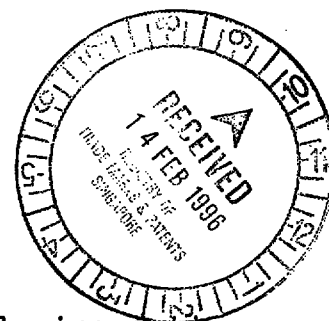


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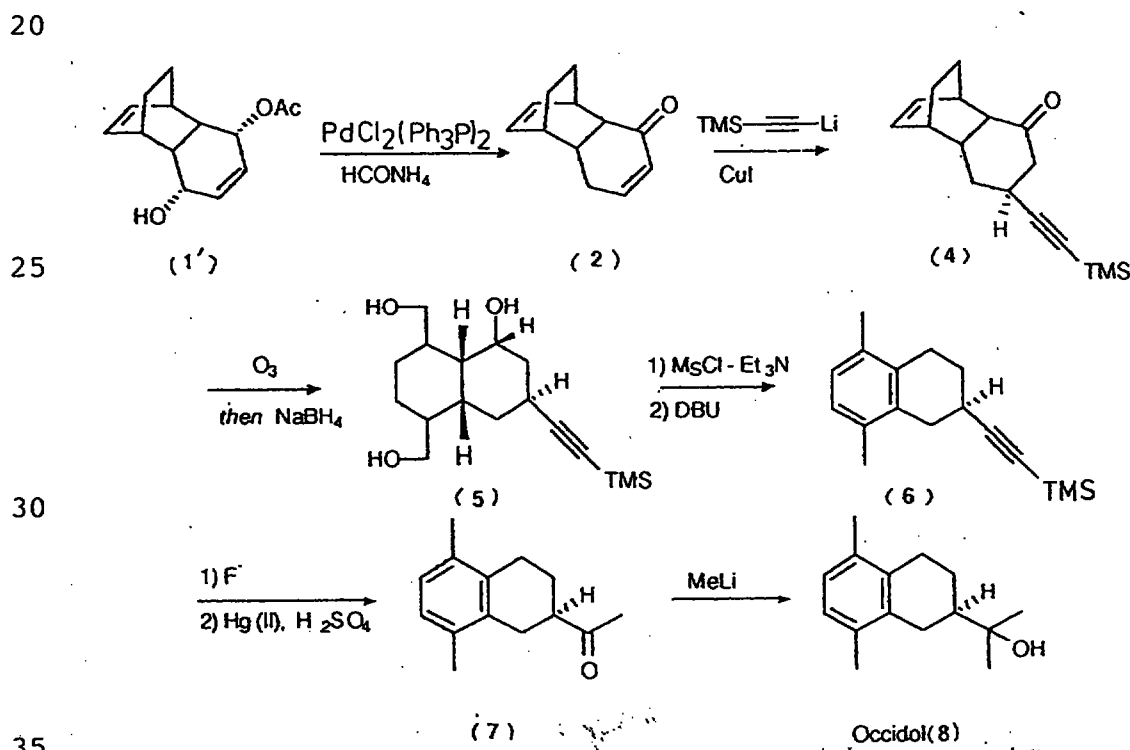
CYCLOHEXENE DIOL DERIVATIVES



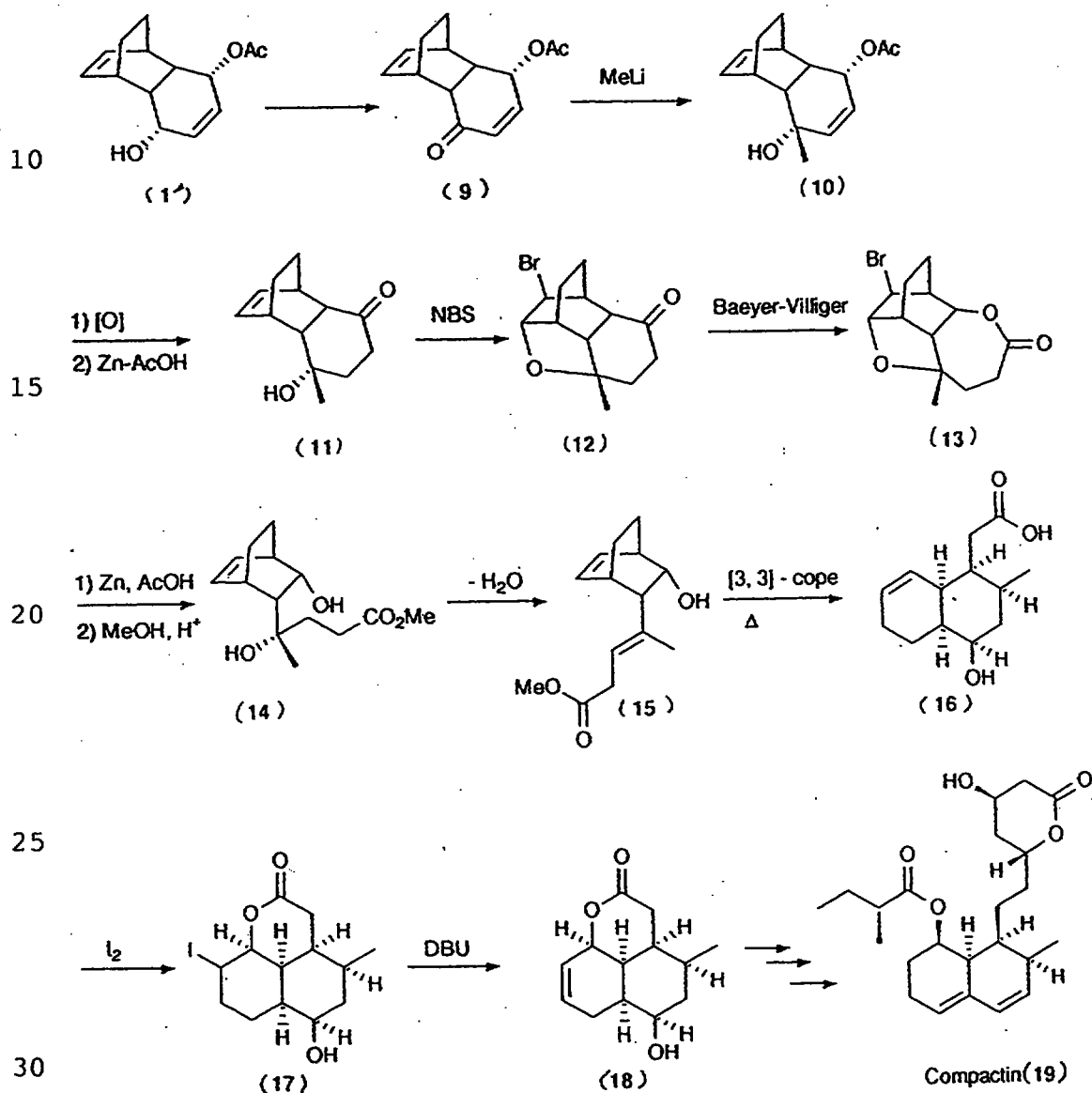
5 The present invention relates to the following optically active cyclohexene diol derivatives (1) and (1'), and optically active cyclohexenone derivatives (2) and (2'), and a process for production of these compounds.

10 The optically active cyclohexene diol derivatives represented by the following formula (1) and (1'), and the optically active cyclohexenone derivatives represented by the following formula (2) and (2') are useful as intermediates for synthesizing physiologically active
15 compounds.

The optically active cyclohexenone derivatives represented by the formula (2), for example, can be used to obtain occidol (8) of a sesquiterpene through six steps as shown in the following.



Further, the optically active cyclohexene diol derivative represented by the formula (1) can be an intermediate for synthesizing compactin (19) which is a hyperlipemia therapeutic drug (HMG CoA reductase synthesis inhibitor) as shown in the following.



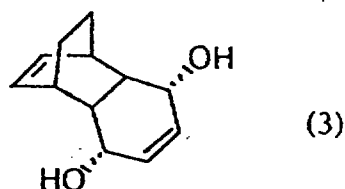
Though the compounds are useful as described above, these have not been prepared by an efficient process.

35 As an example, optically active 5-trimethylsilyl

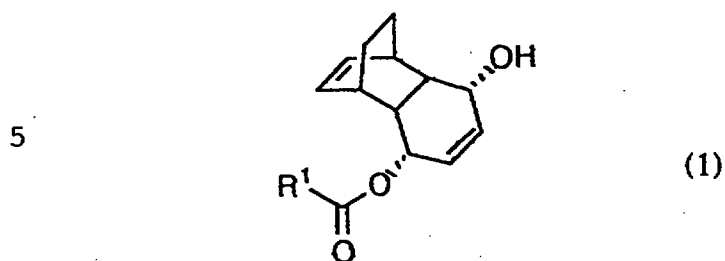
cyclohex-2-enone equivalent to the compounds of the present invention has been obtained by a method comprising reacting the racemate with cinchonidine of an alkaloid and toluenethiol and repeatedly recrystallizing the resulting diastereomer salt. However, the method comprises several steps and the yield is too low (3%) so that such a production process is not efficient (Tetrahedron Lett., 28, 5669 (1987)).

Considering these problems, the inventors of the present invention earnestly studied to efficiently obtain pure optically active cyclohexenone derivatives useful as intermediates for synthesis of physiologically active materials. Then, they have found the optically active cyclohexene diols represented by the following formulas (1) and (1'), and the optically active cyclohexenone derivatives represented by the following formulas (2) and (2'), and the process for efficiently producing these compounds.

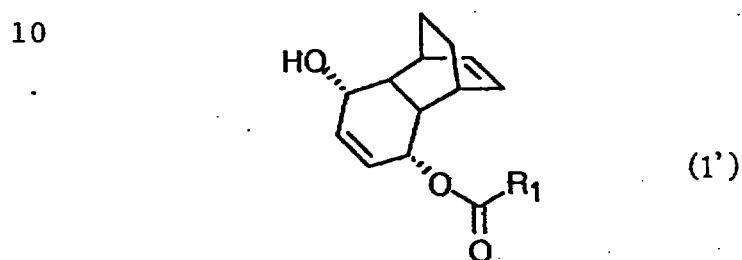
The present invention is characterized in that a cyclohexene diol represented by the formula:



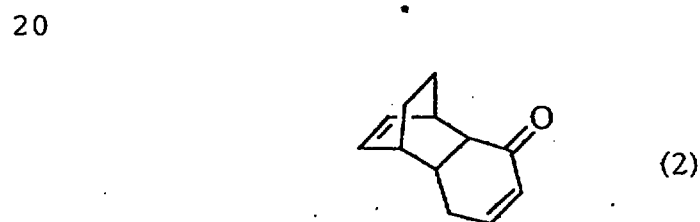
is used as a starting material to react with an acylating agent in the presence of lipase by selectively positioning transesterification, and an optically active cyclohexene diol derivative represented by the formula:



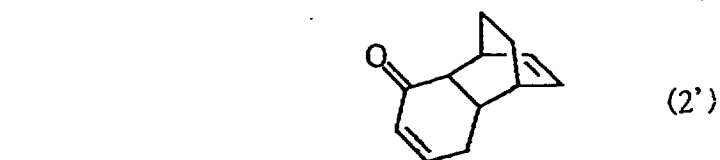
or



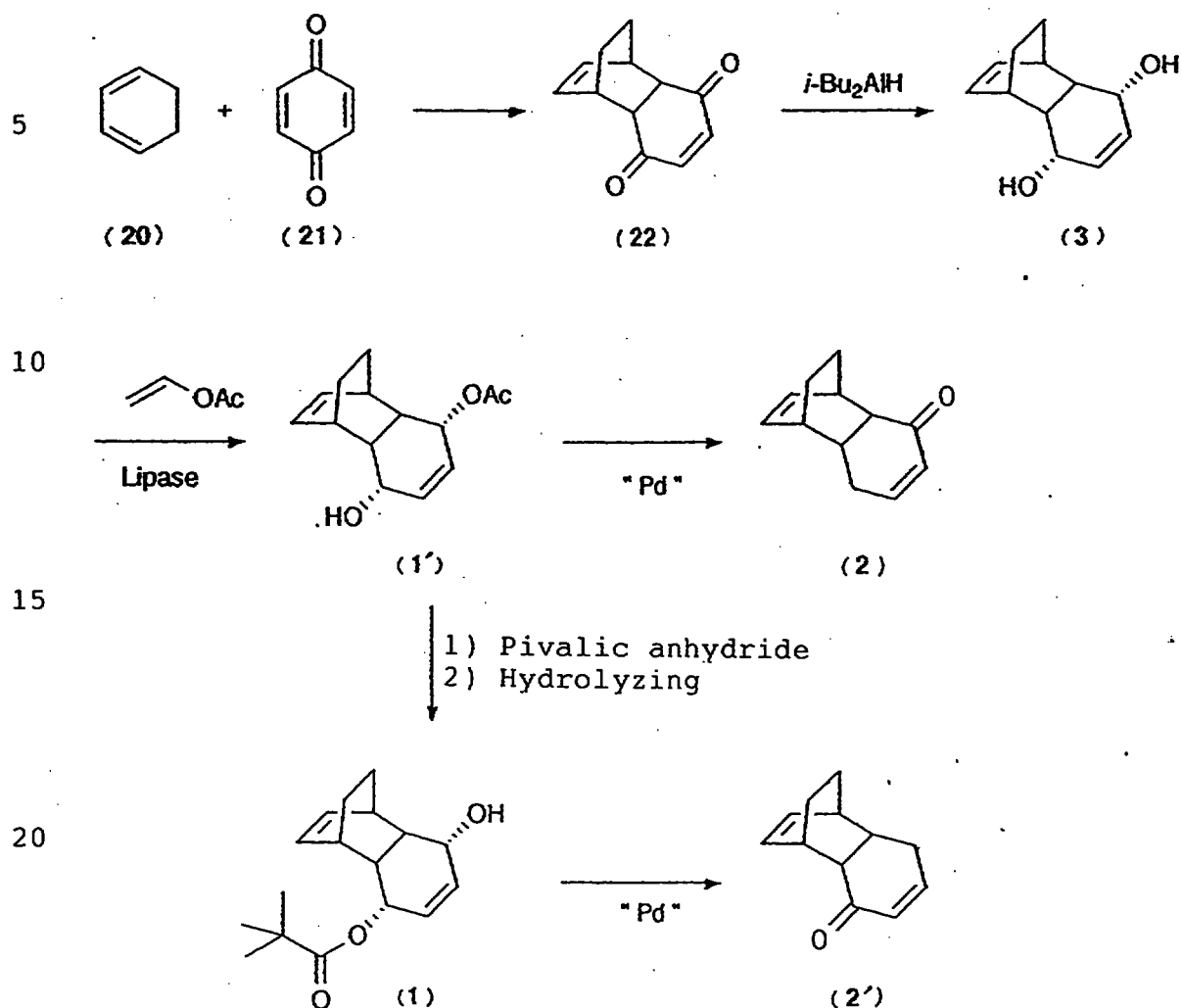
15 wherein R_1 is alkyl, is obtained from the above reaction, and then an optically active cyclohexenone derivative represented by the formula:



25 or



30 is obtained. The reaction steps of the production method of the present invention are shown in the following as an example.



The cyclohexene diol (3) of a starting material in the present invention is easily obtained by reducing a carbonyl group of the cyclohexenone derivative (22) obtained by a general Diels-Alder reaction, in which 1, 3-cyclohexadiene (20) is reacted with hydroquinone (21), in the presence of a reducing agent such as diisobutyl aluminum hydride.

The obtained cyclohexene diol (3) is reacted by selectively positioning transesterification with an acylating agent in the presence of lipase, and then

optically active cyclohexene diol derivatives (1) and (1') can be obtained. As the acylating agent, fatty acid vinyl esters, triglycerides, acid anhydrides, esters are exemplified, and fatty acid vinyl esters are preferred.

5 As the lipase, if it acts as a catalyst, any kinds of lipase may be used in any forms of purified enzyme powder, immobilized enzyme, microorganisms and the like. Particularly, lipase from a Pseudomonas genus, for example, commercially available lipase PS (trade name, manu-

10 factured by Amano Pharmaceutical Co., Ltd.) and TOYOBO lipase (trade name, manufactured by Toyobo Co., Ltd.) are preferred. As a reaction solvent, an organic solvent which does not inhibit the reaction can be preferably used, and more preferably acetonitrile is used. Other-

15 wise, the reaction may be conducted in the presence of substrates without a solvent.

The optically active cyclohexene diol derivatives (1) and (1') can be converted into the optically active cyclohexenone derivatives (2) and (2') by using, for

20 example, bistriphenylphosphine palladium chloride.

By the above described process, the following merits are obtained.

1. It is possible to obtain efficiently, as optically pure compounds, optically active cyclohexene diol derivatives and optically active cyclohexenone derivatives

25 which are useful for synthesis of physiologically active materials.

2. The optically active cyclohexene diol derivatives and optically active cyclohexenone derivatives obtained by

30 the process of the present invention can be converted to useful chiral elements. As described above, for example, these compounds may be starting materials of occidol (8) and compactin (19).

3. The cyclohexene diol represented by formula (3) is a

35 meso compound, so that the optically active cyclohexene

diol derivatives obtained from the compound can be act as both enantiomers by classification of hydroxy and acyl groups.

5. The following examples illustrate the present invention more specifically, but these are not intended as a definition of the limits of the invention.

Example 1

To a solution of cyclohexene diol (formula (3), 200 mg, 1.04 mmol) and vinyl acetate (0.3 ml, 3.36 mmol) in acetonitrile, lipase PS (100 mg) was suspended. The mixture was stirred for 25 days at room temperature. After the lipase was filtered off, the filtrate was concentrated under reduced pressure. The residue was subjected to a column chromatograph over silica gel to obtain colorless solid monoacetate (formula (1')), 202 mg, 83%). The specific rotation of the monoacetate was $[\alpha]_D^{30} -76.5^\circ$ (c 1.02, CHCl_3). Further, the other physical property values were as follows.

20 IR (film) 3444 cm^{-1} , 1737 cm^{-1}

$^1\text{H-NMR}$ (90 MHz), CDCl_3

1.16-1.70 (m, 4H), 1.90 (s, 1H, D_2O exchangeable), 2.03

(s, 3H), 2.26 (ddd, 2H, $J=7.1, 5.4, 1.7\text{ Hz}$), 2.42-2.79

(m, 2H), 4.14 (quint, 1H, $J=5.4\text{ Hz}$), 5.39 (t, 1H, $J=5.4$

25 Hz), 5.96-6.48 (m, 4H)

MS

m/z 234 (M^+), 80 (100%)

HRMS

Calculated for $\text{C}_{14}\text{H}_{18}\text{O}_3$, 234.1256 (M^+), Found, 234.1240

30 Example 2

To a solution (1 ml) of monoacetate (formula (1')), 146 mg, 0.624 mmol) in dichloromethane, triethylamine (0.35 ml, 2.5 mmol), DMAP (5 mg, 0.04 mmol) and pivalonic anhydride (0.38 ml, 1.9 mmol) were added. The mixture was stirred for three days at room temperature. After adding

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water, the mixture was extracted with dichloromethane. The organic layer was washed with a saturated aqueous solution of sodium bicarbonate and then with a saturated solution of sodium chloride, and dried over magnesium sulfate. The solvent was distilled away under reduced pressure. The residue was subjected to a chromatograph over silica gel to obtain a pivalate. The compound was dissolved in methanol (3 ml), and potassium carbonate was added and the mixture was stirred for one hour. Dichloromethane was added, and the mixture was washed with a saturated aqueous solution of sodium chloride twice and dried over magnesium sulfate. The solvent was distilled away under reduced pressure and the residue was subjected to a chromatograph over silica gel to obtain the colorless solid pivalate (formula (1), 152 mg, 88 %). The specific rotation of the compound was $[\alpha]_D^{30} +99.3^\circ$ (c 1.06, CHCl_3). The other physical property values were as follows.

m.p. 72-73°C

IR (nujol) 1731, 1695, 3488 cm^{-1}

$^1\text{H-NMR}$ (90 MHz), CDCl_3

1.17 (s, 9H), 1.17-1.55 (m, 4H), 1.62 (s, 1H), 2.04-2.78 (m, 4H), 4.13 (quint, 1H, $J=5.6$ Hz), 5.29 (t, 1H, $J=5.4$ Hz), 6.00-6.46 (m, 4H)

MS

m/z 276 (M^+), 80 (100%)

HRMS

Calculated for $\text{C}_{17}\text{H}_{24}\text{O}_3$, 276.1725, Found, 276.1725

Example 3

To a solution (2 ml) of a monoacetate (formula (1')), 100 mg, 0.427 mmol) in acetonitrile, ammonium carbonate (41 mg) and bistriphenylphosphine palladium chloride (3 mg, 0.004 mmol) were added, and the mixture was refluxed for 20 minutes. Diethyl ether was added to the reaction mixture. The solution was washed with a saturated aqueous

solution of sodium bicarbonate and then with an aqueous solution of sodium chloride. The organic layer was dried over magnesium sulfate. The solvent was distilled away under reduced pressure. The residue was subjected to a chromatograph over silica gel to obtain the cyclohexenone derivative (62 mg, 84 %) represented by formula (2). The physical property values were as follows. The specific rotation of the compound was $[\alpha]_D^{32} -147^\circ$ (c 0.41, CHCl_3). The other physical property values were as follows.

m.p. 46.5-47.5 °C

IR (nujol) 1650 cm^{-1}

$^1\text{H-NMR}$ (90 MHz), CDCl_3

1.11-1.69 (m, 4H), 1.73-2.26 (m, 1H), 2.27-2.67 (m, 4H), 3.09 (br. s, 1H), 5.79 (ddd, 1H, $J=10.2, 2.5, 1.7$ Hz), 6.03-6.35 (m, 2H), 6.56-6.78 (m, 1H)

MS

m/z 174 (M^+), 80 (100%)

HRMS

Calculated for $\text{C}_{12}\text{H}_{14}\text{O}$, 174.1045, Found, 174.1059

Example 4

The same method as in Example 3 was used except that pivalate (formula (1), 99 mg, 0.359 mmol), ammonium carbonate (34 mg, 0.54 mmol), triphenylphosphine palladium chloride (2.5 mg, 0.0035 mmol) and acetonitrile 3 mg were used to obtain the cyclohexenone derivative (formula (2'), 49 mg, 79 %). The specific rotation was $[\alpha]_D^{31} +144.6^\circ$ (c 0.418, CHCl_3). The melting point was as follows.

m.p. 46-47 °C

In addition, the optical purity was >99 % ee by using optical resolution HPLC (trade name, CHIRAL CEL OB, effluent: i-PrOH/hexane = 1/9).

In the preceding examples R_1 in formulae (1) and (1') is a methyl group. This is most preferred. According to the invention however R_1 may be any alkyl group but is preferably an alkyl group having 1 to 10 carbon atoms, more preferably 1 to 5 carbon atoms.

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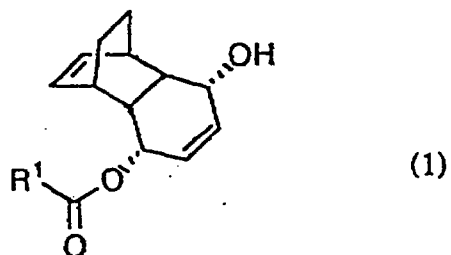
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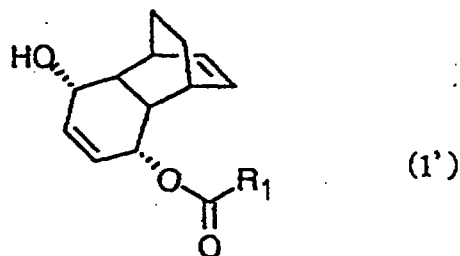
CYCLOHEXENE DIOL DERIVATIVES

Claims

1. An optically active cyclohexene diol derivative represented by the general formula:

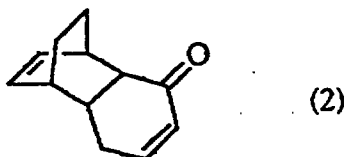


or



20 wherein R_1 is alkyl.

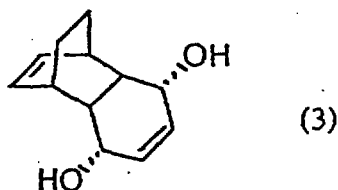
2. An optically active cyclohexenone derivative represented by the formula:



or



3. A process for producing an optically active cyclohexene diol derivative represented by the general formula (1) or (1') described in claim 1, characterized in that it comprises reacting by selectively positioning trans-
5 terification a cyclohexene diol as a starting material represented by the formula:



with an acylating agent in the presence of lipase, and obtaining the said optically active cyclohexene diol
15 derivative.

4. A process for producing an optically active cyclohexenone derivative represented by the formula (2) or (2') described in claim 2, characterized in that it
20 comprises using the optically active cyclohexene diol derivative obtained by the process as claimed in claim 3.

