



(86) Date de dépôt PCT/PCT Filing Date: 1991/08/06

(87) Date publication PCT/PCT Publication Date: 1992/01/20

(45) Date de délivrance/Issue Date: 2002/05/28

(85) Entrée phase nationale/National Entry: 1993/01/28

(86) N° demande PCT/PCT Application No.: US 1991/005578

(87) N° publication PCT/PCT Publication No.: 1992/002511

(30) Priorité/Priority: 1990/08/10 (07/566,200) US

(51) Cl.Int.⁵/Int.Cl.⁵ C07F 9/547, C07D 239/47

(72) Inventeurs/Inventors:

Vemishetti, Purushotham, US;

Brodfehrer, Paul R., US;

Howell, Henry G., US;

Sapino, Chester Jr., US

(73) Propriétaires/Owners:

INSTITUTE OF ORGANIC CHEMISTRY AND

BIOCHEMISTRY OF THE ACADEMY OF

SCIENCES OF THE CZECH REPUBLIC, CZ;

REGA STICHTING, VZW, BE

(74) Agent: GOWLING LAFLEUR HENDERSON LLP

(54) Titre : METHODE DE PREPARATION DE NUCLEOTIDES

(54) Title: PROCESS FOR THE PREPARATION OF NUCLEOTIDES

(57) Abrégé/Abstract:

The present invention relates to a novel and economical process for the synthesis of HPMP-substituted nucleotide antiviral compounds. Also disclosed are novel intermediates produced in the process for the preparation of HPMP.



PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ : C07D 239/46, 473/34 2088363	A1	(11) International Publication Number: WO 92/02511 (43) International Publication Date: 20 February 1992 (20.02.92)
(21) International Application Number: PCT/US91/05578 (22) International Filing Date: 6 August 1991 (06.08.91) (30) Priority data: 566,200 10 August 1990 (10.08.90) US (71) Applicant: BRISTOL-MYERS SQUIBB COMPANY [US/ US]; 345 Park Avenue, New York, NY 10154 (US). (72) Inventors: VEMISHETTI, Purushotham ; 507 Tildon Drive #1, East Syracuse, NY 13057 (US). BRODFUEHRER, Paul, R. ; 108 Wellesley Road, Syracuse, NY 13207 (US). HOWELL, Henry, G. ; 4114 Gates Road North, James- ville, NY 13078 (US). SAPINO, Chester, Jr. ; 6451 Pheasant Road, East Syracuse, NY 13057 (US).		(74) Agents: YANG, Mollie, M. et al.; Bristol-Myers Squibb Company, 5 Research Parkway, P.O. Box 5100, Walling- ford, CT 06492-7660 (US). (81) Designated States: AT (European patent), AU, BE (Euro- pean patent), CA, CH (European patent), DE (Euro- pean patent), DK (European patent), ES (European pa- tent), FI, FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (Eu- ropean patent). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the</i> <i>claims and to be republished in the event of the receipt of</i> <i>amendments.</i>
(54) Title: NOVEL PROCESS FOR THE PREPARATION OF NUCLEOTIDES (57) Abstract The present invention relates to a novel and economical process for the synthesis of HPMP-substituted nucleotide antiviral compounds. Also disclosed are novel intermediates produced in the process for the preparation of HPMPC.		

NOVEL PROCESS FOR THE PREPARATION OF NUCLEOTIDES

1. Field of the Invention

5 The present invention relates to a novel process for the preparation of hydroxyphosphonylmethoxypropyl nucleosides, and novel intermediates produced therein.

2. Background Art

10

Nucleoside analogs possessing a 3-hydroxy-2-(phosphonylmethoxy)propyl (HPMP) side chain have been reported as potent antiviral compounds having a broad spectrum of activity. Examples of compounds belonging to this class include HPMP-adenine (HPMPA), HPMP-guanine (HPMPG) and HPMP-cytosine (HPMPC). HPMP-substituted nucleosides contain a chiral center and it has been postulated that the biological activity may reside in one enantiomer and not the other. It is therefore desirable to develop a synthetic method which will preferentially yield the active enantiomer using readily available and inexpensive starting materials.

25

Bronson et al (J. Med. Chem., 1989, 32:1457) reported the synthesis of (S)-HPMPC which involves the coupling of cytosine with 3-O-benzyl-2-O-[(diethylphosphonyl)methyl]-3-O-(methylsulfonyl)glycerol, followed by subsequent deprotection to afford the product. The glycerol starting material is derived from chiral (R)-glycerol acetonide.

30

Holy et al (Coll. Czech. Chem. Comm., 1989, 54:2470) reported the synthesis of (S)-HPMPC by reacting (R)-glycerol acetonide tosylate with 4-methoxy-2-pyrimidinone, the resultant product is

35

then converted to 1-[(2,3-dihydroxy)propyl]cytosine.
The latter compound is reacted with
chloromethylphosphonyl dichloride, and the product is
converted to (S)-HPMPC by base catalyzed
5 rearrangement.

Glycerol acetonide was also used in the synthesis
of (S)-HPMPA (Webb, Nucleosides and Nucleotides, 1989,
8:619) and HPMPG (Terry et al, Antiviral Res., 1988,
10 10:235). These procedures all require the use of the
expensive chiral glycerol acetonide as starting
material, and involve multi-step process requiring
chromatographic purifications of intermediate
compounds.

15

The reaction of glycidol with adenine, cytosine
or uracil to form the 2,3-dihydroxypropyl substituted
nucleosides was reported by Ueda et al, J.
Heterocyclic Chem., 1971, 8:827. The reaction of
20 (±)-glycidol with thymine or 5-fluorouracil was
reported by Seiter et al, Bull. Chem. Soc. Jpn., 1973,
46:1572. The prior art does not disclose or suggest
the process of the present invention for the
preparation of HPMP-nucleotides which offers marked
25 improvement over previously known methods.

SUMMARY OF THE INVENTION

The present invention provides a novel and
30 improved process for the preparation of
hydroxyphosphonomethoxypropyl (HPMP) nucleoside
antiviral compounds. The process of the instant
invention comprises the steps of reacting an
optionally substituted purine or pyrimidine base with
35 an optionally substituted glycidol; if glycidol is
used in the previous step, protecting the primary

hydroxy group of the intermediate thus formed;
reacting this product with a methanephosphonate
derivative; and removing the various protecting groups
to afford the final product.

5

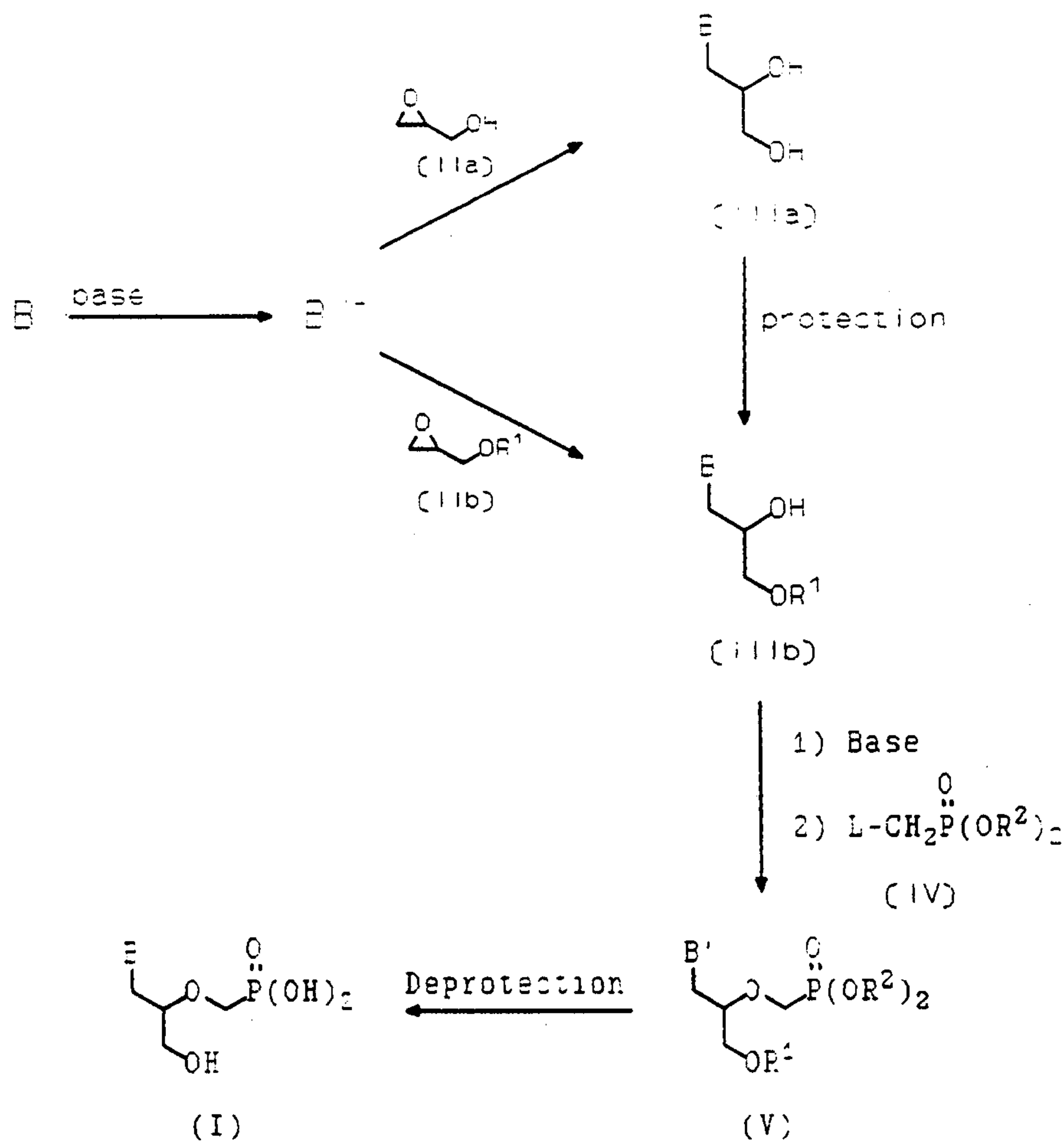
The instant process starts with readily available
purine and pyrimidine bases, and glycidol. The
process offers advantages in economies of both
material and labor costs by virtue of eliminating the
10 need for isomer separations and subsequent
chromatographic purifications; and unlike prior art
processes, the instant process is suitable for large
scale synthesis of the final products. Furthermore,
the process is stereospecific and, starting with a
15 chiral glycidol, produces the products without
racemization.

DETAILED DESCRIPTION OF THE INVENTION

20 The present process for the preparation of HPMP-
type nucleoside antiviral compounds is shown in
Scheme I.

2088363

Scheme I



In Scheme I, B is a purine or a pyrimidine base;
B' is a purine or pyrimidine base or a protected

purine or pyrimidine base; L is a conventional leaving group; R¹ is a hydroxy protecting group; and R² is an alkyl group having 1-5 carbon atoms.

5 "Purine or pyrimidine base" includes, but is not limited to, adenine, guanine, thymine, uracil, cytosine, xanthine, hypoxanthine, 8-bromoguanine, 8-chloroguanine, 8-aminoguanine, 8-hydrazinoguanine, 8-hydroxyguanine, 8-methylguanine, 8-thioguanine,
10 2-aminopurine, 2,6-diaminopurine, 5-ethylcytosine, 5-methylcytosine, 5-bromouracil, 5-iodouracil, 5-ethyluracil, 5-propyluracil, 5-vinyluracil, and 5-bromovinyluracil.

15 "Protected purine or pyrimidine" refers to a purine or pyrimidine base in which functional groups that may interfere with the desired reaction have been blocked by a group stable under basic conditions. For example, the 4-amino group of cytosine may be blocked
20 by the benzoyl group.

"Leaving group" includes, but is not limited to, halides such as chloride, bromide, and iodide; mesylate; and tosylate. "Alkyl" includes both
25 straight and branched carbon chains. "Hydroxy protecting group" includes, for example, trityl, allyl, and benzyl groups.

In Scheme I, the first step involves the
30 preparation of a compound of formula (IIIf). A purine or a pyrimidine base B' is first treated with a base in order to generate the corresponding anion. The base is not particularly restricted and may be selected from metal hydrides such as sodium and
35 potassium hydrides, metal carbonates such as sodium and potassium carbonates, and metal alkoxides such as

SUBSTITUTE SHEET

2088363

6

potassium t-butoxide; preferably the base is used in a catalytic amount.

Where the purine or pyrimidine base contains 1 or
5 more functional groups that may be reactive to form
undesired products under the reaction conditions of
the present process, for example, the 4-amino group of
cytosine and adenine and the 2-amino and 4-oxo groups
of guanine, such functional groups may be blocked
10 using the protecting group commonly employed in
nucleoside chemistry. For example, the 4-amino group
of adenine and cytosine may be protected by benzoyl;
the 4-oxo and 2-amino groups of guanine may be
protected by the triphenylmethyl group. The selection
15 of methods for introducing and subsequent removal of
such protecting groups are well known to one of
ordinary skill in the pertinent art.

The anion B' generated in situ is reacted with
20 glycidol (IIa) to generate the 2,3-dihydroxy
nucleoside of formula (IIIa). The primary alcohol of
the compound of formula (IIIa) is blocked prior to the
addition of the phosphonate group. For the present
process, however, it is preferred that the glycidol
25 reactant is one in which the primary alcohol is
protected, i.e. a compound of formula (IIb). The
reaction of a protected glycidol with B' consistently
gives the corresponding product of formula (IIIb) in
higher yields than reactions in which unprotected
30 glycidol is used. The hydroxy protecting group may
be, for example, triphenylmethyl-type where the phenyl
groups are unsubstituted or 1 or more of the phenyl
groups are substituted, for example with methoxy; or
allyl, benzyl, and the like. Preferably, the hydroxy
35 protecting group is one selected from the group of
triphenylmethyl type compounds.

SUBSTITUTE SHEET

The reaction is carried out in an inert dipolar aprotic organic solvent such as dimethylformamide, N-methyl-2-pyrrolidinone (NMP), dimethyl sulfoxide, and hexamethyl phosphoramide at a temperature that favors the formation of the desired products; generally, the reaction temperature is elevated and may be from about 50°C to about 150°C. Preferably, the reaction is carried out at about 100°C to about 120°C. The starting materials B' and the glycidol are used in molar equivalent or one or the other reactant may be used in a slight excess, e.g., up to about 2 equivalents relative to the other. Preferably, B' is employed in excess in an amount up to about 1.3 equivalent of the glycidol.

The second step of the present process involves the introduction of the methanephosphonate moiety to the secondary hydroxy group of a compound of formula (IIb). Prior to carrying out this step, if B' contains an unprotected functional group, this may be optionally protected. For example, the 4-amino group of cytosine may be converted to the corresponding dimethylformamidino derivative upon treatment with N,N-dimethylformamide or an acetal thereof.

Thus, a compound of formula (IIb) is first treated with a base to generate the corresponding alkoxide anion. The base may be a metal hydride, for example sodium hydride, potassium hydride or lithium hydride; and metal alkoxides, for example, potassium t-butoxide or sodium methoxide and the like. The reaction mixture containing the alkoxide anion is then treated with the methanephosphonate $\text{LCH}_2\text{P}(\text{O})(\text{OR}^2)_2$ (IV) wherein L is a leaving group and R^2 is an alkyl group containing 1-5 carbon atoms as previously defined to provide the protected HPMP nucleoside of formula (V).

L is preferably selected from the group consisting of p-toluenesulfonate (tosylate), methanesulfonate (mesylate), and trifluoromethanesulfonate (triflate); and R² is preferably an alkyl group having from 1-3 carbon atoms, e.g., methyl, ethyl, n-propyl, and isopropyl.

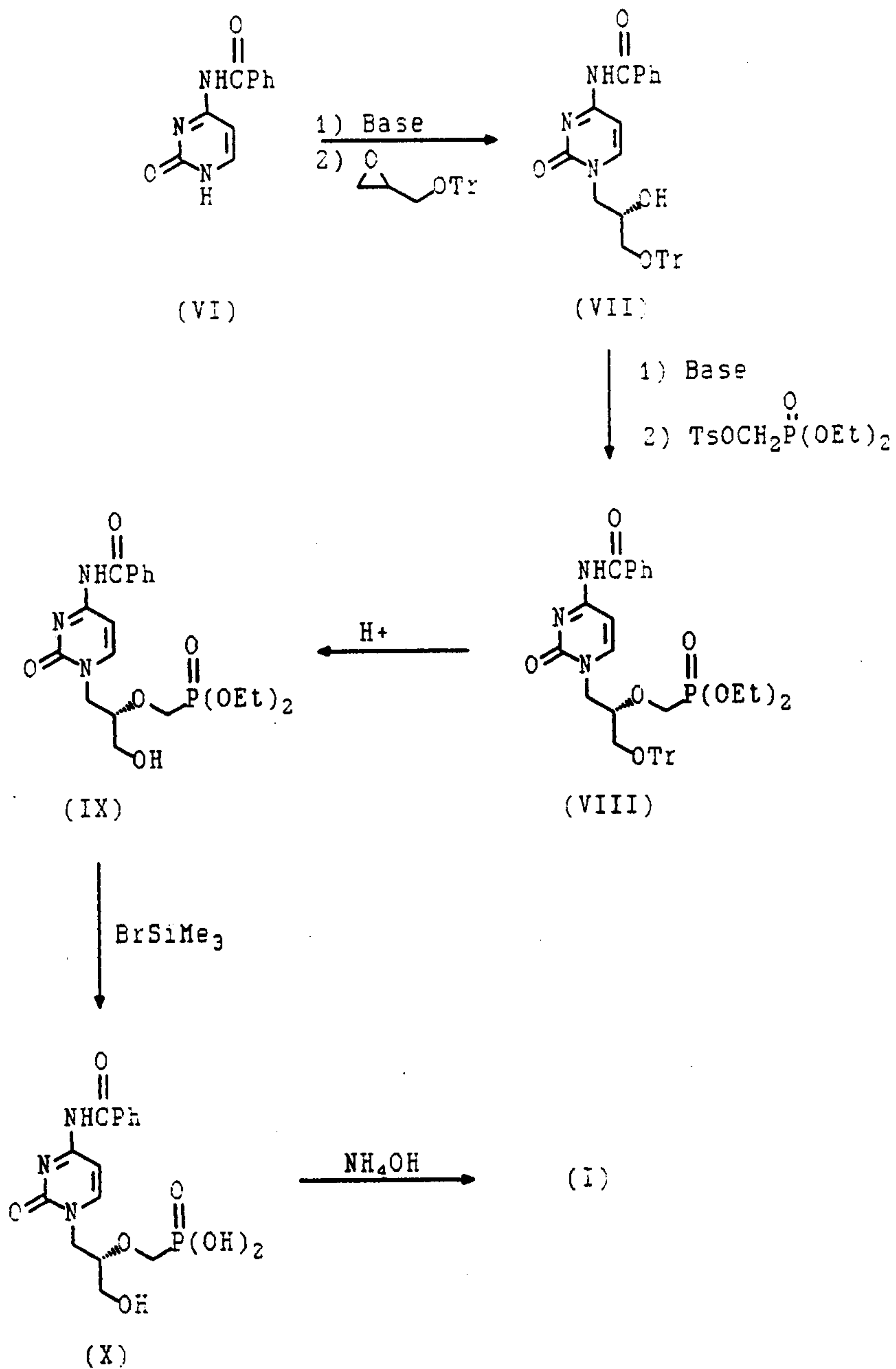
The third step of the process involves the removal of the phosphonic protecting group, i.e. R², the hydroxy protecting group, and if present, any protecting groups on the purine or pyrimidine base. The phosphonate may be converted to the parent acid by treatment with a trialkylsilyl halide such as trimethylsilyl bromide or trimethylsilyl iodide, and optionally followed by the addition of water. Methods to be employed for the removal of the hydroxy protecting group, and if present, protecting groups on the purine or pyrimidine base will of course depend on the nature of the protecting group; examples of typical deprotecting techniques include acid or base catalyzed hydrolysis, hydrogenation, or metal mediated deprotection.

In a preferred embodiment of the present process, the reaction sequence is conveniently carried out from the starting material to the end product without isolating and purifying the intermediate compounds formed. The elimination of the need for costly and labor intensive isolation and purification of intermediates represent a marked improvement over prior processes. Another advantage of the present invention is that the stereochemistry of the glycidol reactant is maintained throughout the process such that end product having the desired stereo configuration is obtained without racemization.

The process of the present invention, while adaptable to the synthesis of a wide variety of HPMP substituted purine and pyrimidine bases, is especially applicable to the synthesis of

5 hydroxyphosphonomethoxypropyl cytosine (HPMPC); particularly (S)-HPMPC. A preferred embodiment of the present process suitable for the preparation of (S)-HPMPC is illustrated in Scheme II.

Scheme II



In Scheme II, Tr is triphenylmethyl and Ts is tosyl. N⁴-Benzoylcytosine (VI) is converted to its anionic form by treatment with a base in an aprotic polar organic solvent at elevated temperature; suitable bases are for example sodium hydride, potassium t-butoxide, potassium or sodium carbonate, and the like; suitable solvents are for example dimethylformamide, N-methyl-2-pyrrolidinone, dimethyl sulfoxide, hexamethylphosphoramide, and the like; and typical reaction temperature ranges from about 70°C to about 150°C. Subsequently, (S)-[(triphenylmethoxy)-methyl]oxirane is added to the above reaction solution and the solution maintained at the elevated temperature to effect the formation of (S)-N⁴-benzoyl-N¹-[(2-hydroxy-3-triphenylmethyl)propyl]-cytosine (VII).

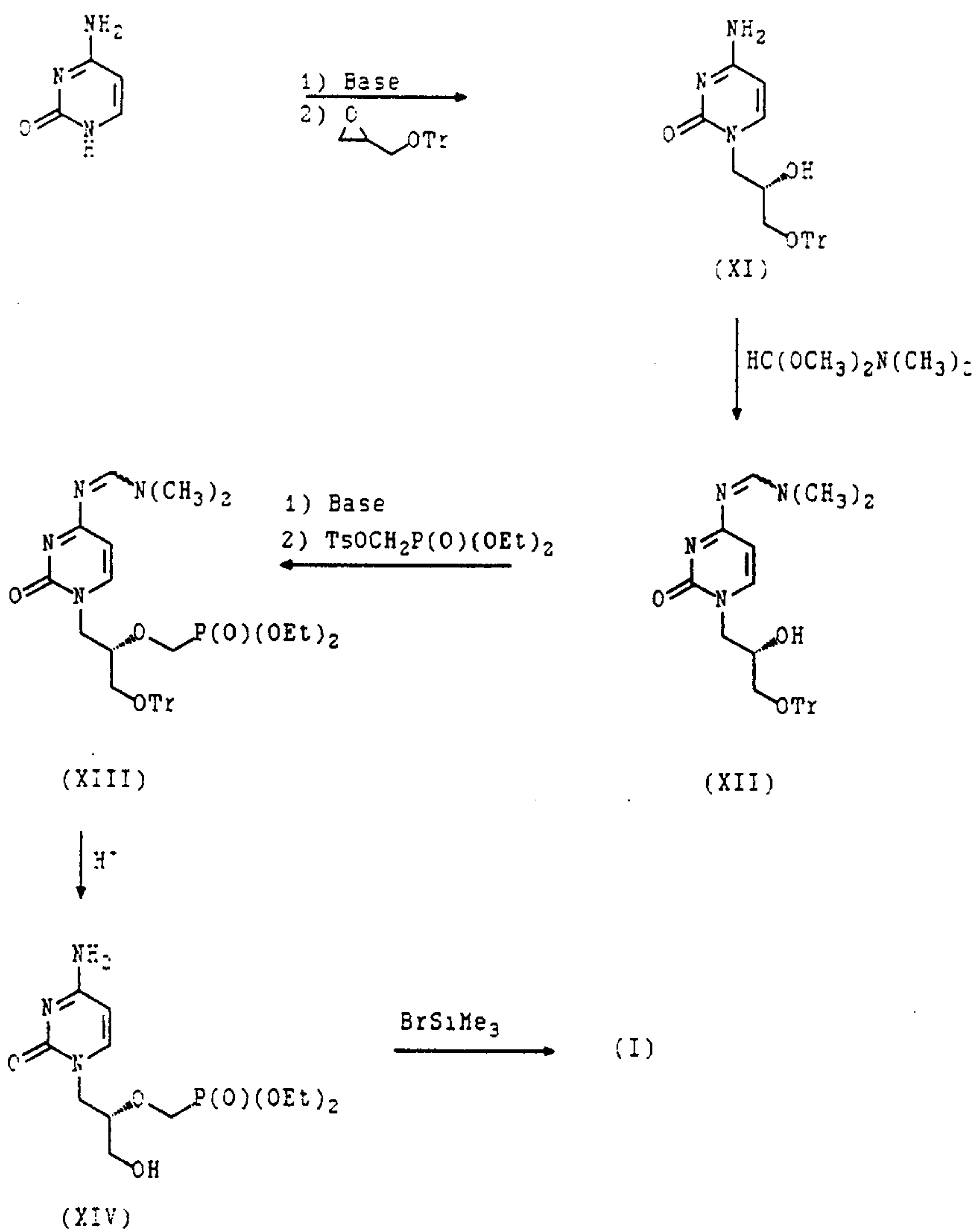
The above obtained diprotected (2,3-dihydroxy)-propyl cytosine is treated with a metal hydride, e.g. sodium hydride, at ice bath temperature, and then treated with diethyl tosyloxymethylphosphonate to provide the compound (S)-N⁴-benzoyl-N¹-[[(2-diethylphosphonylmethoxy)-3-triphenylmethyl]propyl]cytosine (VIII).

Next, the trityl protecting group is removed to provide the compound of formula (IX) by treating the above obtained compound (VIII) with an acidic medium, for example with hydrochloric acid at about 0-5°C. A wide range of other acids may be employed to accomplish this step, and examples include, acetic acid, formic acid, trifluoroacetic acid, zinc bromide, acidic ion exchange resins, to name but a few. Suitable reaction temperature, and time may be readily ascertained by a person skilled in the art.

SUBSTITUTE SHEET

Following detritylation, the resulting compound (X) is treated with a trialkylsilyl halide such as trimethylsilyl bromide at room temperature to convert the diethyl phosphonate to the phosphonic acid. This
5 latter compound is then treated with a base such as ammonium hydroxide to remove the benzoyl protecting group to afford the desired end product (S)-HPMPC.

Another preferred process for the preparation of
10 (S)-HPMPC is illustrated in Scheme III.

Scheme III**SUBSTITUTE SHEET**

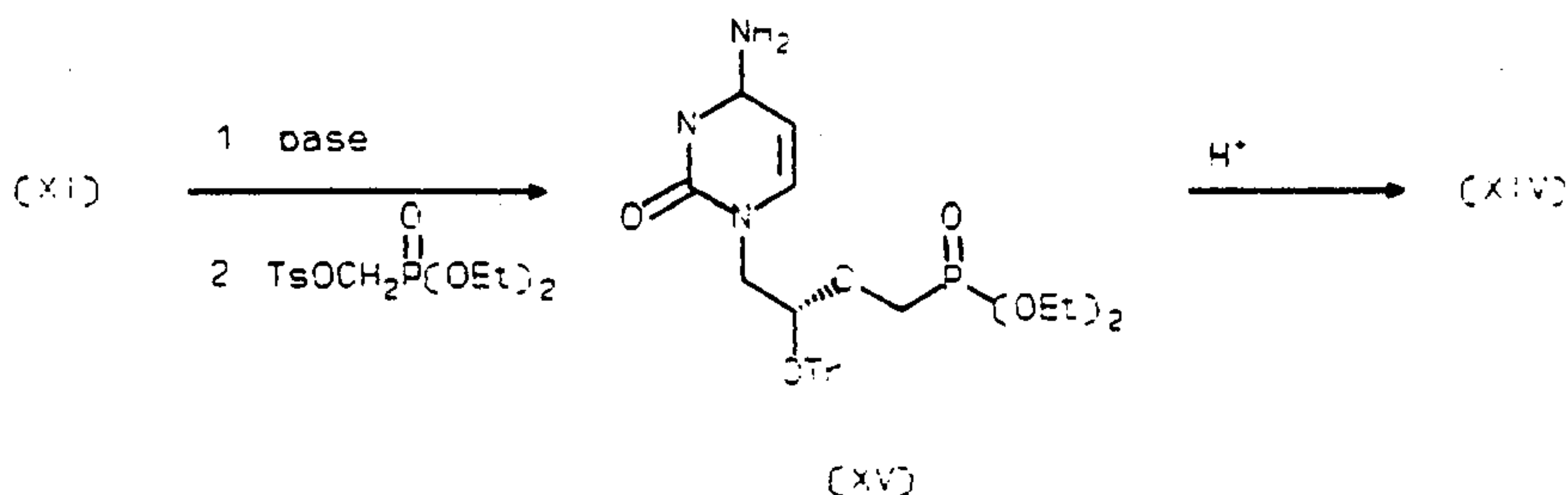
2088363

14

In Scheme III, cytosine is coupled with (S)-[(triphenylmethoxy)methyl]oxirane in the presence of a base such as one previously enumerated to give cytosine derivative of formula (XI). The 4-amino group of compound (XI) is then converted to the corresponding dimethyl formamidine derivative (XII) upon treatment with dimethylformamide or an acetal thereof. Compound (XII) is subjected to base promoted alkylation with diethyl tosyloxymethylphosphonate as previously described to provide compound of formula (XIII). Compound (XIII) is deprotected in an acidic medium and the product thereof is treated with e.g. trimethylsilyl bromide to afford (S)-HPMPC.

In another preferred process for the preparation of (S)-HPMPC, as illustrated in Scheme IV, cytosine derivative of formula (XI) is treated with a base, followed by diethyl tosyloxymethylphosphonate to afford the compound of formula (XV). The latter compound is treated with an acid to remove the trityl protecting group and affords the compound of formula (XIV) which is converted to (S)-HPMPC as previously described.

25 Scheme IV



15

Another aspect of the present invention concerns novel intermediates in the synthesis of (S)-HPMPC. These include compounds of formulas (VII), (VIII), (IX), (X), (XII), (XIII), and (XV).

5

The process of this invention is illustrated in greater detail by the following examples which are not to be construed to limit the scope of the invention in any manner.

10

Preparation I. (+)-Triphenylmethoxymethyloxirane

15 Trityl chloride (18.816 g, 0.067 mol) was added to a stirred solution of (+)-glycidol (5 g, 0.067 mol) and triethylamine (13.84 g, 0.137 mol) in anhydrous methylene chloride (54 ml). After 15 hours of stirring at room temperature, the reaction solution was washed with water (2 x 10 ml) and brine (20 ml). The organic phase was evaporated after drying over 20 anhydrous Na_2SO_4 to give a yellow foam which was purified on silica gel (5% EtOAc in hexane) to afford the title compound (17.64 g, 82.6%) as a solid.

25 ^1H NMR (CDCl_3): 2.62 (dd, $J = 2.4$ and 5.2 Hz, 1H), 2.77 (t, $J = 4.5$ Hz, 1H), 3.08-3.18 (m, 2H), 3.29-3.80 (m, 1H), 7.20-7.38 (m, 3H), 7.45-7.52 (m, 2H).

Preparation II. (S)-Triphenylmethoxymethyloxirane

30

A 5 L 3-neck round bottom flask was charged with trityl chloride (133.8 g, 0.48 mol) and methylene chloride (400 ml). It was cooled to 0°C under N_2 and treated with triethylamine (70.7 g, 0.70 mol). After 35 an hour of stirring at 0°C , a solution of (R)-glycidol (88% ee, 37.03 g, 0.5 mol) in methylene chloride (100

SUBSTITUTE SHEET

16

ml) was added over 0.75 hour. The resulting solution was allowed to warm to ambient temperature and was stirred for 3 hours. It was then filtered, and the filtrate was washed with water (2 x 500 ml) and brine (2 x 500 ml). The organic phase was dried over MgSO_4 and concentrated to a foam, which on crystallization from isopropyl alcohol gave the title compound (116.2 g, 76.5%) as an off-white powder.

$[\alpha]_D = -6.01$ ($C = 1$, MeOH).

Example 1. Preparation of (\pm) -N¹-[(2,3-dihydroxy)-propyl]-cytosine

Cytosine (0.55 g, 4.95 mmol), (\pm) -glycidol (0.404 g, 5.45 mmol), and anhydrous potassium carbonate (5 mg, 0.04 mmol) in dry DMF (6 ml) were stirred at 71°C for 3 hours. Glycidol (4) was totally reacted according to TLC of the reaction mixture. The DMF was distilled off under high vacuum, and the resulting yellowish thick liquid was absorbed on silica gel (3 g). This was placed on top of a silica gel column, which was eluted with 20% MeOH in ethyl acetate to give a mixture (0.540 g) of the title compound and a polymer derived from glycidol. Crystallization from ethanol afforded the title compound (0.44 g, 52.3%) as a solid.

MP: 169°-71°C.

UV: λ_{max} 274 nm ($\epsilon = 8,083$).

^1H NMR ($\text{DMSO}-d_6$): 3.11-3.47 (m, 3H), 3.55-3.75 (m, 1H), 3.88 (dd, $J = 3.3$ and 13.3 Hz, 1H), 4.71 (t, $J = 5.8$ Hz, 1H), 4.95 (d, $J = 5.3$ Hz, 1H), 5.61 (d, J

17

= 7.1 Hz, 1H), 7.00 (bd, J = 23.7 Hz, 2H), 7.44 (d, J = 7.1 Hz, 1H).

Analysis calcd. for $C_7H_{11}N_3O_3 \cdot 0.5H_2O$:

5

C, 43.30; H, 6.23; N, 21.63

Found: C, 43.33; H, 5.92; N, 21.38

Example 2. Preparation of (S)-N1-[(2,3-dihydroxy)-
propyl]-cytosine

10

Reaction of cytosine (2.2 g, 19.8 mmol) with (R)-glycidol (88% ee, 1.51 ml, 22.8 mmol) in the presence of anhydrous potassium carbonate (40 mg, 0.289 mmol) in dry DMF (20 ml) at 72°C for 5 hours, as described in Example 1, furnished the title compound (88% ee) in 43.1% yield.

Example 3. Preparation of (±)-N1-[(2-hydroxy-3-triphenylmethoxy)propyl]cytosine by
tritylation of (±)-N1-[(2,3-dihydroxy)-
propyl]cytosine

20

(a) using 1.1 eq. of glycidol

25

A mixture of cytosine (0.55 g, 4.95 mmol), (±)-glycidol (0.362 ml, 5.46 mol), and anhydrous potassium carbonate (5 mg) in dry DMF (5 ml) was stirred at 71°C for 3 hours. It was cooled to room temperature and treated with DMAP (0.031 g, 0.25 mmol), dry pyridine (0.783 g, 9.9 mmol), and trityl chloride (1.48 g, 5.2 mmol). The resulting reaction mixture was stirred at 80°C for 3 hours and at room temperature for 17 hours. It was diluted with ethyl acetate (60 ml), washed with saturated sodium bicarbonate (2 x 15 ml), water (15 ml), and brine (15 ml), and dried over $MgSO_4$. The ethyl acetate was evaporated to give a crispy foam

30

35

2088363

18

(1.98 g), and purification by chromatography over silica gel (10-15% methanol in ethyl acetate) furnished the title compound as a crystalline solid (0.74 g, 35%).

5

MP: 227°-228°C.

UV: λ_{\max} 274 nm ($\epsilon = 7,149$).

10

^1H NMR (DMSO- d_6): 2.81-2.98 (m, 2H), 3.26-3.42 (m, 1H), 3.85-3.97 (m, 1H), 4.02 (dd, $J = 4.7$ and 14.2 Hz, 1H), 5.23 (d, $J = 5.8$ Hz, 1H), 5.54 (d, $J = 7.1$ Hz, 1H), 7.93 (bd, 2H), 7.1-7.29 (m, 16H).

15

(b) using 1.5 eq. of glycidol

20

Cytosine (0.275 g, 2.48 mmol), (\pm)-glycidol (0.281 g, 3.7 mmol), and anhydrous potassium carbonate (2.5 mg, 0.018 mmol) in dry DMF (2.5 ml) were stirred at 70°C for 1.5 hours. The DMF was distilled under reduced pressure. PMR of the resulting solid showed that it contained (\pm)-N¹-[(2,3-dihydroxy)propyl]-cytosine and cytosine in 89:11 ratio.

25

The above solid was dissolved in dry pyridine (4 ml) and trityl chloride (0.602 g, 2.14 mmol) and DMAP (13 mg) were added successively at room temperature. After 3 hours of stirring at 85°C, followed by work-up as described in Example 3 (a), supra, a foamy solid (0.88 g) was obtained. Crystallization from methylene chloride and toluene gave the title compound (0.360 g 34%). The mother liquor was concentrated and purified by silica gel chromatography (10% methanol in ethyl acetate) to give the title compound (60 mg, 5.7%) and (\pm)-N¹-[[2-[(2-hydroxy-3-triphenylmethoxy)-propyloxy]-

30

35

3-triphenylmethoxy]propyl]cytosine (hereinafter referred to as the dimer) (10 mg, 0.8%).

(c) using 2 eq. of glycidol

5

The above experiment was repeated using 2 eq. of (\pm)-glycidol to provide the title compound in 39.6% yield and the dimer in 1.6% yield.

10 Example 4. Preparation of (\pm)-N¹-[(2-hydroxy-3-triphenylmethoxy)propyl]cytosine by reaction of cytosine and
(\pm)-triphenylmethoxymethyloxirane

15

(a) using a catalytic amount of NaH

Cytosine (80 mg, 0.72 mmol) was added to a stirred suspension of 80% NaH (4 mg, 0.13 mmol) in dry
20 DMF (3 ml). After an hour at room temperature, (\pm)-trityloxymethyl-oxirane (0.19 g, 0.6 mmol) was added to the reaction mixture, and stirring continued at 106°C for 5 hours. The reaction was completed as indicated by TLC of the reaction mixture. It was
25 cooled, and the DMF was distilled off under vacuum. The resulting solid was partitioned between ethyl acetate (20 ml) and water (2 ml). The organic phase was separated, washed once again with water (5 ml), and dried over Na₂SO₄. Evaporation of the ethyl
30 acetate gave the brown solid (0.28 g) which was crystallized from methylene chloride-toluene (2 ml and 30 ml) to furnish the title compound (0.21 g) in 81.7% yield.

35

20

(b) using one equivalent of NaH

Carrying out the above reaction using
(±)-trityloxymethyloxirane (0.190 g, 0.6 mmol),
5 cytosine (67 mg, 0.6 mmol), and sodium hydride (80%,
18 mg, 0.6 mmol) in anhydrous DMF (4 ml) furnished the
title compound (60 mg) in 23.3% yield.

c. using K₂CO₃ instead of NaH

10

Following the procedure described above, the
title compound was obtained in 82% yield from
(±)-trityloxymethyloxirane (0.19 g, 0.6 mmol) and
cytosine (0.08 g, 0.72 mmol) in the presence of
15 potassium carbonate (10 mg, 0.072 mmol) in anhydrous
DMF (3 ml).

Example 5. Preparation of (±)-N⁴-benzoyl-N¹-
[(2-hydroxy-3-triphenylmethoxy)-
20 propyl]cytosine

(a) using 1 equivalent of N⁴-benzoylcytosine

Treatment of N⁴-benzoylcytosine (0.388 g, 1.803
25 mmol) with (±)-trityloxymethyloxirane (0.571 g, 1.805
mmol) in the presence of 80% sodium hydride (12 mg,
0.4 mmol), according to the procedure of Example 4
(a), gave the title compound as a crystalline solid in
72.9% yield after chromatography over silica gel using
30 hexane-EtOAc (1:3).

MP: 105°-7°C.

UV: λ_{max} 259 nm ($\epsilon = 23,500$), 306 nm ($\epsilon =$
35 10,380).

21

^1H NMR (CDCl_3): 3.05-3.18 (m, 1H), 3.21-3.33 (m, 1H), 3.66-3.90 (m, 1H), 4.2 (bs, 1H), 4.35 (d, $J = 13.6$ Hz, 1H), 7.13-7.72 (m, 15H), 7.88 (d, $J = 7.5$ Hz, 1H), 8.73 (bs, 1H).

5

Analysis calcd. for $\text{C}_{33}\text{H}_{29}\text{N}_3\text{O}_4$:

C, 74.56; H, 5.50; N, 7.90

Found: C, 74.02; H, 5.67; N, 7.63

10

(b) using 1.2 equivalents of N^4 -benzoylcytosine

(\pm)-Tityloxymethyloxirane (0.762 g, 2.41 mmol) was reacted with N^4 -benzoylcytosine (0.621 g, 2.89 mmol) in the presence of 80% sodium hydride (16 mg, 0.53 mmol) in dry DMF, as described above, to obtain the title compound in 85% yield.

15

Example 6. Preparation of (S)- N^4 -benzoyl- N^1 -
[(3-allyloxy-2-hydroxy)propyl]
cytosine

20

To sodium hydride (80%, 12 mg, 0.4 mmol) stirring in anhydrous DMF (4.5 ml) at room temperature was added N^4 -benzoylcytosine (0.466 g, 2.17 mmol). The reaction mixture was stirred for an hour and treated with (S)-allyloxymethyl-oxirane (0.206 g, 1.8 mmol). It was then heated at 105°C for 6 hours, cooled, and concentrated in vacuo. The resulting orange red gummy material was treated with water (5 ml) and ethyl acetate (20 ml). It was stirred for 5 minutes, and the insoluble solid (0.145 g, 31.1% of recovery) was collected by filtration and identified as N^4 -benzoylcytosine. The filtrate was transferred into a separatory funnel, and the ethyl acetate layer was separated. It was washed with water (3 x 5 ml), dried over Na_2SO_4 , and evaporated to obtain 0.423 g of pale-

25

30

35

2088363
22

yellow solid. Slurrying of this material in diethyl ether gave the title compound (0.331 g) in 55.7% yield. The ether filtrate was evaporated, and the resulting light greenish gummy material was purified by flash chromatography on silica gel (0-5% MeOH in EtOAc) to furnish the title compound (20 mg) in 3.6% yield.

MP: 139°-41°C.

$[\alpha]_D = -55.06$ (C = 1.155, MeOH).

UV: λ_{\max} 259 nm ($\epsilon = 21,500$), 305 nm ($\epsilon = 10,120$).

^1H NMR (CDCl_3): 3.4-3.56 (m, 2H), 3.77 (dd, J = 7.6 and 13.5 Hz, 1H), 3.98 (d, J = 5.7 Hz, 3H), 4.16-4.25 (m, 1H), 4.28 (dd, J = 2.7 and 13.5 Hz, 1H), 5.10-5.25 (m, 2H), 5.79-5.92 (m, 1H), 7.39-7.62 (m, 4H).

Analysis calcd. for $\text{C}_{17}\text{H}_{19}\text{N}_3\text{O}_4$:

C, 61.97; H, 5.85; N, 12.79

Found: C, 61.82; H, 6.05; N, 12.77

Example 7. Preparation of (\pm)-N⁴-benzoyl-N¹-[(3-allyloxy-2-hydroxy)propyl]-
cytosine

The title compound was prepared in 39.5% yield, following the procedure of Example 6, from (\pm)-allyloxymethyloxirane (9.02 g, 0.079 mol), N⁴-benzoylcytosine (20.40 g, 0.095 mol), and 80% sodium hydride (0.526 g, 0.018 mol) in dry DMF (241 ml).

Example 8. Preparation of (S)-N⁴-benzoyl-N¹-[(3-benzyloxy-2-hydroxy)propyl]-
cytosine

5 (R)-benzyloxymethyloxirane (0.296 g, 1.8 mmol) in dry DMF (0.5 ml) was added to sodium salt of N⁴-benzoylcytosine, prepared from N⁴-benzoylcytosine (0.388 g, 1.8 mmol) and 80% sodium hydride (0.012 g, 0.4 mmol) in dry DMF (4 ml) at room temperature for an
10 hour, and stirred at 110°C for 6 hours. The reaction was complete as confirmed by HPLC of the reaction. Most of the DMF was distilled off under reduced pressure. The resulting gummy product was partitioned between ethyl acetate (20 ml) and water (5 ml). The
15 ethyl acetate layer was separated, washed with water (3 x 10 ml), dried over Na₂SO₄, and evaporated to give a yellow product (0.595 g). Trituration with ethyl acetate furnished the title compound (0.392 g) in 57.3% yield. The mother liquor was concentrated and
20 chromatographed on silica gel (ethyl acetate) to give the title compound (50 mg, 7.3%).

MP: 138°C.

25 $[\alpha]_D = -49.19$ (C = 1.425, MeOH).

UV: λ_{\max} 259 nm ($\epsilon = 22,440$), 306 nm ($\epsilon = 10,220$).

30 ¹H NMR (CDCl₃): 3.45-3.58 (m, 3H), 3.79 (dd, J = 7.1 and 13.3 Hz, 2H), 4.16-4.33 (m, 2H), 4.51 (s, 2H), 7.2-7.6 (m, 8H), 7.69 (d, J = 7.2 Hz, 1H), 7.89 (d, J = 7.4 Hz, 2H), 8.91 (bs, 1H).

Analysis calcd. for $C_{21}H_{21}N_3O_4 \cdot 0.9H_2O$:

C, 63.76; H, 5.81; N, 10.62

Found: C, 63.97; H, 5.50; N, 10.63

5

Example 9. Preparation of (\pm) -N⁴-benzoyl-N¹-[(3-benzyloxy-2-hydroxy)propyl]-
cytosine

10

Treatment of (\pm) -benzyloxymethyloxirane (6.0 g, 0.0365 mol) with N⁴-benzoylcytosine (9.446 g, 0.0439 mol) in the presence of sodium hydride (80% pure, 0.263 g, 8.1 mmol) in dry DMF (85 ml), according to the procedure of Example 8, afforded the title
15 compound (8.2 g) in 59.2% yield.

MP: 144°-6°C.

20

Example 10. Preparation of (\pm) -N¹-[(2-diethylphosphonylmethoxy-2-triphenylmethoxy)-
propyl]cytosine

25

One Pot Synthesis: A mixture of cytosine (0.134 g, 1.21 mmol) and 80% sodium hydride (8 mg, 0.27 mmol) in anhydrous DMF (3 ml) was stirred at room
temperature. After 1 hour, (\pm) -trityloxymethyloxirane (0.38 g, 1.2 mmol) was added in 1 portion, and stirring was continued for 5 hours at 105°C. The
formation of (\pm) -N¹-[(2-hydroxy-3-trityloxy)propyl]-
30 cytosine was noted by its HPLC.

35

The above homogenous reaction solution was cooled in an ice bath and successively treated with 80% sodium hydride (0.100 g, 3.3 mmol) and diethyl tosyloxymethylphosphonate (85% pure, 0.682 g, 1.8 mmol). After being stirred at 0°C for 0.5 hour and at

25

room temperature for 15 hours, a few drops of ethanol were added to quench excess sodium hydride. The solvent was removed under reduced pressure, and the resulting orange residue was partitioned between ethyl acetate (30 ml) and water (5 ml). The organic phase was separated and washed with saturated sodium bicarbonate (10 ml) and brine (10 ml). After drying over Na_2SO_4 , the ethyl acetate was evaporated to give the orange-colored product (0.550 g), which was purified by chromatography on silica gel (10-15% MeOH in CH_2Cl_2) to furnish the title compound (0.26 g, 37.4%) as a foamy solid.

^1H NMR (CDCl_3): 1.25 (t, $J = 7$ Hz, 6H), 2.97-3.12 (m, 1H), 3.33 (dd, $J = 3$ and 10.5 Hz, 1H), 3.55-3.68 (m, 2H), 3.84-3.96 (m, 2H), 3.96-4.24 (m, 5H), 5.63 (d, $J = 6.9$ Hz, 1H), 7.0-7.6 (m, 18H).

Example 11. Preparation of (\pm)-N¹-[(2-dimethoxyphosphorylmethoxy-3-triphenylmethoxy)-propyl]cytosine

Repeating the experiment of Example 10, using dimethyl tosyloxymethylphosphonate instead of diethylphosphonate afforded the title compound in 15.6% yield.

^1H NMR (CDCl_3): 3.0-3.1 (m, 1H), 3.27 (dd, $J = 2.8$ and 10.5 Hz, 1H), 3.51-4.26 (m, 10H), 4.17 (dd, $J = 3.0$ and 13.6 Hz, 1H), 5.69 (d, $J = 6.9$ Hz, 1H), 7.0-7.66 (m, 18H).

Example 12. Preparation of (\pm) -N¹-[(2-diethylphosphonylmethoxy-3-hydroxy)propyl]cytosine

5 Treatment of cytosine (0.249 g, 2.24 mmol) with (\pm) -trityloxymethyloxirane (0.590 g, 1.87 mmol) in the presence of a catalytic amount of 80% sodium hydride (13 mg, 0.44 mmol) followed by in situ alkylation of the intermediate with diethyl tosyloxymethylphosphonate (85.1% pure, 1.06 g, 2.80 mmol) in the
10 presence of 80% sodium hydride (0.099 g, 3.3 mmol), according to the procedure of Example 10, gave the crude (\pm) -N¹-[(2-diethylphosphonylmethoxy-3-trityloxy)propyl]cytosine (1.267 g).

15 To the above nucleotide, 80% acetic acid (20 ml) was added and stirred at 95°C for 3 hours. Water (20 ml) was added to the reaction which was then cooled to -0°C. The precipitated trityl alcohol was collected by filtration. The filtrate was evaporated, and the
20 resulting thick product was co-distilled with water (3 x 30 ml) and with toluene (3 x 30 ml) to remove acetic acid. It was then applied on a silica gel column which, on elution with 15% MeOH in CH₂Cl₂, afforded the title compound (0.147 g, 23.5%) as a gummy material.
25 Further elution of the column with 20% MeOH in CH₂Cl₂ gave (\pm) -N¹-[(2,3-dihydroxy)propyl]cytosine (20.2 mg, 6%).

¹H NMR (MeOH-d₄): 1.30 (t, J = 7.1 Hz, 3H), 1.31
30 (t, J = 7.1 Hz, 3H), 3.5-3.63 (m, 1H), 3.67-3.92 (m, 4H), 3.97-4.22 (m, 6H), 5.85 (d, J = 7.2 Hz, 1H), 7.53 (d, J = 7.2 Hz, 1H).

2088363

27

Example 13. Preparation of (\pm) -N¹-[(2-diethylphosphonylmethoxy-3-hydroxy)propyl]cytosine
via formamidine method

5 A mixture of the sodium salt of cytosine, obtained from cytosine (0.134 g, 1.21 mmol) and 80% sodium hydride (8 mg, 0.27 mmol) in dry DMF (3 ml) at room temperature for 1 hour, and (\pm) -trityloxymethyl-oxirane (0.38 g, 1.2 mmol) was stirred at 110°C for 5
10 hours. The resulting solution of 12 was cooled to room temperature, and DMF dimethyl acetal (0.286 g, 2.4 mmol) was added in 1 portion. It was then stirred at 85°C for 1.5 hours and concentrated under reduced pressure to ca. 1 ml of the crude dimethylformamidine
15 derivative of 11. This and diethyl tosyloxymethylphosphonate (0.909 g, 2.4 mmol) in anhydrous DMF (3 ml) was cooled to 0°C and treated with 80% sodium hydride (64 mg, 2.13 mmol). The resulting yellow reaction mixture was stirred at 0°C for 1.5 hours and
20 at room temperature for 14 hours. The crude product obtained after work-up is a mixture of (\pm) -N¹-[(2-diethylphosphonylmethoxy-3-trityloxy)propyl]cytosine and its N⁴-dimethylformamidine derivative. This mixture was dissolved in 80% acetic acid (11 ml) and
25 refluxed for 3 hours. After work-up, the yellowish gummy product (0.693 g) was obtained which, on purification by chromatography on silica gel (15% MeOH in EtOAc), afforded the title compound (0.175 g) in 43.6% yield.

30

Example 14. Preparation of (\pm) -N¹-[(2-ethylhydrogenphosphonylmethoxy-3-hydroxy)propyl]-
cytosine

35

2N Sodium hydroxide solution (4.5 ml) was added to (\pm) -N¹-[(2-diethylphosphonylmethoxy-3-hydroxy)-

2088363

28

propyl]cytosine (0.230 g, 0.69 mmol). TLC of the reaction after 1.25 hours at room temperature showed that starting material was completely consumed. The reaction was acidified with Dowex 50 x 8 (H⁺) and
5 filtered. The resin was washed with 20 ml of water. The combined filtrate was evaporated to provide the title compound (0.163 g) in 77.3% yield.

¹H NMR (D₂O): 1.26 (t, J = 7.1 Hz, 3H), 2.52-2.68
10 (m, 2H), 3.75-4.0 (m, 6H), 4.21 (dd, J = 2.8 and 14.1 Hz, 1H), 6.19 (d, J = 7.6 Hz, 1H), 7.88 (d, J = 7.6 Hz, 1H).

MS: molecular ion (m/e) for C₁₀H₁₈N₃O₆P, 308.1011:
15 Found: 308.1009

Example 15. Preparation of (S)-N⁴-benzoyl-N¹-[(2-hydroxy-3-triphenylmethoxy)-
propyl]cytosine

20

(a) To N⁴-benzoylcytosine (100.1 g, 0.47 mol) in dry DMF (1,000 ml) at 100°C under N₂ was added 80% sodium hydride (3.0 g, 0.10 mol) in 1 portion, and the slurry was stirred for 0.25 hour. (S)-trityloxy-
25 methyloxirane (88% ee, 125.1 g, 0.40 mol) was added and further stirred at 110°C for 4 hours. The reaction was completed as confirmed by its HPLC. The reaction mixture was filtered and used in the subsequent reaction without further purification. The
30 filtrate contained a 90% in solution yield of the title compound based on HPLC.

(b) In a separate experiment, the crude product obtained from the above reaction was purified by

chromatography on silica gel (3-5% MeOH in CH₂Cl₂) and provided analytically pure title compound.

MP: 105°-7°C.

5

UV: λ_{\max} 259 nm (ϵ = 23,500), 306 nm (ϵ = 10,380).

10 ¹H NMR (CDCl₃): 3.05-3.18 (m, 1H), 3.21-3.33 (m, 1H), 3.66-3.90 (m, 1H), 4.2 (bS, 1H), 4.35 (d, J = 13.6 Hz, 1H), 7.13-7.72 (m, 15H), 7.88 (d, J = 7.5 Hz, 1H), 8.73 (bS, 1H).

Analysis calcd. for C₃₃H₂₉N₃O₄:

15

C, 74.56; H, 5.50; N, 7.90

Found: C, 74.02; H, 5.67; N, 7.63

20 (c) The reaction described in (a) supra was also repeated using solvents and conditions to afford the title compound.

(1) NaH, NMPO, 70°-80°C for 2 hours followed by 100°-104° for 3.5 hours.

25

(2) NaH, 18-crown-6, DMF, 103°C, 5 hours.

(3) NaH, benzyltriethylammonium chloride, DMF, 70°C for 6 hours, 105°C for 4 hours.

30

(4) KOC(CH₃)₃, DMF, 70°C for 16 hours followed by 105°C for 8 hours.

Example 16. Preparation of (S)-N⁴-benzoyl-
[(diethylphosphonylmethoxy-3-
triphenylmethoxy)propyl]cytosine

5 (a) A solution of the crude (S)-N⁴-benzoyl-N¹-
[(2-hydroxy-3-triphenylmethoxy)propyl]cytosine in DMF,
obtained in Example 15 (a), was placed in a 5 L 3-neck
round bottom flask and cooled to 0°C. 80% sodium
hydride (32.4 g, 1.06 mol) was added in 2 portions,
10 and an exotherm of 8°C was noted. Immediately,
diethyl tosyloxymethylphosphonate (80% pure, 215.6 g,
0.54 mol) was added, and the reaction was completed
after 6 hours of stirring. The reaction was diluted
with ethyl acetate (2 L), quenched with water, washed
15 with water (2 x 1 L) and saturated NaHCO₃ (1 L), dried
over MgSO₄, and concentrated to afford crude title
compound (230.1 g) with 2% of (S)-trityloxymethy-
loxirane, as indicated by its proton NMR spectrum.
This crude product was used in the next procedure
20 without further purification.

(b) In a separate experiment, a small amount of
the crude product was purified by column
chromatography on silica gel (1-3% MeOH in CH₂Cl₂) to
25 provide an analytical sample of the title compound.

¹H NMR (DMSO-d₆): 1.14 (t, J = 7 Hz, 3H), 1.16
(t, J = 7 Hz, 3H), 2.94-2.98 (m, 1H), 3.24-3.31 (m,
1H), 3.58-4.09 (m, 9H), 7.23-7.63 (m, 19H), 7.98 (d, J
30 = 7 Hz, 3H), 11.19 (bS, 1H).

Analysis calcd. for C₃₈H₄₀N₃O₇P·0.5H₂O:

C, 66.07; H, 5.98; N, 6.08

Found: C, 65.96; H, 5.84; N, 6.09

2088363

31

Example 17. Preparation of (S)-N⁴-benzoyl-N¹-[(2-diethylphosphonylmethoxy-3-hydroxy)-propyl]cytosine

5 (a) Hydrogen chloride gas was bubbled into a solution of the crude (S)-N⁴-benzoyl-N¹-[(2-diethylphosphonyl-3-triphenylmethoxy)propyl]cytosine (230.1 g, obtained from Example 16) in methylene chloride (1.2 L) at 0°-5°C until starting material was
10 consumed as determined by HPLC (ca 10 minutes). Water (500 ml) was added, and the resulting 2-phase mixture stirred rigorously for 5 minutes. The organic phase was separated and extracted with 10% hydrochloric acid (2 x 250 ml). The combined aqueous solution was
15 cooled to 0°-5°C, adjusted to pH = 8 with 40% sodium hydroxide solution, and then extracted with CH₂Cl₂ (2 x 500 ml). The combined CH₂Cl₂ solution was dried over MgSO₄ and concentrated in vacuo to give crude title compound (96.2 g), as a viscous oil, in 55% yield from
20 (S)-trityloxymethoxy-oxirane after 3 steps.

¹H NMR (DMSO-d₆): 1.16 (t, J = 7 Hz, 3H), 1.18 (t, J = Hz, 3H), 3.44-3.57 (m, 2H), 3.68-3.80 (m, 3H), 3.88-4.01 (m, 5H), 4.13 (dd, J = 8 and 17 Hz, 1H),
25 4.88 (t, J = 6 Hz, 1H), 7.27 (br d, J = 7 Hz, 1H), 7.49 (t, J = 7 Hz, 2H), 7.60 (t, J = 7 Hz, 1H), 7.98 (d, J = 7 Hz, 3H), 11.18 (br s, 1H).

Analysis calcd. for C₁₉H₂₆N₃O₇P·0.5H₂O:

30 C, 50.89; H, 6.07; N, 9.37

Found: C, 50.99; H, 6.03; N, 9.32

(b) Detritylation was carried out with the following reagents and conditions to afford the title
35 compound in moderate to excellent yields:

SUBSTITUTE SHEET

WO 92/02511

2088363

PCT/US91/05579

32

- (1) 80% acetic acid, 75°C, 45 minutes.
- (2) 80% acetic acid, 100°C, 30 minutes.
- 5 (3) 80% acetic acid, 60°C, 3 hours.
- (4) 80% formic acid, 0°-5°C, 30 minutes.
- 10 (5) 95-97% formic acid, room temperature, 5 minutes.
- (6) Trifluoroacetic acid, n-butanol or isopropyl alcohol, or CH₂Cl₂, 22 hours.
- 15 (7) ZnBr₂, CH₂Cl₂, room temperature, 10 minutes-3 hours.
- (8) Amberlyst 15*(H⁺), MeOH, 50°C, 24 minutes.
- 20 (9) Amberlyst 15 (H⁺) activated by HCl/MeOH wash, 50°C, 6.5 hours.
- (10) Dowex 50*x 8 (H⁺) activated by HCl/MeOH.

25 Example 18. Preparation of (S)-N⁴-benzoyl-N¹-[(3-hydroxy-2-phosphonylmethoxy)-propyl]cytosine

30 A solution of (S)-N¹-[(2-diethylphosphonylmethoxy-3-hydroxy)propyl-N⁴]-benzoylcytosine (188 g, 0.428 mol) in methylene chloride (1.2 L) at room temperature under argon was treated with bromotrimethylsilane (200 ml, 1.52 mol), and the resulting mixture was stirred for 18 hours. It was then concentrated in vacuo to a residue which was redissolved in methylene chloride 35 (500 ml) and reconcentrated to furnish the crude

SUBSTITUTE SHEET

persilylated title compound (289 g) as a tan foam. This material was used in the next step without further purification. An analytical sample of the title compound was prepared by treating the crude foam
5 with water from which the desired title compound crystallized.

^1H NMR ($\text{DMSO}-d_6$): 3.45-3.81 (m, 6H), 4.11 (dd, J = 4 and 13 Hz, 1H), 7.26 (d, J = 7 Hz, 1H), 7.49 (t, J = 7 Hz, 2H), 7.61 (t, J = 7 Hz, 1H), 7.98 (d, J = 7 Hz, 2H), 8.04 (d, J = 7 Hz, 1H).
10

Analysis calcd. for $\text{C}_{15}\text{H}_{18}\text{N}_3\text{O}_7\text{P} \cdot 0.5\text{H}_2\text{O}$:

C, 45.93; H, 4.84; N, 10.71

15 Found: C, 46.04; H, 4.67; N, 10.71

Example 19. Preparation of (S)-N¹-[(3-hydroxy-2-phosphonylmethoxy)propyl]cytosine

20 The crude persilylated (S)-N⁴-benzoyl-N¹-[(3-hydroxy-2-phosphonylmethoxy)propyl]cytosine (289 g), obtained from the previous example, was dissolved on conc NH_4OH (850 ml) and stirred at room temperature for 4 hours. The aqueous reaction mixture was extracted
25 with CH_2Cl_2 (2 x 600 ml) to remove most of the benzamide and then filtered and concentrated in vacuo until the pH of the aqueous solution was neutral. The concentrated solution was diluted with water to a volume of 800 ml, and ethanol (600 ml) was added. The
30 product was precipitated by adjusting the pH to 3.0 with careful addition of conc HCl (65 ml). The resulting thick slurry was stirred at room temperature for 1 hour and then stored at 0°-5°C for 16 hours. The solid product was collected by filtration, washed
35 with water ethanol (2:1, 2 x 150 ml), and dried to constant weight in vacuo at 40°C to give (S)-HPMPC

(105 g) in 78% yield from 22S after 2 steps. This material contained 5% of the undesired (R)-isomer as determined by chiral HPLC. Two crystallizations of the crude product by adjusting an aqueous slurry to pH = 6 with 40% NaOH solution, followed by reprecipitation with conc HCl to pH = 3, reduced the level of the undesired (R)-isomer to 2.4, a 90% weight recovery.

10 MP: 260°C (decomp).

$[\alpha]_D = -86.65$ (C = 0.40, H₂O).

15 ¹H NMR (D₂O): d 3.59-3.67 (m, 2H), 3.79-3.94 (m, 4H), 4.20 (dd, J = 3 and 14 Hz, 1H), 6.17 (d, J = 8 Hz, 1H), 7.90 (d, J = 8 Hz, 1H).

Analysis calcd. for C₈H₁₄N₃O₆·2H₂O:

C, 30.48; H, 5.75; N, 13.33

20 Found: C, 30.30; H, 5.70; N, 13.25

Example 20. Preparation of (±)-N¹-[(3-hydroxy-2-phosphonylmethoxy)propyl]cytosine

25 Synthesis of (±)-HPMPC was achieved in 42.4% yield after 5 steps (Examples 15, 16, 17, 18, and 19) starting from (±)-trityloxymethyloxirane and N⁴-benzoylcytosine.

30 Example 21. Preparation of (R)-N¹-[(3-hydroxy-2-phosphonylmethoxy)propyl]cytosine

The title compound (R)-HPMPC was prepared from (S)-glycidol (88% ee) and N⁴-benzoylcytosine, following the method described for (S)-HPMPC.

35

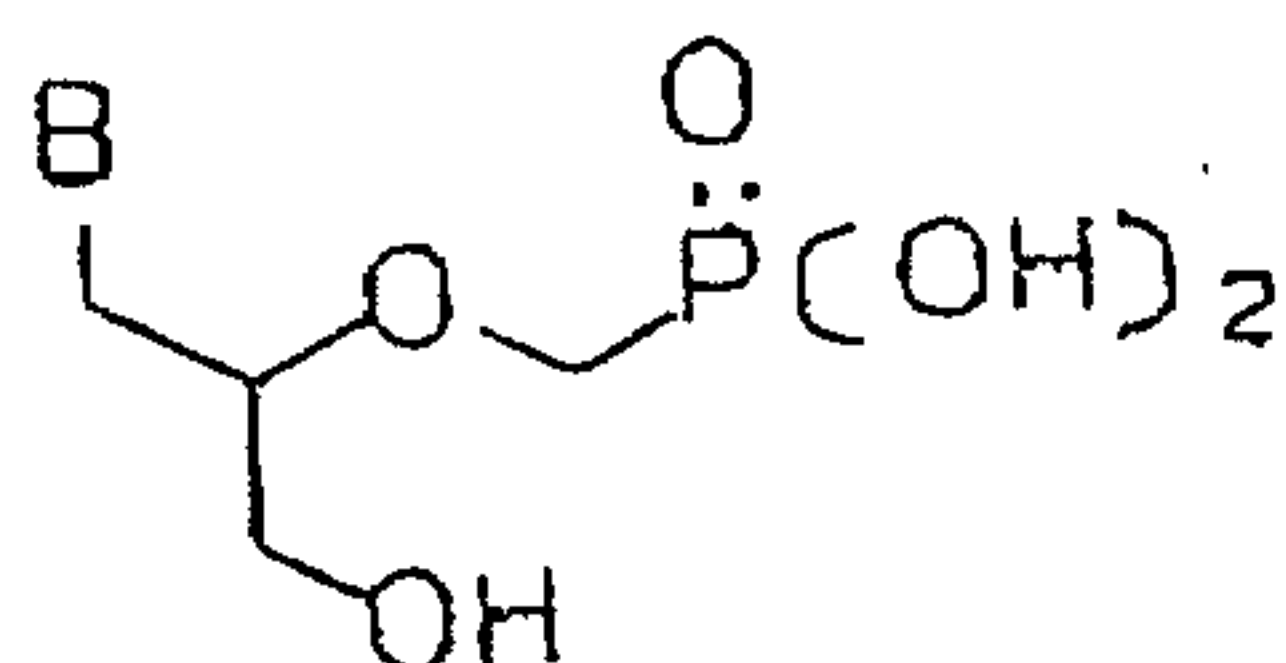
Example 22. Preparation of (\pm) -[(3-hydroxy-2-phosphonylomethoxy)propyl]uracil

A solution of (\pm) -N¹-[(2-diethylphosphonyl-3-hydroxy)propyl]cytosine (0.228 g, 0.68 mol) in 2N sodium hydroxide (4.5 ml) was heated at 82°C for 60 hours. The reaction was complete as indicated by its HPLC. It was acidified with Dowex 50 x 8 (H⁺) form at room temperature and filtered, and the resin was washed with water (30 ml). Evaporation of the filtrate afforded the title compound (0.157 g, 82.4%) as a solid.

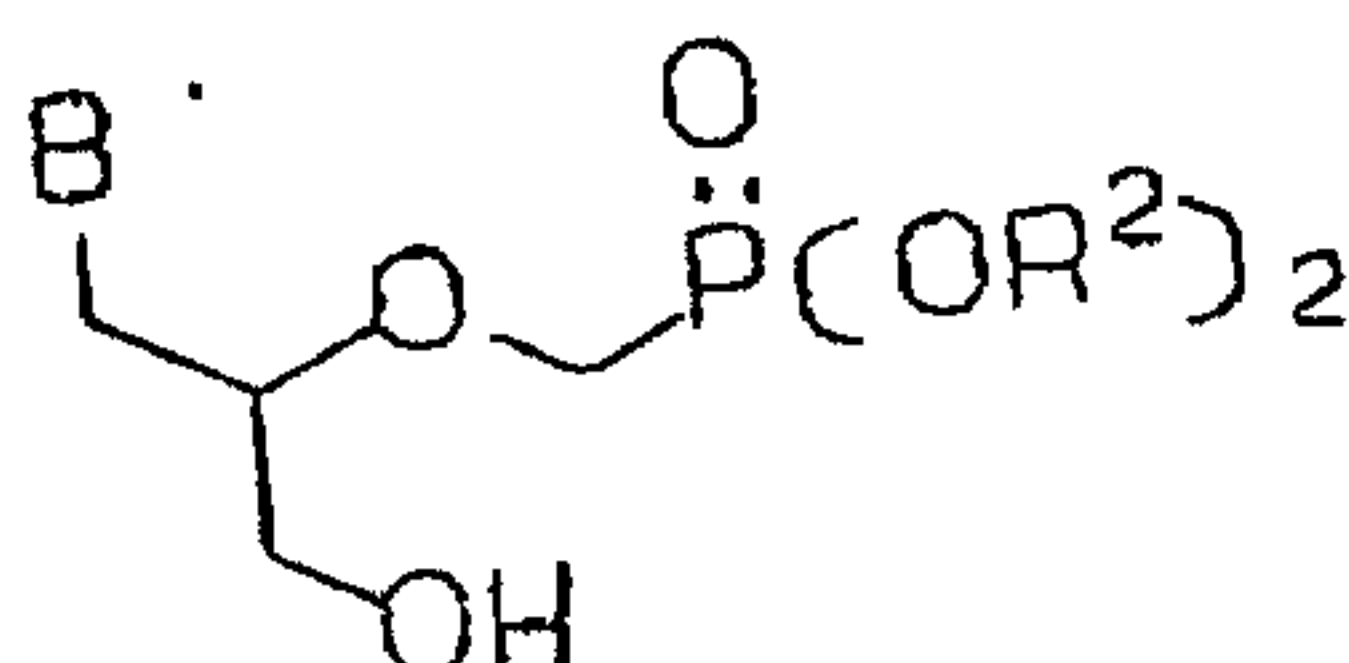
¹H NMR (D₂O): 3.16-3.29 (m, 1H), 2.55-4.17 (m, 9H), 5.87 (d, J = 7.9 Hz, 1H), 7.72 (d, J = 7.9 Hz, 1H).

What is claimed is:

1. A process for preparing a compound of formula (Ia) or (Ib).



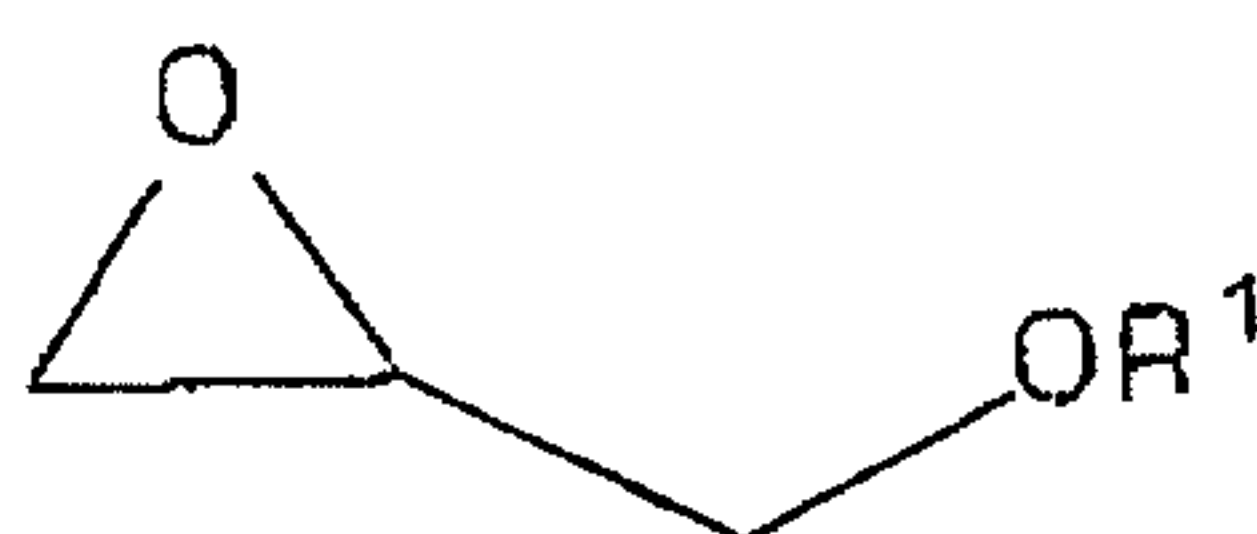
(Ia)



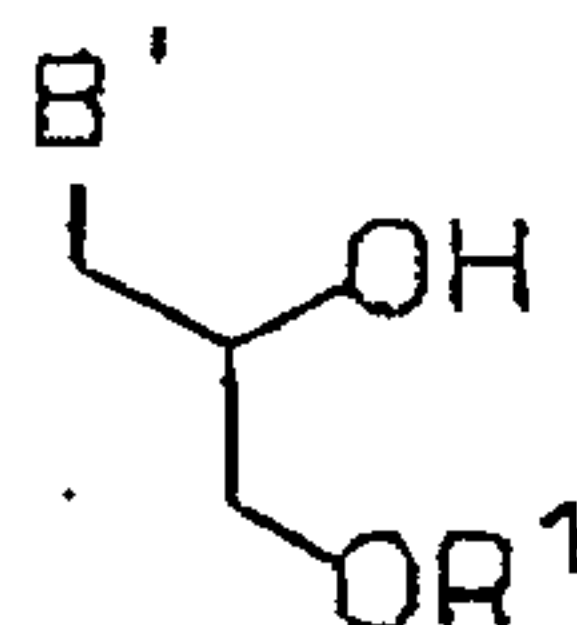
(Ib)

15 wherein B is a purine or pyrimidine base, which comprises the steps of:

- (a) reacting, in a reaction mixture, B' in the presence of a base with a compound of formula (IIb) to form the intermediate (IIIb)
- 20



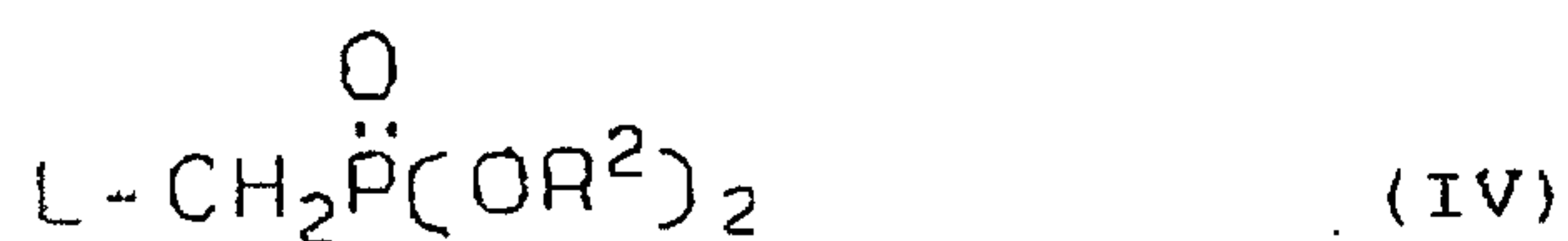
(IIb)



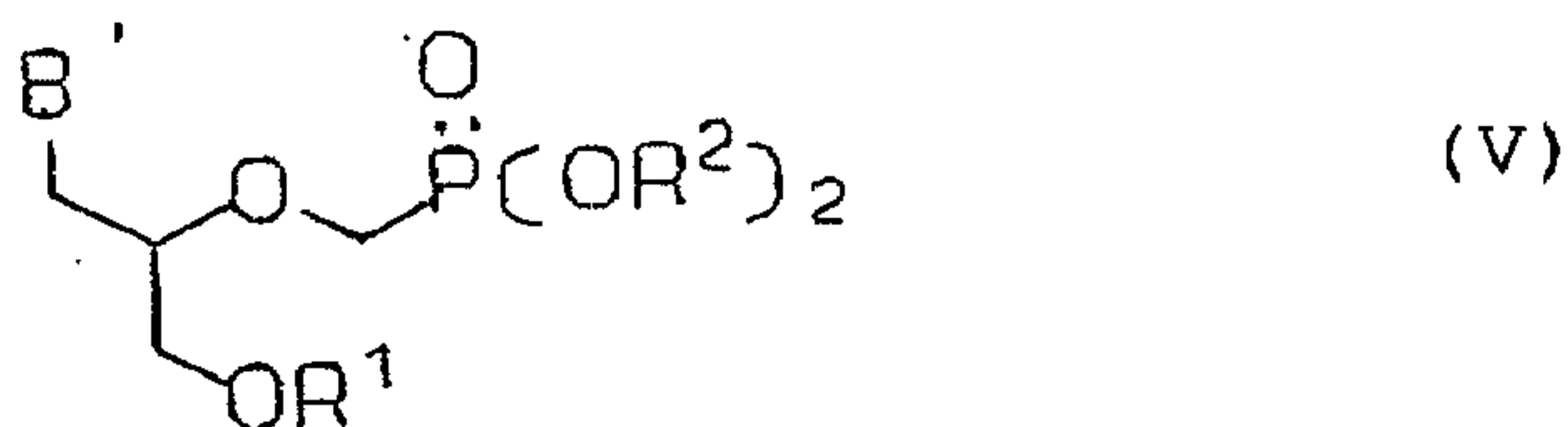
(IIIb)

37

and, without separating intermediate (IIIb) from the
 reaction mixture, reacting intermediate (IIIb) with
 a phosphonate of formula (IV)



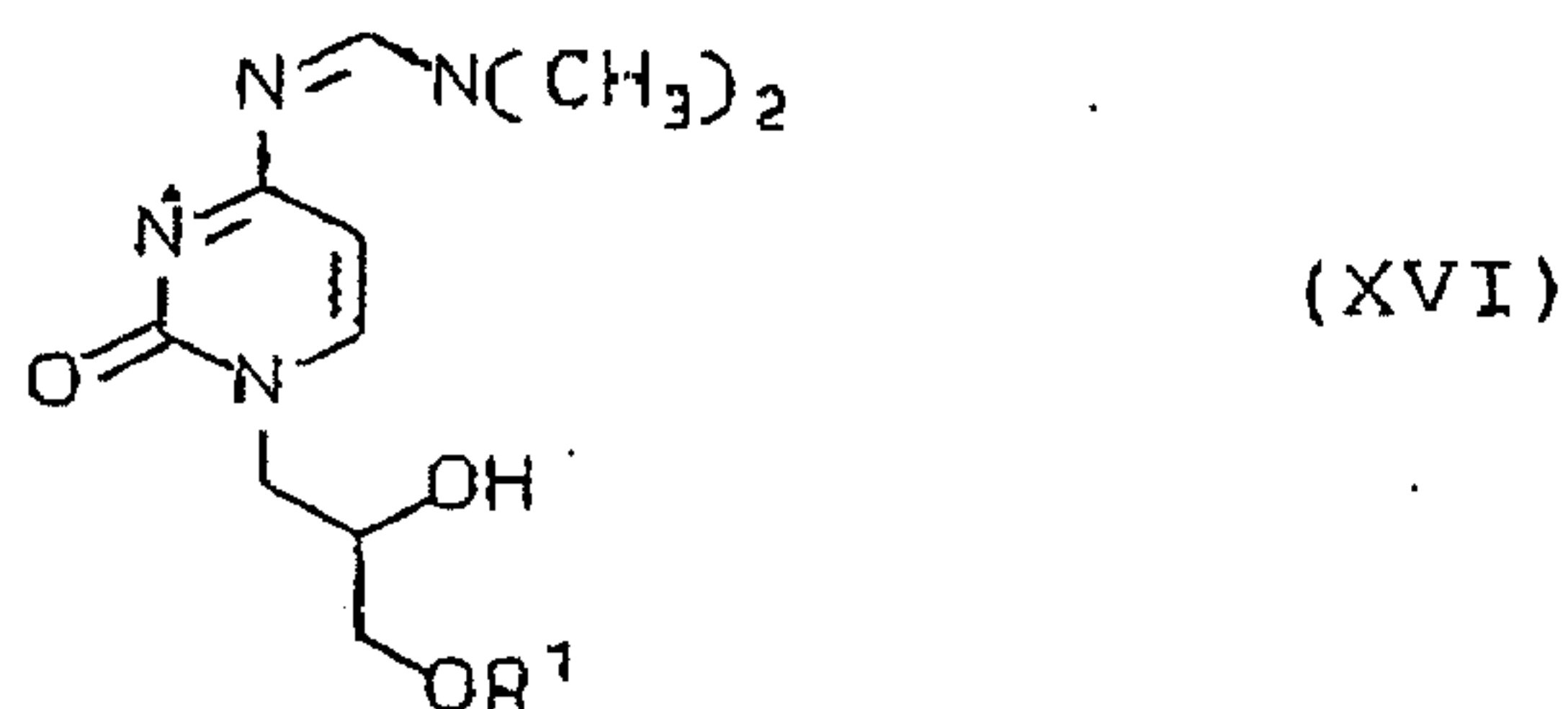
to form an intermediate of formula (V)



where B' is a purine or pyrimidine base or a
 suitably protected purine or pyrimidine base, R¹ is a
 hydroxy protecting group, L is a leaving group, and
 R² is a phosphonic protecting group selected from
 alkyl having 1-5 carbon atoms; and

- (b) replacing the R¹ hydroxy protecting group, and
 optionally, the R² or B' protecting groups, with
 hydrogen to form the product of formula (Ia) or
 (Ib).

2. The process of claim 1 wherein R^1 is replaced with hydrogen by treatment with an acidic medium.
3. The process of claim 1 wherein R^1 of a compound of formula (IIb) is triphenylmethyl and R^2 is ethyl or isopropyl.
4. The process of claim 1 wherein B' is cytosine or N^4 -protected cytosine.
5. The process of claim 1 wherein the process is carried out in an inert polar aprotic solvent.
6. The process of claim 1 wherein B' is N^4 -benzoylcytosine and R^1 is triphenylmethyl.
7. The process of claim 1 which further comprises reacting a compound of formula (IIb) wherein B' is cytosine with dimethylformamide dimethyl acetal to form a compound of formula (XVI)



wherein R^1 is as defined in claim 1.

8. The process of claim 1 wherein compound (IIb) is (S)-triphenylmethoxymethyloxirane.

- 5 9. The process of claim 1 wherein the product is
(S)-N¹-[3-hydroxy-2-(phosphonylmethoxy)propyl]cytosine.
10. The process of claim 1 wherein the base is a metal
hydride or metal alkoxide.
- 10 11. The process of claim 10 wherein the base is sodium
hydride.
12. The process of claim 5 wherein the solvent is
dimethylformamide.
- 15
- 20
- 25