 8''-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-
pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

19. 1''-(phenylmethyl)- 8''-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-
pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

20. 1''-(phenylethyl)- 8''-pyridin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-
pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

21. 1''-(phenylethyl)- 8''-pyridin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-
pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

22. 1''-(phenylethyl)- 8''-pyridin-4-yl-3',4'-dihydrospiro-[cyclopropane-1,2'-
pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

23. 1''-(phenylethyl)- 8''-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-
pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

24. 1''-(phenylethyl)- 8''-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-
pyrimido[1,2-a]pyrimidin]-6'(1''H)-one

25. 1''-(2-Hydroxy-2-(3-bromo-phenylethyl))- 8''-pyrimidin-4-yl-3',4'-
dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

26. 1'-(2-Oxo-2-(3-bromo-phenylethyl))- 8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one.

As a further object, the present invention concerns also methods for preparing the dihydrospiro-[cycloalkyl]-pyrimidone compounds represented by the aforementioned formula (I).

These compounds can be prepared, for example, according to methods explained below.
Preparation method

Dihydropyrido-[cycloalkyl]-pyrimidone compounds represented by the aforementioned formula (I), may be prepared according to the method described in the scheme 1.

Scheme 1

(In the above scheme the definition of R1, R2, R3, X, Y, m, n, p and q are the same as those already described for compound of formula (I)).

Following this method, the pyrimidinone derivative represented by the above formula (III), wherein R1, R3, m, n, p and q are as defined for compound of formula (I), is allowed to react with a base such as sodium hydride, sodium carbonate or potassium carbonate in a solvent such as N,N-dimethylformamide, N-methylpyrrolidone, N,N-dimethylacetamide or chloroform at a suitable temperature ranging from 0 to 130°C under ordinary air, then with a compound of formula (II), wherein R2, X, Y and n are as defined for compound of formula (I) and L represents a leaving group preferably bromide or mesyl group, to obtain the compound of the aforementioned formula (I).

Alternatively compounds of formula (I) wherein Y represents a carbonyl group may be prepared by oxidation of a compound of formula (I) wherein Y represents a methylene group substituted by a hydroxyl group according to well known methods to one skilled in the art.

Compound of formula (II) is commercially available or may be synthesized according to well-known methods to one skilled in the art.
Compound of formula (III) may be prepared according to the method defined in scheme 2.

![Chemical structure](image)

**Scheme 2.**

(In the above scheme the definition of R1, R3, m, p and q are the same as already described.)

According to this method, the 3-ketoester of formula (IV), wherein R1 and R3 are as defined for compound of formula (I) and R is an alkyl group such as for example methyl or ethyl, is allowed to react with a compound of formula (V). The reaction may be carried out in the presence of a base such as potassium carbonate, in an alcoholic solvent such as methanol, ethanol and the like or without, at a suitable temperature ranging from 25° to 140°C under ordinary air.

Alternatively, compound of formula (III) wherein R3 represents a hydrogen atom may be halogenated in order to give compounds of formula (III) wherein R3 is a halogen atom such as a bromine atom or a chlorine atom. The reaction may be carried out in an acidic medium such as acetic acid or propionic acid, in presence of bromosuccinimide or chlorosuccimide, or bromine.

In addition, compounds of formula (III) wherein R3 represents a fluorine atom may be obtained by analogy to the method described in *Tetrahedron Letters*, Vol.30, N°45, pp 6113-6116, 1989.

As a further object, the present invention concerns also the compound of formula (III) as intermediate for preparing compound of formula (I).

Compound of formula (IV) is commercially available or may be synthesized according to well-known methods to one skilled in the art.

For example compounds of formula (IV), wherein R1 represent a pyridine
ring or a pyrimidine ring, optionally substituted by a C 1-4 alkyl group, C 1-4 alkoxy group or a halogen atom, can be prepared by reacting respectively an isonicotinic acid or a pyrimidine-carboxylic acid, optionally substituted by a C 1-4 alkyl group, C 1-4 alkoxy group or a halogen, with the corresponding malonic acid monoester. The reaction can be carried out using methods well known to one skilled in the art, such as for example in presence of a coupling agent such as 1,1'-carbonylbis-1H-imidazole in a solvent such as tetrahydrofuran at a temperature ranging from 20 to 70°C.

Compound of formula (V) is commercially available or may be synthesized according to well-known methods of one skilled in the art.

For example compound of formula (V), when m represents 1, p represents 2 and q represents 0, may be prepared according to the method defined in scheme 3 and according to the method described by Smith and Christensen (J. Org. Chem. 1955, 20, 829) for the last step. The conditions which may be used are given in the chemical examples.

![Scheme 3](image)

(In the above scheme Pg represents an amino-protecting group and L a leaving group)

As another example compound of formula (V), when m equals 3, p represents 2 and q represents 0, may be prepared according to the method defined in scheme 4 and according to the method described by Smith and Christensen (J. Org. Chem. 1955, 20, 829) for the last step. The conditions which
may be used are given in the chemical examples.

\[ \text{(X)} \xrightarrow{\text{Amination}} \text{(XI)} \xrightarrow{\text{Amino-Protection}} \text{(XII)} \]

\[ \text{(V)} \xrightarrow{\text{Hydrogenation}} \xrightarrow{\text{Cyclisation}} \text{(XIII)} \]

**Scheme 4**

(In the above scheme Pg represents a protecting group)

Compound of formula (VI) may be synthesized according to the method described by Bertus and Szymoniak (Chem. Commun. 2001, 1792).

Compound of formula (X) may be synthesized according to the method described by Suzuki et al. (Synthetic Communication 1998, 28(4), 701).

In the above reactions protection or deprotection of a functional group may sometimes be necessary. A suitable protecting group Pg can be chosen depending on the type of the functional group, and a method described in the literature may be applied. Examples of protecting groups, of protection and deprotection methods are given for example in Protective groups in Organic Synthesis Greene et al., 2nd Ed. (John Wiley & Sons, Inc., New York).

The compounds of the present invention have inhibitory activity against GSK3\(\beta\). Accordingly, the compounds of the present invention are useful as an active ingredient for the preparation of a medicament, which enables preventive and/or therapeutic treatment of a disease caused by abnormal GSK3\(\beta\) activity and more particularly of neurodegenerative diseases such as Alzheimer's disease. In addition, the compounds of the present invention are also useful as an active
ingredient for the preparation of a medicament for preventive and/or therapeutic
treatment of neurodegenerative diseases such as Parkinson's disease,
tauopathies (e.g. frontotemporoparietal dementia, corticobasal degeneration,
Pick's disease, progressive supranuclear palsy) and other dementia including
vascular dementia; acute stroke and others traumatic injuries; cerebrovascular
accidents (e.g. age related macular degeneration); brain and spinal cord trauma;
peripheral neuropathies; retinopathies and glaucoma; and other diseases such as
non-insulin dependent diabetes (such as diabetes type II) and obesity; manic
depressive illness; schizophrenia; alopecia; cancers such as breast cancer, non-
small cell lung carcinoma, thyroid cancer, T or B-cell leukemia and several virus-
induced tumors.

The present invention further relates to a method for treating
neurodegenerative diseases caused by abnormal activity of GSK3β and of the
aforementioned diseases which comprises administering to a mammalian
organism in need thereof an effective amount of a compound of the formula (I).

As the active ingredient of the medicament of the present invention, a
substance may be used which is selected from the group consisting of the
compound represented by the aforementioned formula (I) and pharmacologically
acceptable salts thereof, and solvates thereof and hydrates thereof. The
substance, per se, may be administered as the medicament of the present
invention, however, it is desirable to administer the medicament in a form of a
pharmaceutical composition which comprises the aforementioned substance as an
active ingredient and one or more pharmaceutical additives. As the active
ingredient of the medicament of the present invention, two or more of the
aforementioned substances may be used in combination. The above
pharmaceutical composition may be supplemented with an active ingredient of
another medicament for the treatment of the above mentioned diseases. The type
of pharmaceutical composition is not particularly limited, and the composition may
be provided as any formulation for oral or parenteral administration. For example,
the pharmaceutical composition may be formulated, for example, in the form of
pharmaceutical compositions for oral administration such as granules, fine
granules, powders, hard capsules, soft capsules, syrups, emulsions, suspensions,
solutions and the like, or in the form of pharmaceutical compositions for parenteral
administrations such as injections for intravenous, intramuscular, or subcutaneous
administration, drip infusions, transdermal preparations, transmucosal
preparations, nasal drops, inhalants, suppositories and the like. Injections or drip
infusions may be prepared as powdery preparations such as in the form of lyophilized preparations, and may be used by dissolving just before use in an appropriate aqueous medium such as physiological saline. Sustained-release preparations such as those coated with a polymer may be directly administered intracerebrally.

Types of pharmaceutical additives used for the manufacture of the pharmaceutical composition, content ratios of the pharmaceutical additives relative to the active ingredient, and methods for preparing the pharmaceutical composition may be appropriately chosen by those skilled in the art. Inorganic or organic substances, or solid or liquid substances may be used as pharmaceutical additives. Generally, the pharmaceutical additives may be incorporated in a ratio ranging from 1% by weight to 90% by weight based on the weight of an active ingredient.

Examples of excipients used for the preparation of solid pharmaceutical compositions include, for example, lactose, sucrose, starch, talc, cellulose, dextrin, kaolin, calcium carbonate and the like. For the preparation of liquid compositions for oral administration, a conventional inert diluent such as water or a vegetable oil may be used. The liquid composition may contain, in addition to the inert diluent, auxiliaries such as moistening agents, suspension aids, sweeteners, aromatics, colorants, and preservatives. The liquid composition may be filled in capsules made of an absorbable material such as gelatin. Examples of solvents or suspension mediums used for the preparation of compositions for parenteral administration, e.g. injections, suppositories, include water, propylene glycol, polyethylene glycol, benzyl alcohol, ethyl oleate, lecithin and the like. Examples of base materials used for suppositories include, for example, cacao butter, emulsified cacao butter, lauric lipid, witepsol.

The dose and frequency of administration of the medicament of the present invention are not particularly limited, and they may be appropriately chosen depending on conditions such as a purpose of preventive and/or therapeutic treatment, a type of a disease, the body weight or age of a patient, severity of a disease and the like. Generally, a daily dose for oral administration to an adult may be 0.01 to 1,000 mg (the weight of an active ingredient), and the dose may be administered once a day or several times a day as divided portions, or once in several days. When the medicament is used as an injection, administrations may preferably be performed continuously or intermittently in a daily dose of 0.001 to 100 mg (the weight of an active ingredient) to an adult.
Chemical Examples

The present invention will be explained more specifically with reference to the following general examples, however, the scope of the present invention is not limited to these examples.

Example 1 (Compound No 1 of table 1)

1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yi-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H')-one. (1:1) (hydrochloride)

1.1 2-(1-Amino-cyclopropyl)-ethanol hydrochloride (1:1)

To a solution of 8.63g (45.11 mmol) of 1-(2-benzylxoy-ethyl)-cyclopropylamine and 3g of palladium 10 wt. % on activated carbon in 100 ml of isopropanol was added 100 ml of a solution of hydrochloric acid in isopropanol (5-6 N). The mixture was shaken at 40°C under hydrogen pressure of 4 atmospheres until hydrogen uptake ceased. The catalyst was removed by filtration and washed with isopropanol. The filtrate was evaporated to dryness to afford 6.22g of pure product as a viscous oil.

1.2 Tert-Butyl 1-(2-hydroxyethyl)cyclopropylcarbamate

To a solution of 6.21g (45.11 mmol) of 2-(1-amino-cyclopropyl)-ethanol hydrochloride (1:1) in 63 ml of tetrahydrofuran was added 1 ml of water, 12.68 ml (90.22 mmol) of triethylamine and 9.84g (45.11 mmol) of di-tert-butyl dicarbonate in 21 ml of tetrahydrofuran. The resulting mixture was stirred at room temperature for 16h. The mixture was evaporated, dissolved in 100 ml of diethyl ether and was treated with an aqueous hydrochloric acid solution (0.1 N). The combined extracts were washed with saturated aqueous sodium chloride and evaporated. The crude product was triturated with water and filtered to afford 6.68g of pure product as a white solid.

Mp : 93-95°C.
1.3. 2-1-[(Tert-butoxycarbonyl)amino]cyclopropyl|ethyl methanesulfonate

To a solution of 6.472g (32.16 mmol) of tert-butyl 1-(2-hydroxyethyl)cyclopropylcarbamate in 61 ml of anhydrous dichloromethane was added 12.79 ml (91 mmol) of anhydrous triethylamine. The resulting mixture is cooled at −20°C. Then 3.54 ml (45.66 mmol) of mesyl chloride in 11 ml of anhydrous dichloromethane was added. The resulting mixture was stirred at room temperature for 2h. The mixture was poured into ice-water and the organic layer was washed with saturated aqueous sodium chloride, dried over sodium sulfate and evaporated. The crude product was triturated with petroleum ether and filtered to give 7.82g of pure product as an orange solid.
Mp : 88-89°C

1.4. Tert-butyl 1-[2-(1,3-dioxo-1,3-dihydro-2H-isoindol-2-yl)ethyl]-cyclopropylcarbamate

To a solution of 7.82g (28 mmol) of 2-1-[(tert-butoxycarbonyl)amino]-cyclopropyl|ethyl methanesulfonate in 35 ml of anhydrous dimethylformamide was added 5.45g (29.4 mmol) of potassium phthalimide. The resulting mixture was stirred at 150°C for 18h. The mixture was then filtered and washed with diethyl ether. The filtrate was evaporated to dryness, the crude product was heated in water and the precipitate was filtered. The product was dried to give 4.63g of pure compound as an orange solid.
Mp : 125-127°C.

1.5. Tert-butyl 1-(2-aminoethyl)cyclopropylcarbamate

To a solution of 4.57g (13.83 mmol) of tert-butyl 1-[2-(1,3-dioxo-1,3-dihydro-2H-isoindol-2-yl)ethyl]cyclopropylcarbamate in 80 ml of ethanol was added 3.36ml (69.16 mmol) of hydrazine hydrate and the resulting mixture was heated under reflux for 16h. The mixture was filtered and washed with diethyl ether. The filtrate was evaporated to dryness to give 2.3g of pure compound as an orange oil.

1.6. 1-(2-Aminoethyl)cyclopropanamine hydrobromide (1:2)

To a solution of 20 ml of hydrobromide (33%) in acetic acid was added 2.29g (11.46 mmol) of tert-butyl 1-(2-aminoethyl)cyclopropylcarbamate and the resulting solution was stirred at 60°C for 1h.
The mixture was cooled and diethyl ether was added. The resulting precipitate was filtered. The product was dried to give 2.69g of pure compound as a brown solid.
Mp : 233-235°C

1.7  4,6-Diazaspiro[2.5]oct-5-en-5-amine hydrobromide (1:1)

To a solution of 2.65g (10.11 mmol) of 1-(2-aminoethyl)cyclopropanamine hydrobromide in 21ml of methanol was added 3.83 ml (21.24 mmol) of a solution of sodium methoxide in methanol (5.55 N). The mixture was stirred at room temperature for 2h. The precipitate was filtered and the filtrate was evaporated. The crude was dissolved in 9 ml of water and 1.07g (10.11 mmol) of cyanogen bromide was added portion wise. The resulting mixture was stirred at room temperature for 2h and evaporated to dryness to give 2.08g of pure compound as an orange oil.

1.8  8'-Pyridinyl-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a] pyrimidin]-6'(1'H)-one

A mixture of 1.77g (9.19 mmol) of ethyl 3-(pyridin-4-yl)-3-oxopropionate, 2.084g (10.11 mmol) of 4,6-diazaspiro[2.5]oct-5-en-5-amine hydrobromide and 2.79g (20.22 mmol) of potassium carbonate in 17ml of ethanol was heated at reflux temperature during 12 h. The cooled solution was evaporated to removed solvent, the residue was treated with water and the precipitate was filtered to give 0.88g of product as a yellow powder.
Mp : 277-278°C.

1.9  1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro
[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one (1:1) (hydrochloride)

To a solution of 0.5g (1.97 mmol) of 8'-pyridinyl-4-yl-3',4'-dihydrospiro-[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one in 10ml of anhydrous dimethylformamide was added 0.173g (4.33 mmol) of sodium hydride (60% suspension in mineral oil). The mixture was allowed to stir at 50°C for 1h. Then 0.4g (2.56 mmol) of (1-S)-2-chloro-1-phenyl ethanol was added and the mixture allowed to stir at 120°C for 16h.
Water was added and the mixture extracted with ethyl acetate. The extracts were
washed with a saturated aqueous solution of sodium chloride, dried and evaporated to give crude product. Purification by chromatography on silica gel eluting with a mixture of ethyl dichloromethane/methanol in the proportions 100/0 to 95/5 led to compound in the form of free base. The base was transformed into its hydrochloride salt to give 0.443g of pure product.

Mp : 219-221 °C, [α]D = -9.5 (c=0.4, CH3OH).
RMN (200 MHz ; DMSO-d6) : δ 8.90 (d, 2H) ; 8.35 (d, 2H) ; 7.12-7.46 (m, 5H) ; 6.61 (s, 1H) ; 4.88 (t, 1H) ; 3.4-4.05 (m, 4H) ; 1.83 (t, 2H) ; 1.03-1.33 (m, 2H) ; 0.58-0.85 (m, 2H).

Example 2 (Compound No 2 of table 1)

1'-[(2-Oxo-2-phenylethyl)-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one (1:1) (hydrochloride)

0.31g (0.83 mmol) of 1'-[(2S)-2-hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one was dissolved in 8ml of anhydrous dichloromethane and mixed with 0.145g (1.24 mmol) of N-methylmorpholine N-oxide, 0.003g (0.0083 mmol) of tetra-n-propylammonium perruthenate and 1g of powdered molecular sieves (4A). The mixture was stirred at 20°C under nitrogen atmosphere for 12h.

The mixture was filtered. The filtrate was washed with a saturated aqueous solution of ammonium chloride, dried and evaporated to give crude product. Purification by chromatography on silica gel eluting with a mixture of dichloromethane/methanol in the proportions 100/0 to 95/5 gave the compound in the form of free base which was transformed into its hydrochloride salt to give 0.078g of pure product.

Mp : 232-234 °C.
RMN (200 MHz ; DMSO-d6) : δ 8.62 (d, 2H) ; 8.03 (d, 2H) ; 8.00 (d, 2H) ; 7.51-7.78 (m, 3H) ; 6.61 (s, 1H) ; 5.15 (s, 2H) ; 4.01 (t, 2H) ; 2.04 (t, 2H) ; 1.17 (t, 2H) ; 0.78 (t, 2H).

Example 3 (Compound No 3 of table 1)

1'-[(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one (1:1) (hydrochloride)

3.1 (1-Aminocyclopentyl)acetonitrile
A solution of 15.91g (0.15 mol) of cyclopentylideneacetonitrile in 170 ml of an aqueous ammonia solution (29%) and 57 ml of methanol was heated at 100°C in a sealed tube for 24h. The reaction mixture was concentrated, and the residue was chromatographed on silica gel eluting with a mixture of dichloromethane/methanol in the proportions 90/10 to afford 12.15g of the product as a colorless oil.

3.2 Tert-butyl 1-(cyanomethyl)cyclopentylcarbamate

The product was obtained by analogy with the method described in step 1.2 and using (1-aminocyclopentyl)acetonitrile. The compound was used as such in the next step.

3.3 Tert-butyl 1-(2-aminoethyl)cyclopentylcarbamate

To a suspension of 8.48g (223.63 mmol) of lithium aluminium hydride in 687 ml of diethyl ether at 0°C was added dropwise 16.7g (74.54 mmol) of tert-butyl 1-(cyanomethyl)cyclopentylcarbamate dissolved in 344 ml of diethyl ether. The resulting mixture was stirred at 0°C under nitrogen atmosphere for 1h. The reaction mixture was diluted with 100 ml of diethyl ether at 0°C and treated with excess of a saturated aqueous solution of sodium sulfate. Further solid sodium sulfate was added and the organic phase was filtered to remove salts. The solvent was evaporated to dryness to give 13.83g of product as an oil.

3.4 1-(2-Aminoethyl)cyclopentanamine hydrobromide (1:2)

The product was obtained by analogy with the method described in step 1.6 and using tert-butyl 1-(2-aminoethyl)cyclopentylcarbamate. The compound was used as such in the next step.

Mp : 194-196 °C.

3.5 6,8-Diazaspiro[4.5]dec-7-en-7amine hydrobromide (1 : 1)

The product was obtained by analogy with the method described in step 1.7 and using 1-(2-aminoethyl)cyclopentanamine hydrobromide (1:2). The compound was used as such in the next step.

3.6 8'-Pyridinyl-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]
pyrimidin]-6'(1'H)-one

The product was obtained by analogy with the method described in step 1.8 and using 6,8-diazaspiro[4.5]dec-7-en-7amine hydrobromide (1 : 1). The compound was used as such in the next step.

Mp: 241-243 °C.

3.7 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one (1:1) (hydrochloride)

The product was obtained by analogy with the method described in step 1.9 and using 8'-pyridinyl-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one.

Mp: 221-223 °C, [α]D = -32.8 (c=1.036, CH3OH).

RMN (200 MHz ; DMSO-d6) : δ 8.91 (d, 2H) ; 8.41 (d, 2H) ; 7.13-7.47 (m, 5H) ; 6.67 (s, 1H) ; 5.22 (dd, 1H) ; 3.71-4.04 (m, 3H) ; 3.38-3.59 (m, 1H) ; 2.26-2.62 (m, 2H) ; 1.76-2.15 (dm, 2H) ; 1.30-1.76 (m, 6H).

Example 4 (Compound N° 4 of table 1)

1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

4.1 8'-Pyrimidinyl-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

The product was obtained by analogy with the method described in step 1.8, using ethyl 3-(4-pyridinyl)-3-oxopropionate, (prepared by analogy to the method described in patent DE 2705582) and 6,8-Diazaspiro[4.5]dec-7-en-7amine hydrobromide (1 : 1) (prepared according to example 3.5). The compound obtained was treated with water and the precipitate recovered by filtration to give 2.92g of product.

Mp: 243-244°C.

4.2 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

The product was obtained by analogy with the method described in step 1.9 and using 8'-pyridinyl-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]
pyrimidin]-6'(1'H)-one.
RMN (200 MHz ; DMSO-d6) : δ 9.28 (s, 1H) ; 9.01 (d, 1H) ; 8.14 (d, 1H) ; 7.15-7.50 
(m, 5H) ; 6.72 (s, 1H) ; 5.19 (t, 1H) ; 3.70-4.04 (m, 3H) ; 3.38-3.58 (m, 1H) ; 2.26-
2.55 (m, 2H) ; 1.74-2.12 (dm, 2H) ; 1.25-1.74 (m, 6H).

A list of chemical structures and physical data for compounds of the 
aforementioned formula (I), illustrating the present invention, is given in table 1. 
The compounds have been prepared according to the methods of the examples.

In the table, R1 is an unsubstituted pyrimidin-4-yl group or an unsubstituted 
pyridin-4-yl group, p represents 2, q represents 0, Ph represents a phenyl group, 
(S), (R) or (Rac.) indicates in the column “Y” the stereochemistry of the carbon atom:

(rac.) means racemic mixture
(R) means absolute R configuration
(S) means absolute S configuration
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<tr>
<td>----</td>
<td>-----</td>
<td>------</td>
<td>------</td>
<td>-----</td>
<td>----</td>
<td>----</td>
<td>---</td>
<td>--------</td>
<td>-----------------</td>
</tr>
<tr>
<td>20</td>
<td>Ph</td>
<td>bond</td>
<td>H,H</td>
<td>H</td>
<td>H</td>
<td>3</td>
<td>1</td>
<td>208-210</td>
<td>(1:1) (hydrochloride)</td>
</tr>
<tr>
<td>21</td>
<td>Ph</td>
<td>bond</td>
<td>H,H</td>
<td>H</td>
<td>H</td>
<td>2</td>
<td>1</td>
<td>210-211</td>
<td>(1:1) (hydrochloride)</td>
</tr>
<tr>
<td>22</td>
<td>Ph</td>
<td>bond</td>
<td>H,H</td>
<td>H</td>
<td>H</td>
<td>1</td>
<td>1</td>
<td>224-225</td>
<td>(1:1) (hydrochloride)</td>
</tr>
<tr>
<td>23</td>
<td>Ph</td>
<td>bond</td>
<td>H,H</td>
<td>H</td>
<td>H</td>
<td>2</td>
<td>1</td>
<td>166-167</td>
<td>Free base</td>
</tr>
<tr>
<td>24</td>
<td>Ph</td>
<td>bond</td>
<td>H,H</td>
<td>H</td>
<td>H</td>
<td>3</td>
<td>1</td>
<td>190-191</td>
<td>Free base</td>
</tr>
<tr>
<td>25</td>
<td>3-Br-Ph</td>
<td>C(H)(OH)</td>
<td>H,H</td>
<td>H</td>
<td>H</td>
<td>2</td>
<td>1</td>
<td>177-178</td>
<td>Free Base</td>
</tr>
<tr>
<td>26</td>
<td>3-Br-Ph</td>
<td>CO</td>
<td>H,H</td>
<td>H</td>
<td>H</td>
<td>2</td>
<td>1</td>
<td>169-171</td>
<td>Free Base</td>
</tr>
</tbody>
</table>
Test Example: Inhibitory activity of the medicament of the present invention against GSK3β:

Two different protocols can be used.

In a first protocol: 7.5 μM of prephosphorylated GS1 peptide and 10 μM ATP (containing 300,000 cpm of 33P-ATP) were incubated in 25 mM Tris-HCl, pH 7.5, 0.6 mM DTT, 6 mM MgCl₂, 0.6 mM EGTA, 0.05 mg/ml BSA buffer for 1 hour at room temperature in the presence of GSK3β (total reaction volume: 100 microliters).

In a second protocol: 4.1 μM of prephosphorylated GS1 peptide and 42 μM ATP (containing 260,000 cpm 33P-ATP) were incubated in 80 mM Mes-NaOH, pH 6.5, 1 mM Mg acetate, 0.5 mM EGTA, 5 mM 2-mercaptoethanol, 0.02% Tween 20, 10% glycerol buffer for 2 hours at room temperature in the presence of GSK3β. Inhibitors were solubilised in DMSO (final solvent concentration in the reaction medium, 1%).

The reaction was stopped with 100 microliters of a solution made of 25 g polyphosphoric acid (85% P₂O₅), 126 ml 85% H₃PO₄, H₂O to 500 ml and then diluted to 1:100 before use. An aliquot of the reaction mixture was then transferred to Whatman P81 cation exchange filters and rinsed with the solution described above. Incorporated 33P radioactivity was determined by liquid scintillation spectrometry.

The phosphorylated GS-1 peptide had the following sequence:

NH₂-YRRAAVPPSPSLSRHSSPHQS(P)EDEE-COOH.

The GSK3β inhibitory activity of the compounds of the present invention are expressed in IC₅₀, and as an illustration the range of IC₅₀'s of the compounds in table 1 is between 1 nanomolar to 1 micromolar concentrations.

For example compound No. 10 of table 1 shows an IC₅₀ of 0.0006 μM.
Formulation Example

(1) Tablets

The ingredients below were mixed by an ordinary method and compressed by using a conventional apparatus.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound of Example 1</td>
<td>30 mg</td>
</tr>
<tr>
<td>Crystalline cellulose</td>
<td>60 mg</td>
</tr>
<tr>
<td>Corn starch</td>
<td>100 mg</td>
</tr>
<tr>
<td>Lactose</td>
<td>200 mg</td>
</tr>
<tr>
<td>Magnesium stearate</td>
<td>4 mg</td>
</tr>
</tbody>
</table>

(2) Soft capsules

The ingredients below were mixed by an ordinary method and filled in soft capsules.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound of Example 1</td>
<td>30 mg</td>
</tr>
<tr>
<td>Olive oil</td>
<td>300 mg</td>
</tr>
<tr>
<td>Lecithin</td>
<td>20 mg</td>
</tr>
</tbody>
</table>

(1) Parenteral preparations

The ingredients below were mixed by an ordinary method to prepare injections contained in a 1 ml ampoule.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound of Example 1</td>
<td>3 mg</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>4 mg</td>
</tr>
<tr>
<td>Distilled water for injection</td>
<td>1 ml</td>
</tr>
</tbody>
</table>

Industrial Applicability

The compounds of the present invention have GSK3β inhibitory activity and are useful as an active ingredient of a medicament for preventive and/or therapeutic treatment of diseases caused by abnormal activity of GSK3β and more particularly of neurodegenerative diseases.
What is claimed is:

1. A dihydrospiro-[cycloalkyl]-pyrimidone derivative represented by formula (I) or a salt thereof, or a solvate thereof or a hydrate thereof:

   ![Chemical Structure](image)

   wherein:
   X represents two hydrogen atoms, a sulfur atom, an oxygen atom or a C\textsubscript{1-2} alkyl group and a hydrogen atom;

   Y represents a bond, a carbonyl group, a methylene group optionally substituted by one or two groups chosen from a C\textsubscript{1-8} alkyl group, a hydroxyl group, a C\textsubscript{1-4} alkoxy group, a C\textsubscript{1-2} perhalogenated alkyl group or an amino group;

   R\textsubscript{1} represents a 2, 3 or 4-pyridine ring or a 2, 4 or 5-pyrimidine ring, the ring being optionally substituted by a C\textsubscript{1-4} alkyl group, a C\textsubscript{1-4} alkoxy group, or a halogen atom;

   R\textsubscript{2} represents a benzene ring or a naphthalene ring; the rings being optionally substituted by 1 to 4 substituents selected from a C\textsubscript{1-8} alkyl group, a methylendioxy group, a halogen atom, a C\textsubscript{1-2} perhalogenated alkyl group, a C\textsubscript{1-3} halogenated alkyl group, a hydroxyl group, a C\textsubscript{1-4} alkoxy group, a nitro, a cyano, an amino, a C\textsubscript{1-6} monoalkylamino group or a C\textsubscript{2-10} dialkylamino group;

   R\textsubscript{3} represents a hydrogen atom, a C\textsubscript{1-6} alkyl group or a halogen atom;

m represents 1 to 4;
n represents 0 to 3;
p represents 0 to 2; and
q represents 0 to 2, p+q being inferior to 4.
2. A dihydrospiro-[cycloalkyl]-pyrimidone derivative or a salt thereof, or a solvate thereof or a hydrate thereof according to claim 1, wherein R1 represents an unsubstituted 4-pyridinyl group or unsubstituted 4-pyrimidinyl group.

3. A dihydrospiro-[cycloalkyl]-pyrimidone derivative or a salt thereof, or a solvate thereof or a hydrate thereof according to claim 1 or 2, wherein
   - R1 represents an unsubstituted 4-pyridine ring or a 4-pyrimidine ring; and
   - R2 represents a benzene ring, the ring being optionally substituted 1 to 4 substituents selected from a C_{1,3} alkyl group, a halogen atom, a hydroxyl group or a C_{1,2} alkoxy group; and
   - R3 represents a hydrogen atom; and
   - X represents two hydrogen atoms; and
   - Y represents a bond, a carbonyl group or a methylene group optionally substituted by a hydroxyl group; and
   - p represents 2 and q represents 0.

4. A dihydrospiro-[cycloalkyl]-pyrimidone derivative which is selected from the group consisting of:
   - 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
   - 1'-(2-Oxo-2-phenylethyl)-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
   - 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
   - 1'-(2R)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
   - 1'-(2-Oxo-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
   - 1'-(2-Oxo-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one,
   - 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
   - 1'-(2-Oxo-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
   - 1'-(2-Oxo-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
   - 1'-(2-Oxo-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2S)-2-Hydroxy-2-phenylethyl]- 8'-pyrimidin-4-yl-3',4'-dihydropyrido-
  [cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2R)-2-Hydroxy-2-phenylethyl]- 8'-pyrimidin-4-yl-3',4'-dihydropyrido-
  [cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2R)-2-Hydroxy-2-phenylethyl]- 8'-pyridin-4-yl-3',4'-dihydropyrido-
  [cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylmethyl)- 8'-pyrimidin-4-yl-3',4'-dihydropyrido-[cyclobutane-1,2'-
  pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2R)-2-Hydroxy-2-phenylethyl]- 8'-pyridin-4-yl-3',4'-dihydropyrido-
  [cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylmethyl)- 8'-pyrimidin-4-yl-3',4'-dihydropyrido-[cyclopentane-1,2'-
  pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylmethyl)- 8'-pyridin-4-yl-3',4'-dihydropyrido-[cyclopropane-1,2'-
  pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydropyrido-[cyclobutane-1,2'-
  pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydropyrido-[cyclobutane-1,2'-
  pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydropyrido-[cyclobutane-1,2'-
  pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydropyrido-[cyclopropane-1,2'-
  pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylethyl)- 8'-pyrimidin-4-yl-3',4'-dihydropyrido-[cyclobutane-1,2'-
  pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2-Hydroxy-2-(3-bromo-phenylethyl))- 8'-pyrimidin-4-yl-3',4'-
  dihydropyrido[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2-Oxo-2-(3-bromo-phenylethyl))- 8'-pyrimidin-4-yl-3',4'-
  dihydropyrido[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- or a salt thereof, or a solvate thereof or a hydrate thereof.
5. A compound of formula (III)

\[
\begin{align*}
&\text{wherein } R_1, R_3, m, p, q \text{ and } p \text{ are as defined for compound of formula (I)} \\
&\text{according to claim 1.}
\end{align*}
\]

6. A medicament comprising as the active ingredient a dihydrosso-
[cycloan lyn]-pyrimidine derivative represented by formula (I) or salts thereof, or a solvate
thereof or a hydrate thereof as defined in claim 1 together with a pharmaceutically
acceptable carrier or diluent.

7. Use of a compound as defined in any one of claims 1 to 4 for the
preparation of a medicament for preventive and/or therapeutic treatment of a disease
caused by abnormal GSK3β activity.

8. Use of a compound as defined in any one of claims 1 to 4 for the
preparation of a medicament for preventive and/or therapeutic treatment of a
neurodegenerative disease.

9. Use of a compound according to claim 8, wherein the neurodegenerative
disease is selected from the group consisting of Alzheimer's disease, Parkinson's disease,
tauopathies, vascular dementia; acute stroke, traumatic injuries; cerebrovascular
accidents, brain cord trauma, spinal cord trauma; peripheral neuropathies; retinopathies
and glaucoma.

10. Use of a compound as defined in any one of claims 1 to 4 for the
preparation of a medicament for preventive and/or therapeutic treatment of non-insulin
dependent diabetes; obesity; manic depressive illness; schizophrenia; alopecia; or
cancers.

11. Use according to claim 10, wherein cancer is breast cancer, non-small cell
lung carcinoma, thyroid cancer, T or B-cell leukemia or virus-induced tumors.