

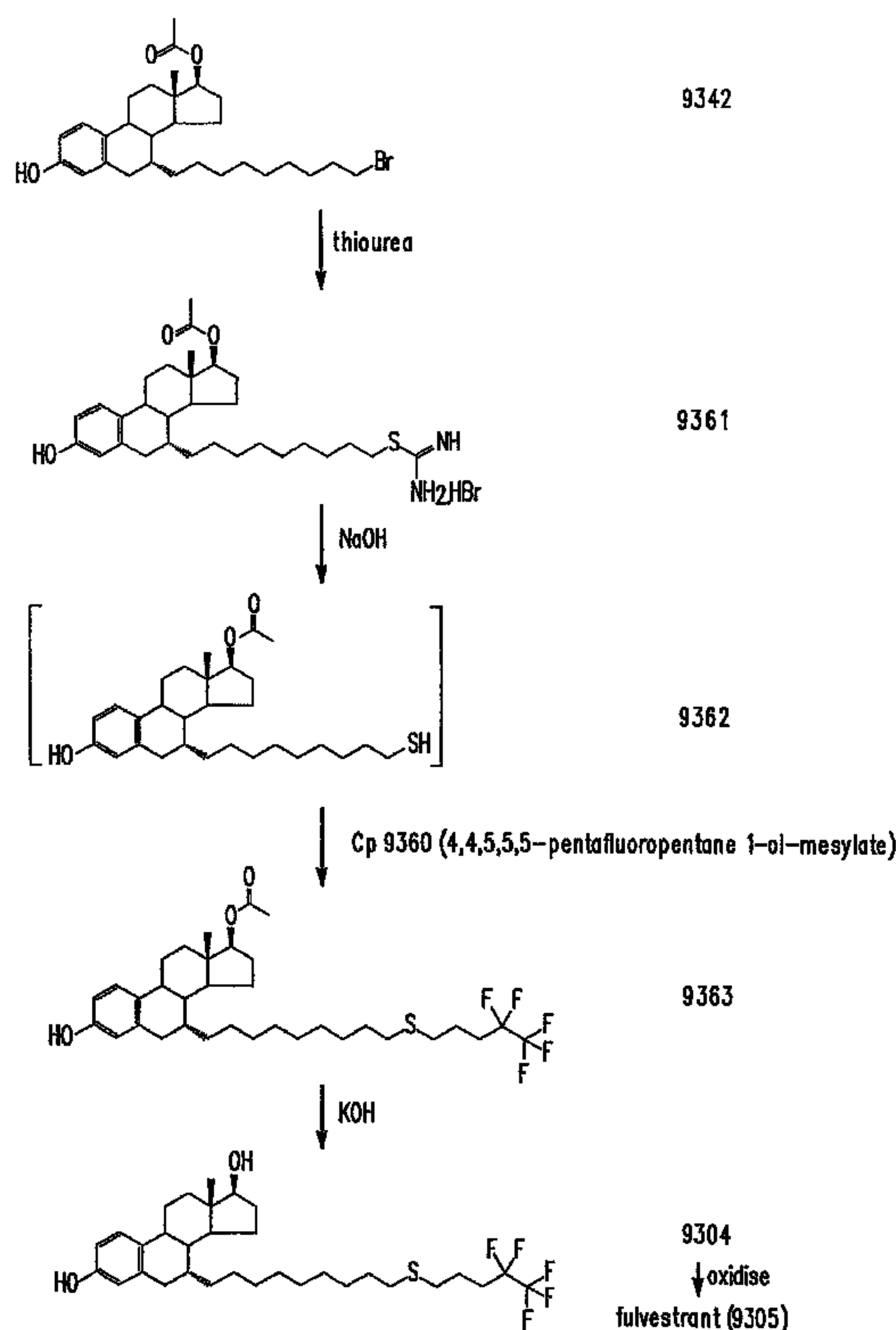


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(54) Titre : PROCÉDE DE PREPARATION DE 19-NORSTEROIDES 7 α -ALKYLES

(54) Title: A PROCESS FOR THE PREPARATION OF 7 α -ALKYLATED 19-NORSTEROIDS



(57) Abrégé/Abstract:

Processes useful in the preparation of pharmaceutical compounds such as fulvestrant and processes for the preparation of fulvestrant.



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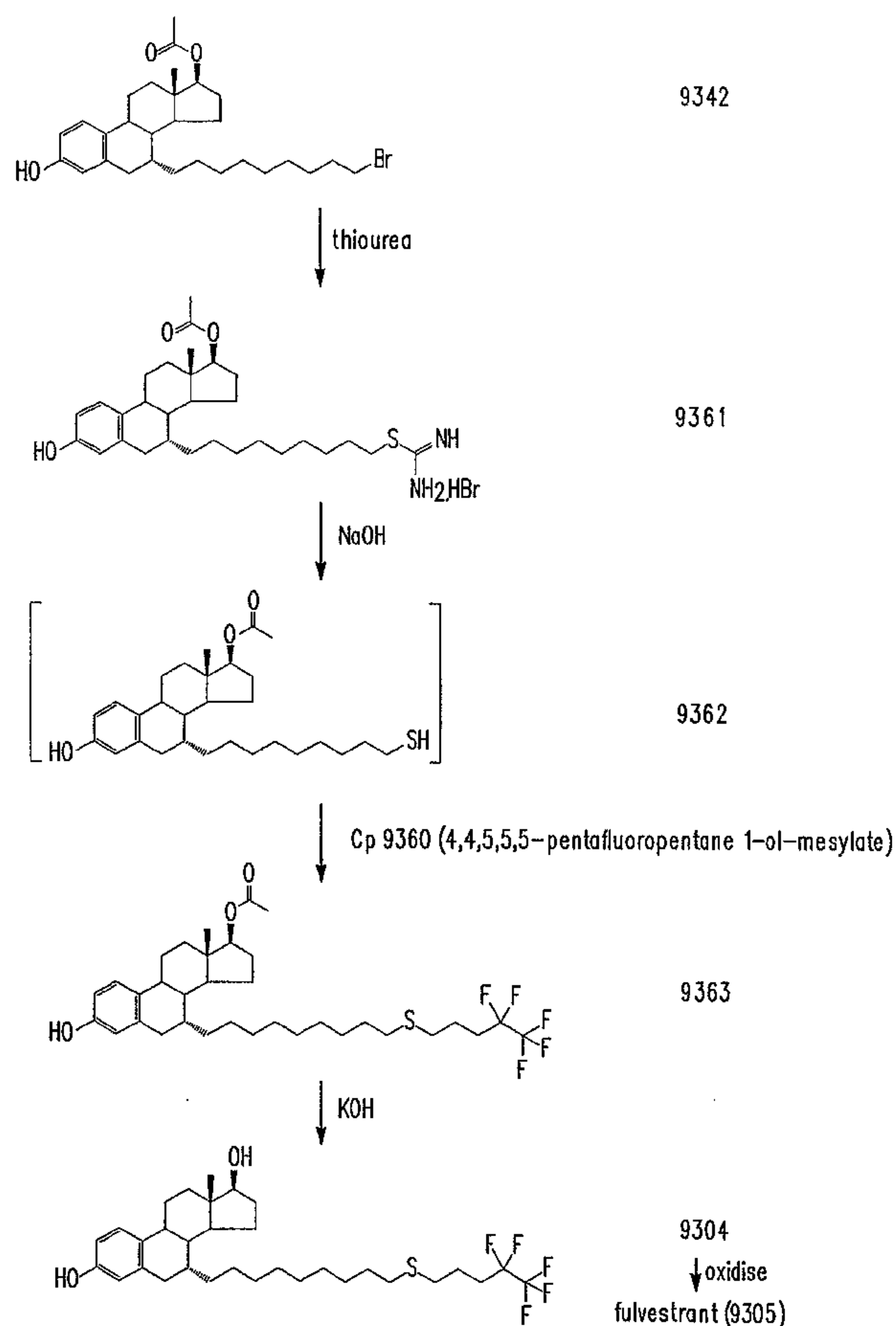
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[Continued on next page]

(54) Title: A PROCESS FOR THE PREPARATION OF 7 α -ALKYLATED 19-NORSTERIODS

(57) Abstract: Processes useful in the preparation of pharmaceutical compounds such as fulvestrant and processes for the preparation of fulvestrant.

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A PROCESS FOR THE PREPARATION OF 7 α -ALKYLATED 19-NORSTERIODS

CROSS REFERENCE TO RELATED APPLICATIONS

5 This application claims the benefit of U.S. provisional application serial nos. 60/591,689, filed July 27, 2004; 60/600,292, filed August 9, 2004; and 60/633,927, filed December 6, 2004, the contents of which are incorporated herein in their entirety

FIELD OF THE INVENTION

10 The invention relates to a new processes useful in the preparation of pharmaceutical compounds such as fulvestrant.

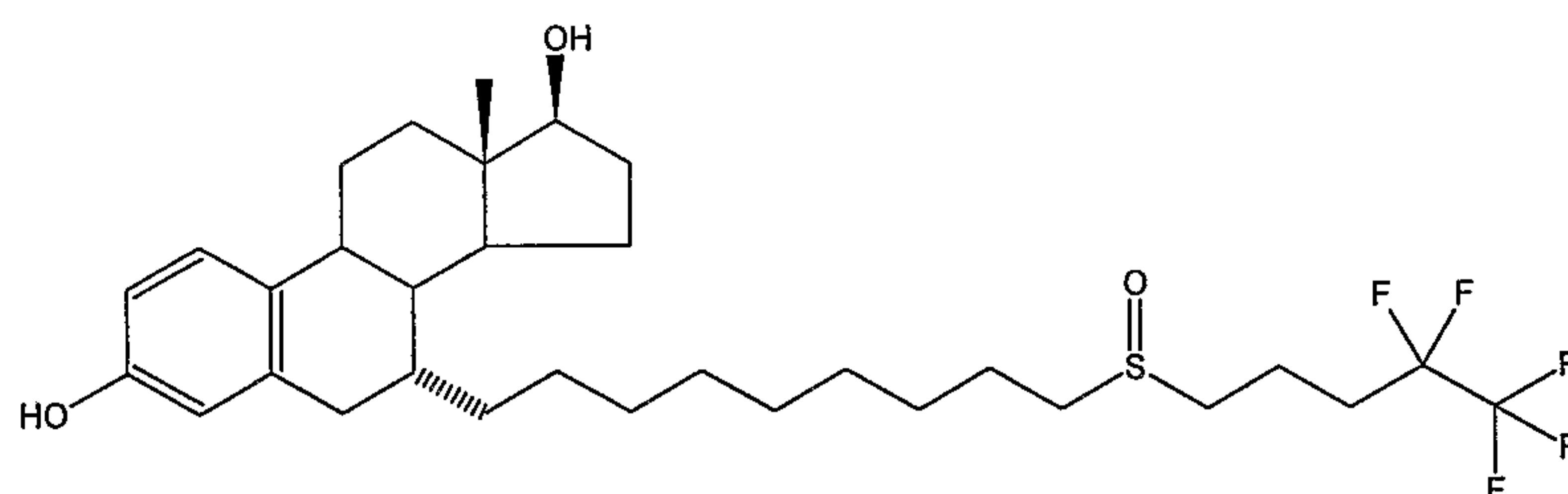
BACKGROUND

15 There is a growing recognition of the need for effective therapeutic strategies to treat breast cancer patients that are less toxic than chemotherapy. Since the discovery of the hormonal dependency of many breast cancers, endocrine therapy has been extensively investigated.

20 Fulvestrant is a pure antiestrogen that represent a significant breakthrough in the treatment of breast cancer. Despite its pure antagonist activity, studies on ovariectomized rats have confirmed that fulvestrant, in contrast to Tamoxifen which acts like estrogen to reduce periosteal bone formation, does not alter estrogen-like or antiestrogenic effects. Fulvestrant also has some distinct advantages on target organs other than breast tissue.

25 Fulvestrant is a steroidal pure antiestrogen with a chemical structure similar to estradiol. Studies of estrogen receptor (ER) function have demonstrated that estradiol binding to the ER initiate a sequence of events. Fulvestrant antagonizes estrogen action by occupying the ER and preventing estrogen-stimulated gene activation, thus interfering with the estrogen related processes essential for cell-cycle competition.

Fulvestrant, 7- α - [9-(4,4,5,5,5pentafluoropentylsulphanyl) nonyl]-estra-1,3,5(10)-triene-3,17 β -diol, has the following formula:



fulvestrant

WO Patent application No. 02/32922 describes a process for preparing an
 5 intermediate compound useful for preparing, e.g. fulvestrant, which process comprises
 aromatization of a compound, and thereafter if necessary or desired, carrying out one or
 more of the following steps: (i) removing any hydroxy protecting group; (ii) converting a
 precursor group to a different such group.

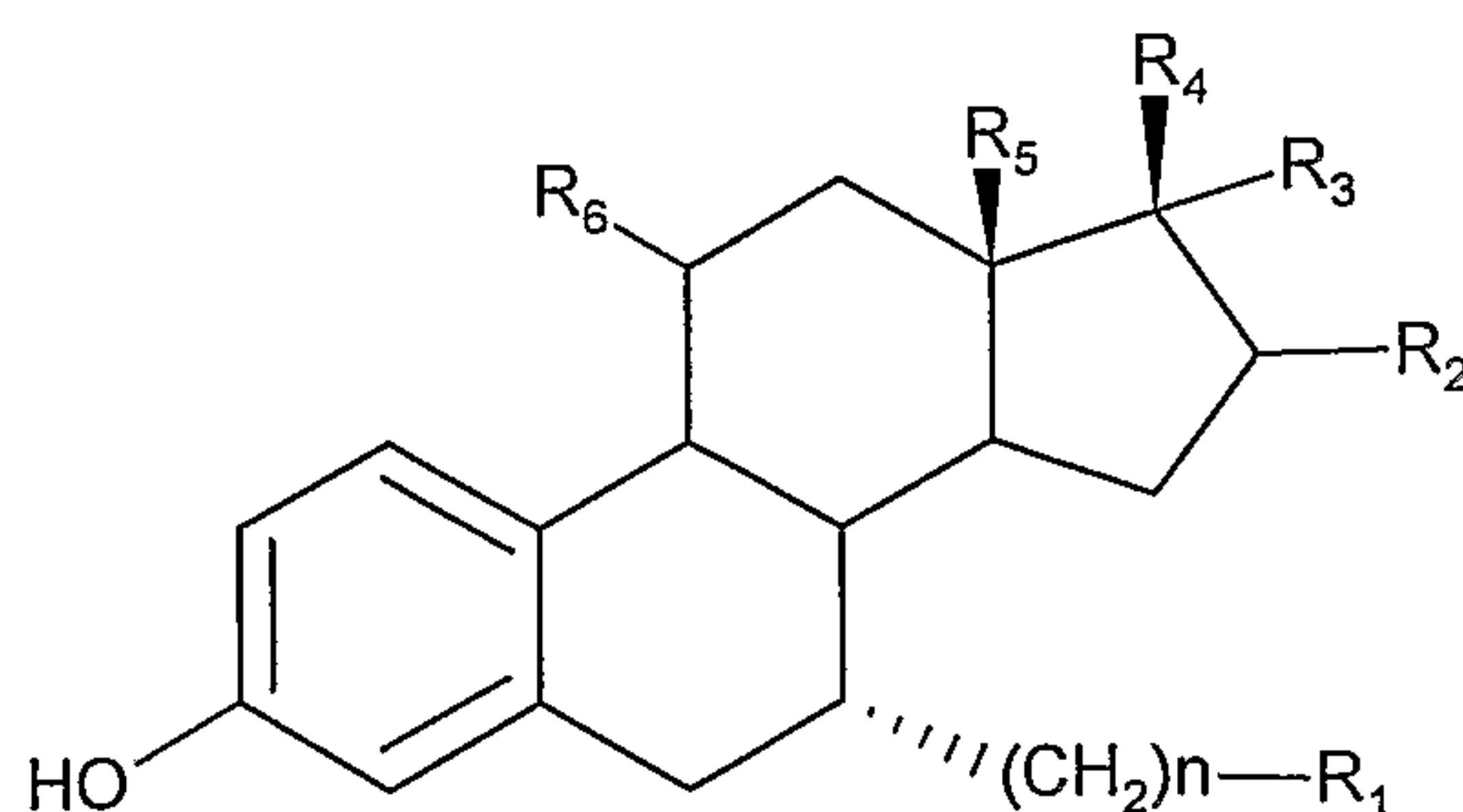
EP Patent No. 0138504 relates to certain 7α -substituted derivatives of oestradiol
 10 and related steroids which possess antioestrogenic activity. US Patent No. 4659516, EP
 Patent No. 0138504 and Bowler, Steroids 1989, 54, 71 describe a process for making
 steroids such as fulvestrant, by which 1,6-conjugate addition of an alkyl group to an estra-
 4,6-diene-3-one gave a ratio of 7α - to 7β -epimer of 1.2 : 1 (isolated). In WO 02/92322 it
 is stated that the ratio of epimers obtained using this process on an industrial scale is 1.9:
 15 1.

US patent No 6288051 describes 7α -(5 -methylaminopenty1)-estratrienes.

There remains a need in the art for improved methods of preparing fluvestrant and
 other 7α -alkylated 19-norsteroids.

SUMMARY OF THE INVENTION

20 The invention relates to A compound of formula (I):



(I)

wherein

n is an integer ranging from 3 to 14,

R₁ is selected from the group consisting of Br, Cl, I, free base or a salt form of isothiuronium, or SH;

R₂ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo;

R₃ is either hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl, or C₂₋₆ alkynyl;

R₄ is either hydroxy, or a C₁₋₆ acyloxy;

R₅ is C₁₋₆ alkyl; and

R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo.

In one embodiment, n is 9, R₁ is Br, R₂, R₃, and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl.

In one embodiment, n is 9, R₁ is Br, R₂, R₃, and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

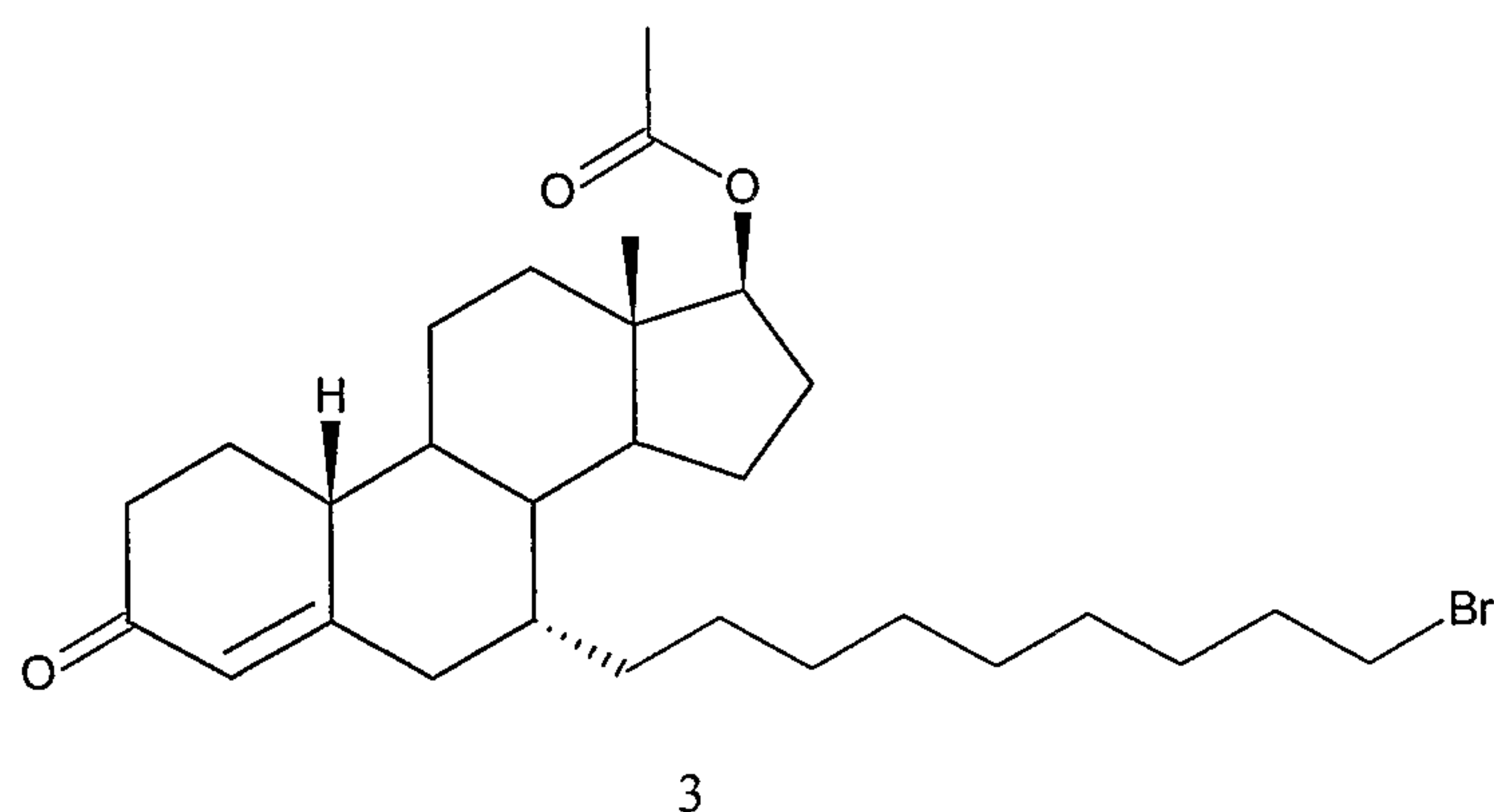
In one embodiment, n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃, and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

In one embodiment, n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃, and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl.

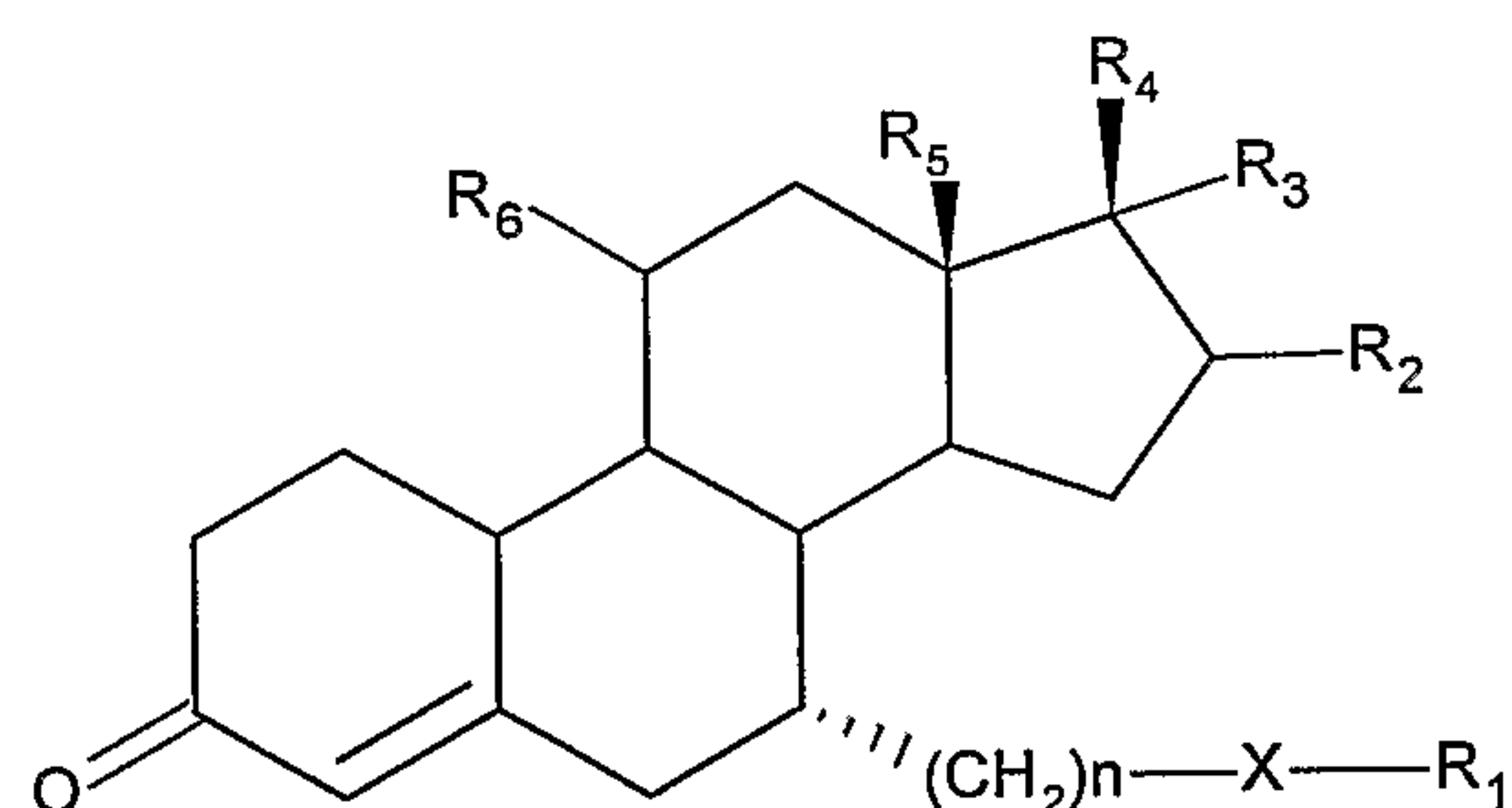
In one embodiment, n is 9, R₁ is SH, R₂, R₃, and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

In one embodiment, n is 9, R₁ is SH, R₂, R₃, and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl.

The invention also relates to a compound of formula



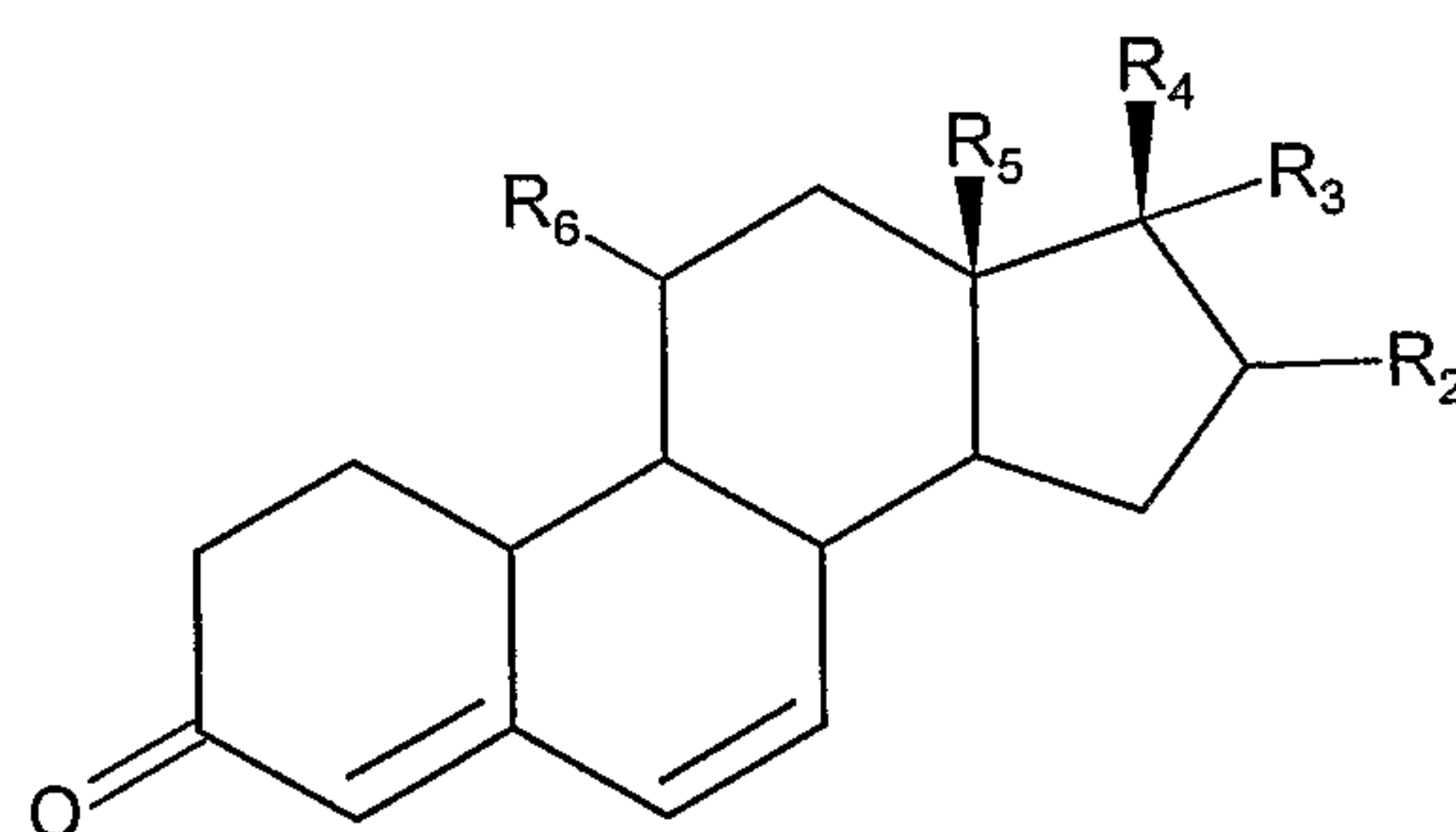
The invention also relates to a process for preparing the compound of formula (II),



(II)

comprising:

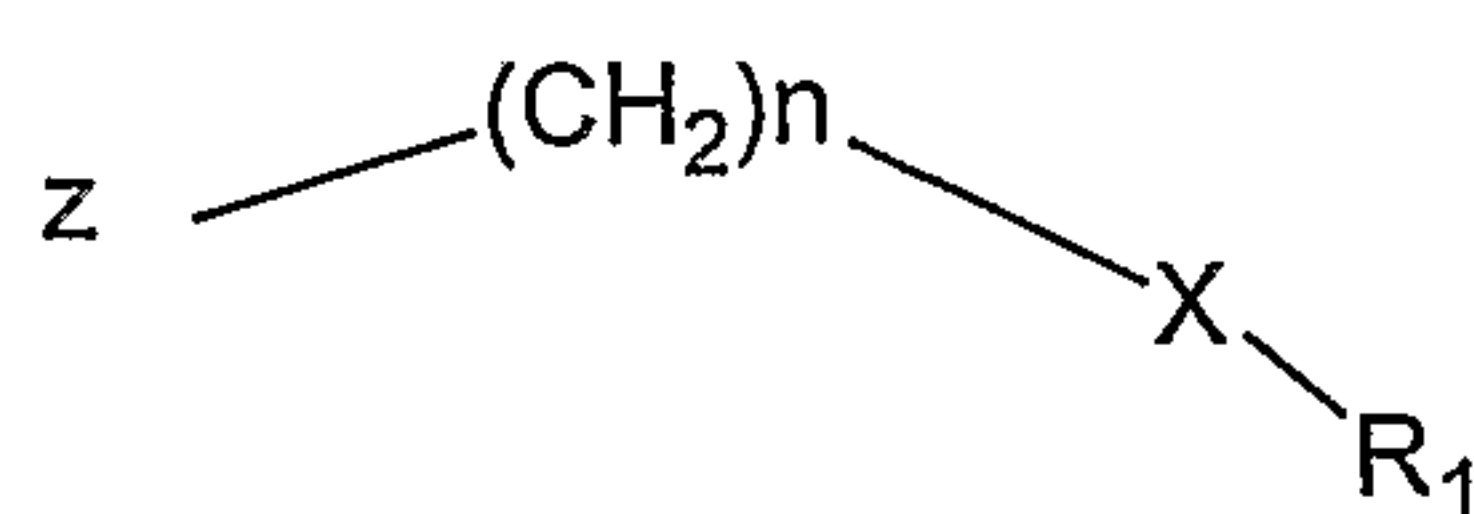
- a) combining a 19-nor-androsta-4,6-diene-3-one of formula (III)



b) (III)

with an ethereal solvent, to obtain a solution;

- b) cooling the solution to a temperature of about -60°C to about 30°C;
c) adding to the solution of step b), in a drop-wise manner, a solution of the compound of formula (IV)



(IV)

in an ethereal solvent to obtain a reaction mixture;

- d) quenching the reaction mixture; and
e) recovering the compound of formula (II);

* wherein

n is an integer ranging from 3 to 14,

X is either O or S;

R₁ is a C₁₋₁₀ haloalkyl or a hydroxy protecting group;

5 R₂ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo;

R₃ is either hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl, or C₂₋₆ alkynyl;

R₄ is a C₁₋₆ acyloxy;

R₅ is C₁₋₆ alkyl; and

R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo; and

10 z is a metal halide of the formula R₇M, wherein

M is a metal atom; and

R₇ is a halogen atom.

In one embodiment of the process, n is 9, X is O, R₁ is tertbutyl-dimethylsilyl (TBDMS), R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

15 In one embodiment of the process, n is 5, X is O, R₁ is TBDMS, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

In one embodiment of the process, n is 9, X is S, R₁ is –(CH₂)₃CF₂CF₃, R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

20 In one embodiment of the process, M is a metal atom selected from the group consisting of magnesium, zinc, aluminum, copper, copper-lithium and titanium.

In one embodiment of the process, M is magnesium.

In one embodiment of the process, R₇ is selected from the group consisting of Cl, Br and I.

In one embodiment of the process, R₇ is Br.

25 In one embodiment of the process, a copper catalyst is a combined in step a) with the 19-nor-androsta-4,6-diene-3-one of formula (III) and the etheral solvent.

In one embodiment of the process, said copper catalyst is in the form of Cu(I)Y, wherein Y is Cl, Br or I.

In one embodiment of the process, said copper catalyst is Cu(I)Cl.

In one embodiment of the process, the compound of formula (II) obtained in step e) has a ratio of 7 α -to 7 β -epimer of about 2.5:1 to about 12.1:1.

In one embodiment of the process, the compound of formula (II) obtained in step e) has a ratio of 7 α -to 7 β -epimer of about 12.1:1.

In one embodiment of the process, the etheral solvent in step a) is selected from the group consisting of: diethyl ether, THF and glyme.

In one embodiment of the process, said etheral solvent is THF.

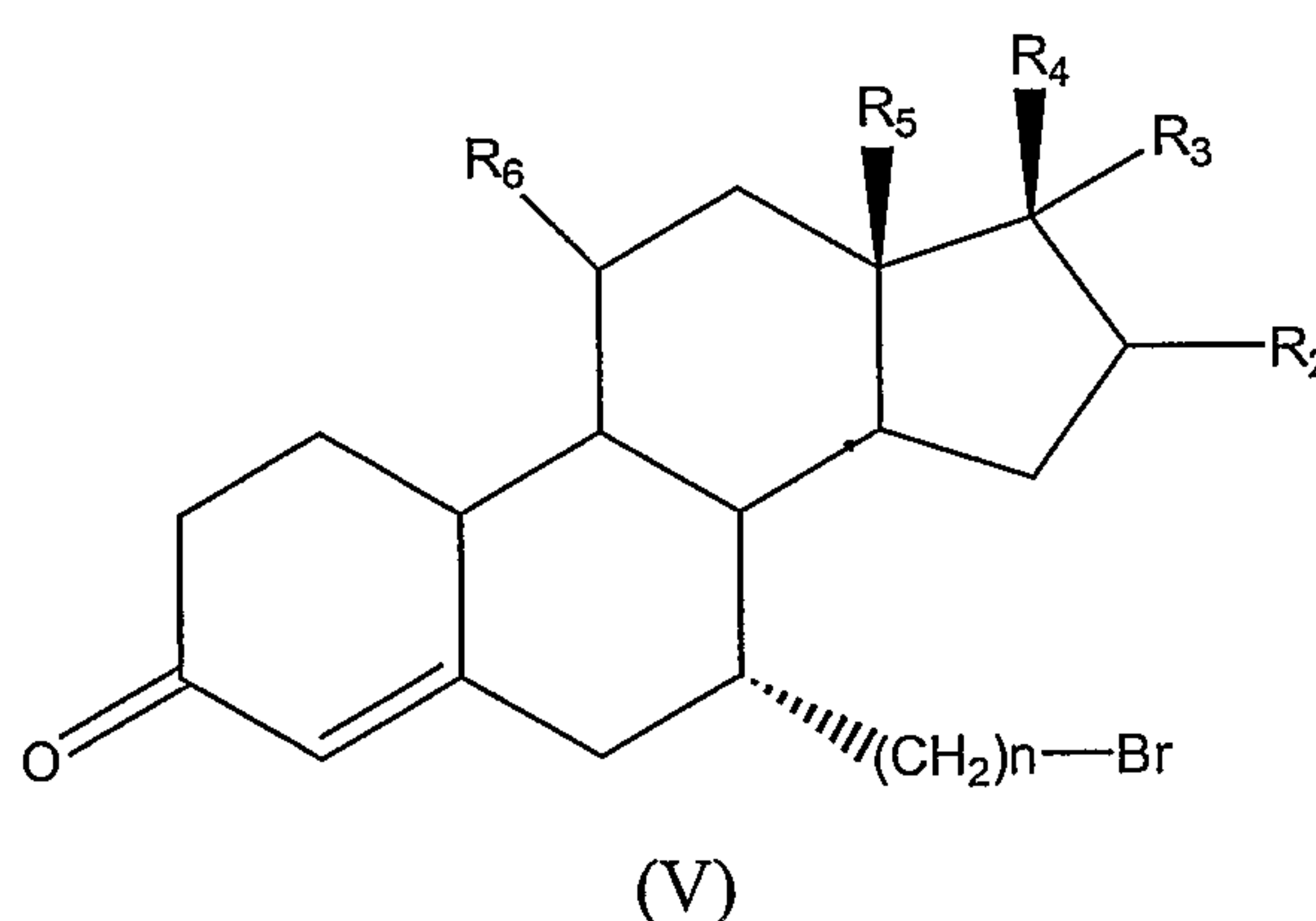
In one embodiment of the process, the solution of step b) is cooled to a temperature of about -20°C to about -10°C.

In one embodiment of the process, the reaction mixture in step d) is quenched by one of the reagents selected from the group consisting of: NH₄Cl, HCl, water, acetic acid and a mixture of NH₄Cl with NH₄OH.

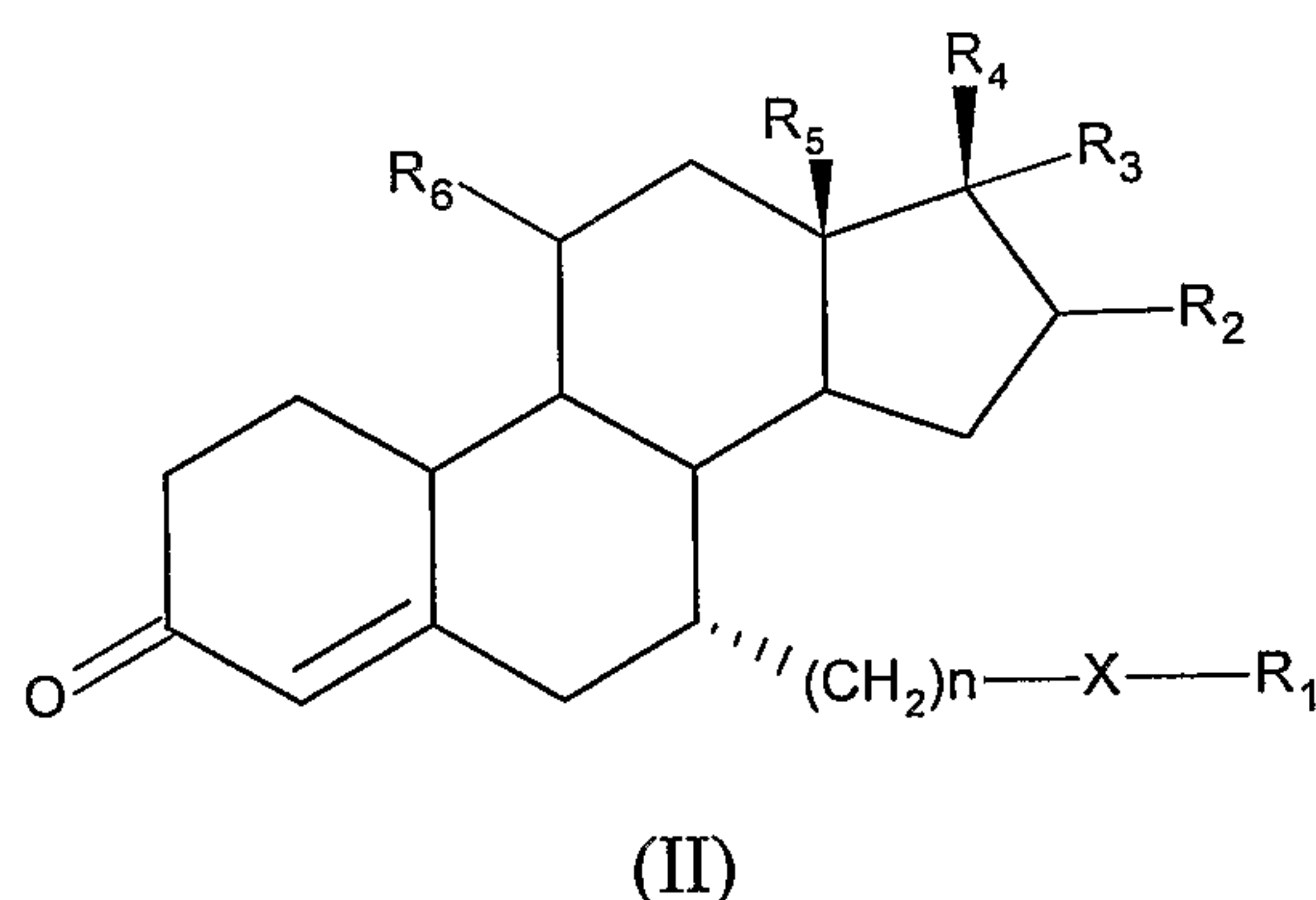
In one embodiment of the process, the reaction mixture is quenched with acetic acid.

In one embodiment of the process, the process further comprises converting the compound of formula (II) obtained in step e) to fulvestrant.

The invention further relates to a process for preparing the compound of formula (V),



comprising combining a compound of formula (II)



with acetonitrile and triphenylphosphine dibromide for a sufficient amount of time for conversion into the compound of formula (V);

10 wherein

n is an integer ranging from 3 to 14,

X is O;

R₁ is a hydroxy protecting group;

R₂ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo;

15 R₃ is either hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl, or C₂₋₆ alkynyl;

R₄ is a C₁₋₆ acyloxy;

R₅ is C₁₋₆ alkyl; and

R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo.

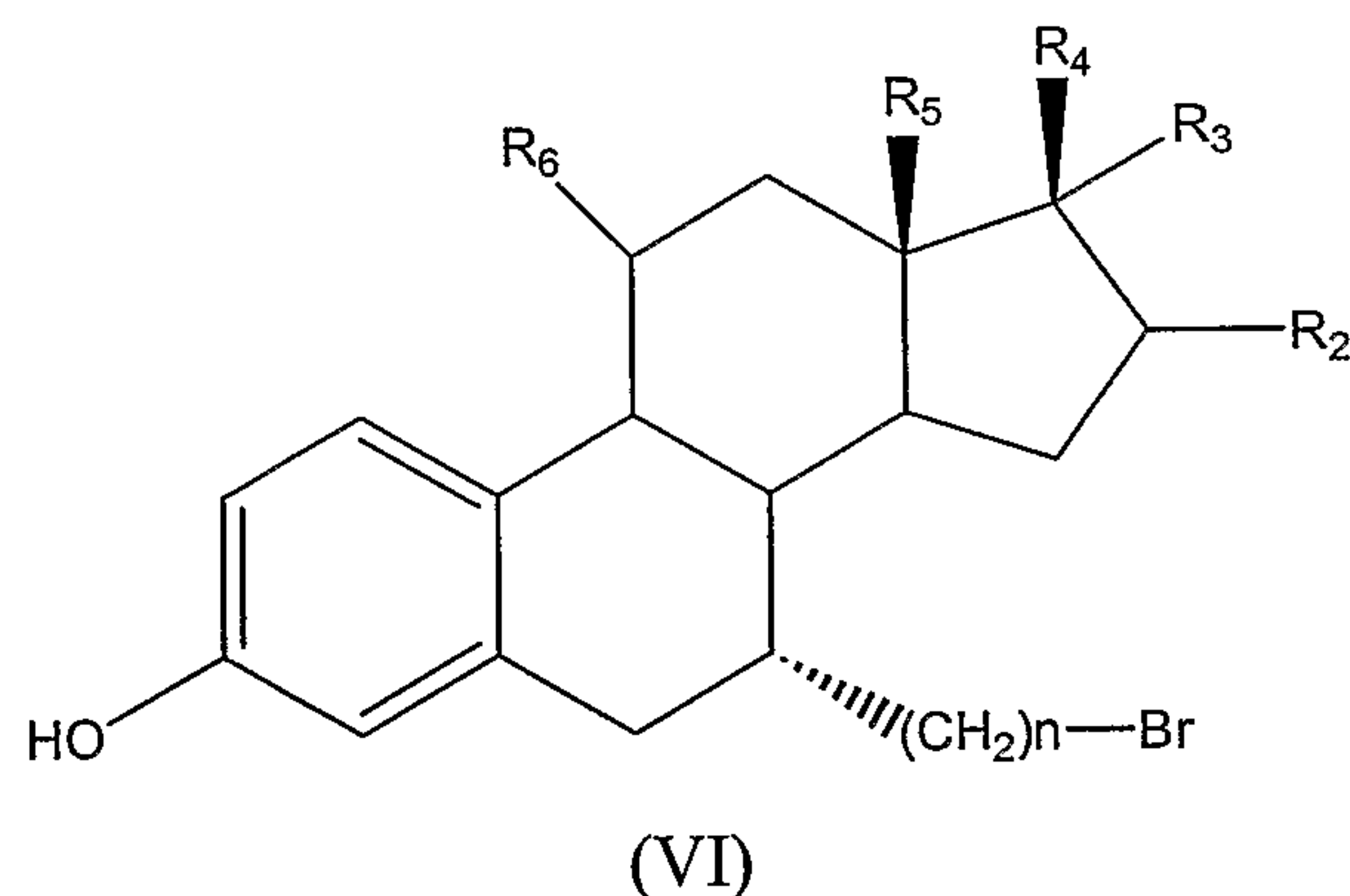
In one embodiment of the process, n is 9, R₁ is tertbutyl-dimethylsilyl (TBDMS),

20 R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

In one embodiment of the process, the compound of formula (II) is combined with the acetonitrile and triphenylphosphine dibromide at a temperature of about 10°C to about 12°C.

In one embodiment of the process, the process further comprises converting the
25 obtained product to fulvestrant.

The invention further relates to a process for preparing the compound of formula
(VI)



wherein R_4 is hydroxy, comprising

5 combining the compound of formula (VI), wherein R_4 is a C_{1-6} acyloxy, with a C_{1-6} alcohol and mineral acid, at a temperature of about 50°C to about 70°C ;

wherein

n is an integer ranging from 3 to 14,

R_2 is either hydrogen, C_{1-6} alkyl, hydroxyl, protected hydroxy, or halo;

10 R_3 is either hydrogen, C_{1-6} alkyl, C_{2-6} alkenyl, or C_{2-6} alkynyl;

R_5 is C_{1-6} alkyl; and

R_6 is either hydrogen, C_{1-6} alkyl, hydroxyl, protected hydroxy, or halo.

In one embodiment of the process, R_2 , R_3 and R_6 are hydrogens, and R_5 is methyl.

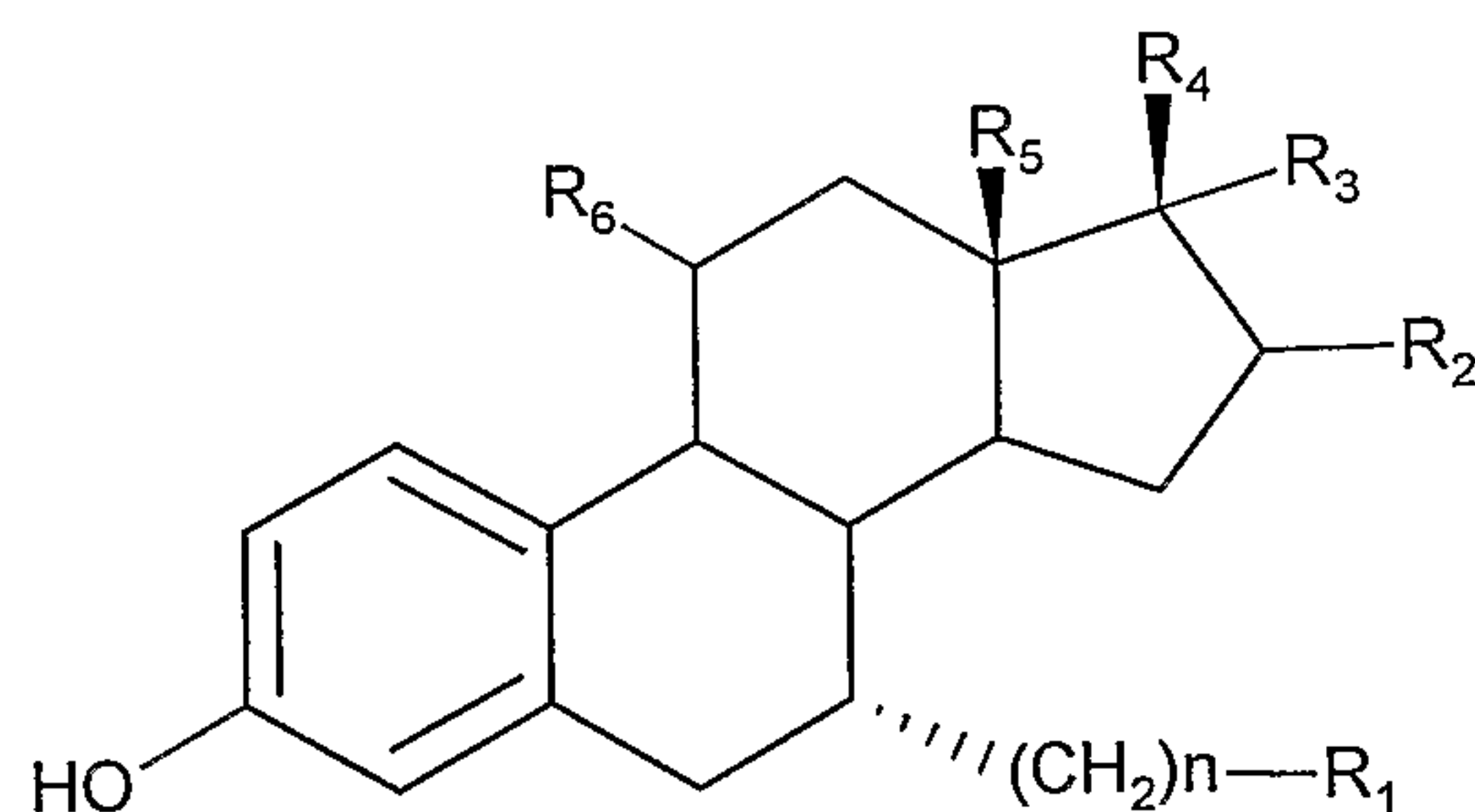
In one embodiment of the process, the mineral acid is HBr.

15 In one embodiment of the process, the temperature is about 60°C .

In one embodiment of the process, the process further comprises converting the obtained product to fulvestrant.

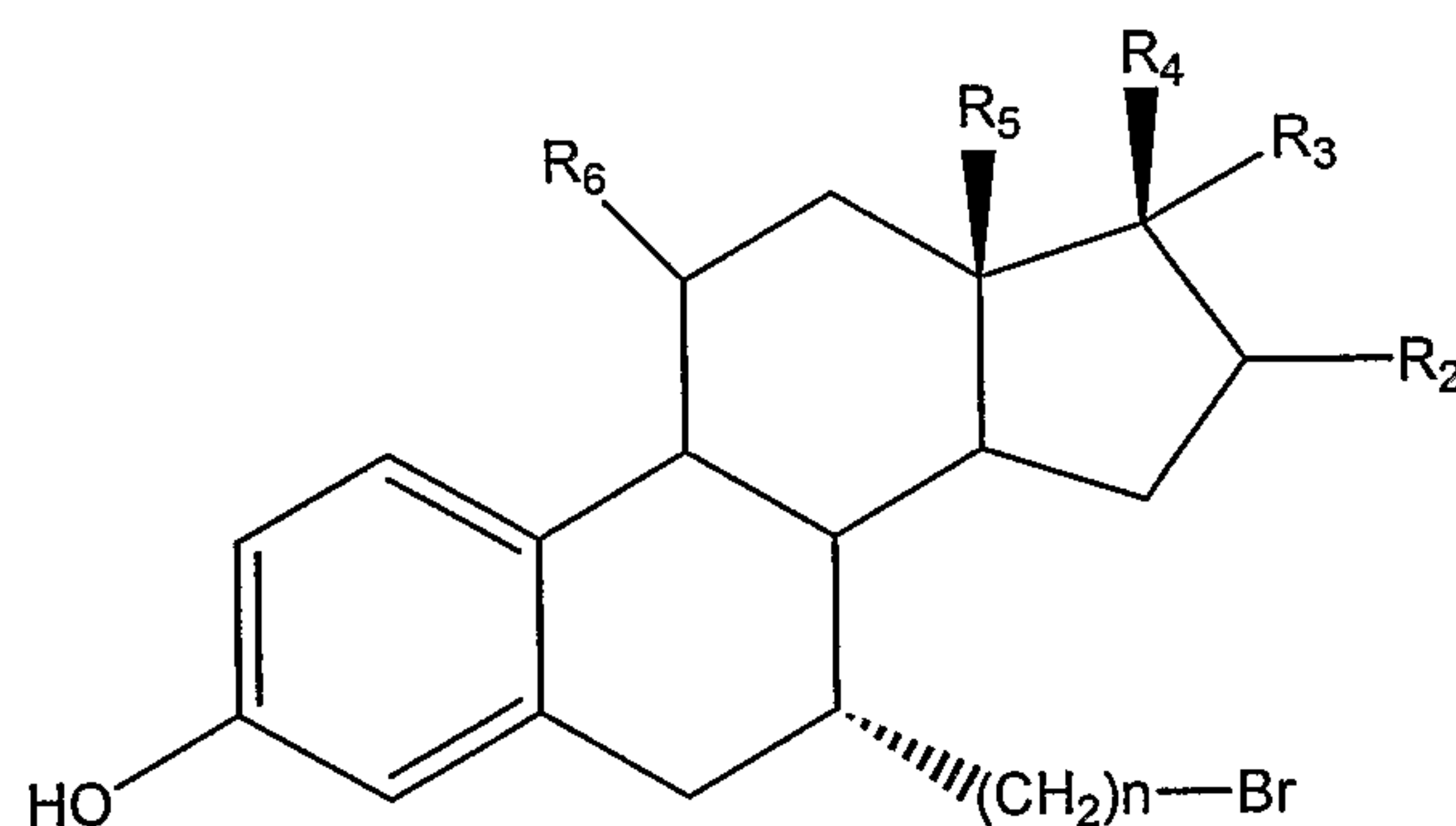
The invention further relates to a process for preparing the compound of the formula (I)

20



(I)

10 comprising combining the compound of formula (VI)



(VI)

15 with a solvent selected from a C₁₋₆ aromatic hydrocarbon, a straight or branched C₁₋₄ alcohol, a C₁₋₄ alkyl amide and mixtures thereof and thiourea; and recovering the compound of formula (I)

wherein

n is an integer ranging from 3 to 14,

R₁ is a free base or a salt form of isothiuronium;

R₂ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo;

20 R₃ is either hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl, or C₂₋₆ alkynyl;

R₄ is either hydroxy or C₁₋₆ acyloxy;

R₅ is C₁₋₆ alkyl; and

R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo.

25 In one embodiment of the process, n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

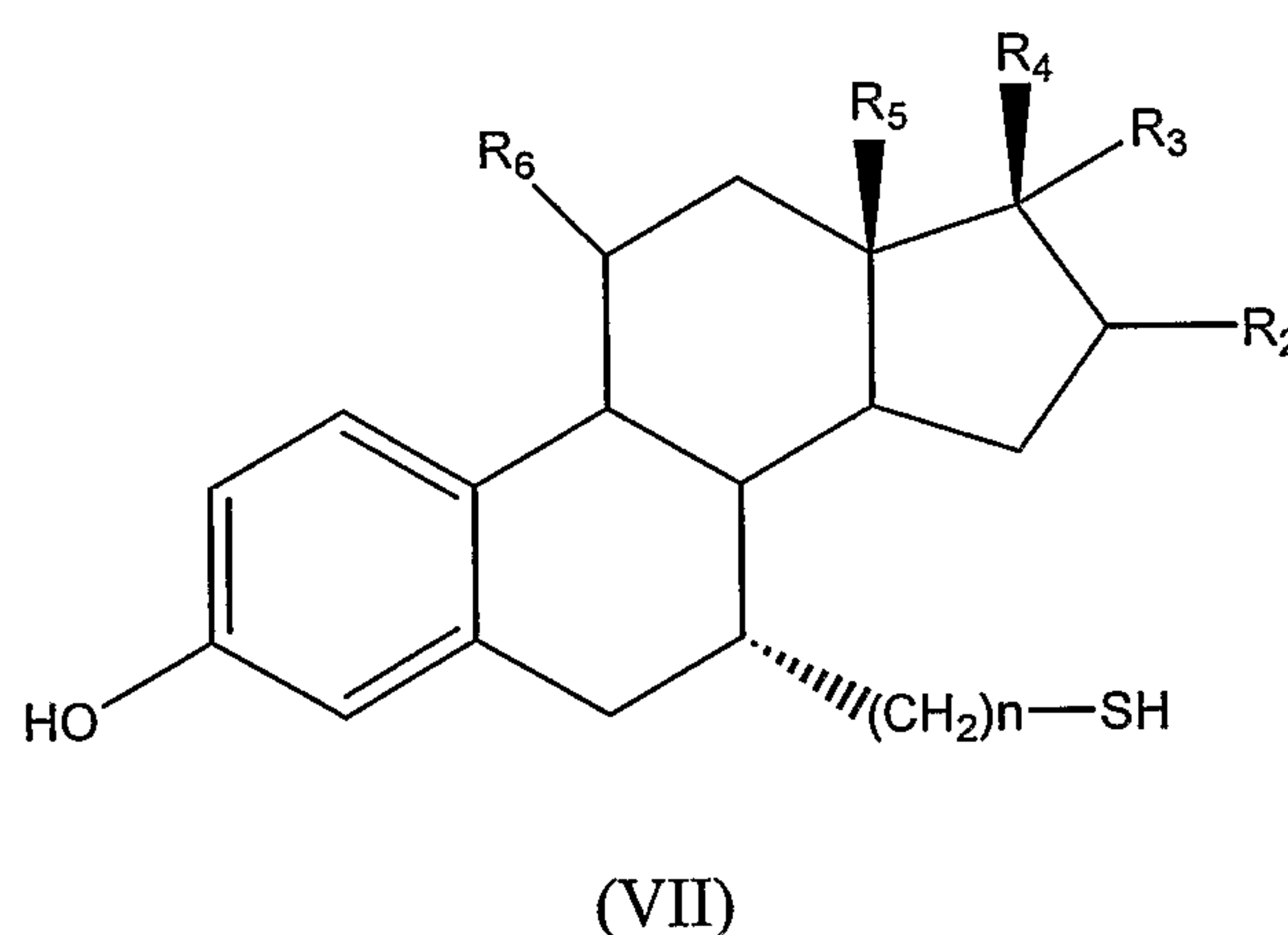
In one embodiment of the process, n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃ and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl.

In one embodiment of the process, the solvent is selected from the group consisting of toluene, xylene, benzene, methanol, ethanol, propanol, isopropanol, butanol,
5 dimethylacetamide and mixtures thereof.

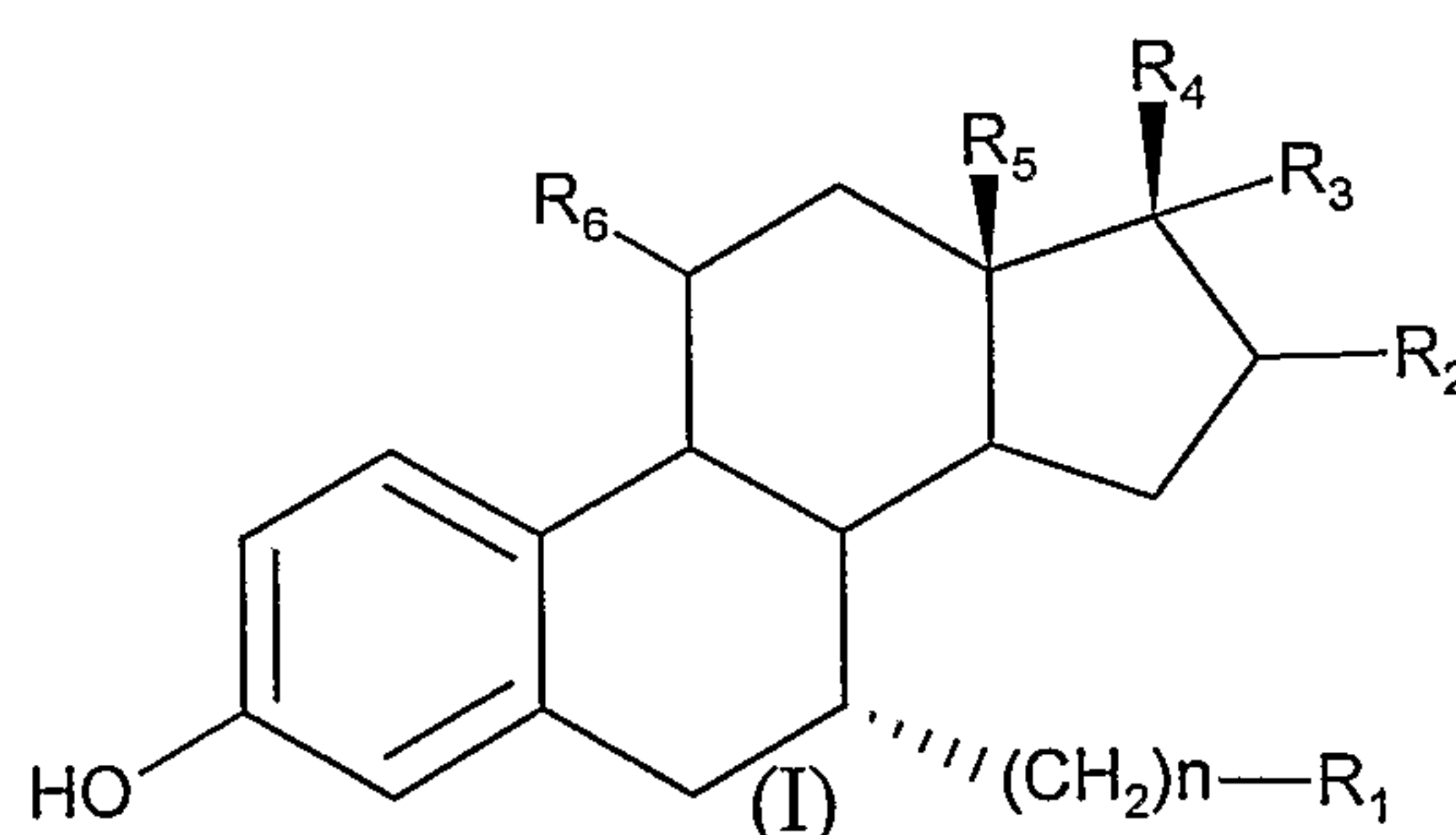
In one embodiment of the process, the solvent is a mixture of toluene and isopropanol or dimethylacetamide.

In one embodiment of the process, the process further comprises converting the obtained product to fulvestrant.

10 The invention further relates to a process for preparing the compound of the formula (VII)



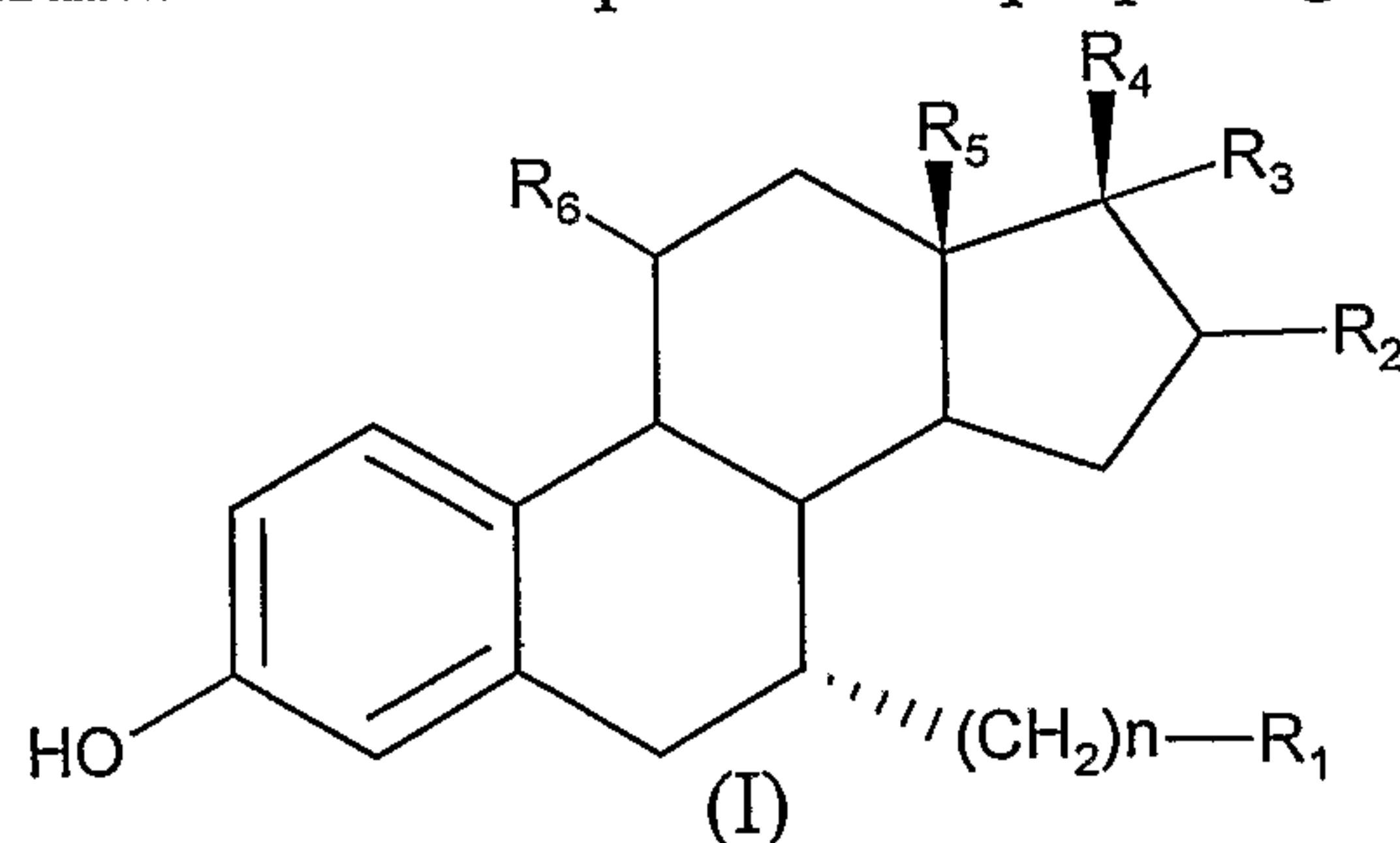
15 comprising combining compound of the formula (I)

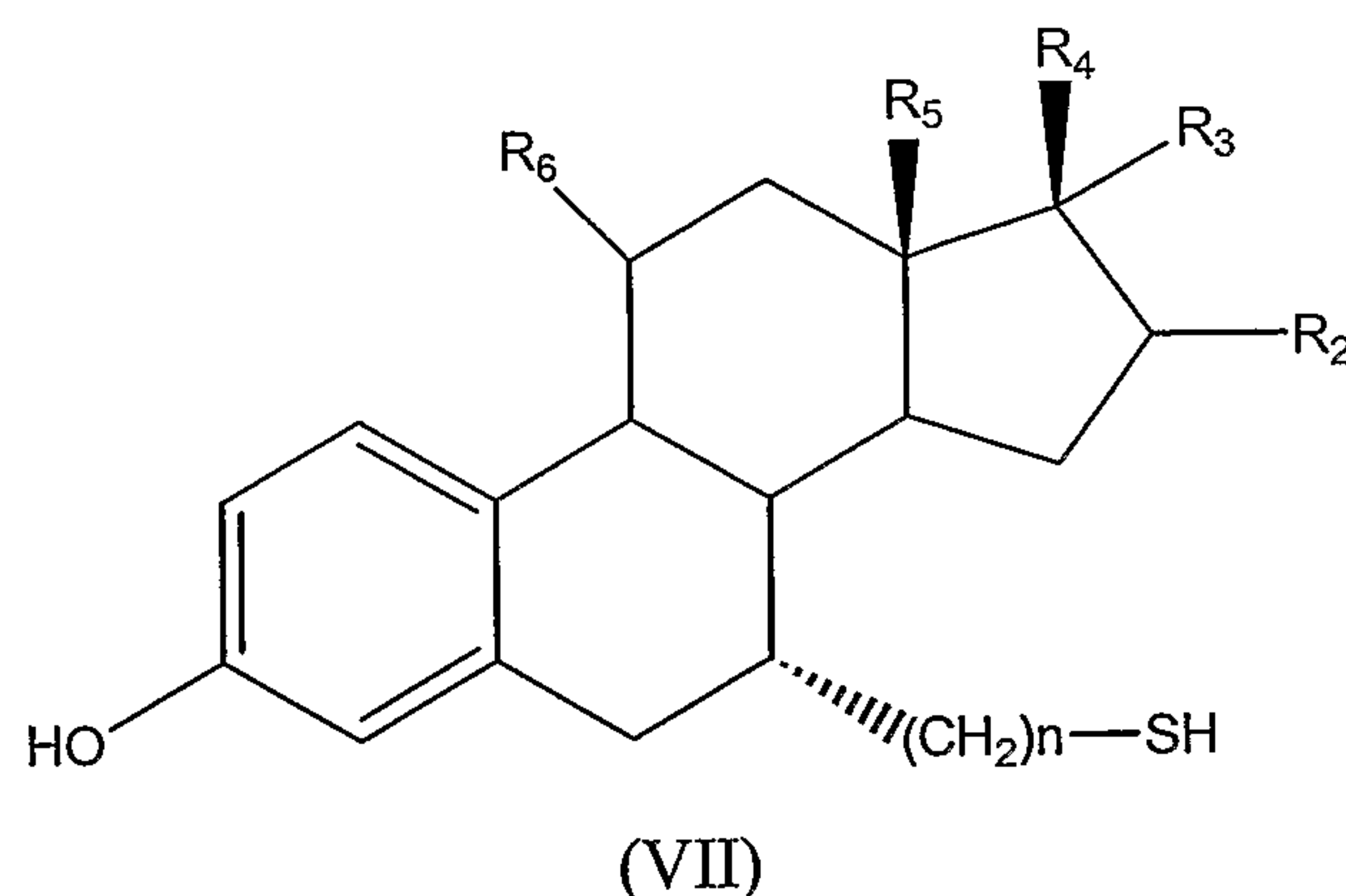


20 with a base in the presence of an apolar protic organic solvent at ambient temperature;
wherein

n is an integer ranging from 3 to 14,

R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo.





with 4,4,5,5,5-pentafluoropentane-1-ol mesylate at an ambient temperature;
 5 combining the obtained reaction mixture with a base in the presence of an organic solvent; and recovering the compound of the formula (I);
 wherein

n is an integer ranging from 3 to 14,

R₁ is $-\text{S}-(\text{CH}_2)_3\text{CF}_2\text{CF}_3$

10 R₂ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo;

R₃ is either hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl, or C₂₋₆ alkynyl;

R₄ is either hydroxy or C₁₋₆ acyloxy;

R₅ is C₁₋₆ alkyl; and

R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo.

15 The process of claim 51, wherein n is 9, R₂, R₃ and R₆ are hydrogens, R₄ is a acetyloxy and R₅ is methyl.

In one embodiment of the process, n is 9, R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

In one embodiment of the process, the base is an alkali metal base.

20 In one embodiment of the process, the base is KOH.

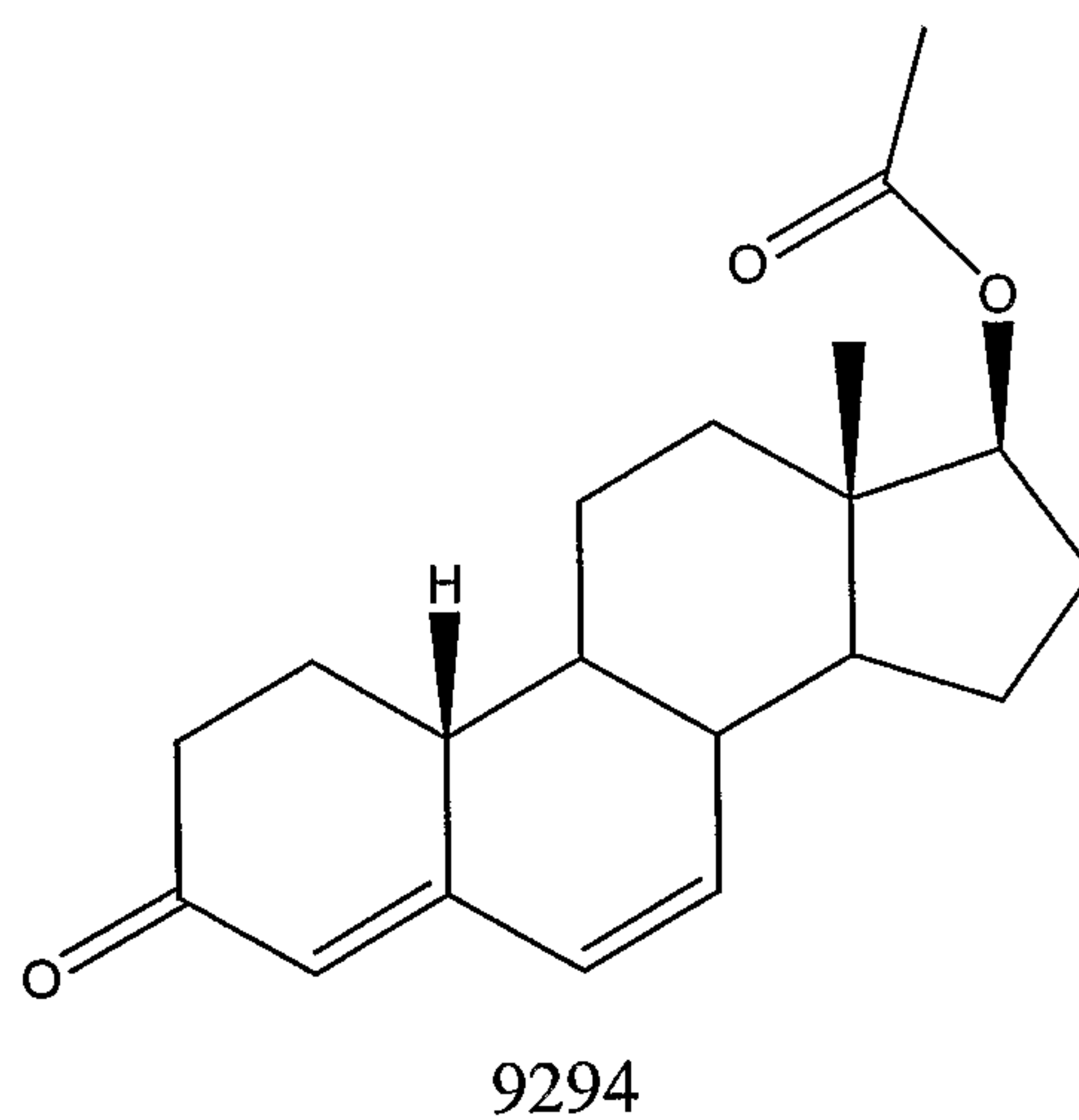
In one embodiment of the process, the organic solvent is a C₁₋₆ alcohol.

In one embodiment of the process, the organic solvent is methanol.

In one embodiment of the process, wherein the process further comprises converting the obtained product to fulvestrant.

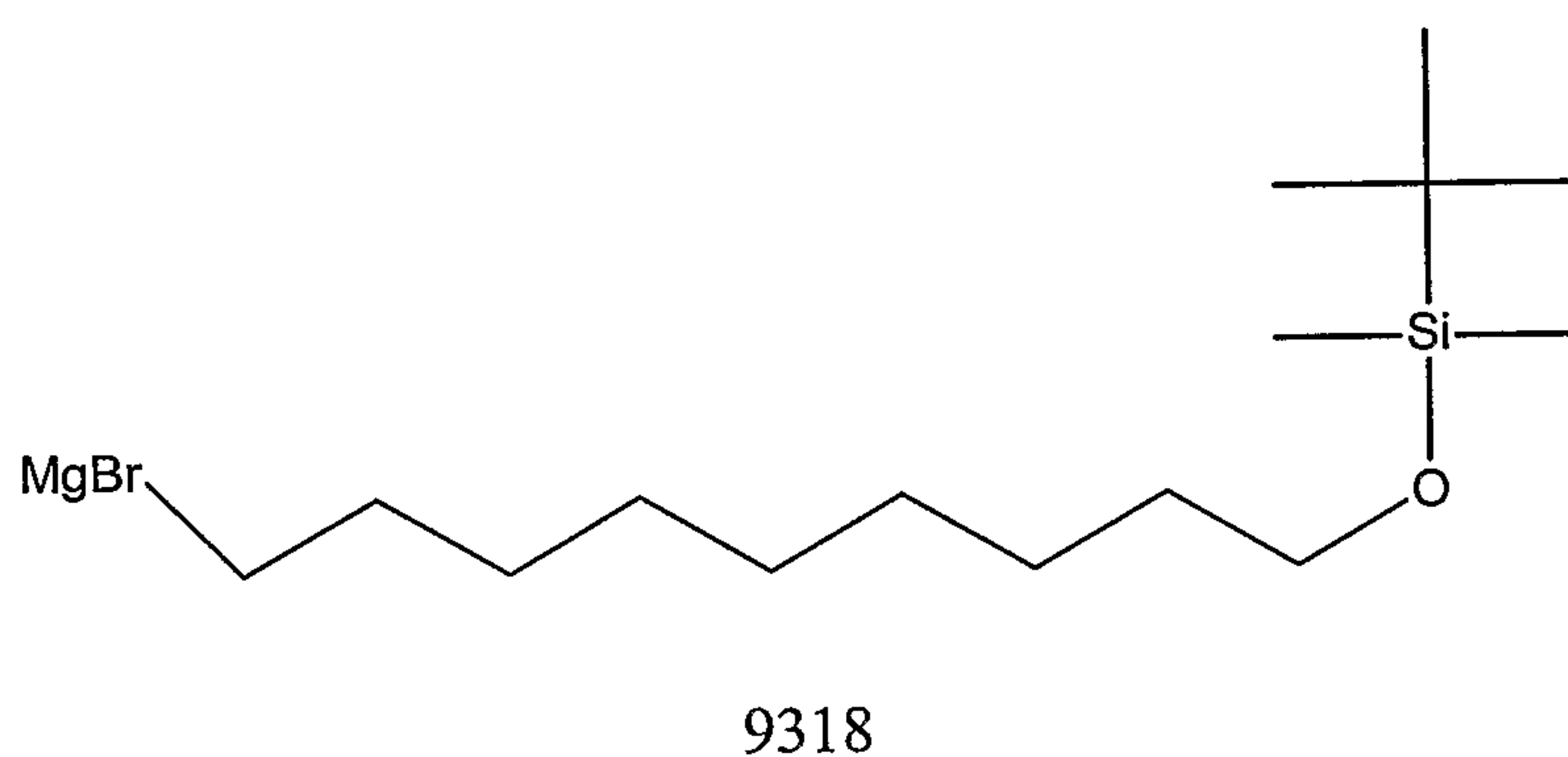
The invention further relates to a process for preparing fulvestrant comprising:

a) combining compound of formula 9294

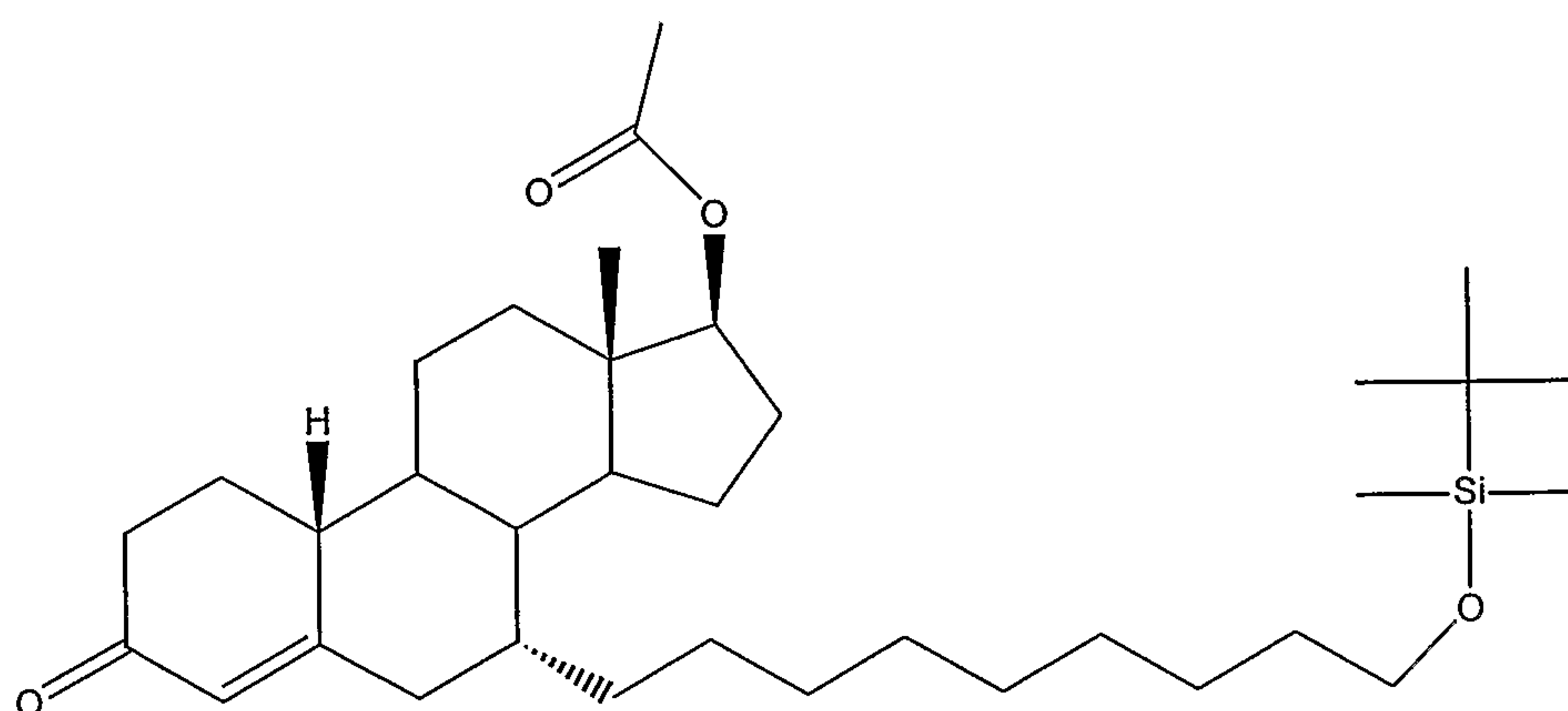


5 with an etheral solvent, to obtain a solution;

b) adding to the solution of step a), in a drop-wise manner, a solution of the compound of formula 9318



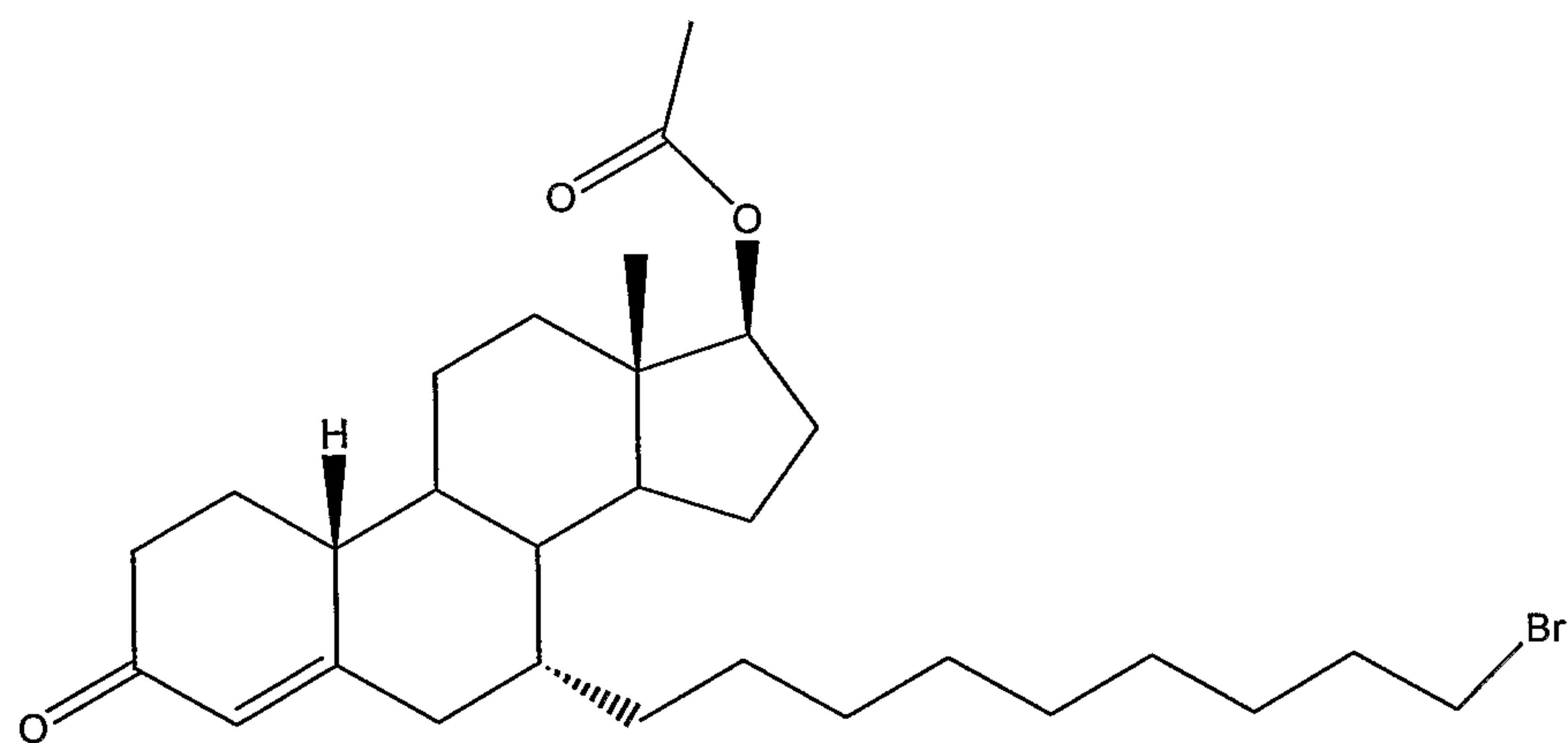
10 in an etheral solvent to obtain a first reaction mixture comprising a compound of formula 9295;



c) quenching the first reaction mixture;

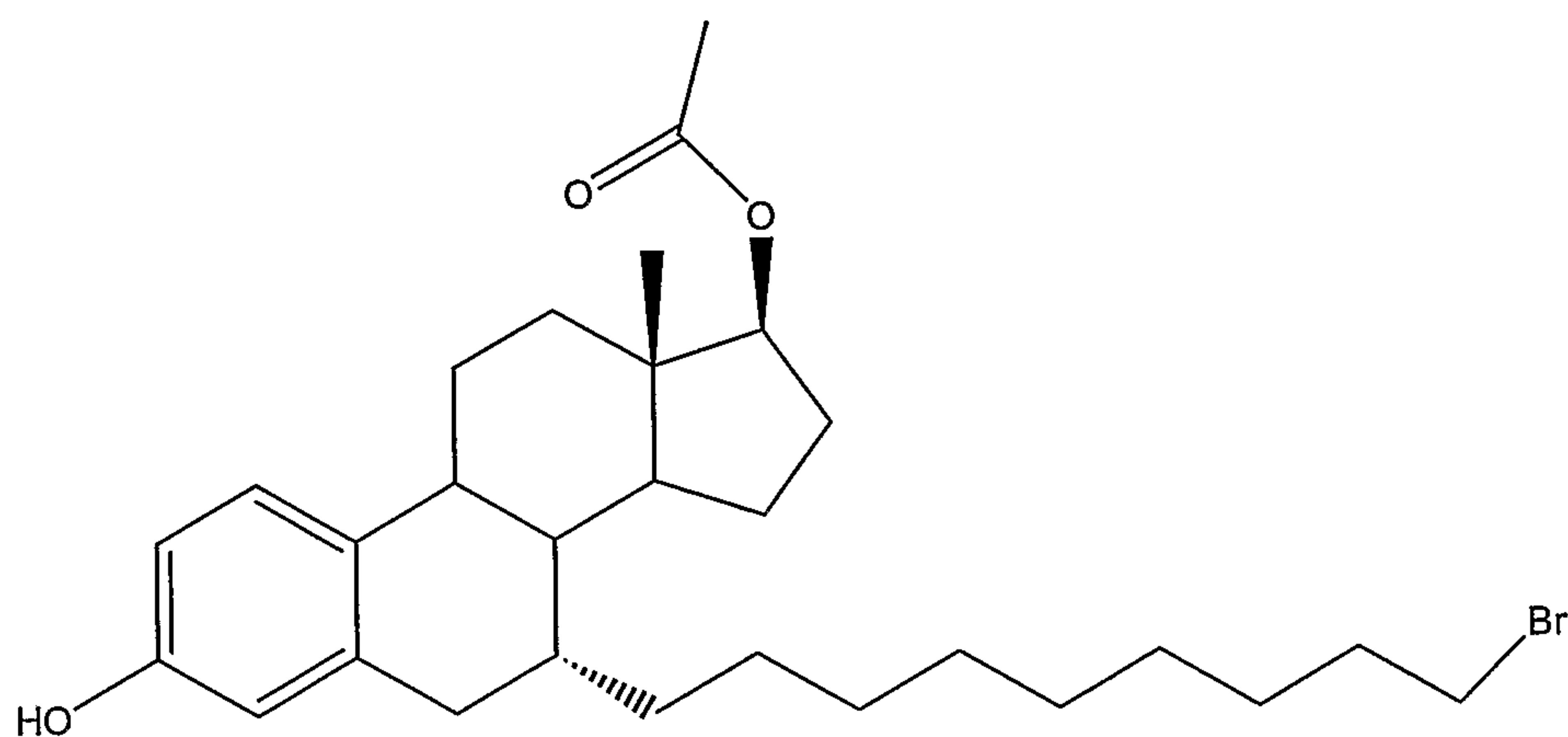
d) recovering compound 9295;

e) combining compound 9295 with acetonitrile and triphenylphosphine dibromide for a time sufficient to convert compound 9295 into a compound of formula 9341



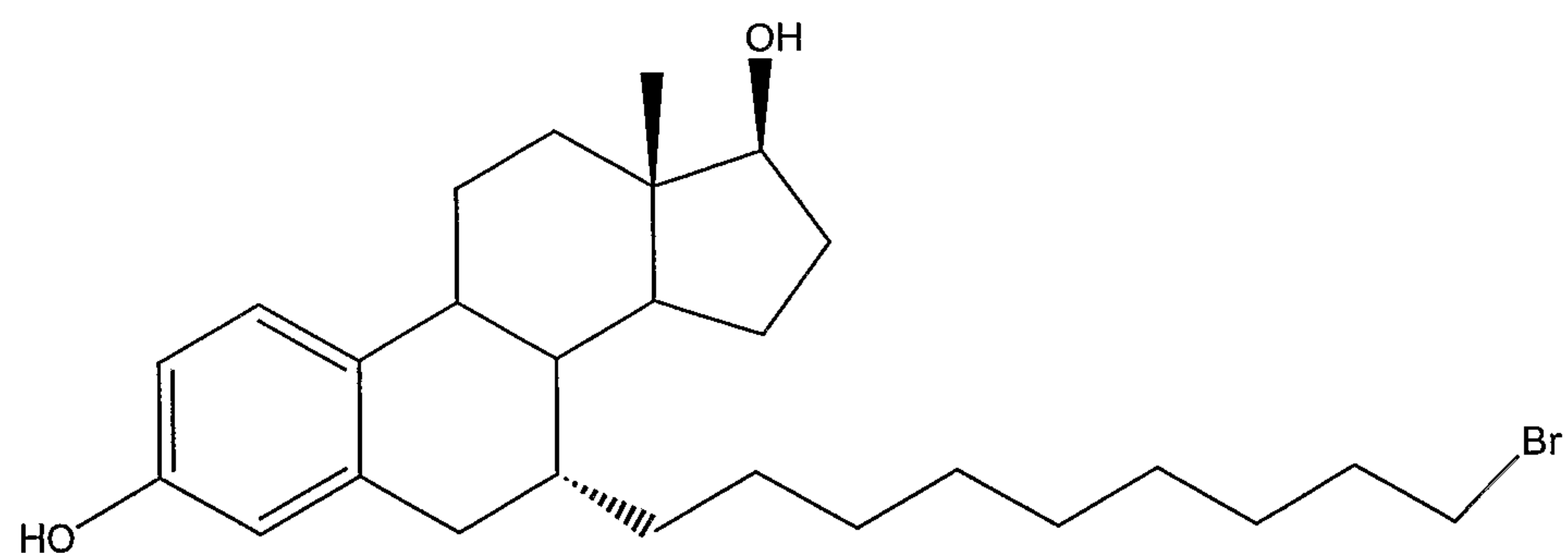
9341;

f) aromatizing the A ring of compound 9341 by reacting compound 9341 with a mixture of lithium bromide and copper bromide in acetonitrile to obtain a compound of formula 9342



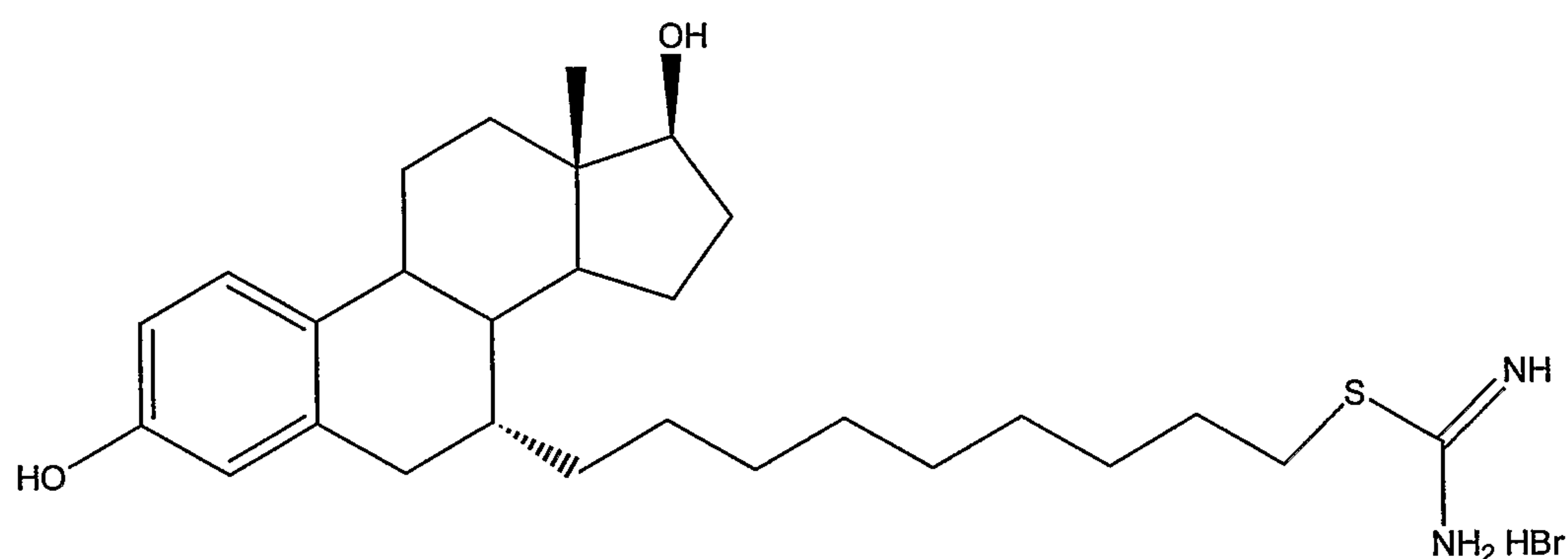
9342;

g) combining compound 9342 with C₁₋₆ alcohol and a mineral acid, at a temperature of about 50°C to about 70°C to obtain a compound of formula 9354



9354;

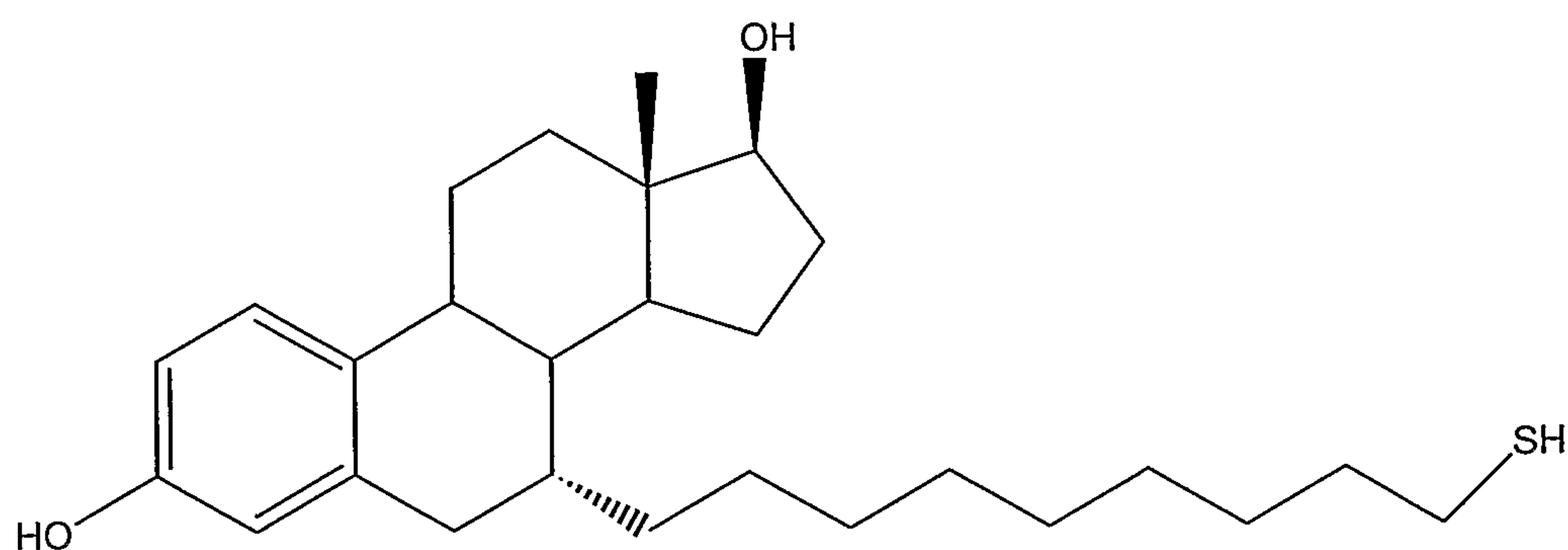
h) combining compound 9354 with a solvent selected from a C₁₋₆ aromatic hydrocarbon, a straight or branched C₁₋₄ alkyl amide and mixtures thereof and thiourea to
5 provide a compound of formula 9388



9388

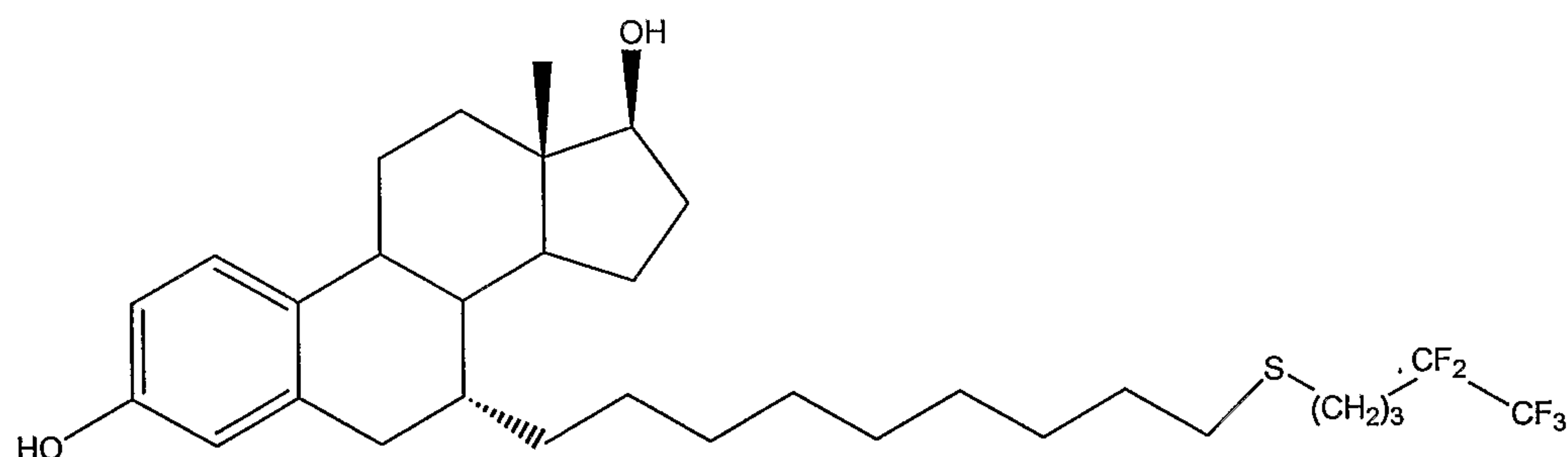
and recovering compound 9388;

i) combining compound 9388 with a base at ambient temperature to obtain a
10 compound of formula 9389



9389

j) combining compound 9389 with 4,4,5,5,5-pentafluoropentane-1-ol mesylate at an ambient temperature to provide a second reaction mixture and then combining the second reaction mixture with a base to obtain a compound of formula 9304



5

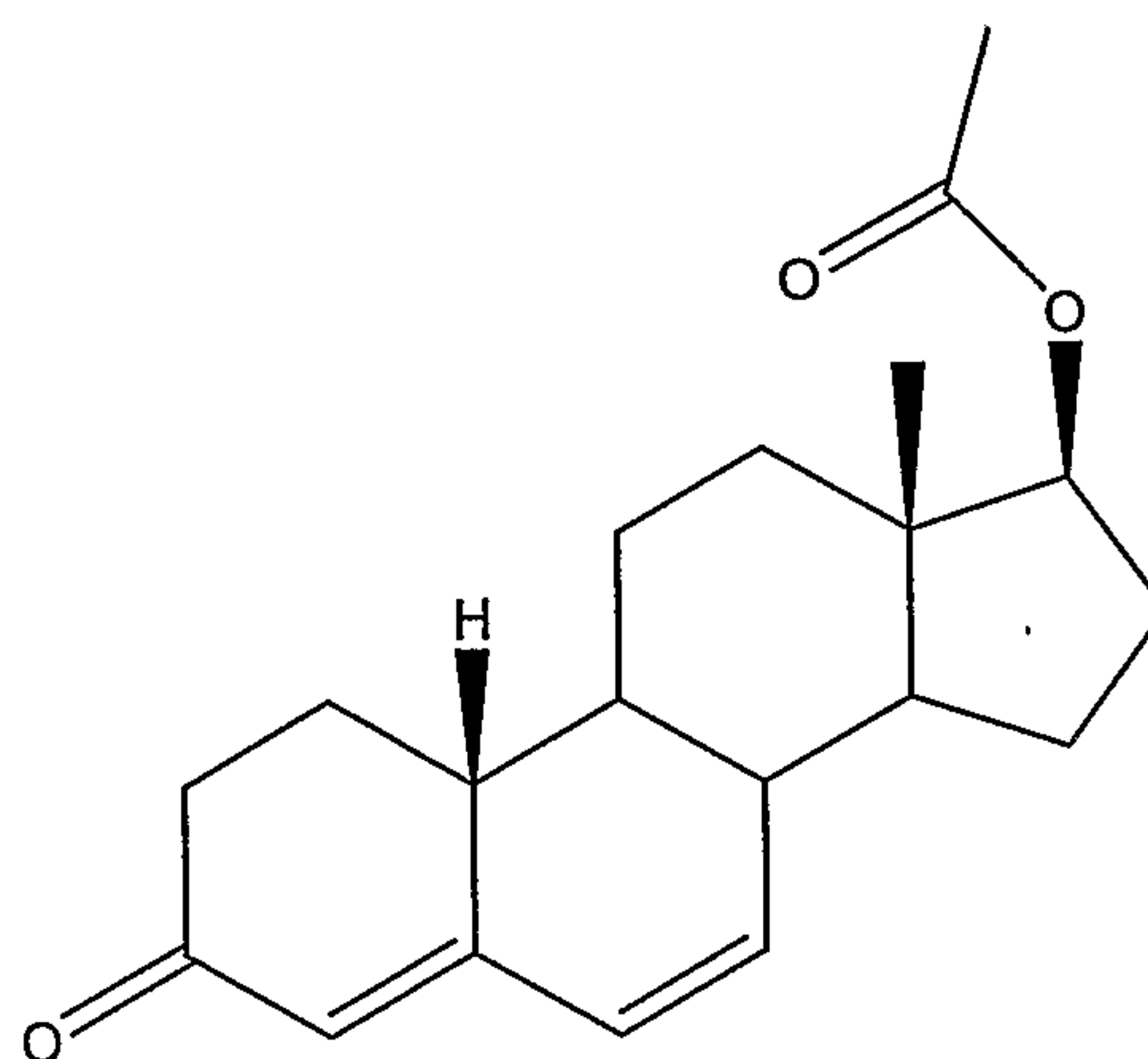
9304;

and

k) combining compound 9304 and a mixture of a C₁₋₄ alcohol and an etheral solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide fulvestant.

10 The invention further relates to a process for preparing fulvestrant comprising:

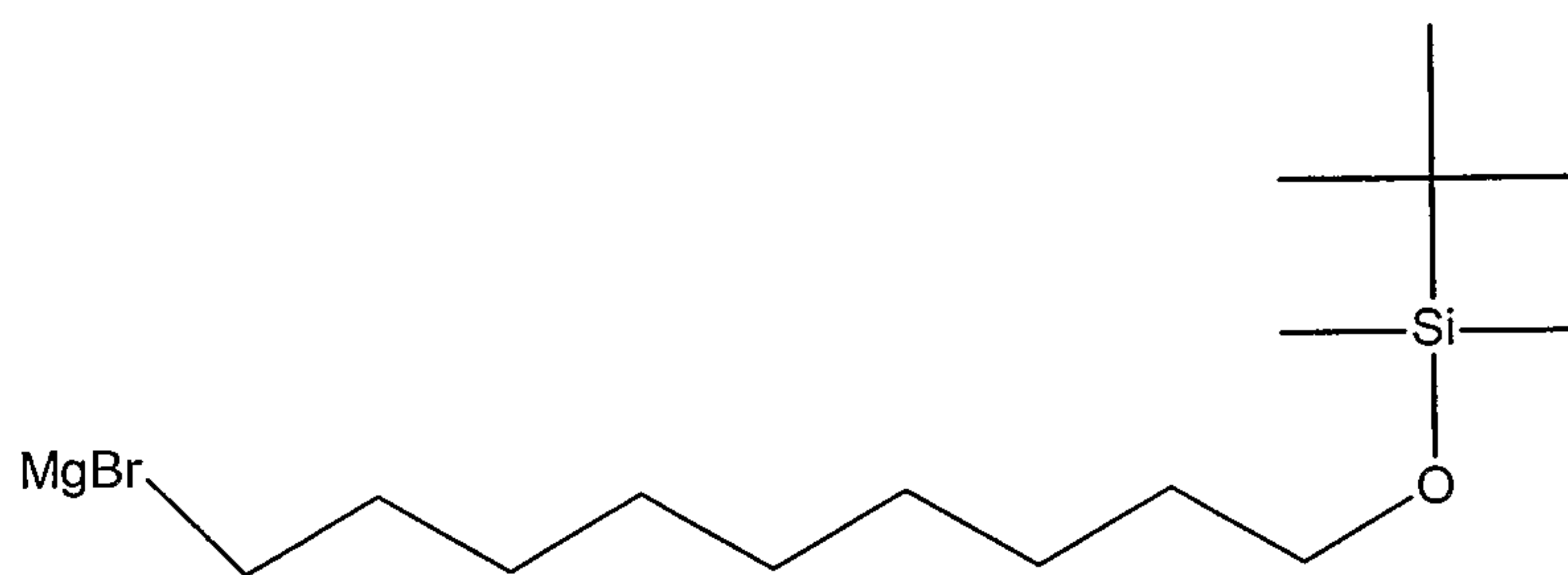
a) combining compound of formula 9294



9294

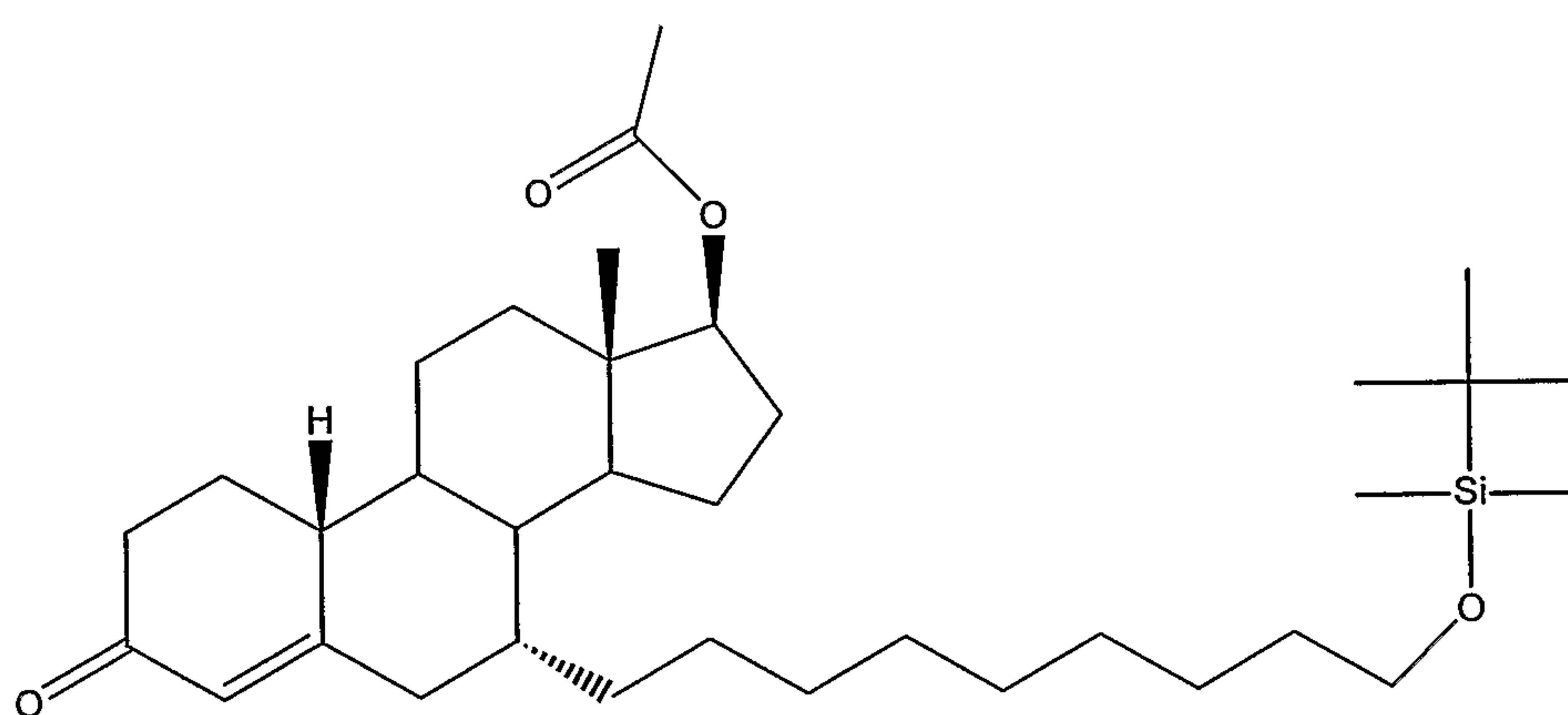
with an etheral solvent, to obtain a solution;

15 b) adding to the solution of step a), in a drop-wise manner, a solution of the compound of formula 9318



9318

in an etheral solvent to obtain afirst reaction mixture comprising a compound of formula 9295;

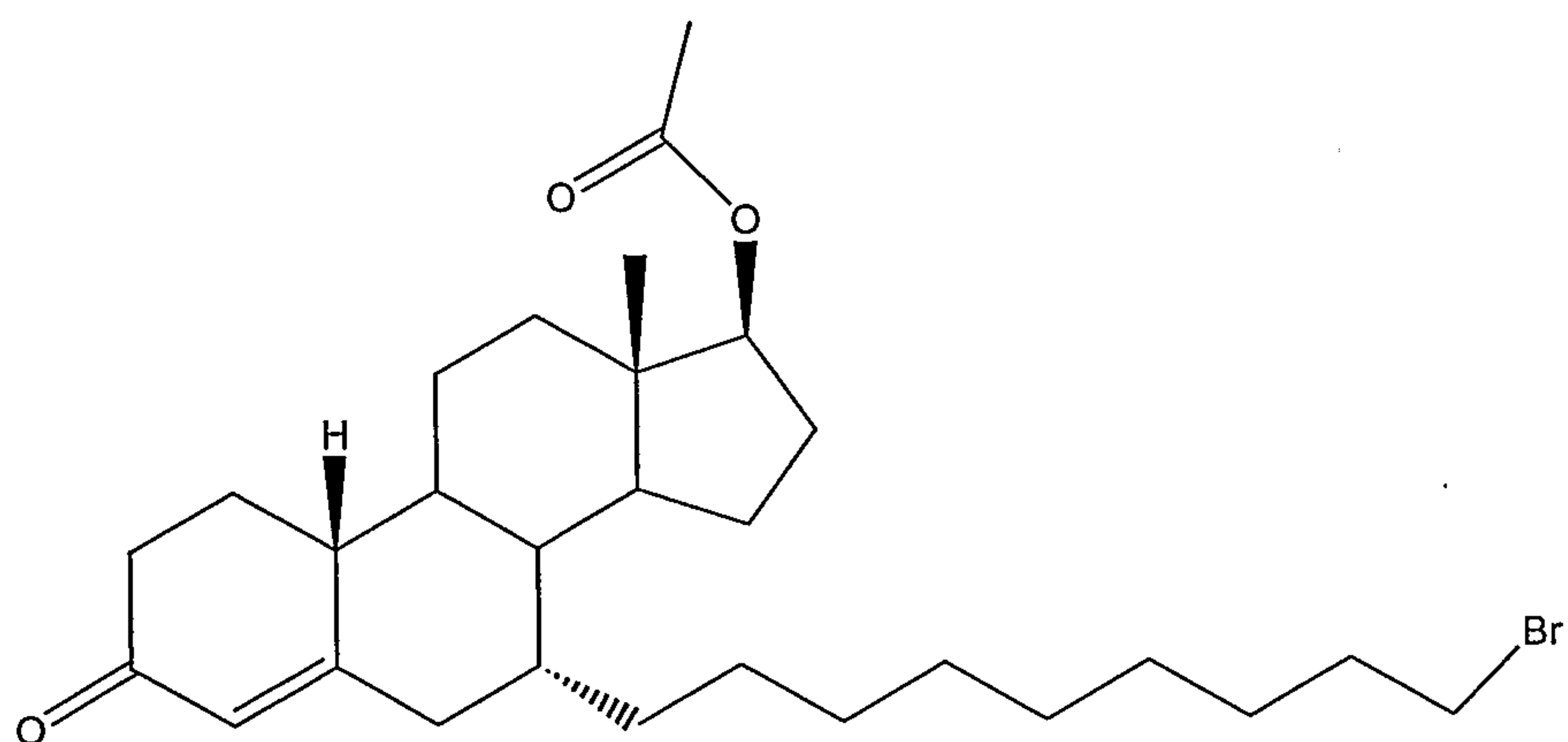


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c) quenching the first reaction mixture;

d) recovering compound 9295;

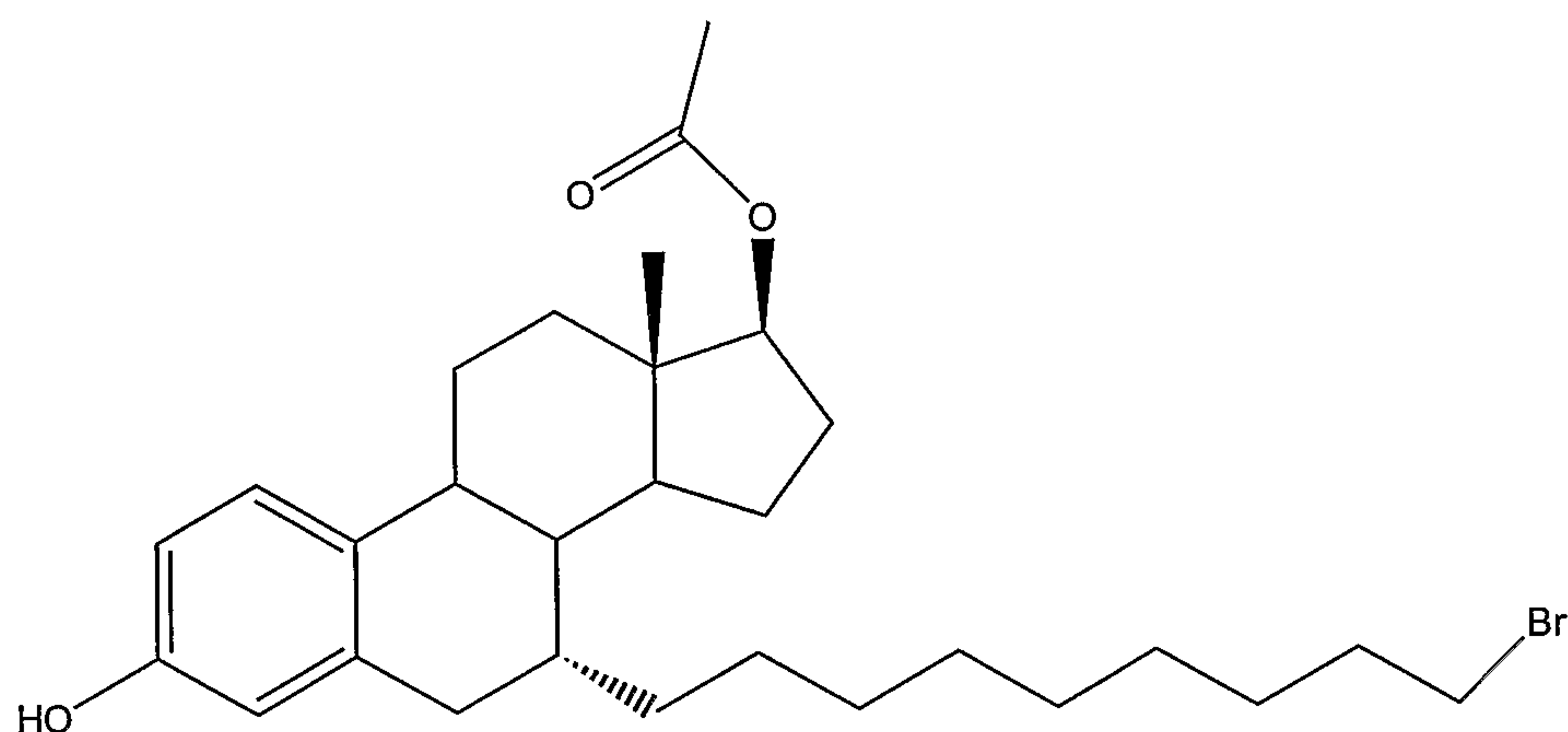
e) combining compound 9295 with acetonitrile and triphenylphosphine dibromide for a time sufficient to convert compound 9295 into a compound of formula 9341



10

9341;

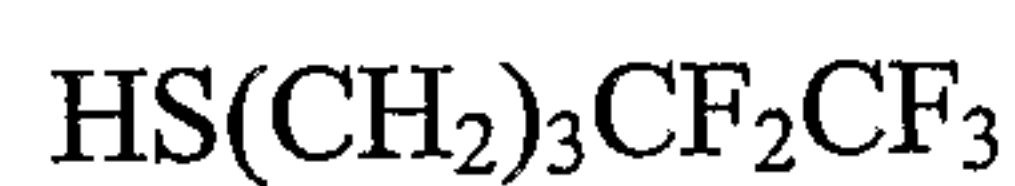
f) aromatizing the A ring of compound 9341 by reacting compound 9341 with a mixture of lithium bromide and copper bromide in acetonitrile to obtain a compound of formula 9342



5

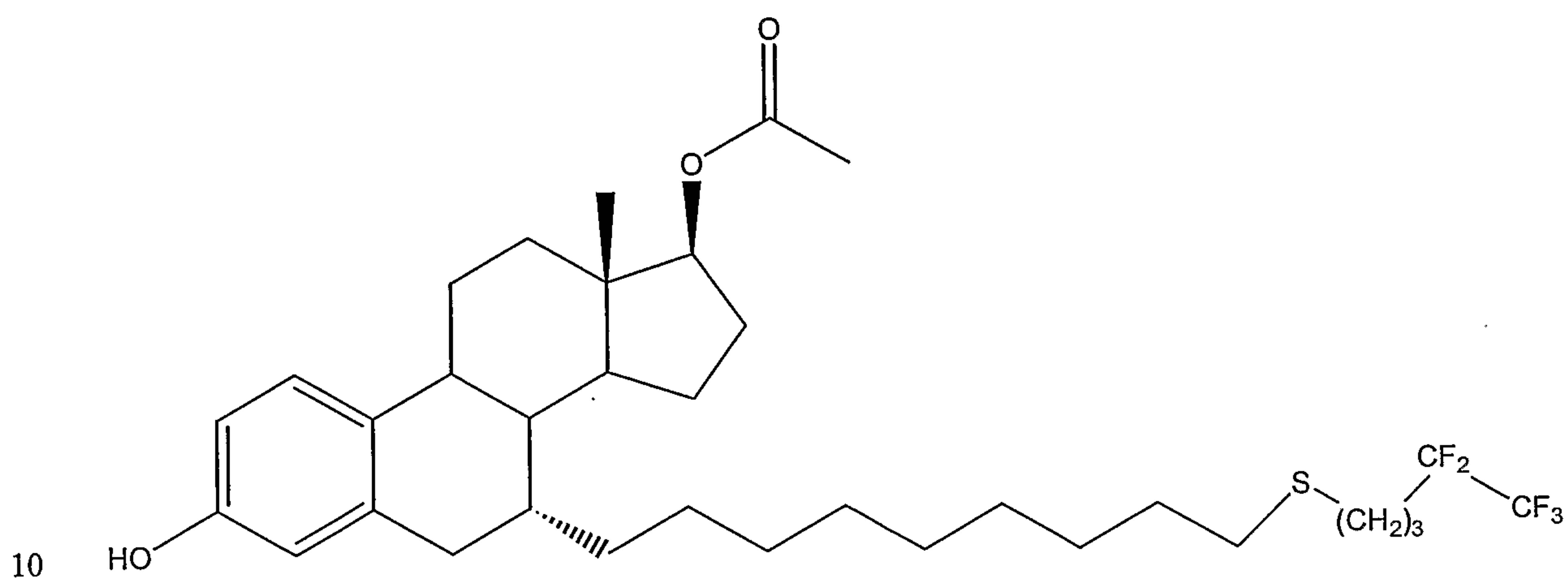
9342;

g) combining compound 9342 with a compound of formula 9383



9383;

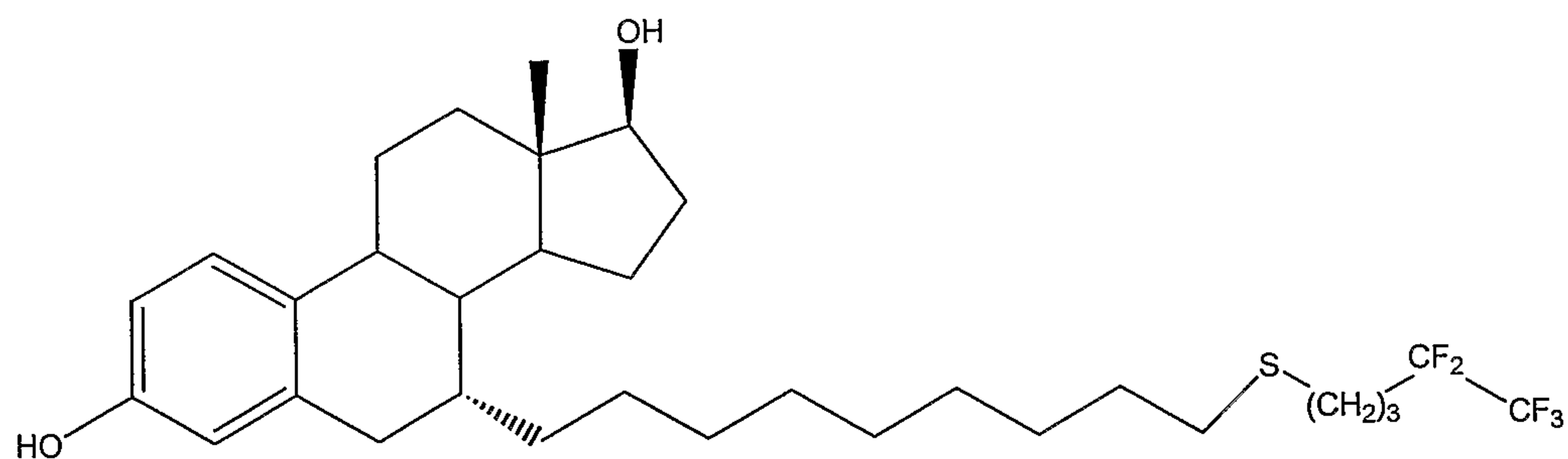
to provide a compound of formula 9363



10

9363;

h) combining at ambient temperature, compound 9363 and a C₁₋₄ alcohol with an alkali base to obtain compound 9304



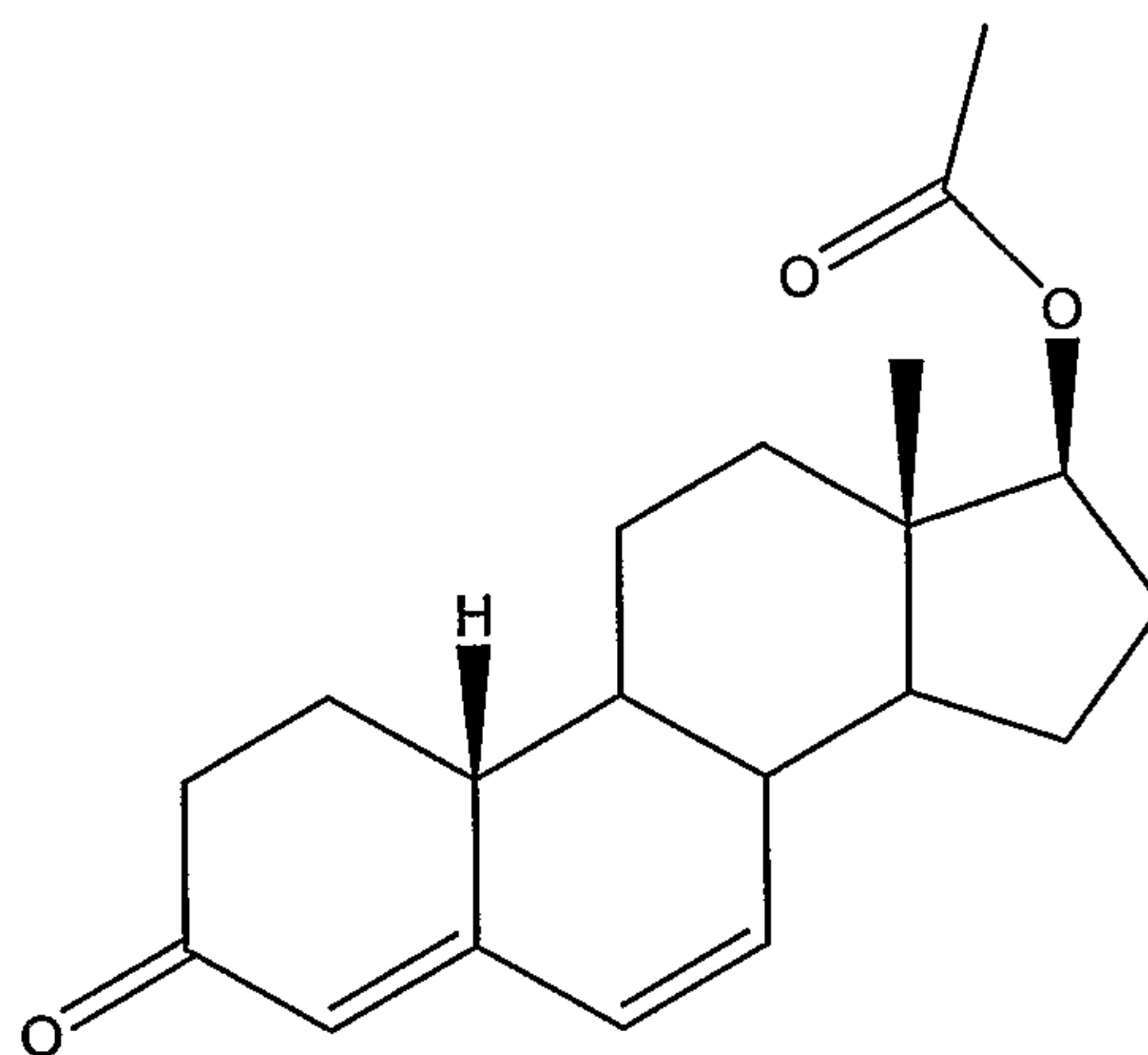
9304;

and

- i) combining compound 9304 and a mixture of a C₁₋₄ alcohol and an etheral solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide fulvestant.

The invention further relates to a process for preparing fulvestrant comprising

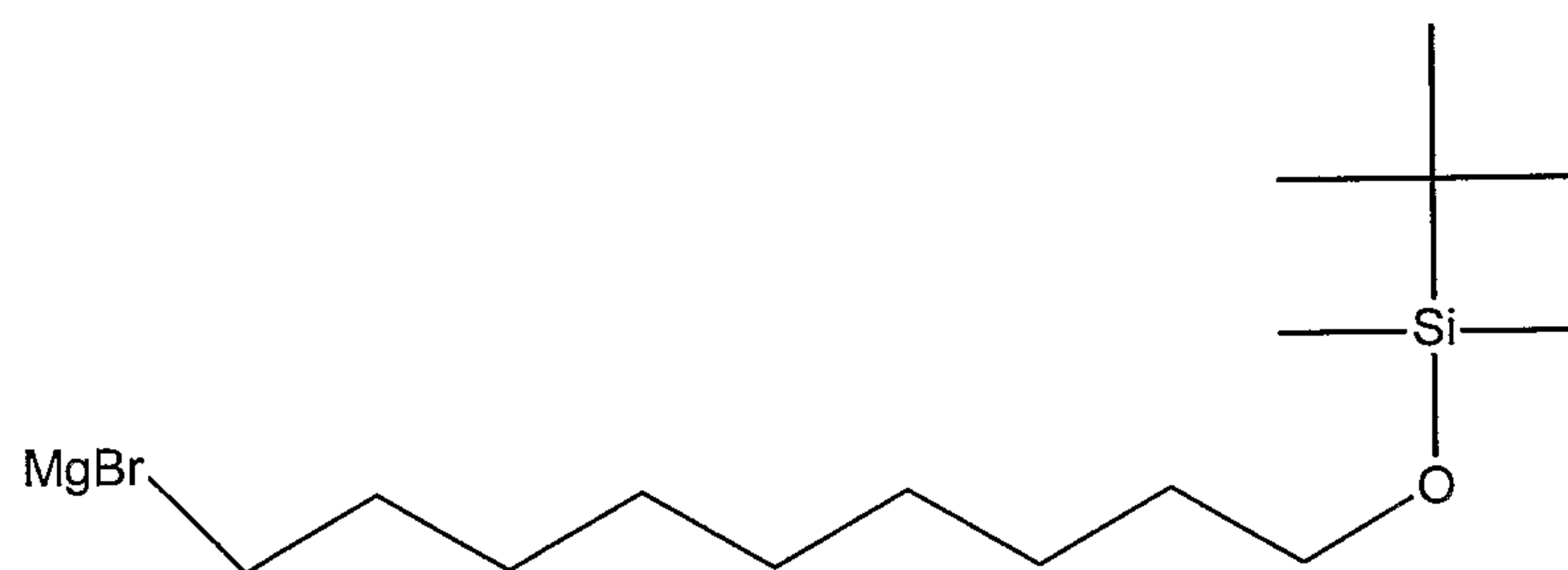
- a) combining compound of formula 9294



9294

with an etheral solvent, to obtain a solution;

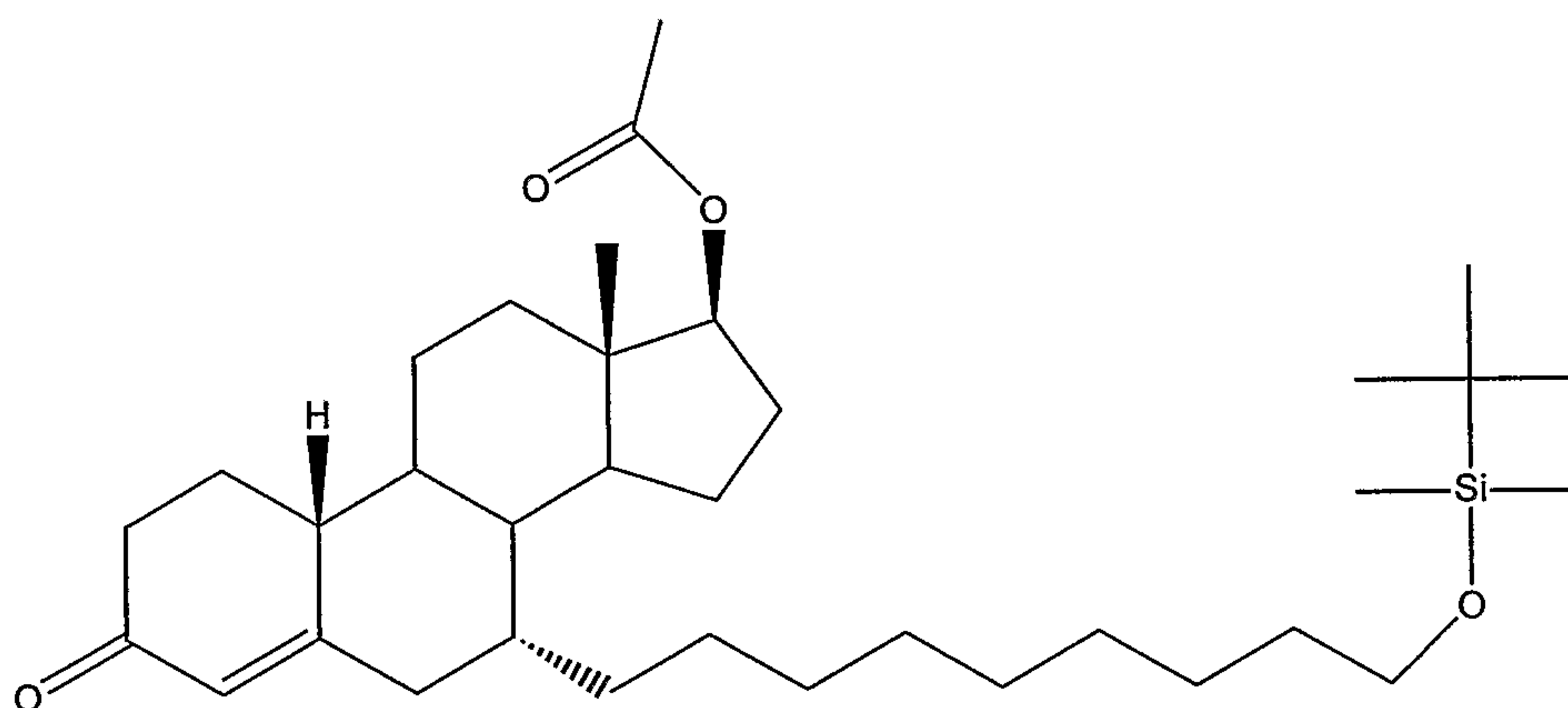
- b) adding to the solution of step a), in a drop-wise manner, a solution of the compound of formula 9318



9318

in an ethereal solvent to obtain a first reaction mixture comprising a compound of formula 9295;

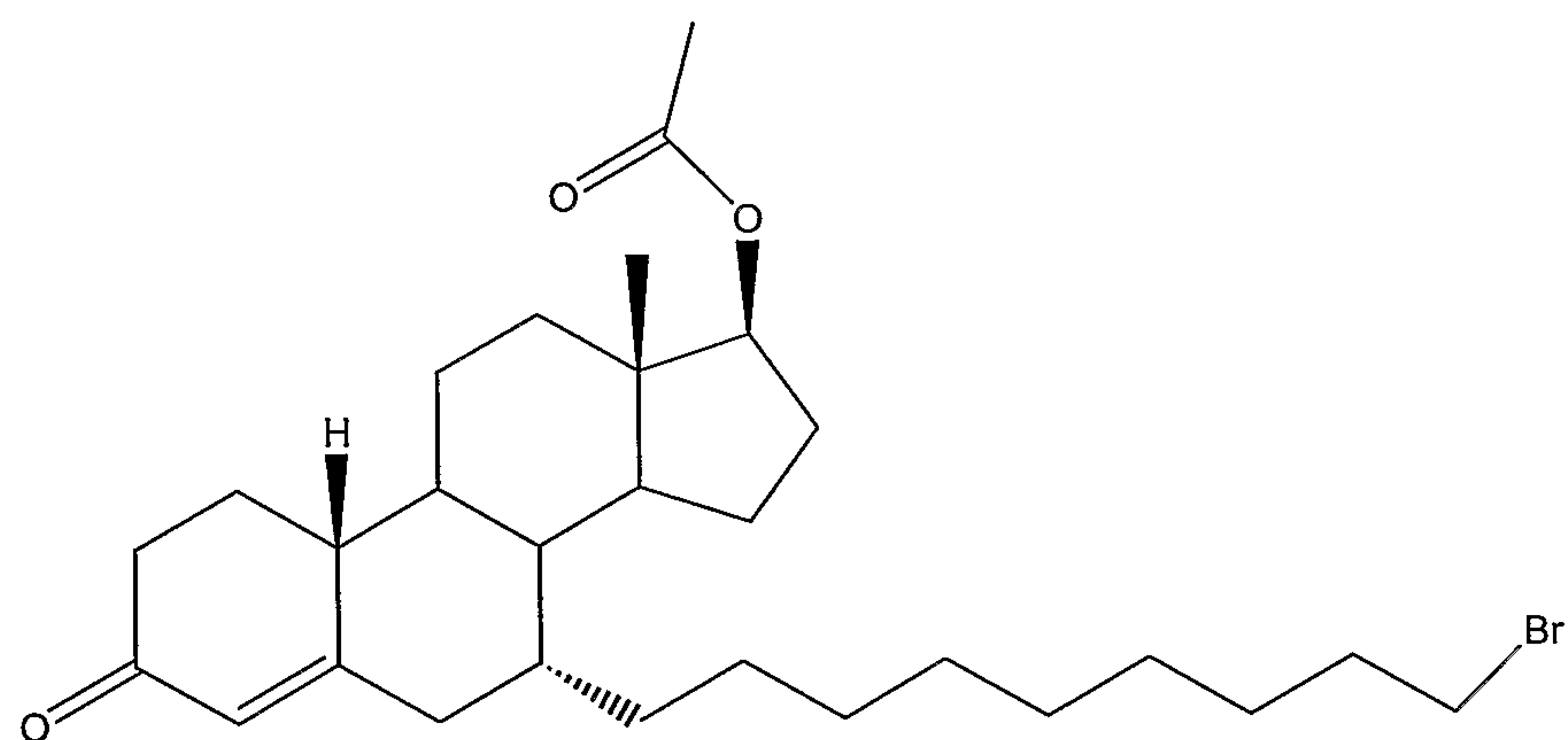
5



c) quenching the first reaction mixture;

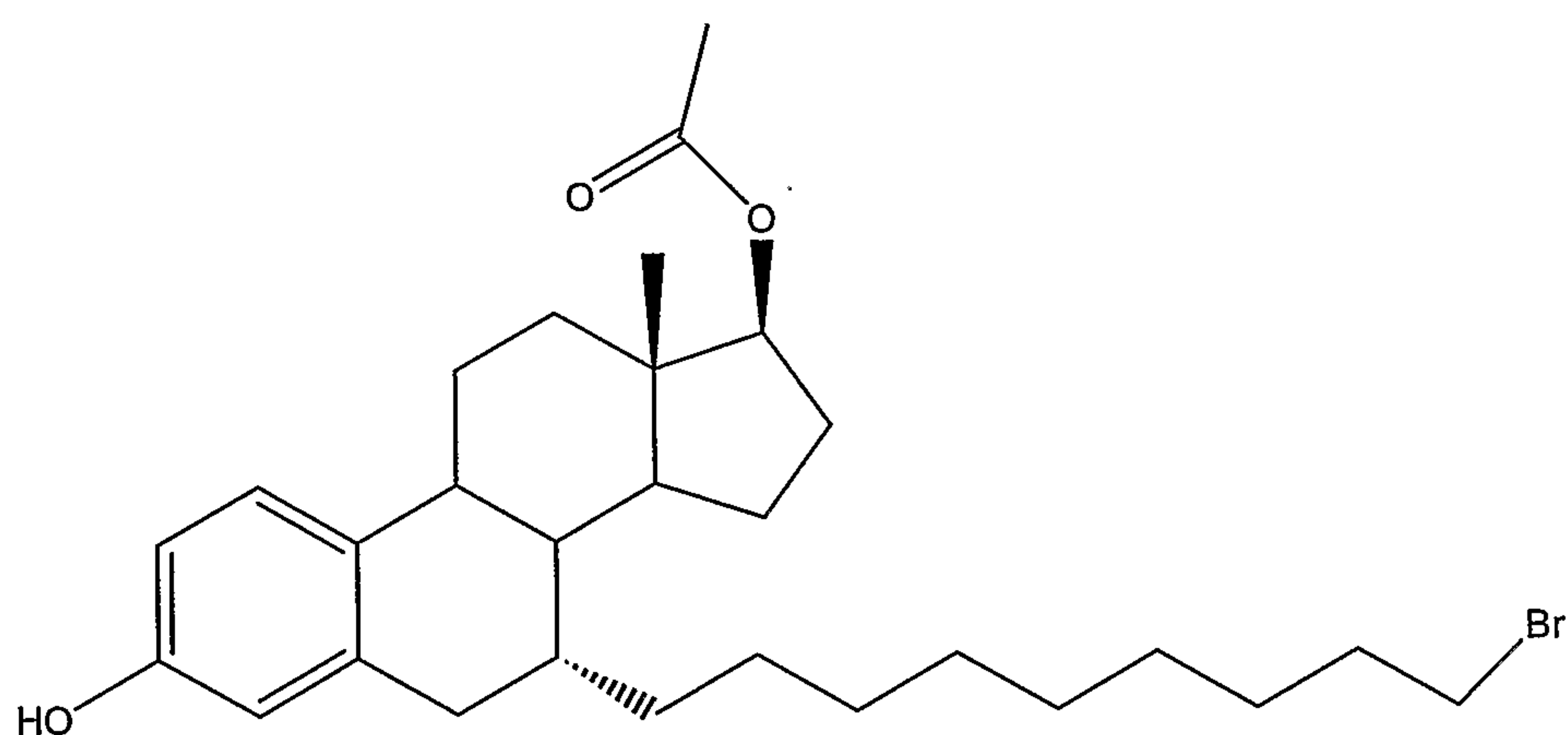
d) recovering compound 9295;

10 e) combining compound 9295 with acetonitrile and triphenylphosphine dibromide for a time sufficient to convert compound 9295 into a compound of formula 9341



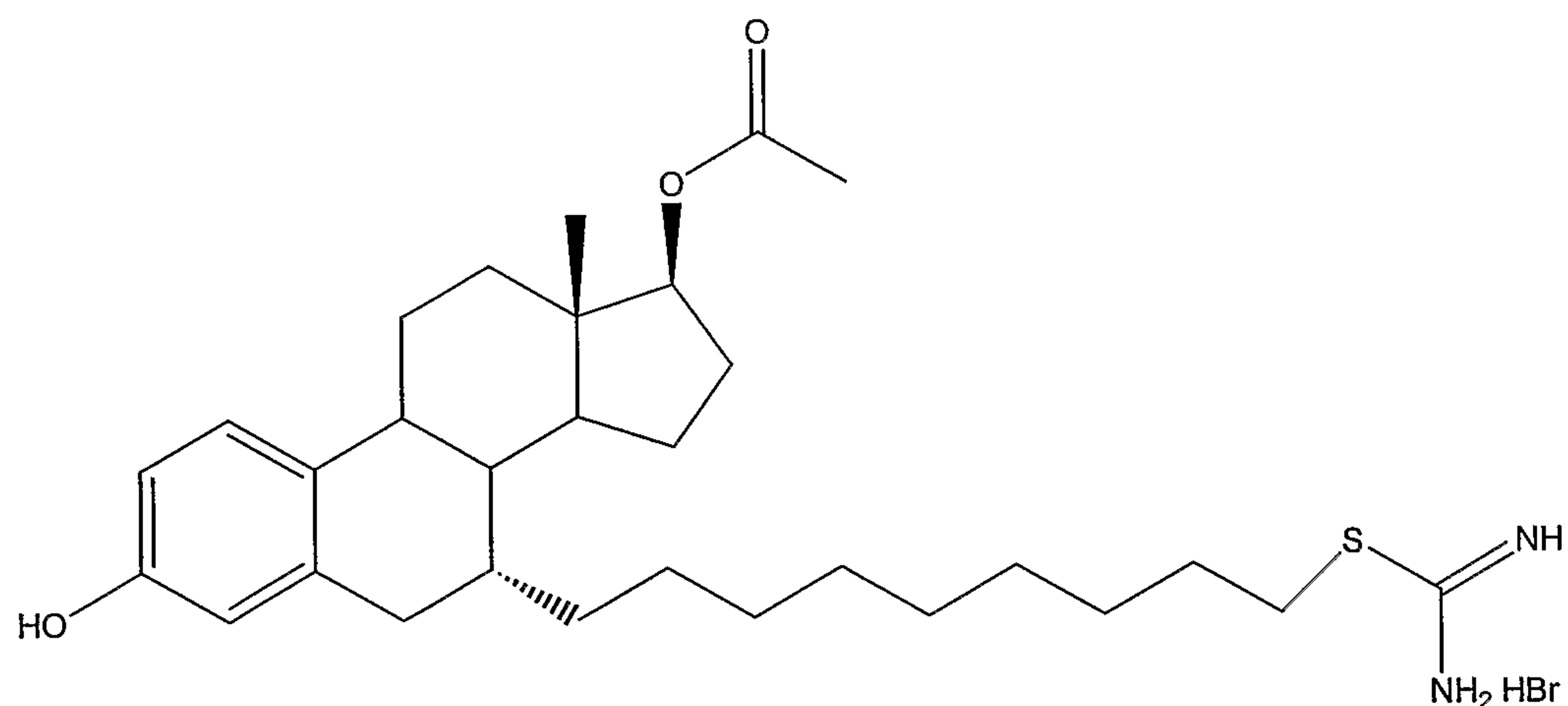
9341;

f) aromatizing the A ring of compound 9341 by reacting compound 9341 with a mixture of lithium bromide and copper bromide in acetonitrile to obtain a compound of
5 formula 9342



9342;

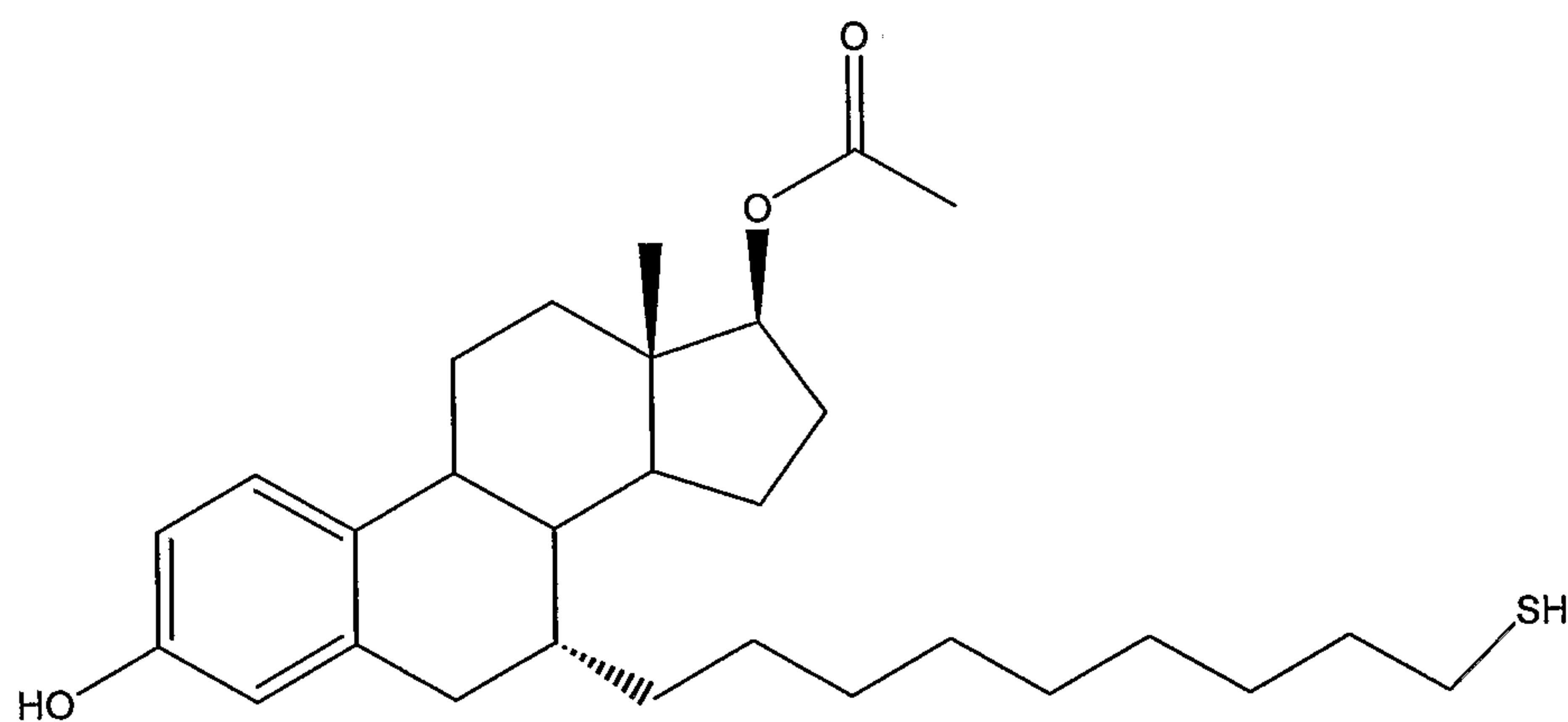
g) combining compound 9342 with with a solvent selected from a C₁₋₆ aromatic hydrocarbon, a straight or branched C₁₋₄ alkyl amide and mixtures thereof and thiourea to
10 provide a compound of formula 9361



9361

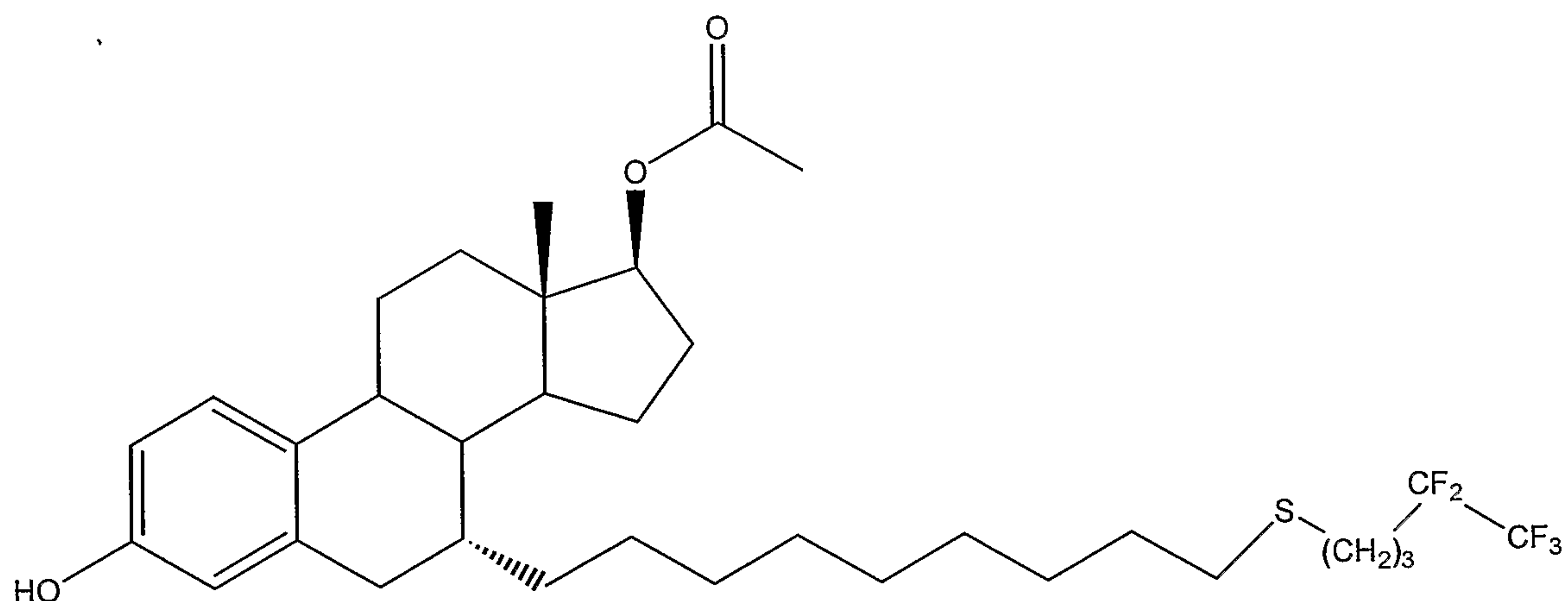
and recovering compound 9361.

- h) combining compound 9361 with a base at an ambient temperature to obtain a
 5 compound of formula 9362



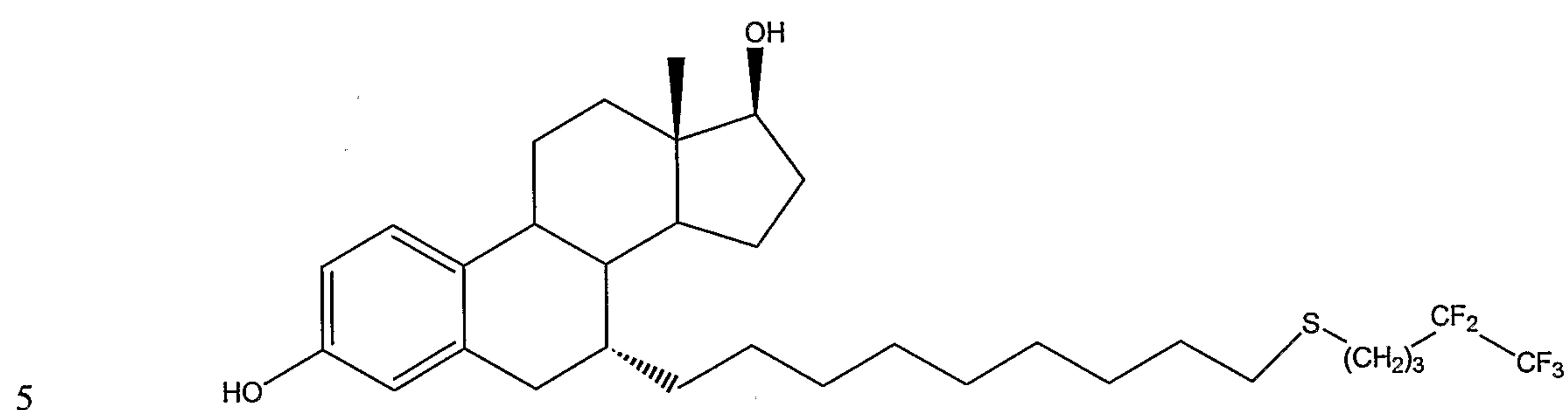
9362

- i) combining compound 9362 with 4,4,5,5,5-pentafluoropentane-1-ol mesylate at
 ambient temperature to provide a second reaction mixture followed by combining the
 10 second reaction mixture with a base to obtain a compound of formula 9363



9363;

j) combining at ambient temperature compound 9363 and a C₁₋₄ alcohol with an alkali base to obtain a compound of formula 9304



9304;

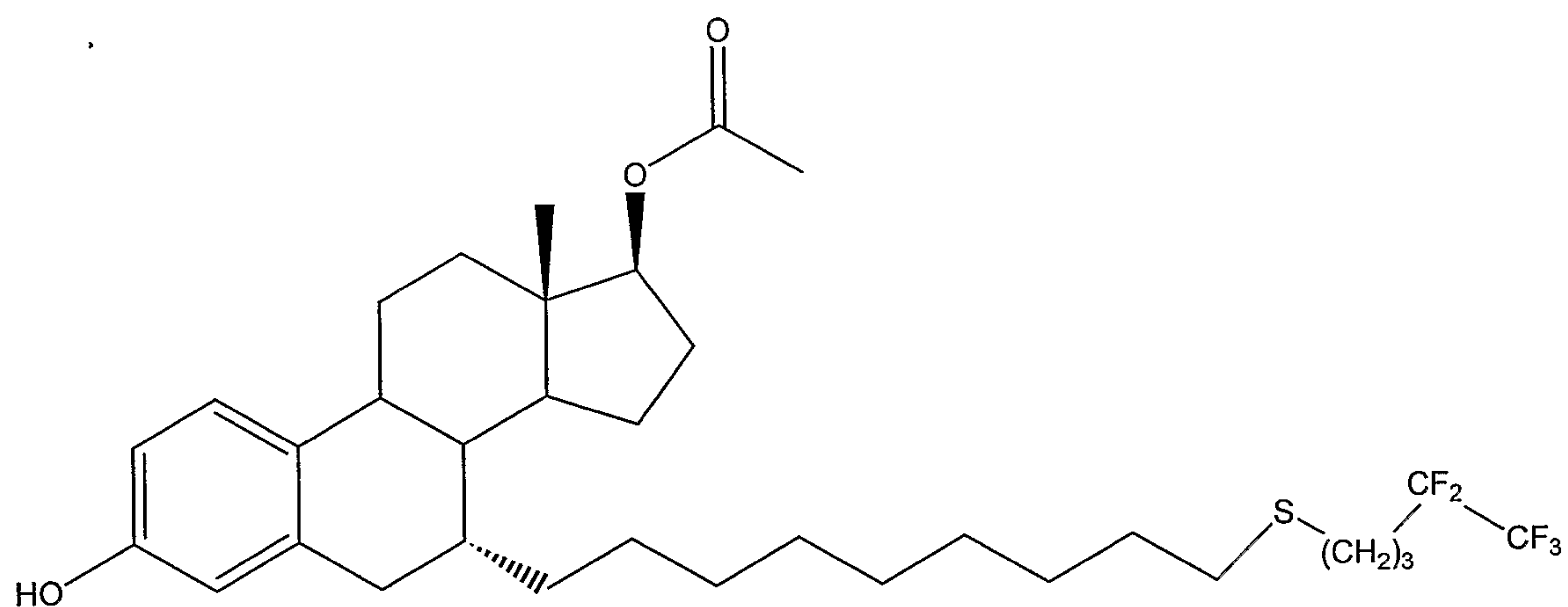
and

k) combining compound 9304 and a mixture of a C₁₋₄ alcohol and an etheral solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide fulvestant.

10

The invention further relates to a process for preparing fulvestrant comprising

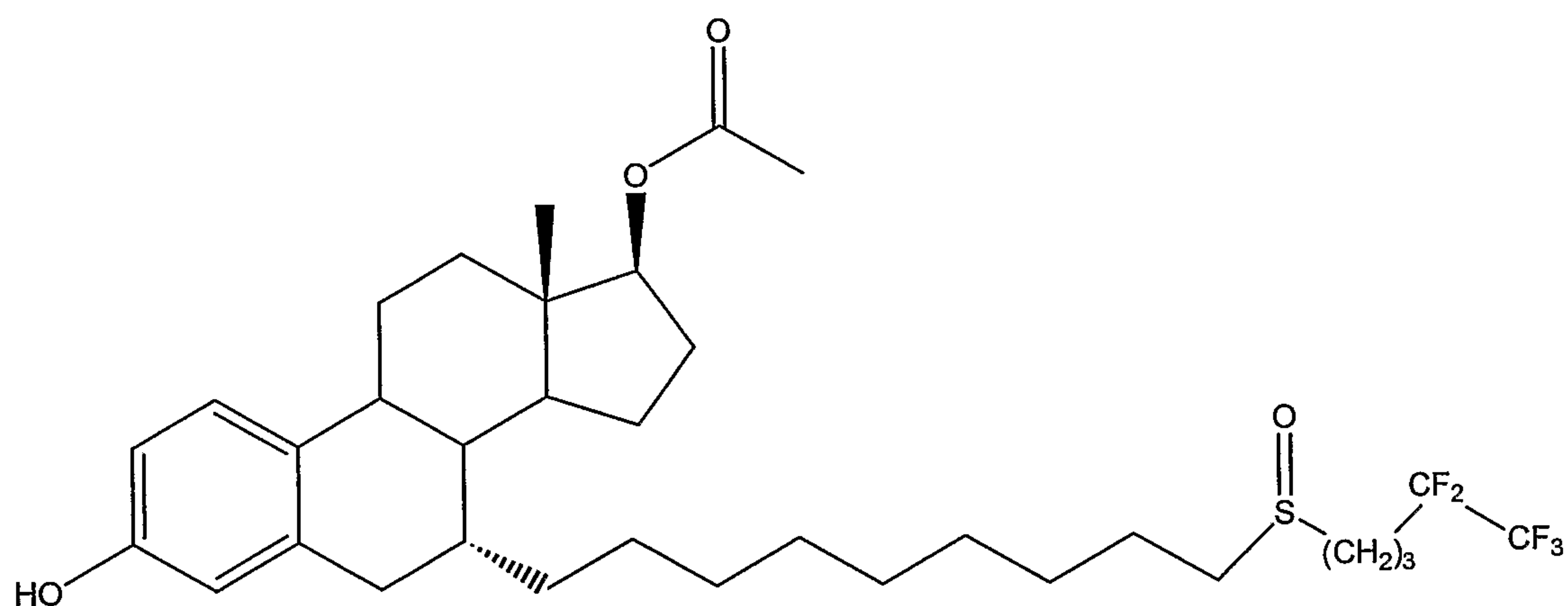
a) reacting a compound of formula 9363



9363;

with a mixture of a C₁₋₄ alcohol and an ethereal solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide a compound

5 of formula 9368



9368;

and

10 b) combining at ambient temperature compound 9368 and a C₁₋₄ alcohol with an alkali base to obtain fulvestant.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic showing a method for making an intermediate, useful in the preparation of fluvestrant, according to the method of the invention.

FIG. 2 is a schematic showing a method for making an intermediate, useful in the preparation of fluvestrant, according to the method of the invention.

FIG. 3 is a schematic showing a method for making an intermediate, useful in the preparation of fluvestrant, according to the method of the invention.

5 FIG. 4 is a schematic showing a method for making an intermediate, useful in the preparation of fluvestrant, according to the method of the invention.

FIG. 5 is a schematic showing a method for making an intermediate, useful in the preparation of fluvestrant, according to the method of the invention.

10 FIG. 6 is a schematic showing a method for making an intermediate, useful in the preparation of fluvestrant, according to the method of the invention.

FIG. 7 is a schematic showing a method for making an intermediate, useful in the preparation of fluvestrant, according to the method of the invention.

FIG. 8 is a schematic showing a method for making fluvestrant according to the method of the invention.

15 FIG. 9 is a schematic showing a method for making fluvestrant according to the method of the invention.

FIG. 10 is a schematic showing a method for making fluvestrant according to the method of the invention.

20 FIG. 11 is a schematic showing a method for making fluvestrant according to the method of the invention.

FIG. 12 is a schematic showing a method for making fluvestrant according to the method of the invention.

FIG. 13 is a schematic showing a method for making fluvestrant according to the method of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The phrase “precursor group,” as used herein, means a functional group that can be readily converted to another functional group. Accordingly, the phrase “a group R₄ or a precursor group thereof” means a group R₄ or a group that can be readily converted to R₄. As a representative example, esters are a precursor group for an alcohol because the ester can be readily hydrolyzed to provide the alcohol.

The phrase “hydroxy protecting group” or “protected hydroxy,” as used herein means a group that can replace the hydrogen of a hydroxyl, *i.e.*, the hydrogen of an -OH group, and then be subsequently be removed and replaced by a hydrogen to reform the hydroxyl group. The hydroxyl protecting group prevents the hydroxyl from reacting under a given set of conditions, which typically are necessary to perform a reaction at another part of a molecule. After reaction at the other part of the molecule, the hydroxyl protecting group can be removed to provide the hydroxyl group. A list of suitable hydroxy protecting groups can be found in Protective Groups in Organic Synthesis, Third Edition, John Wiley, New York 1999. Representative hydroxyl protecting groups include, but are not limited to: alkyl or aryl ethers, silyl ethers and esters.

Representative hydroxyl protecting groups include, but are not limited to:

methylethers including, but not limited to, methoxymethyl; methylthiomethyl; *t*-butylthiomethyl; (phenyldimethyldiyl)methoxy-methyl; benzyloxymethyl; *p*-methoxybenzyl-oxymethyl; (4-methoxyphenoxy)methyl; guaiacolmethyl; *t*-butoxymethyl; 4-pentenylloxymethyl; siloxymethyl; 2-methoxyethoxymethyl; 2,2,2-trichloroethoxymethyl; bis(2-chloroethoxy)methyl; 2-(trimethylsilyl)ethoxymethyl; tetrahydropyran-2-yl; 3-bromotetrahydropyran-2-yl; 1-methoxycyclohexyl; 4-methoxytetrahydropyran-2-yl; 4-methoxytetrahydrothiopyran-2-yl; 4-methoxytetrahydrothiopyran-2-yl-S,S-dioxido; 1-[(2-chloro-4-methyl)phenyl]-4-methoxypiperidin-4-yl; 1,4-dioxan-2-yl; tetrahydrofuranyl; tetrahydrothiofuranyl; and 2,3,3a,4,5,6,7,7a-octahydro-7,8,8-trimethyl-4,7-methanobenzofuran-2-yl;

ethyl ethers including, but not limited to, 1-ethoxyethyl; 1-(2-chloroethoxy)ethyl; 1-methyl-1-methoxyethyl; 1-methyl-*i*-benzyloxy-2-fluoroethyl; 2,2,2-trichloroethyl; 2-trimethylsilylethyl; 2-(phenylselenyl)ethyl; *t*-butyl; allyl; *p*-chlorophenyl; *p*-methoxyphenyl; and 2,4-dinitrophenyl,

benzyl ethers including, but not limited to, benzyl; p-methoxybenzyl; 3,4-dimethoxybenzyl; o-nitrobenzyl; p-nitrobenzyl; p-halobenzyl; 2,6-dichlorobenzyl; p-cyanobenzyl; p-phenylbenzyl; 2- and 4-picolyl; 3-methyl-2-picolyl-N-oxido; diphenylmethyl; p,p'-dinitrobenzhydryl; 5-dibenzosuberyl; triphenylmethyl; a-naphthyldiphenylmethyl; p-methoxyphenyldiphenylmethyl; di(p-methoxyphenyl)phenylmethyl; tri(p-methoxyphenyl)methyl; 4-(4'-bromophenacyloxy)phenyldiphenylmethyl; 4,4',4''-tris(4,5-dichlorophthalimidophenyl)methyl; 4,4',4''-tris(levulinoyloxyphenyl)methyl; 4,4',4''-tris(benzoyloxyphenyl)methyl; 3-(imidazol-1-ylmethyl)bis(4',4''-dimethoxyphenyl)-methyl; 1,1-bis(4-methoxyphenyl)-1'-pyrenylmethyl; 9-anthryl; 9-(9-phenyl)xanthenyl; 9-(9-phenyl-10-oxo)anthryl; 1,3-benzodithiolan-2-yl; and benzisothiazolyl S,S-dioxido;

silyl ethers including, but not limited to, trimethylsilyl; triethylsilyl; triisopropylsilyl; dimethylisopropylsilyl; diethylisopropylsilyl; dimethylhexylsilyl; t-butyl dimethylsilyl; t-butyl-diphenylsilyl; tribenzylsilyl; tri-p-xylylsilyl; triphenylsilyl; diphenylmethylsilyl; and t-butylmethoxyphenylsilyl;

esters including, but not limited to, formate; benzoylformate; acetate; chloroacetate; trichloroacetate; methoxyacetate; triphenylmethoxyacetate; phenoxyacetate; p-chlorophenoxyacetate; p-(phosphate)phenylacetate; 3-phenylpropionate; 4-oxopentanoate (levulinate); 4,4-(ethylenedithio)pentanoate; pivaloate; adamantate; crotonate; 4-methoxycrotonate; benzoate; p-phenylbenzoate; and 2,4,6-trimethylbenzoate;

carbonates including, but not limited to, methyl carbonate; 9-fluorenylmethylcarbonate; ethyl carbonate; 2,2,2-trichloroethyl carbonate; 2-(trimethylsilyl)ethyl carbonate; 2-(phenylsulfonyl)ethyl carbonate; 2-(triphenylphosphono)ethyl carbonate; isobutyl carbonate; vinyl carbonate; allyl carbonate; p-nitrophenyl carbonate; benzyl carbonate; p-methoxybenzyl carbonate; 3,4-dimethoxybenzyl carbonate; o-nitrobenzyl carbonate; p-nitrobenzyl carbonate; S-benzyl thiocarbonate; 4-ethoxy-1-naphthyl carbonate; and methyl dithiocarbonate;

protecting groups with assisted cleavage including, but not limited to, 2-iodobenzoate; 4-azidobutyrate; 4-nitro-4-methylpentanoate; o-(dibromomethyl)benzoate;

2-formylbenzenesulfonate; 2-(methylthiomethoxy)ethyl carbonate; 4-(methylthiomethoxy)-butyrate; and 2-(methylthiomethoxymethyl) benzoate;

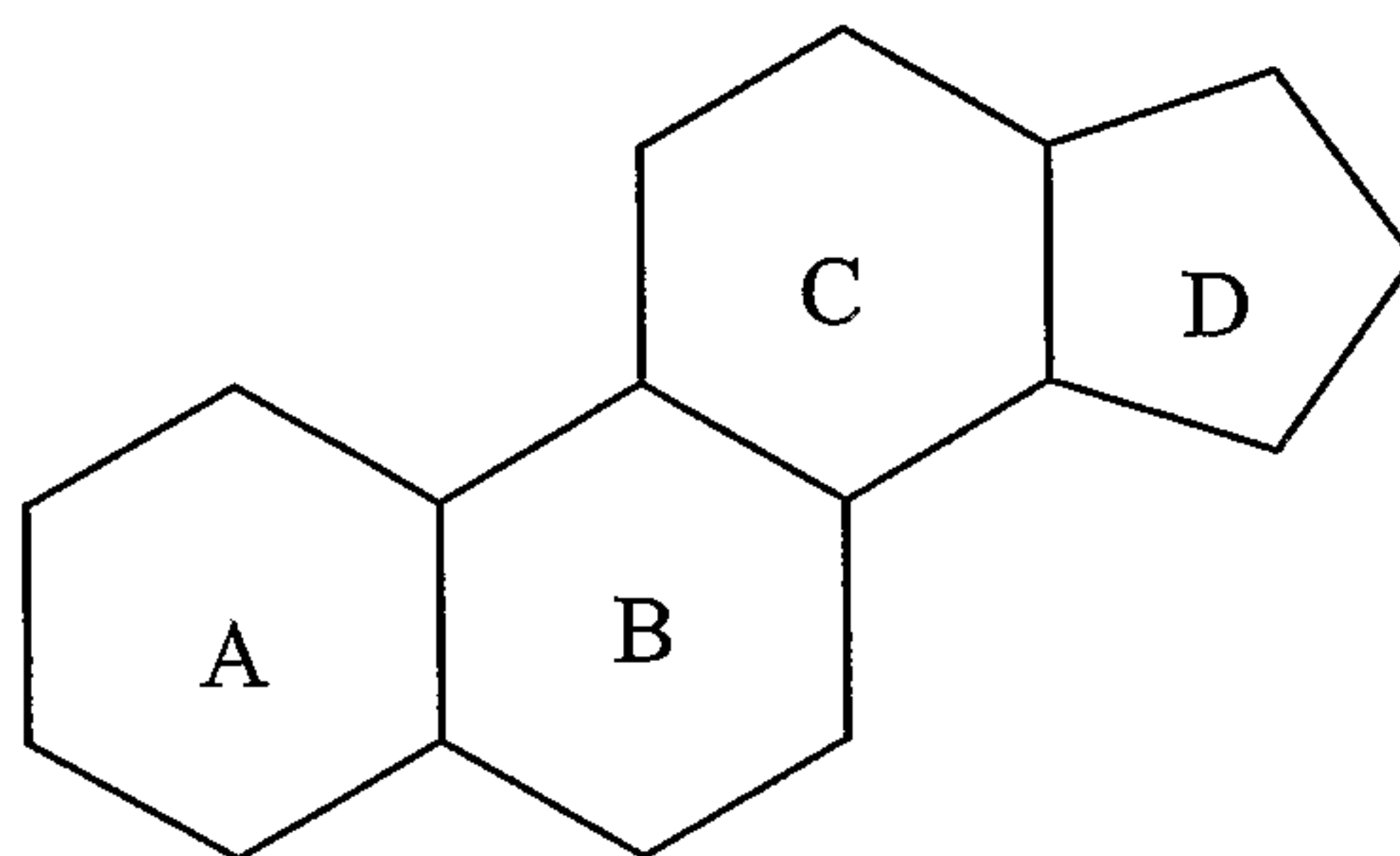
miscellaneous esters including, but not limited to, 2,6-dichloro-4-methylphenoxyacetate; 2,6-dichloro-4-(1,1,3,3-tetramethyl-butyl)phenoxyacetate; 2,4-bis(1,1-dimethylpropyl)-phenoxy-acetate; chlorodiphenylacetate; isobutyrate; 5 monosuccinoate; (E)-2-methyl-2-butenate (tigloate); o-(methoxycarbonyl)benzoate; p-benzoate; a-naphthoate; nitrate; alkyl N,N,N',N'-tetramethylphosphorodiamidate; N-phenylcarbamate; borate; dimethylphosphinothioyl; and 2,4-dinitrophenyl-sulfenate;

sulfonates including, but not limited to, methanesulfonate (mesylate); 10 benzylsulfonate; and tosylate; and

silyl derivatives including, but not limited to, di-t-butylsilylene group; 1,3-(1,1,3,3-tetraisopropylidisiloxanylidene) derivative; tetra-t-butoxydisiloxane-1,3-diylidene derivative; cyclic carbonates; cyclic boronates; ethyl boronate; and phenyl boronate.

A preferred hydroxy protecting groups is $\text{SiR}_8\text{R}_9\text{R}_{10}$, wherein R_8 , R_9 , and R_{10} are 15 alkyl or branched alkyl containing 1 to 6 carbon atoms. Most preferably, R_8 and R_9 are methyl and R_{10} is t-butyl.

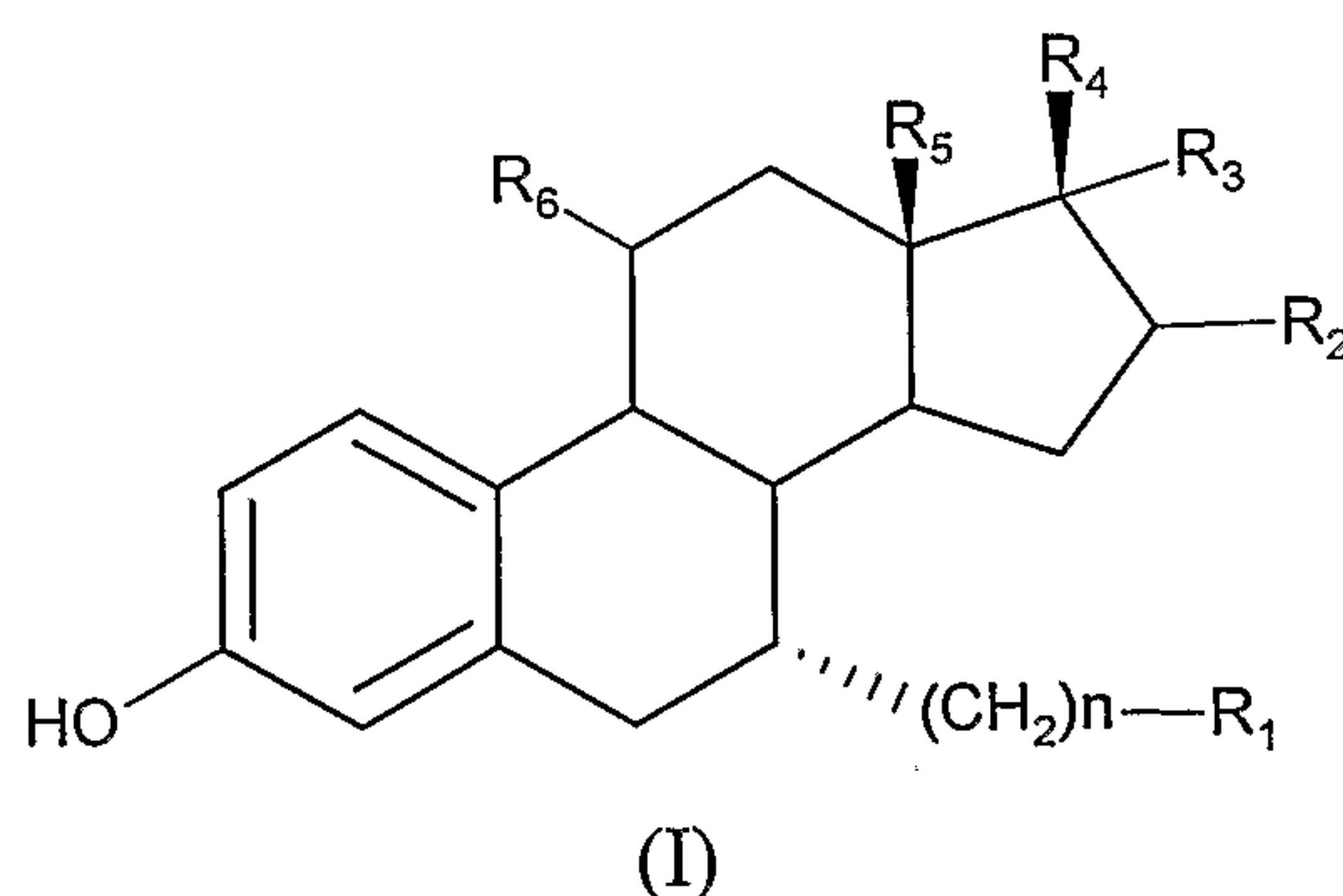
Throughout this specification the rings of the compounds of the invention are designated using the lettering conventionally used for designationg the rings of a steroid as depicted below:



Accordingly, the A ring of a steroid is the most left ring of the compound of formula as drawn above.

The term "aromatizing," as used herein, means changing a ring structure that is not aromatic, *i.e.*, either unsaturated or partially saturated, to a ring systems that is aromatic, *i.e.*, a ring system that has a cyclic cloud of $4n+2$ delocalized Π electrons.

One aspect of the present invention is a compound of formula (I):



wherein

n is an integer ranging from 3 to 14,

15 R_1 is selected from the group consisting of Br, Cl, I, free base or a salt form of isothiuronium, or SH;

R_2 is either hydrogen, C_{1-6} alkyl, hydroxyl, protected hydroxy, or halo;

R_3 is either hydrogen, C_{1-6} alkyl, C_{2-6} alkenyl, or C_{2-6} alkynyl;

R_4 is either hydroxy, or a C_{1-6} acyloxy;

R_5 is C_{1-6} alkyl; and

20 R_6 is either hydrogen, C_{1-6} alkyl, hydroxyl, protected hydroxy, or halo.

Preferably, n is 9, R_1 is Br, R_2 , R_3 , and R_6 are hydrogens, R_4 is hydroxy and R_5 is methyl. Said compound of formula (I) correspond to compound 9354 in Figure 7.

Preferably, n is 9, R_1 is Br, R_2 , R_3 , and R_6 are hydrogens, R_4 is acetyloxy and R_5 is methyl. Said compound of formula (I) correspond to compound 9342 in Figure 6.

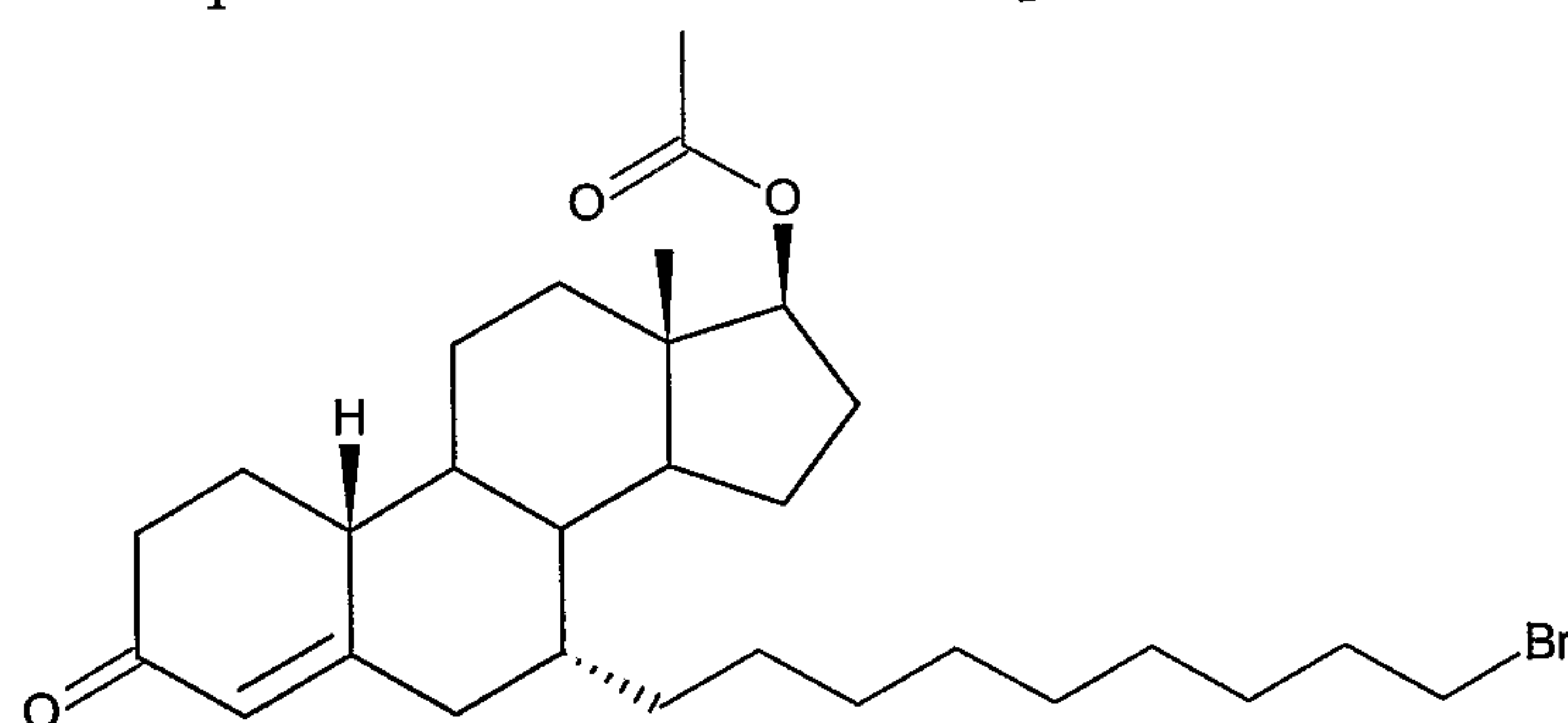
25 Preferably, n is 9, R_1 is a hydrobromide salt of isothiuronium, R_2 , R_3 , and R_6 are hydrogens, R_4 is acetyloxy and R_5 is methyl. Said compound of formula (I) correspond to compound 9361 in Figure 8.

Preferably, n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃, and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl. Said compound of formula (I) correspond to compound 9388 in Figure 9.

Preferably, n is 9, R₁ is SH, R₂, R₃, and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl. Said compound of formula (I) correspond to compound 9362 in Figure 8.

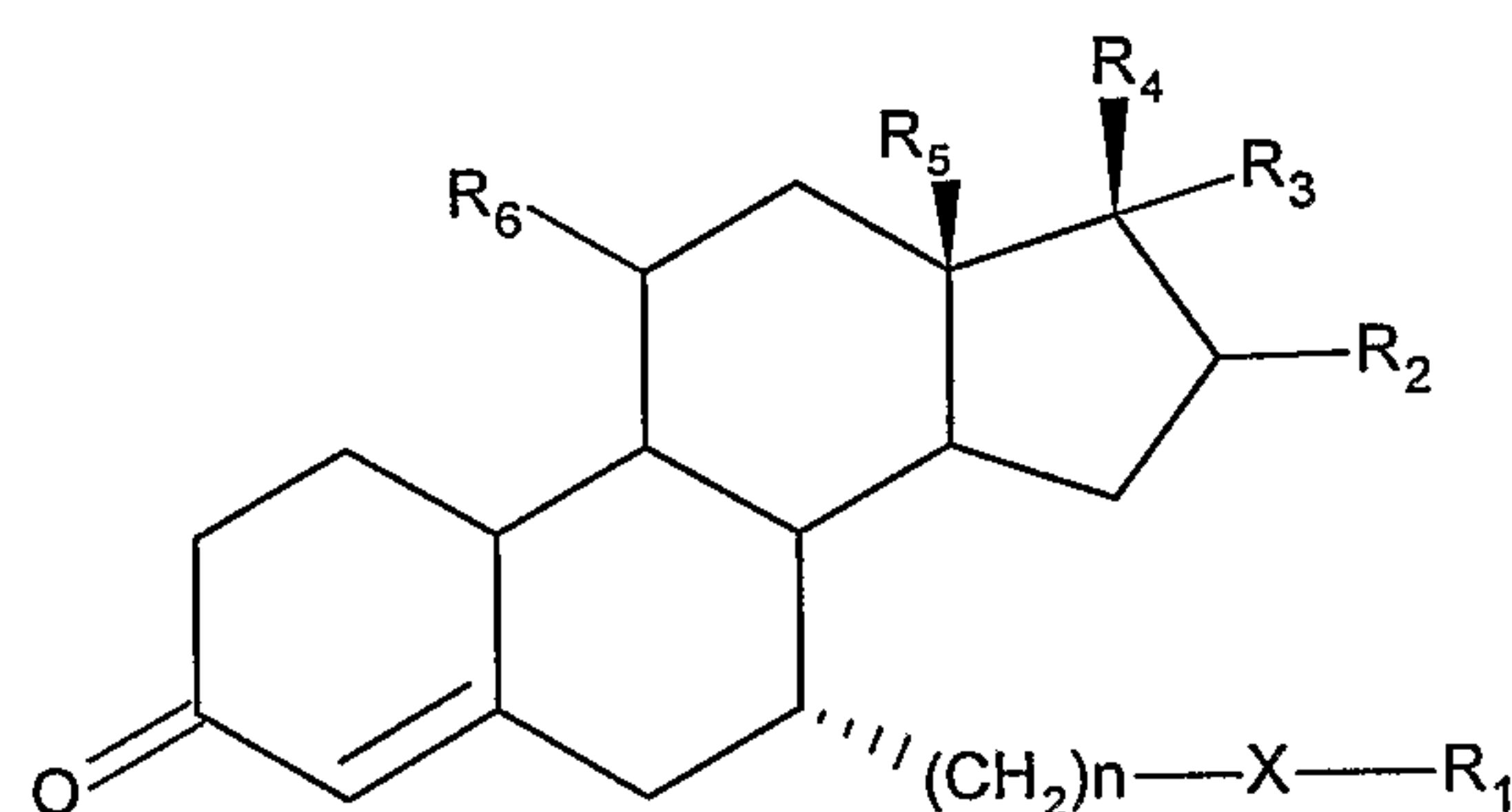
Preferably, n is 9, R₁ is SH, R₂, R₃, and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl. Said compound of formula (I) correspond to compound 9389 in Figure 9.

Another aspect of the present invention is is a compound of formula



Compound 9341 (in Figure 5)

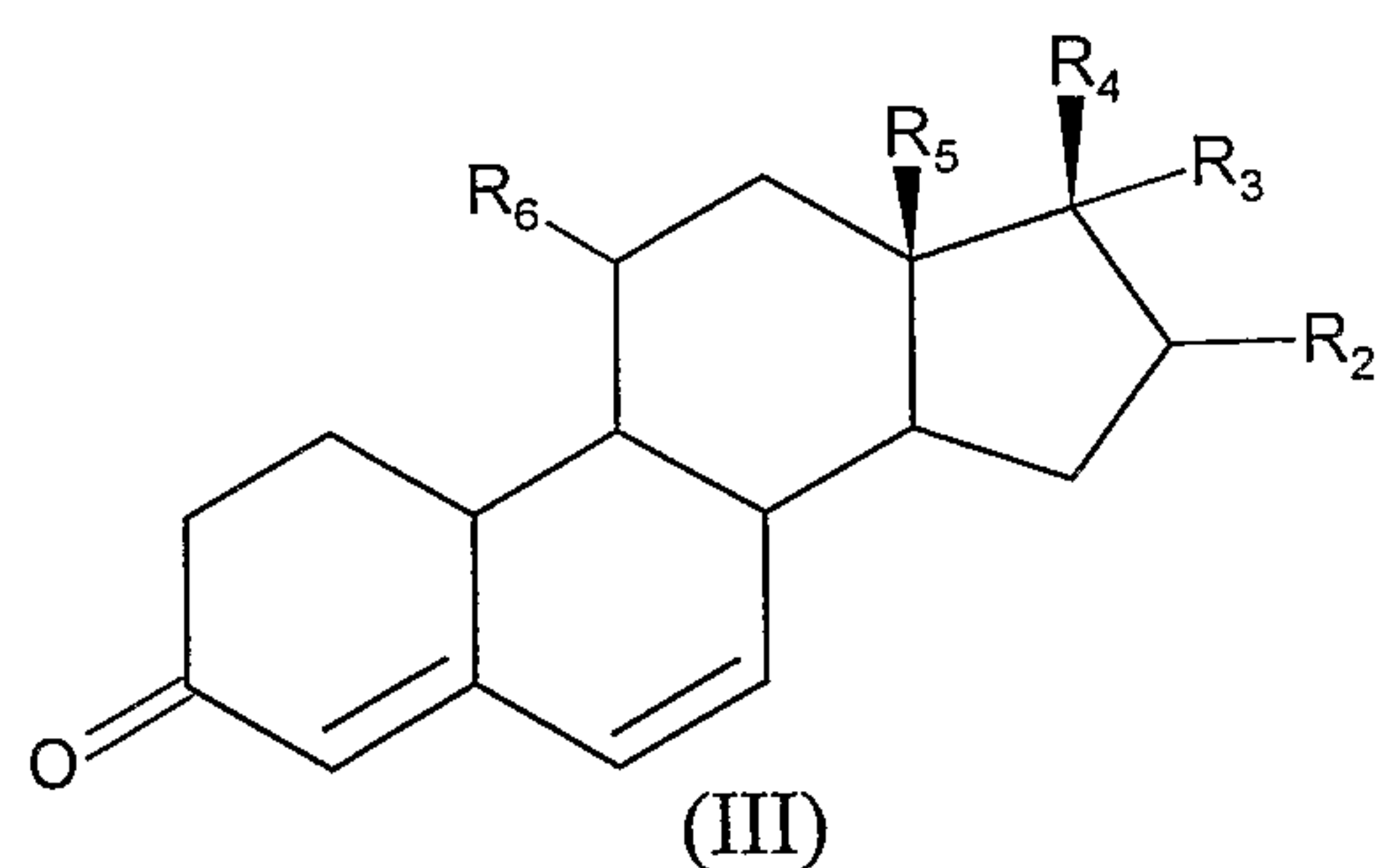
Another aspect of the present invention is a process for preparing the compound of formula (II),



(II)

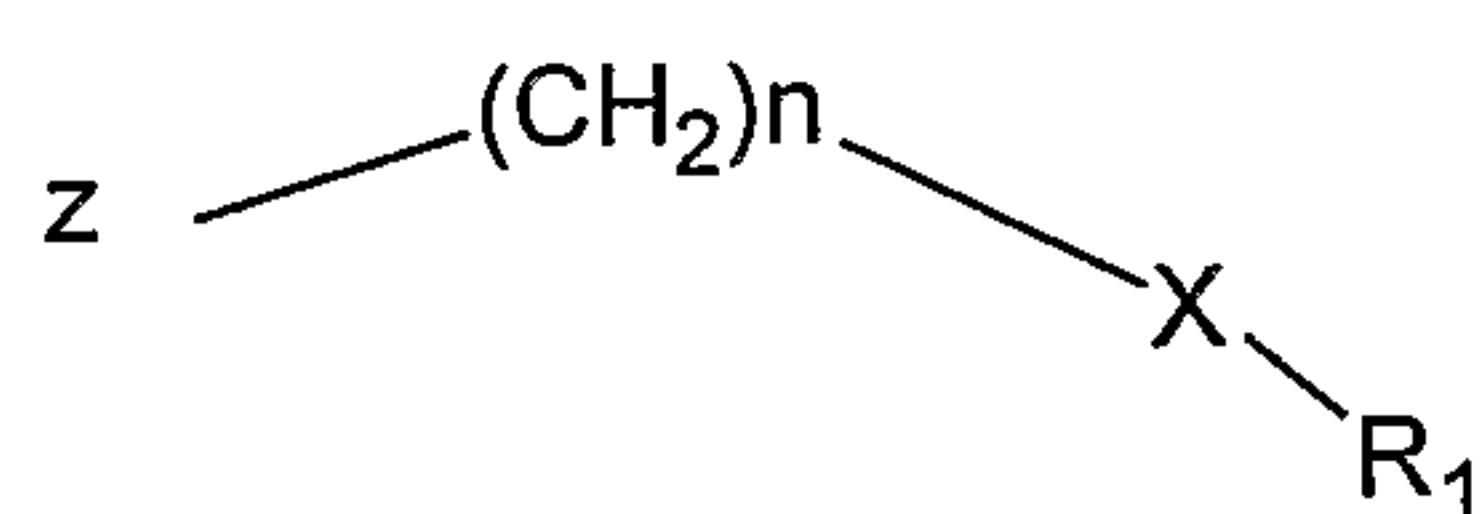
comprising:

- a) combining a 19-nor-androsta-4,6-diene-3-one of formula (III)



with an etheral solvent, to obtain a solution; and

- b) adding to the solution of step a), in a drop-wise manner, a solution of the compound of formula (IV)



15 (IV)

in an etheral solvent to obtain a reaction mixture.

wherein

n is an integer ranging from 3 to 14,

X is either O or S;

20 R₁ is a C₁₋₁₀ haloalkyl or a hydroxy protecting group;

R₂, R₃, R₅ and R₆ are as defined above;

R₄ is a C₁₋₆ acyloxy; and

z is a metal halide of the formula R₇M, wherein

M is a metal atom; and

25 R₇ is a halogen atom;

In one embodiment, the solution is cooled to a temperature of about -60°C to about 30°C.

In one embodiment, the method further comprises quenching the reaction mixture.

In one embodiment, the invention further comprises recovering the compound of formula (II).

After combining the compound of formula (IV) and the compound of formula (III), the resulting reaction mixture can be analyzed using conventional methods, known to those skilled in the art, to determine completion of the reaction. For example, the reaction mixture may be analyzed by thin layer chromatography (TLC), high pressure liquid chromatography (HPLC), gas chromatography (GC), mass spectrometry (MS), or nuclear magnetic resonance (NMR).

In one embodiment, the addition of the compound of formula (IV) to the solution of the compound of formula (III) is done over a time period of at least about 1 minute. Typically, the addition of the compound of formula (IV) to the solution of the compound of formula (III) is done over a time period of at least about 30 minutes, preferably at least about 60 minutes, more preferably at least about 90 minutes, and most preferably at least about 120 minutes. Preferably, the addition is slow enough to prevent any substantive color changes in the mixture. It was found that the slower the addition, the better the isomer ratio obtained (other factors being unchanged). The addition time, however, may be governed by practical concerns (such as efficient use of available reactors) and it is not usually worthwhile to extend the addition period beyond 5 hours.

In another embodiment, addition of the compound of formula (IV) to the solution of the compound of formula (III) is done at a specified rate, *i.e.*, mol equivalents of compound of formula (IV) per equivalent of compound of formula (III) per time unit. For example, the average rate of adding the compound of formula (IV) to the solution of the compound of formula (III) can range from about 0.001 mol equivalents to about 1 mol equivalents of compound of formula (IV) per equivalent of compound of formula (III) per minute. Preferably, the average rate of addition ranges from about 0.002 to about 0.100 mol equivalents of compound of formula (IV) per equivalent of compound of formula (III) per minute. More preferably, the average rate of addition ranges from about 0.005 to about 0.020 mol equivalents of compound of formula (IV) per equivalent of compound of formula (III) per minute.

Preferably, *n* is 9, *X* is O, *R*₁ is tertbutyl-dimethylsilyl (TBDMS), *R*₂, *R*₃ and *R*₆ are hydrogens, *R*₄ is acetyloxy and *R*₅ is methyl. Said compound of formula (III) corresponds to Compound 9294 in Figure 1, said compound of formula (IV) corresponds to Compound 9318 in Figure 1, and the obtained compound of formula (II) corresponds to Compound 9295 in Figure 1.

Alternatively, n is 5, X is O, R₁ is TBDMS, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl. Said compound of formula (III) corresponds to Compound 9294 in Figure 2, said compound of formula (IV) corresponds to Compound 9339 in Figure 2, and the obtained compound of formula (II) corresponds to Compound 9340 in Figure 2.

Alternatively, n is 9, X is S, R₁ is $-(CH_2)_3CF_2CF_3$, R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl. Said compound of formula (III) corresponds to Compound 9294 in Figure 3, said compound of formula (IV) corresponds to Compound 9330 in Figure 3, and the obtained compound of formula (II) corresponds to Compound 9331 in Figure 3.

M in the compound of formula (IV) is a metal atom selected from the group consisting of magnesium, zinc, aluminum, copper, copper-lithium (*i.e.*, a lithium dialkylcopper reagent), and titanium. The preferred metal atom is Mg. R₇ is a halogen atom selected from the group consisting of Cl, Br and I. Preferably, R₇ is Br.

When the metal is Mg, a copper catalyst should be used, preferably of the form Cu(I)Y, wherein Y is Cl, Br or I, and most preferably Cu(I)Cl.

The compound of formula (II) obtained by this method has a ratio of 7 α -to 7 β -epimer of about 2.5:1 to about 12.1:1.

In one embodiment, the compound of formula (II), has a ratio of 7 α to 7 β epimer (isomer ratio) of at least about 3:1. Preferably, the compound of formula (II) has a 7 α to 7 β ratio of at least about 7:1. More preferably, the compound of formula (II) has a 7 α to 7 β ratio of at least about 10:1. Most preferably, the compound of formula (II) has a 7 α to 7 β ratio of at least about 12:1.

The etheral solvent may be selected from the group consisting of: diethyl ether, THF and glyme. The preferred etheral solvent is THF.

Preferably, the solution of step b) is cooled to a temperature of about -20°C to about -10°C.

The etheral solution of the compound of the formula (IV) is added in a dropwise manner, in order to avoid a local accumulation of it. The reaction mixture is stirred

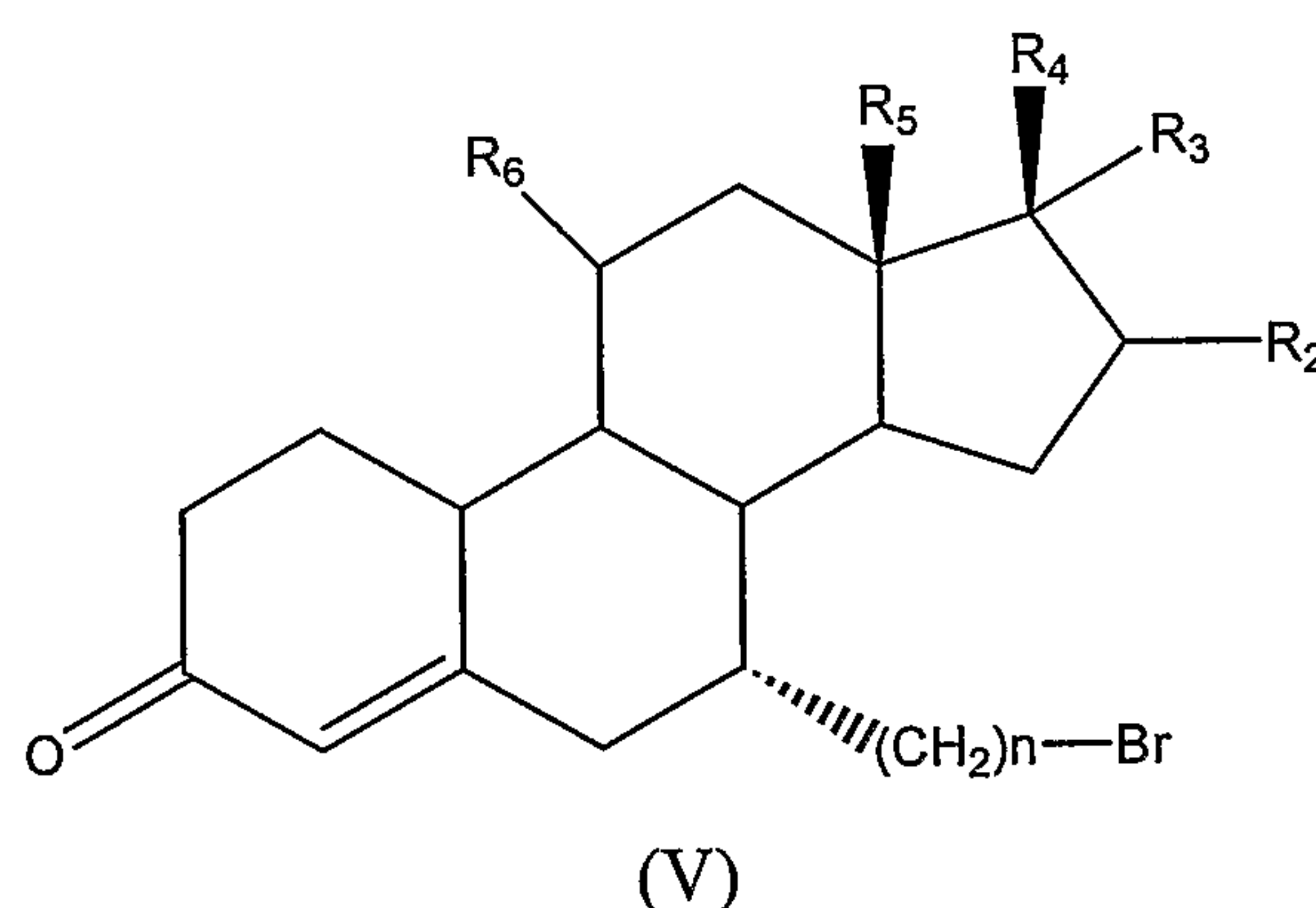
constantly, for the same reason. The dropwise addition of the compound of formula (IV) is what renders the high $7\alpha/7\beta$ -epimer ratio.

The reaction mixture in step d) may be quenched by one of the reagents selected from the group consisting of: NH_4Cl , HCl , water, acetic acid and a mixture of NH_4Cl with NH_4OH . The preferred reagent is acetic acid.

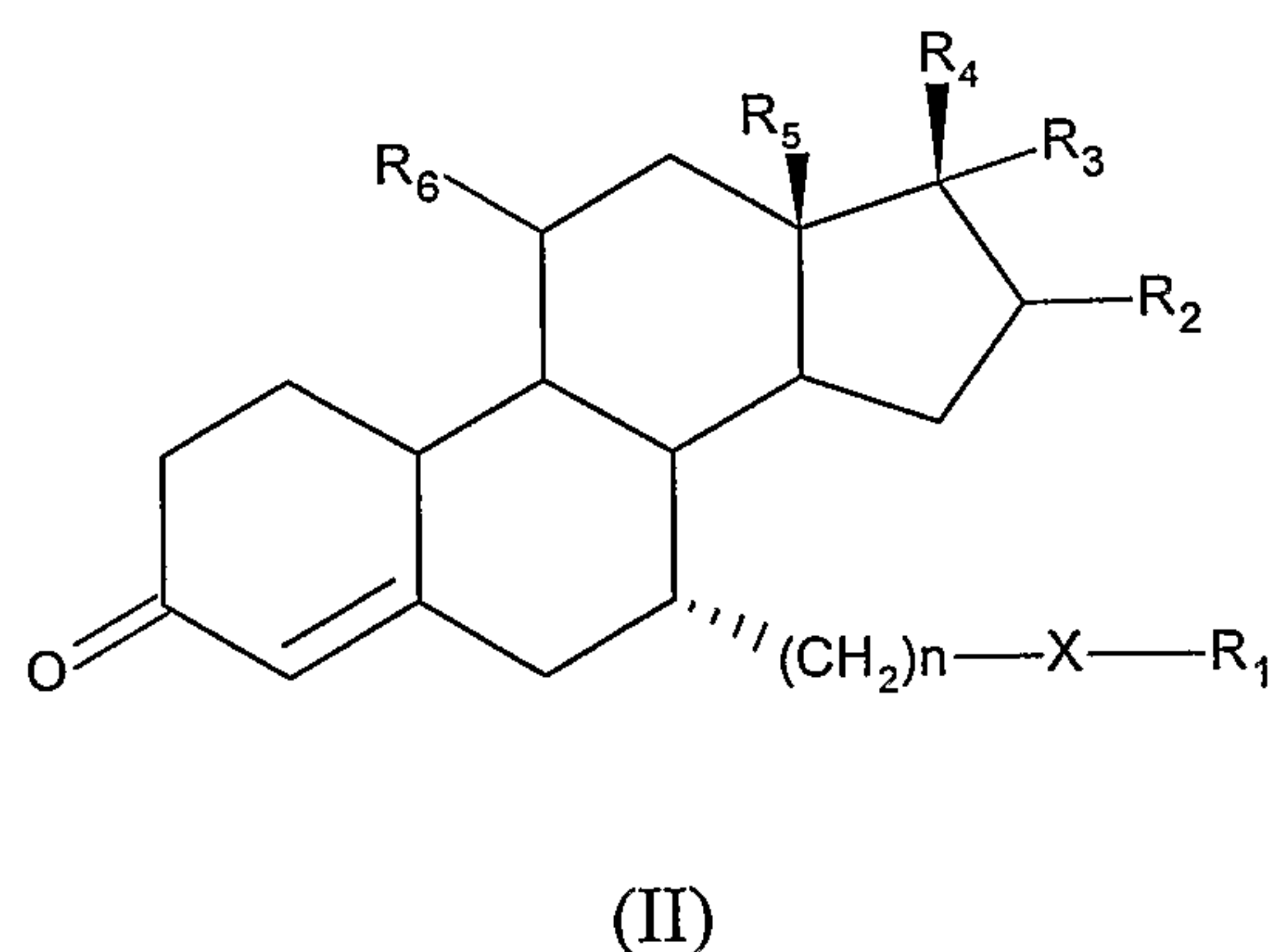
The compound of formula (II) may be recovered by any method known in the art. Preferably, traces of the used catalyst are removed, for example, by reaction with ammonium, followed by separation of the compound of formula (II) from the reaction mixture, for example, by evaporation of the solvents. The compound of formula (II) may be purified by any methods known in the art, such as chromatography.

Compounds 9295 and 9331, obtained as described above, may be further converted to fulvestrant.

Another aspect of the present invention is a process for preparing the compound of formula (V),



comprising combining a compound of formula (II)



with acetonitrile and triphenylphosphine dibromide for a sufficient amount of time for conversion into the compound of formula (V)

wherein

n is an integer ranging from 3 to 14,

X is O;

R₁ is a hydroxy protecting group;

R₂, R₃, R₅ and R₆ are as defined above; and

R₄ is a C₁₋₆ acyloxy;

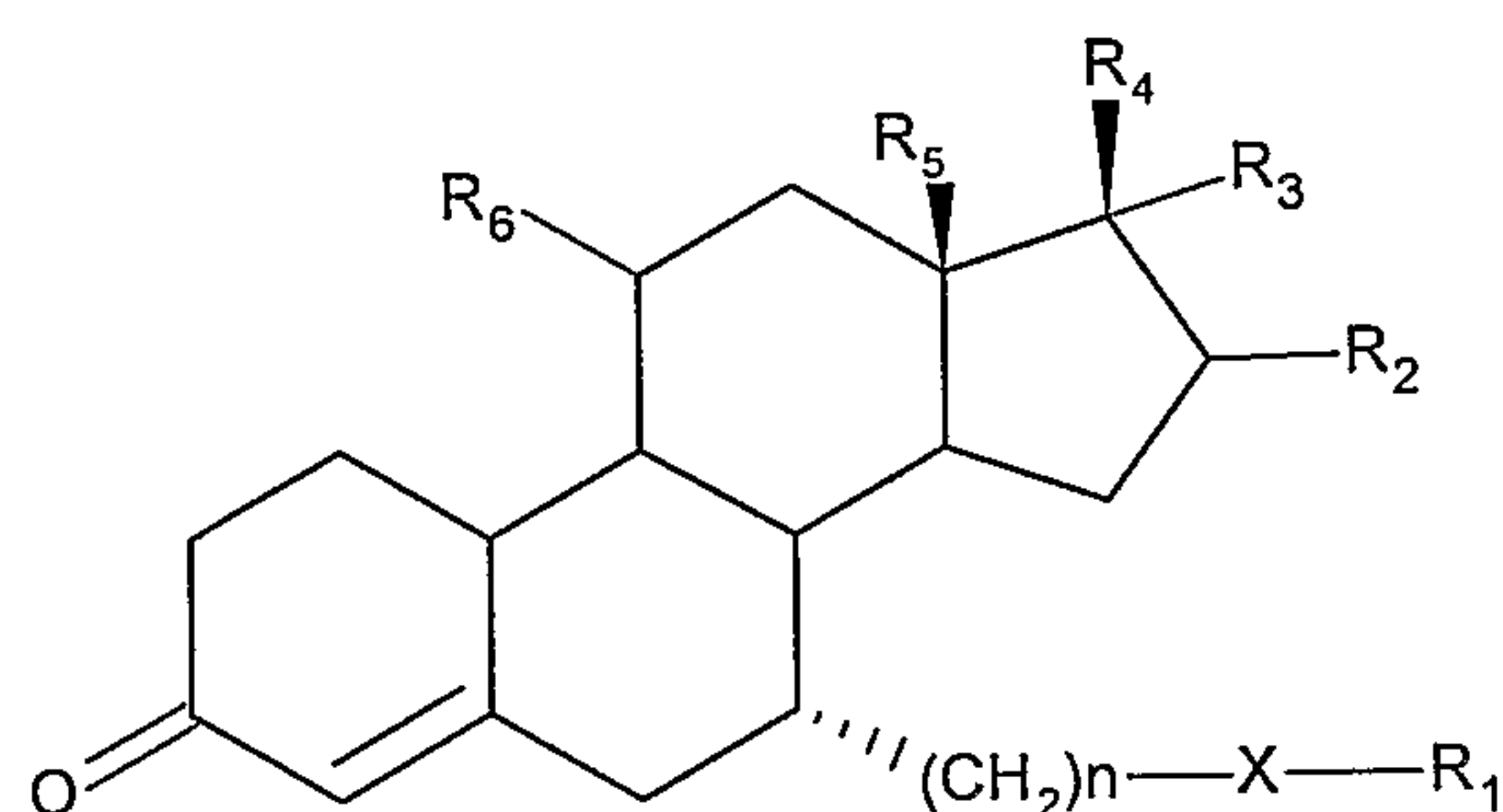
Preferably, n is 9, X is O, R₁ is tertbutyl-dimethylsilyl (TBDMS), R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl. Said compound of formula (II) corresponds to Compound 9295 in Figure 4, and said compound of formula (V) corresponds to Compound 9341 in Figure 4.

Preferably, the compound of formula (II) is combined with the acetonitrile and triphenylphosphine dibromide at a temperature of about 10°C to about 12°C. The compound of formula (V) may be obtained by any methods known in the art, and then it may be further purified by dissolution in toluene and removal of the by-products formed during the reaction.

The compound of formula (V) may be also prepared via the formation of intermediates, as depicted in Figure 5.

Compound 9341, obtained as described above, may be further converted to fulvestrant.

Another aspect of the present invention is a process for preparing the compound of formula (VI)



(VI)

wherein R_4 is hydroxy, comprising

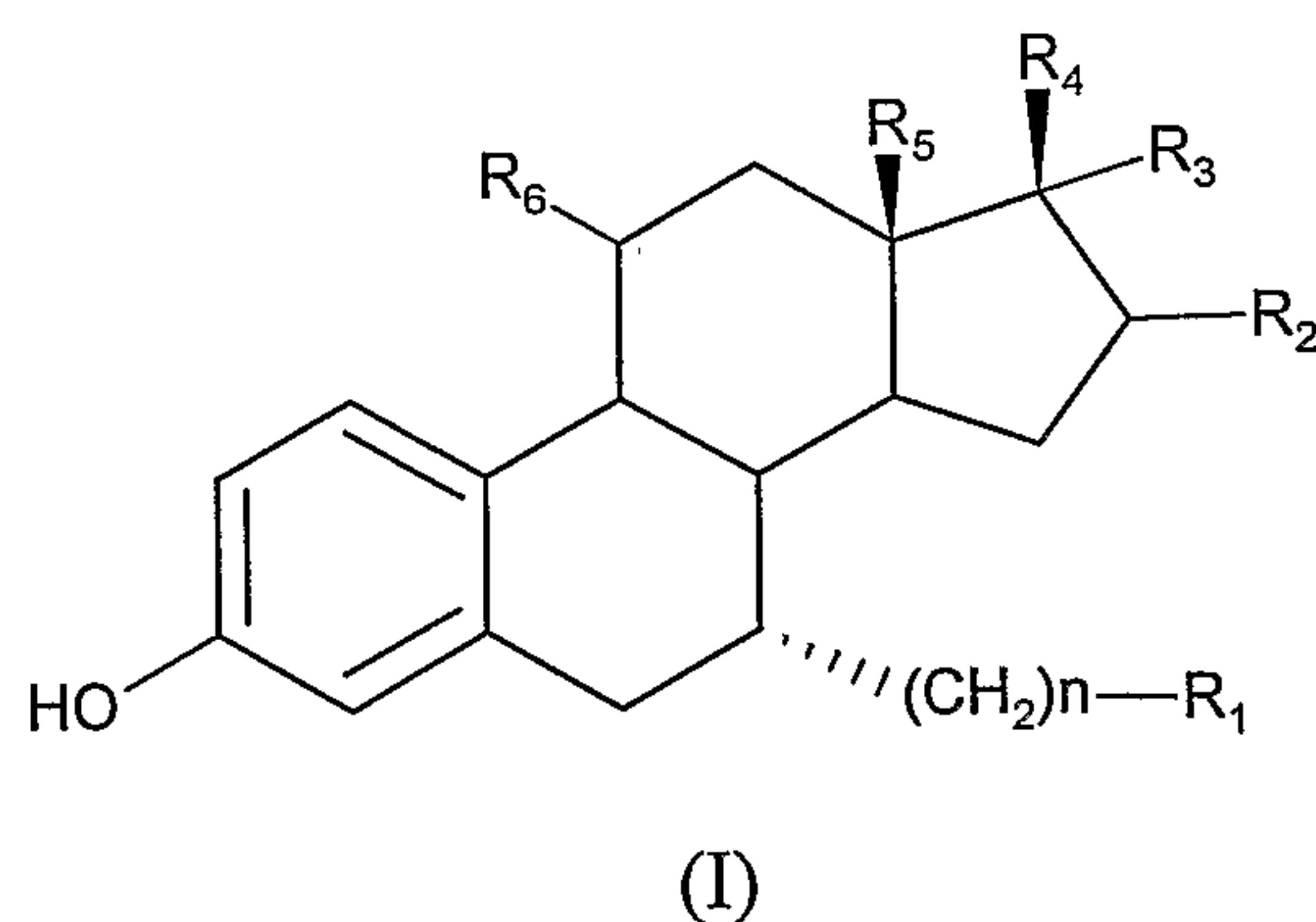
combining the compound of formula (VI), wherein R_4 is a C_{1-6} acyloxy, with a C_{1-6} alcohol and mineral acid, at a temperature of about 50°C to about 70°C .

5 Preferably, R_2 , R_3 and R_6 are hydrogens, and R_5 is methyl. Said compound of formula (VI), wherein R_4 is an acetyloxy corresponds to Compound 9342 in Figure 7, and said compound of formula (VI) wherein R_4 is hydroxy corresponds to Compound 9354 in Figure 7.

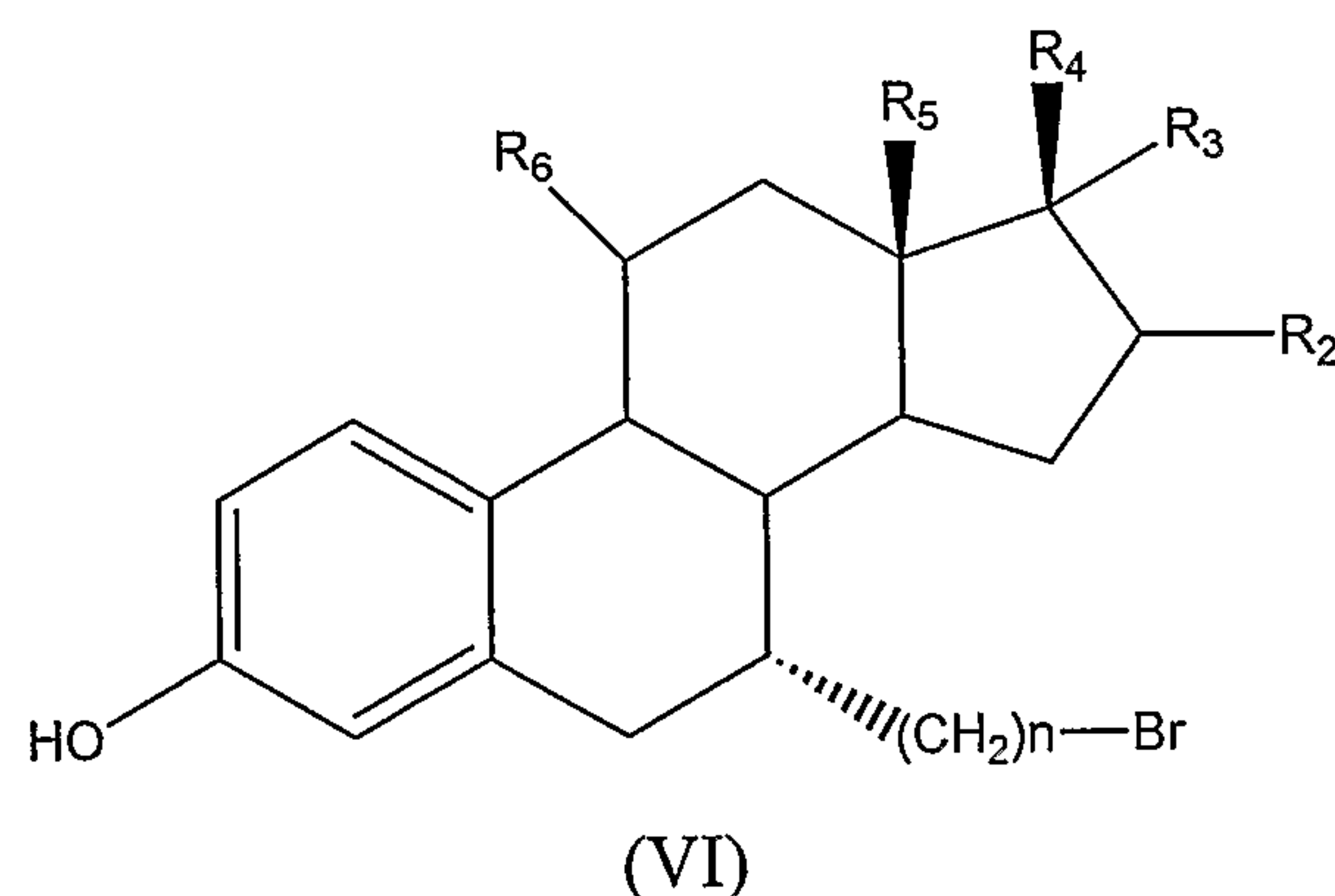
10 Preferably, the mineral acid is HBr. Preferably, the temperature of the reaction is about 60°C .

Compound 9354, obtained as described above, may be further converted to fulvestrant.

A further aspect of the present invention is a process for preparing the compound of the formula (I)



comprising combining the compound of formula (VI)



with a solvent selected from a C₁₋₆ aromatic hydrocarbon, a straight or branched C₁₋₄ alcohol, a C₁₋₄ alkyl amide and mixtures thereof and thiourea; and recovering the compound of formula (I)

wherein

- 5 n is an integer ranging from 3 to 14,
 R₁ is a free base or a salt form of isothiuronium;
 R₂, R₃, R₅ and R₆ are as defined above; and
 R₄ is either hydroxy or C₁₋₆ acyloxy.

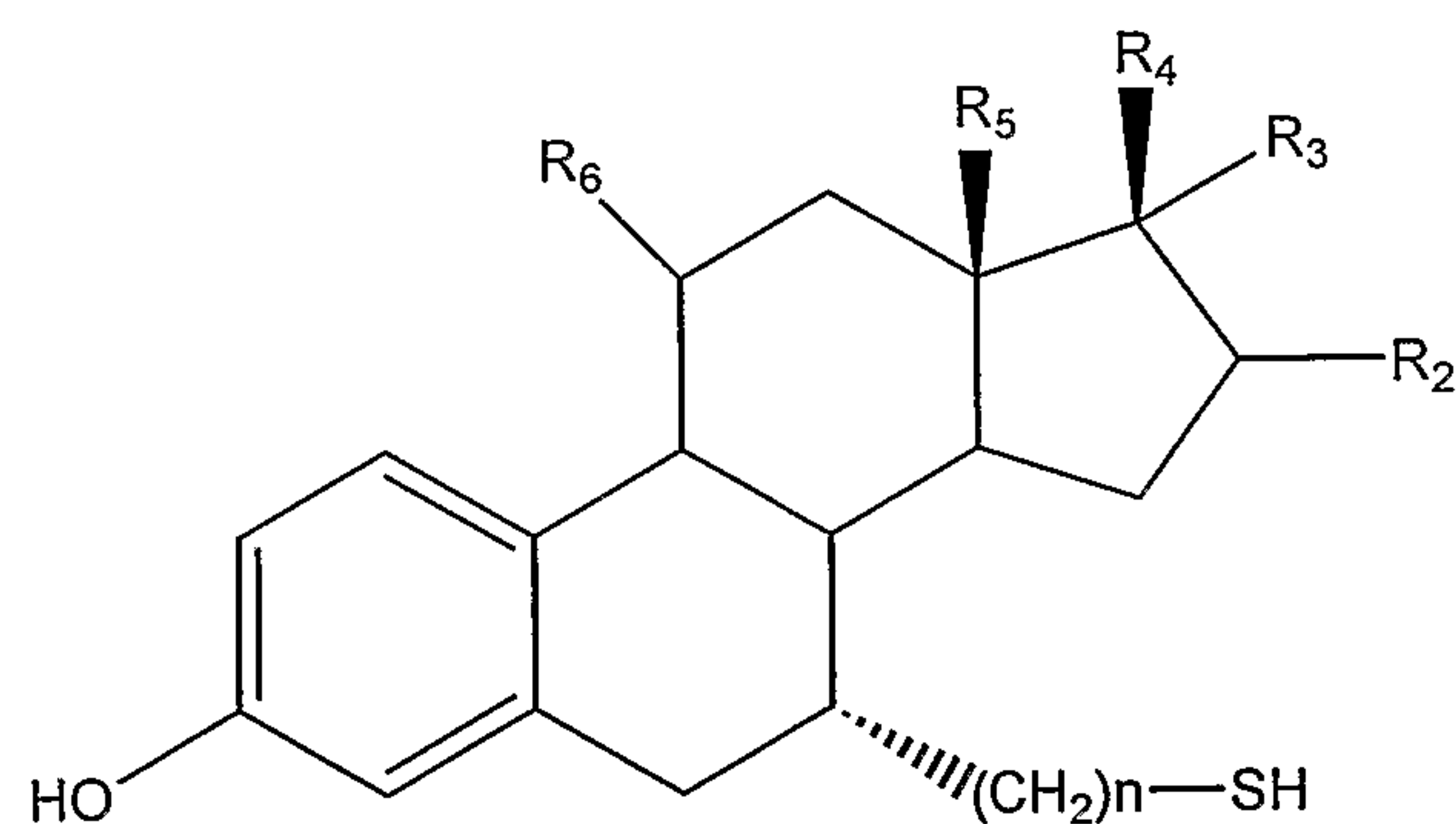
10 Preferably, n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl. Said compound of formula (VI) corresponds to Compound 9342 in Figure 8, and said compound of formula (I) corresponds to Compound 9361 in Figure 8.

15 Preferably, n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃ and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl. Said compound of formula (VI) corresponds to Compound 9354 in Figure 9, and said compound of formula (I) corresponds to Compound 9388 in Figure 9.

20 A C₁₋₆ aromatic hydrocarbon may be toluene, xylene or benzene. A straight or branched C₁₋₄ alcohol may be methanol, ethanol, propanol, isopropanol or butanol. A C₁₋₄ alkyl amide may be dimethylacetamide. Most preferably the solvent a mixture of toluene and isopropanol or dimethylacetamide.

Compounds 9361 and 9388, obtained as described above, may be further converted to fulvestrant.

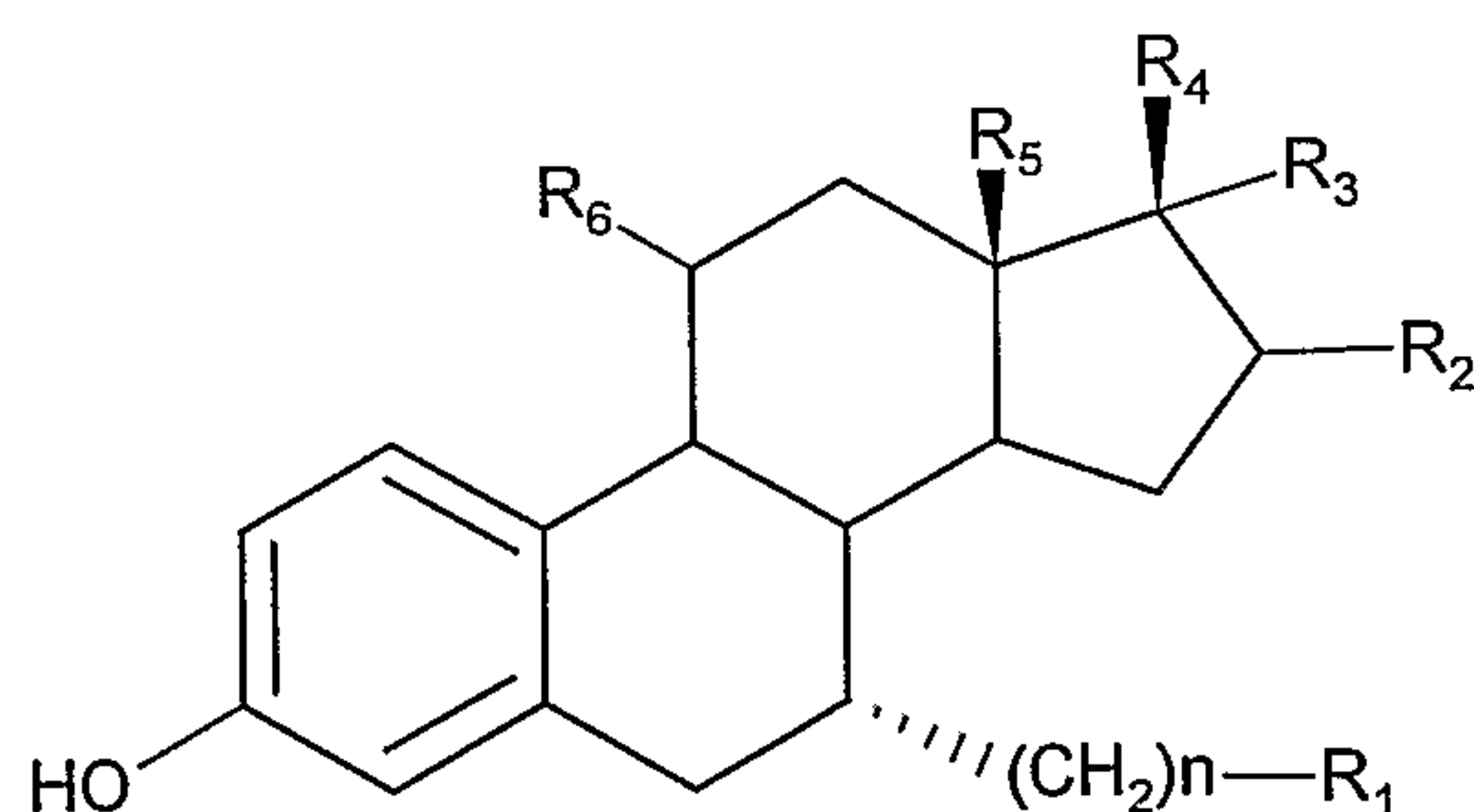
One aspect of the present invention is a process for preparing the compound of the formula (VII)



(VII)

comprising combining a compound of the formula (I)

5



(I)

10

with a base in the presence of an apolar protic organic solvent at ambient temperature;
wherein

n is an integer ranging from 3 to 14,

R_1 is a free base or a salt form of isothiuronium;

15

R_2 , R_3 , R_5 and R_6 are as defined above; and

R_4 is either hydroxy or C_{1-6} acyloxy.

Preferably, n is 9, R_1 is a hydrobromide salt of isothiuronium, R_2 , R_3 and R_6 are hydrogens, R_4 is acetyloxy and R_5 is methyl. Said compound of formula (VII) corresponds to Compound 9362 in Figure 8, and said compound of formula (I) corresponds to Compound 9361 in Figure 8.

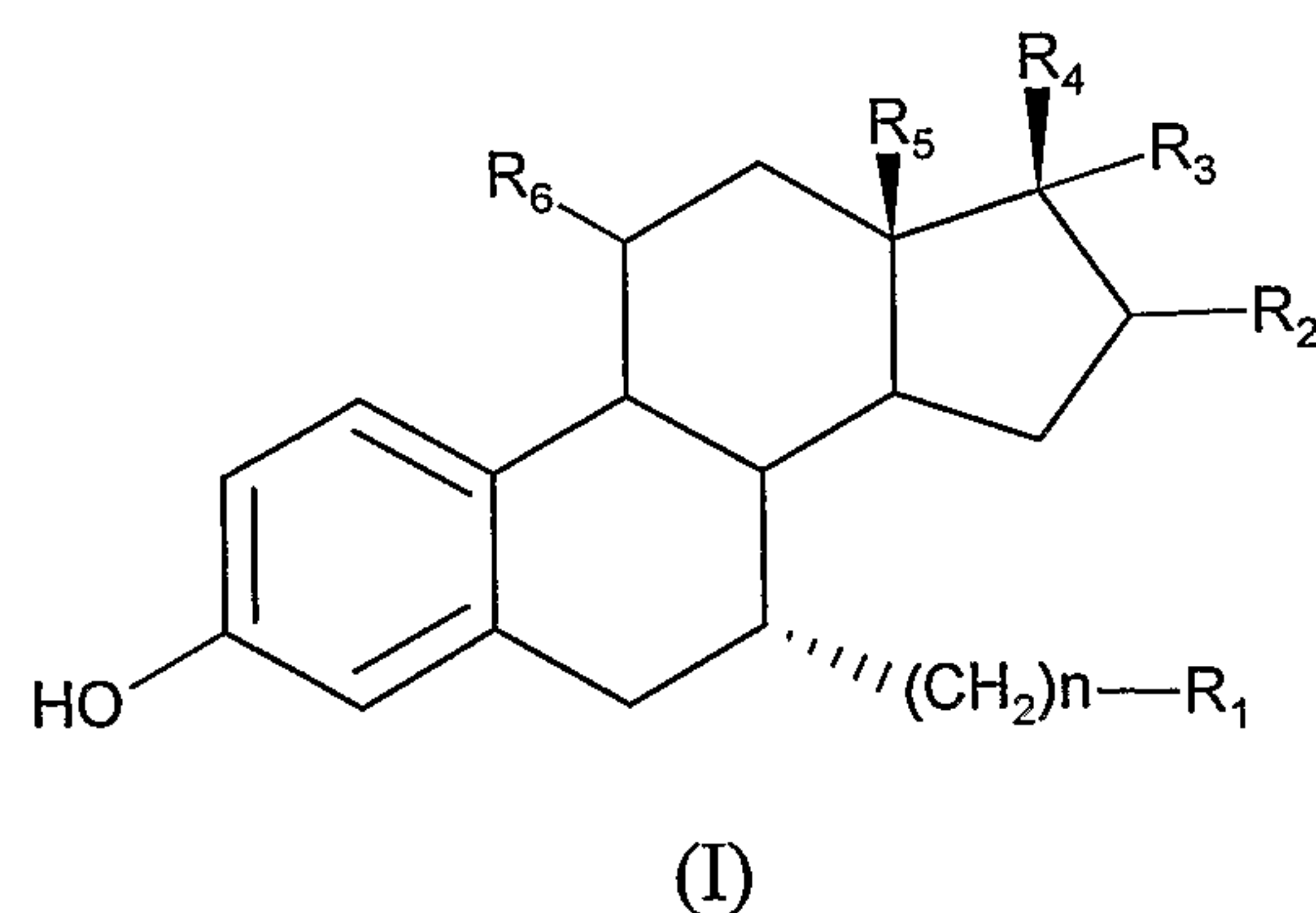
20

Preferably, n is 9, R_1 is a hydrobromide salt of isothiuronium, R_2 , R_3 and R_6 are hydrogens, R_4 is hydroxy and R_5 is methyl. Said compound of formula (VII) corresponds to Compound 9389 in Figure 9, and said compound of formula (I) corresponds to Compound 9388 in Figure 9.

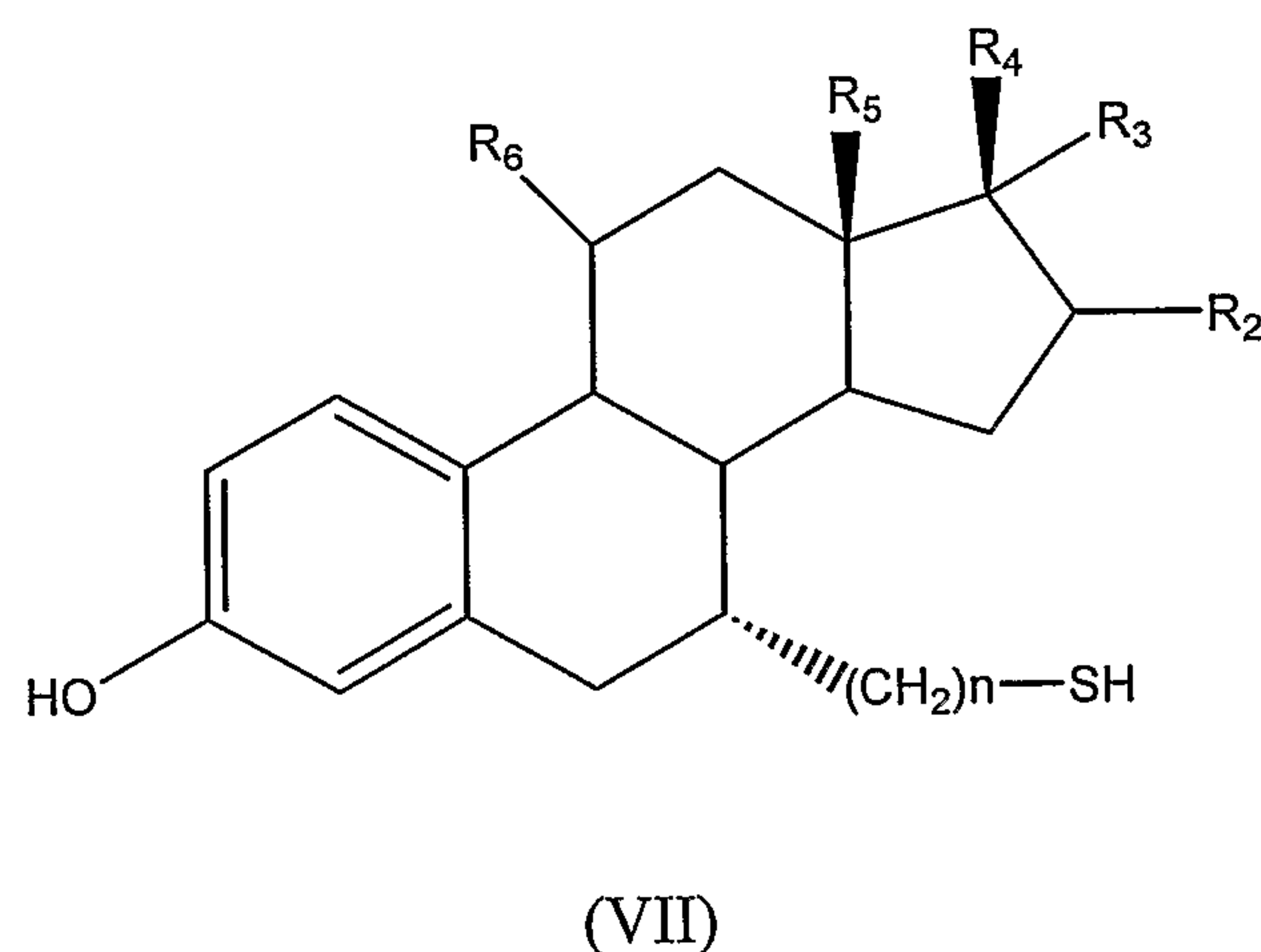
Preferably, the base is an alkali metal base such as NaOH and KOH. Most preferably, the base is NaOH. The aprotic polar organic solvent may be dimethylacetamide or acetonitrile. Preferably, the aprotic polar organic solvent is dimethylacetamide.

Compounds 9362 and 9389, obtained as described above, may be further converted to fulvestrant.

Another aspect of the present invention is a process for preparing the compound of the formula (I)



comprising combining the compound of formula (VII)



with 4,4,5,5,5-pentafluoropentane-1-ol mesylate, followed by combining the obtained reaction mixture with a base in the presence of an organic solvent; wherein

n is an integer ranging from 3 to 14,

R_1 is $-S-(CH_2)_3CF_2CF_3$

R_2 , R_3 , R_5 and R_6 are as defined above; and

R_4 is either hydroxy or C_{1-6} acyloxy.

In one embodiment, the compound of formula (VII) and 4,4,5,5,5-pentafluoropentane-1-ol mesylate are contacted at ambient temperature.

Preferably, n is 9, R_2 , R_3 and R_6 are hydrogens, R_4 is an acetyloxy and R_5 is methyl.

5 Said compound of formula (I) corresponds to Compound 9363 in Figure 8, and said compound of formula (VII) corresponds to Compound 9362 in Figure 8.

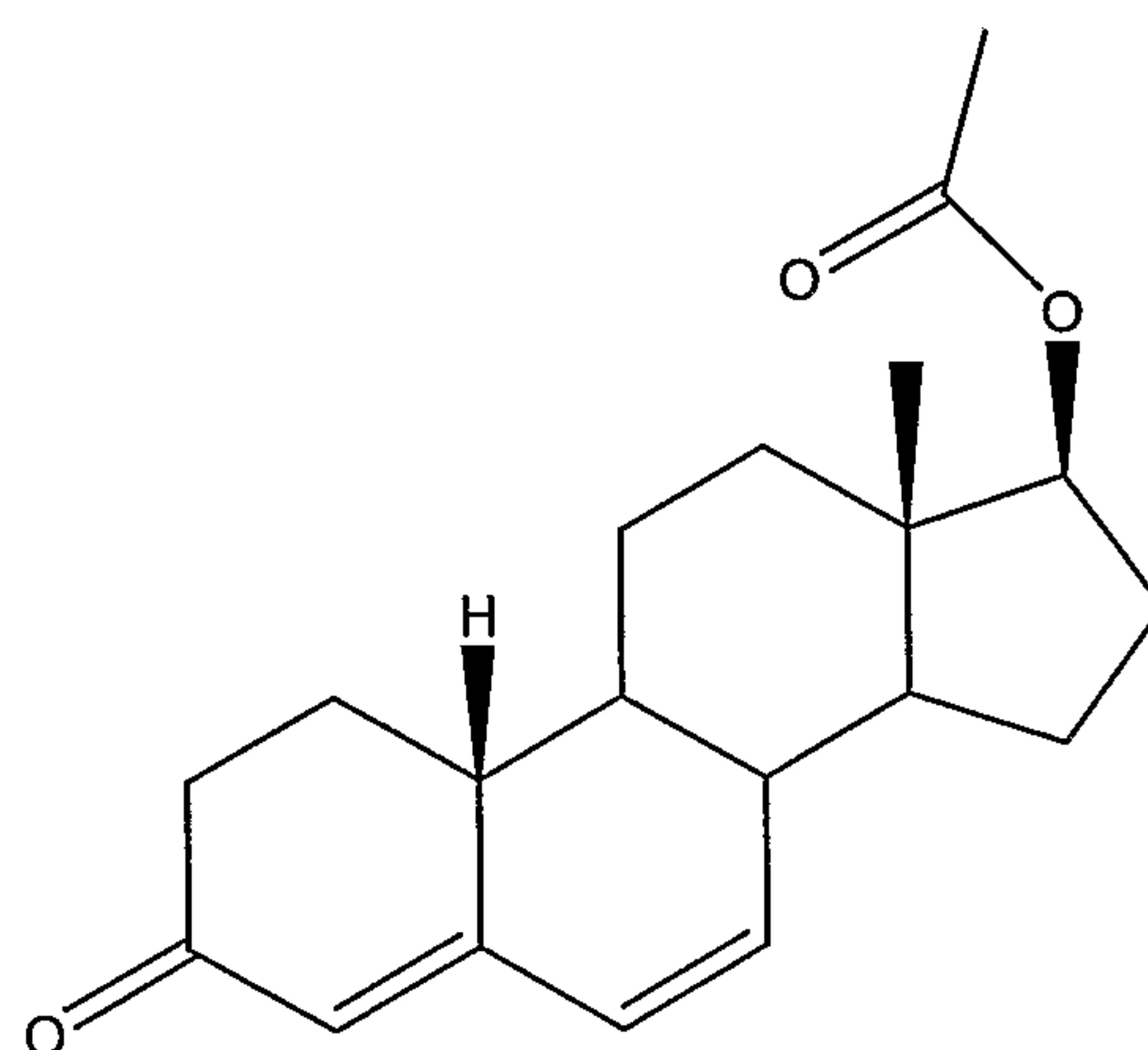
Preferably, n is 9, R_2 , R_3 and R_6 are hydrogens, R_4 is an acetyloxy and R_5 is methyl.

Said compound of formula (I) corresponds to Compound 9304 in Figure 9, and said compound of formula (VII) corresponds to Compound 9389 in Figure 9.

10 Preferably, the base is an alkali metal base such as NaOH and KOH. Most preferably, the base is KOH. Preferably, the organic solvent is a C_{1-6} alcohol. Most preferably, the organic solvent is methanol.

Compounds 9363 and 9304, obtained as described above, may be further converted to fulvestrant.

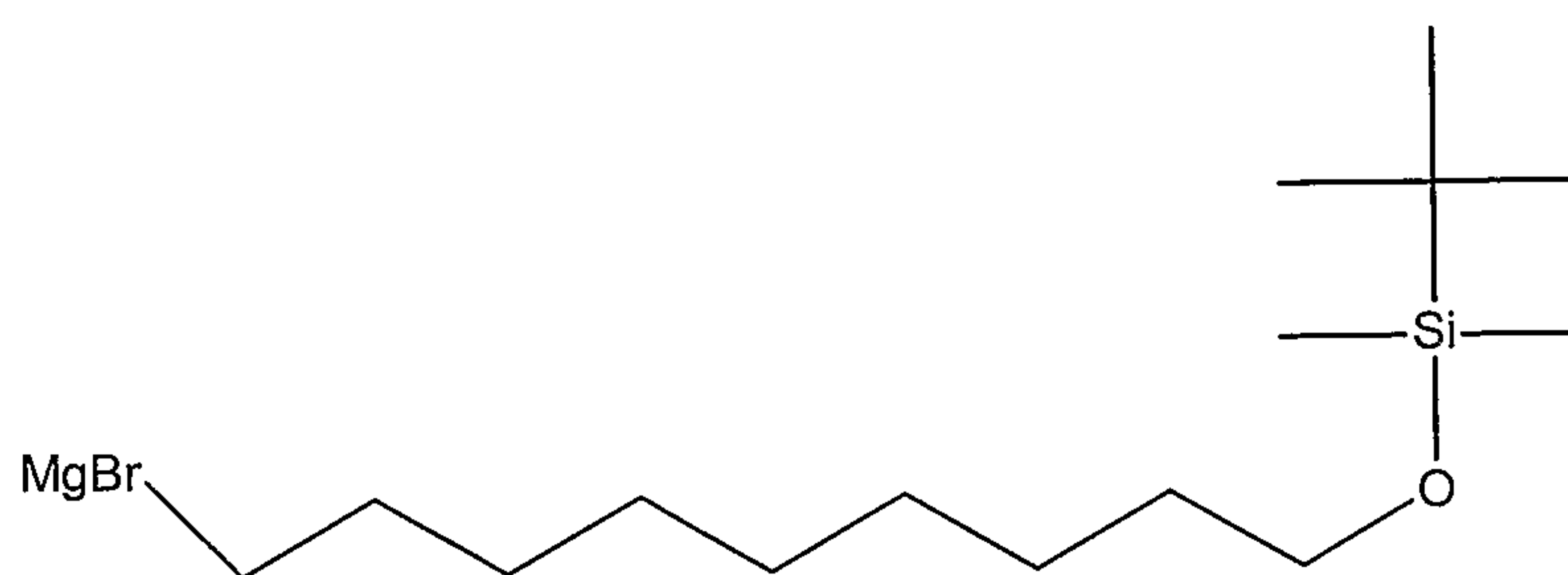
15 Another aspect of the invention is a process for preparing fulvestrant comprising
a) combining compound of formula 9294



9294

with an etheral solvent, to obtain a solution;

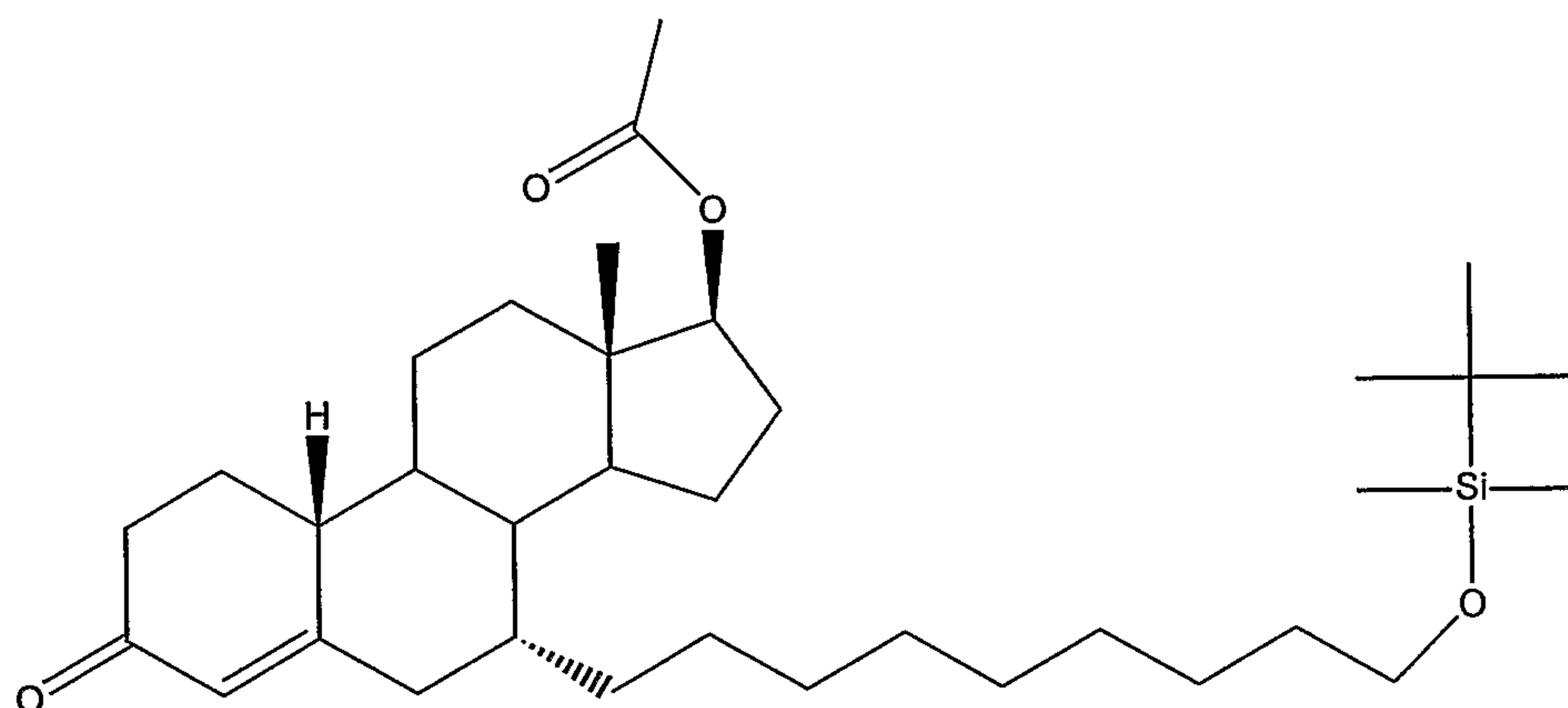
20 b) adding to the solution of step a), in a drop-wise manner, a solution of the compound of formula 9318



9318

in an ethereal solvent to obtain a first reaction mixture comprising a compound of formula 9295;

5

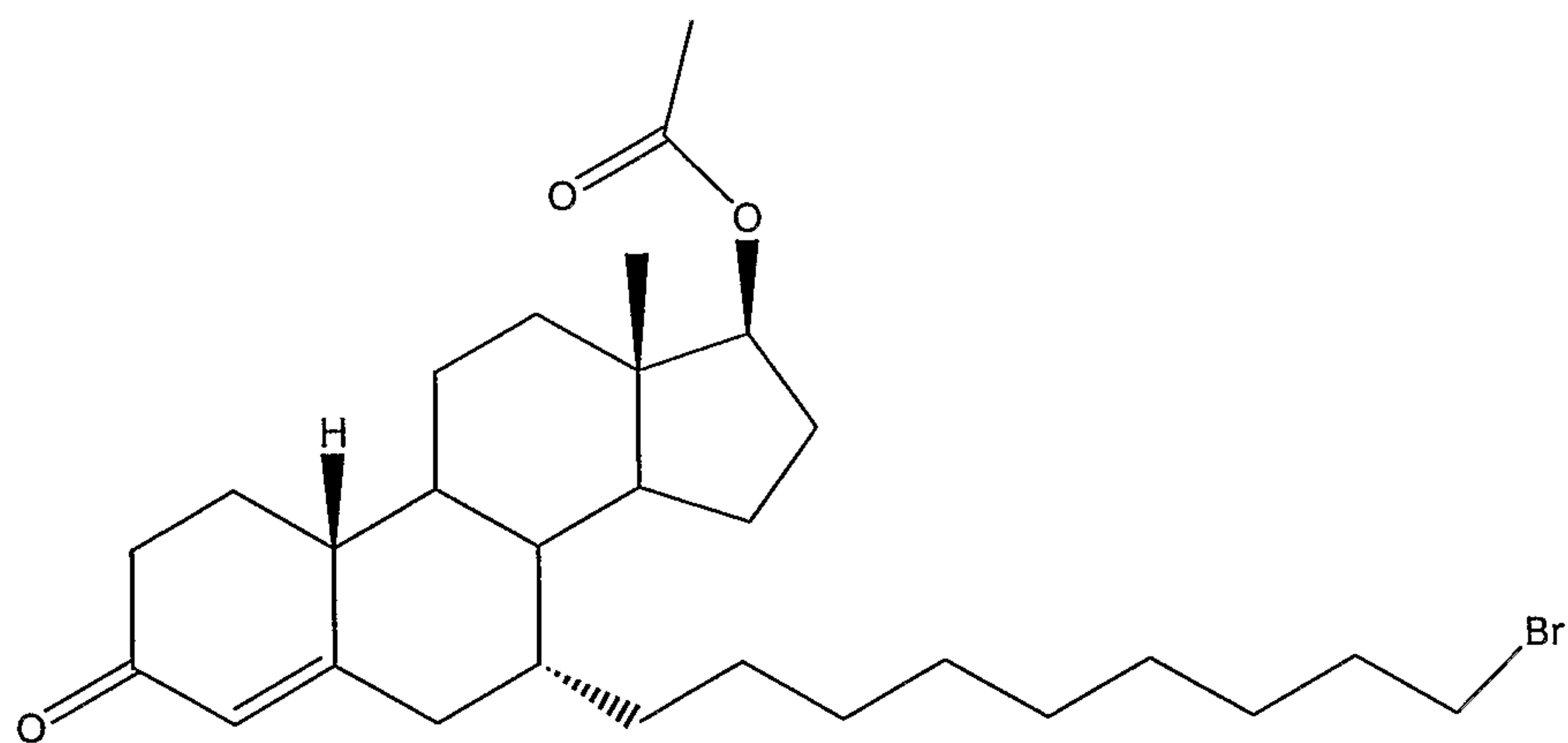


c) quenching the first reaction mixture;

d) recovering compound 9295;

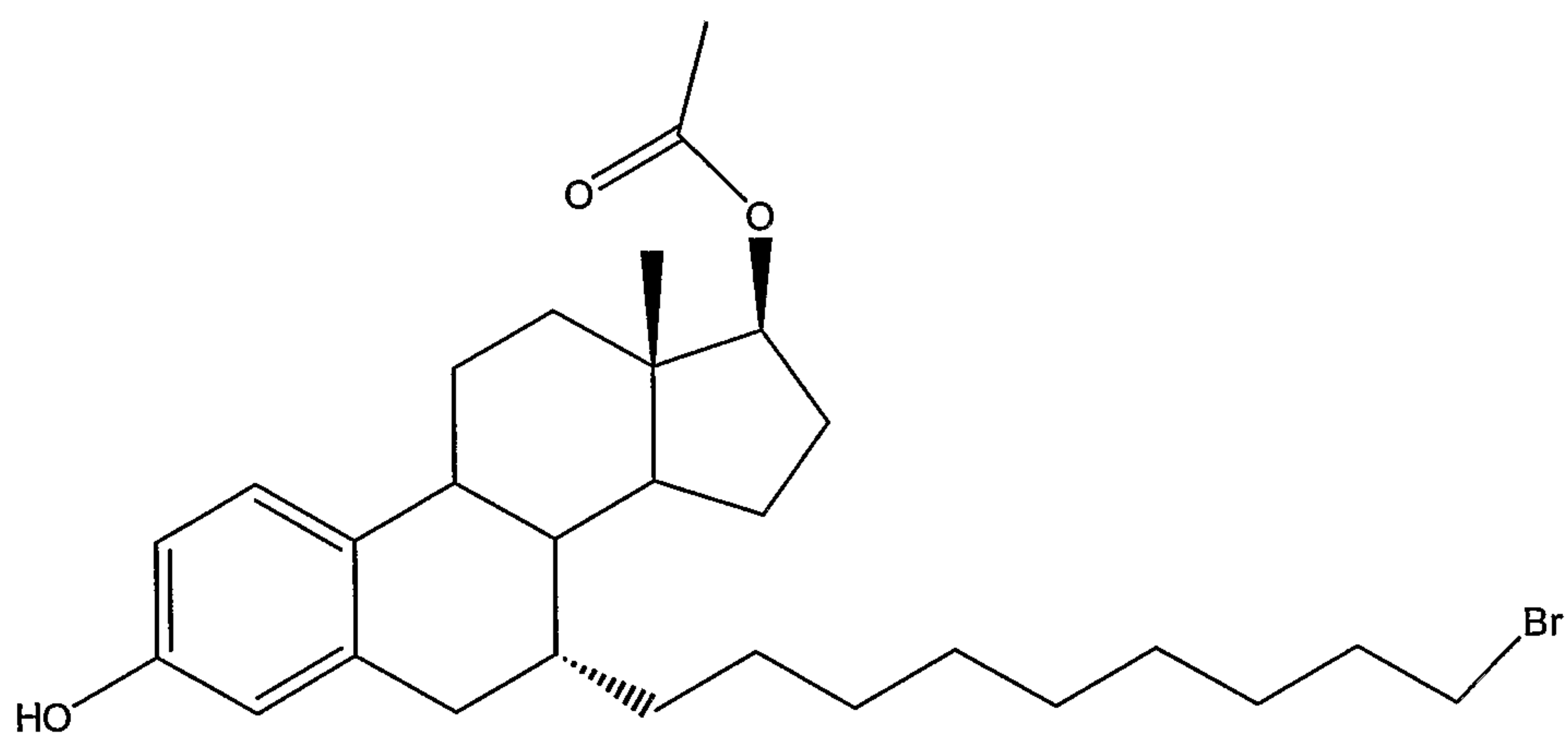
10

e) combining compound 9295 with acetonitrile and triphenylphosphine dibromide for a time sufficient to convert compound 9295 into a compound of formula 9341



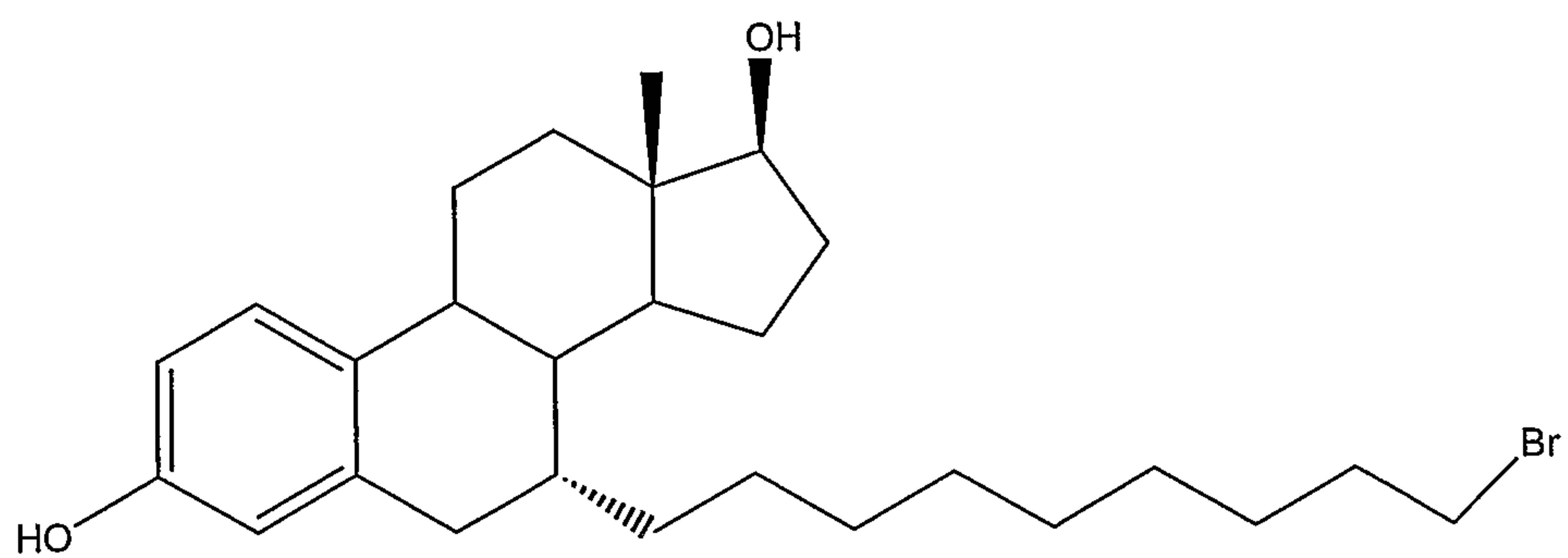
9341;

f) aromatizing the A ring of compound 9341 by reacting compound 9341 with a mixture of lithium bromide and copper bromide in acetonitrile to obtain a compound of
5 formula 9342



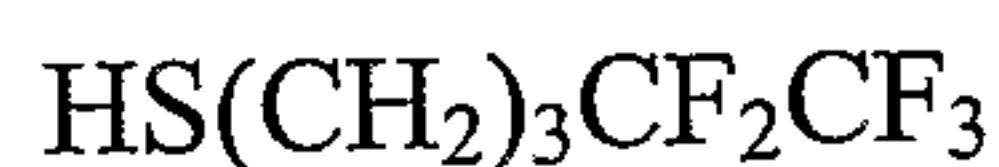
9342;

g) combining compound 9342 with C₁₋₆ alcohol and a mineral acid, at a temperature of about 50°C to about 70°C to obtain a compound of formula 9354



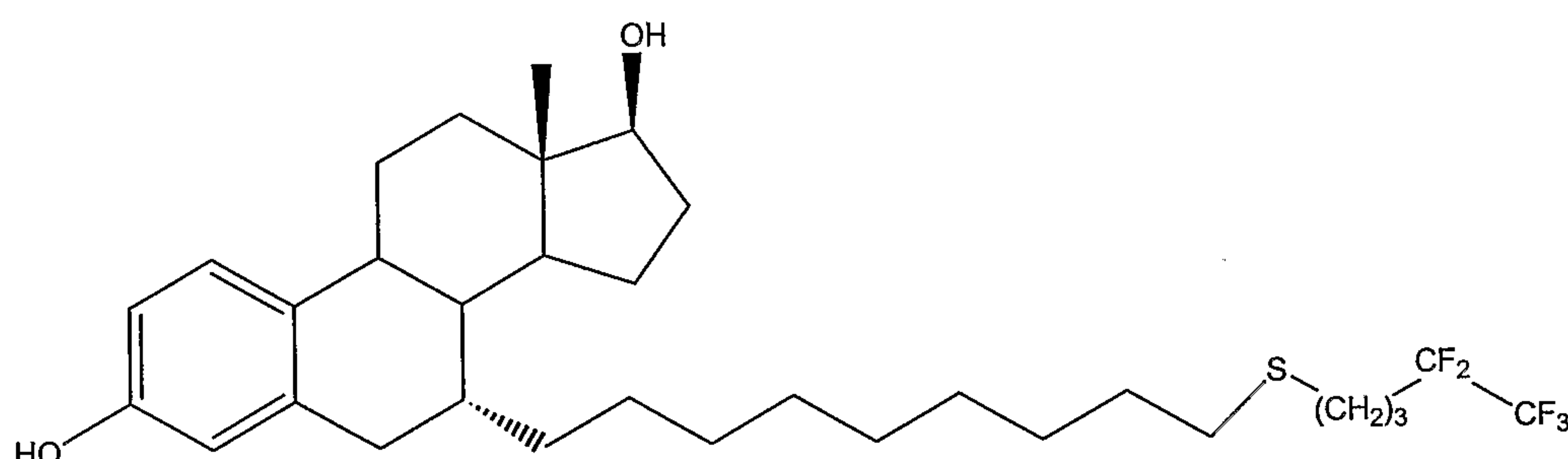
9354

h) combining compound 9354 with a compound of formula 9383



9383;

in the presence of an amide and an alkaline base to obtain compound 9304



9304;

and

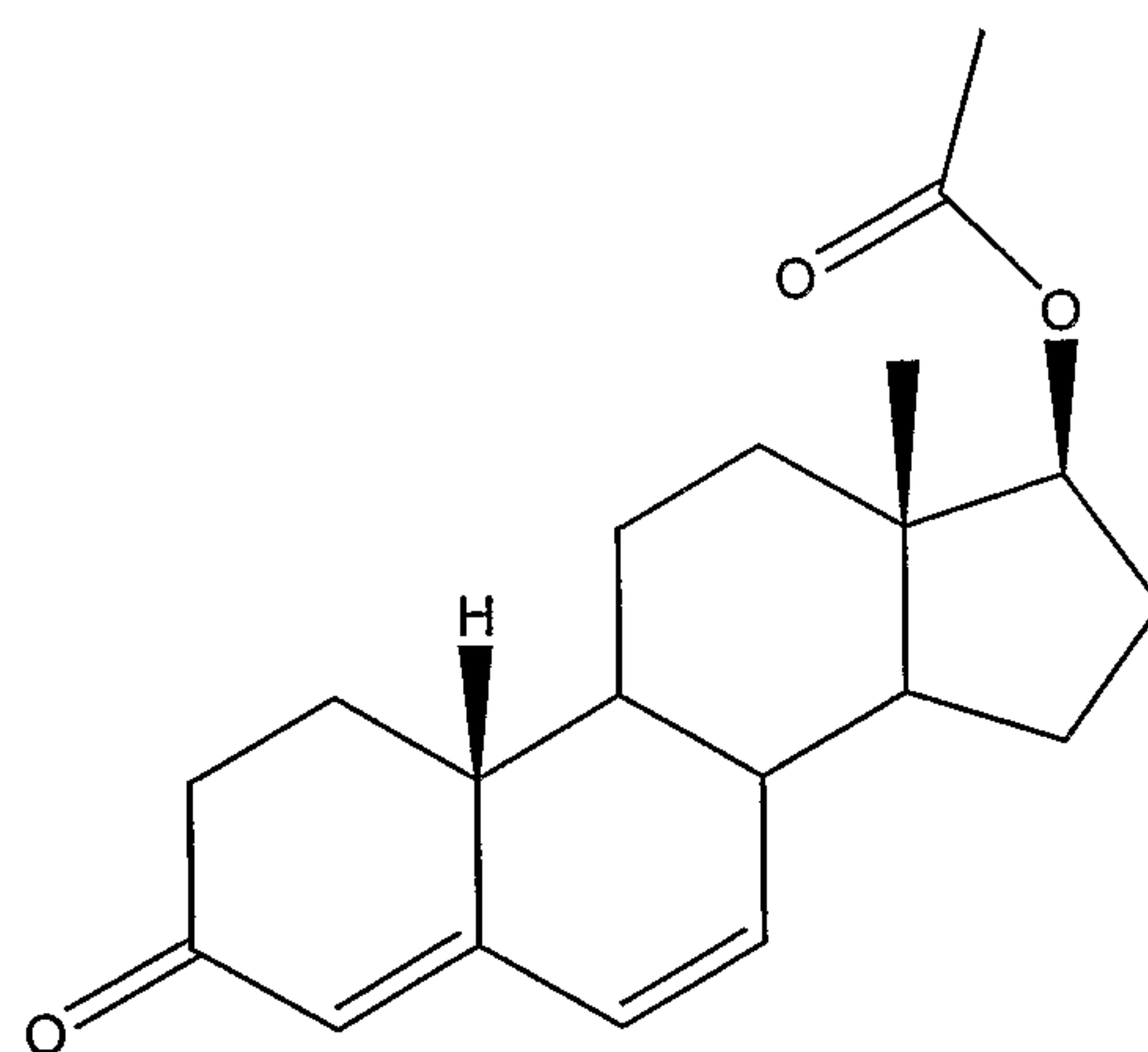
i) combining compound 9304 and a mixture of a C_{1-4} alcohol and an etheral solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide fulvestrant.

Fulvestrant can be recovered by any methods known in the art, such as evaporating the solvents, and can be further purified by crystallization from a C_{1-6} aromatic hydrocarbon.

In one embodiment, the solution of the compound of formula 9318 is added to the solution of the compound of formula 9294 at a temperature of about -60°C to about 30°C .

Another aspect of the invention is a process for preparing fulvestrant comprising:

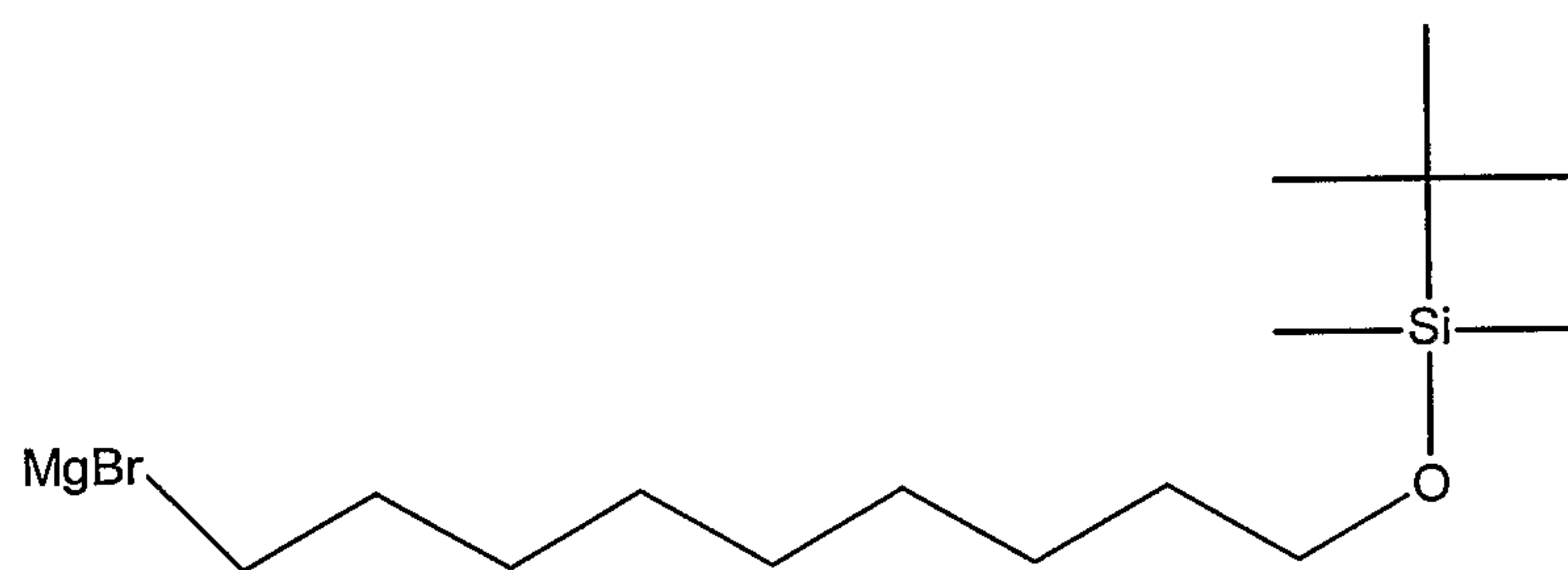
a) combining compound of formula 9294



9294

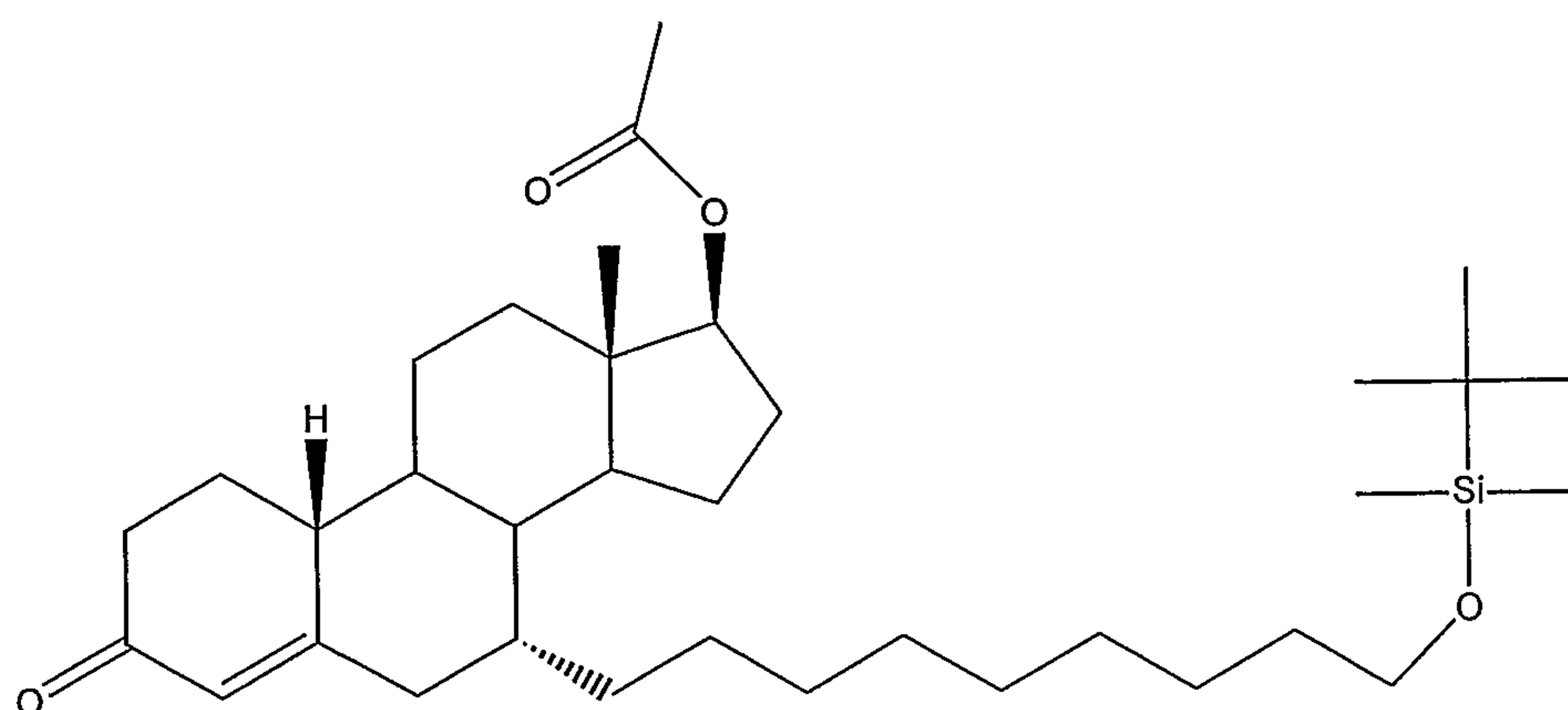
with an ethereal solvent, to obtain a solution;

- b) adding to the solution of step a), in a drop-wise manner, a solution of the
5 compound of formula 9318



9318

in an ethereal solvent to obtain a first reaction mixture comprising a compound of formula
9295;

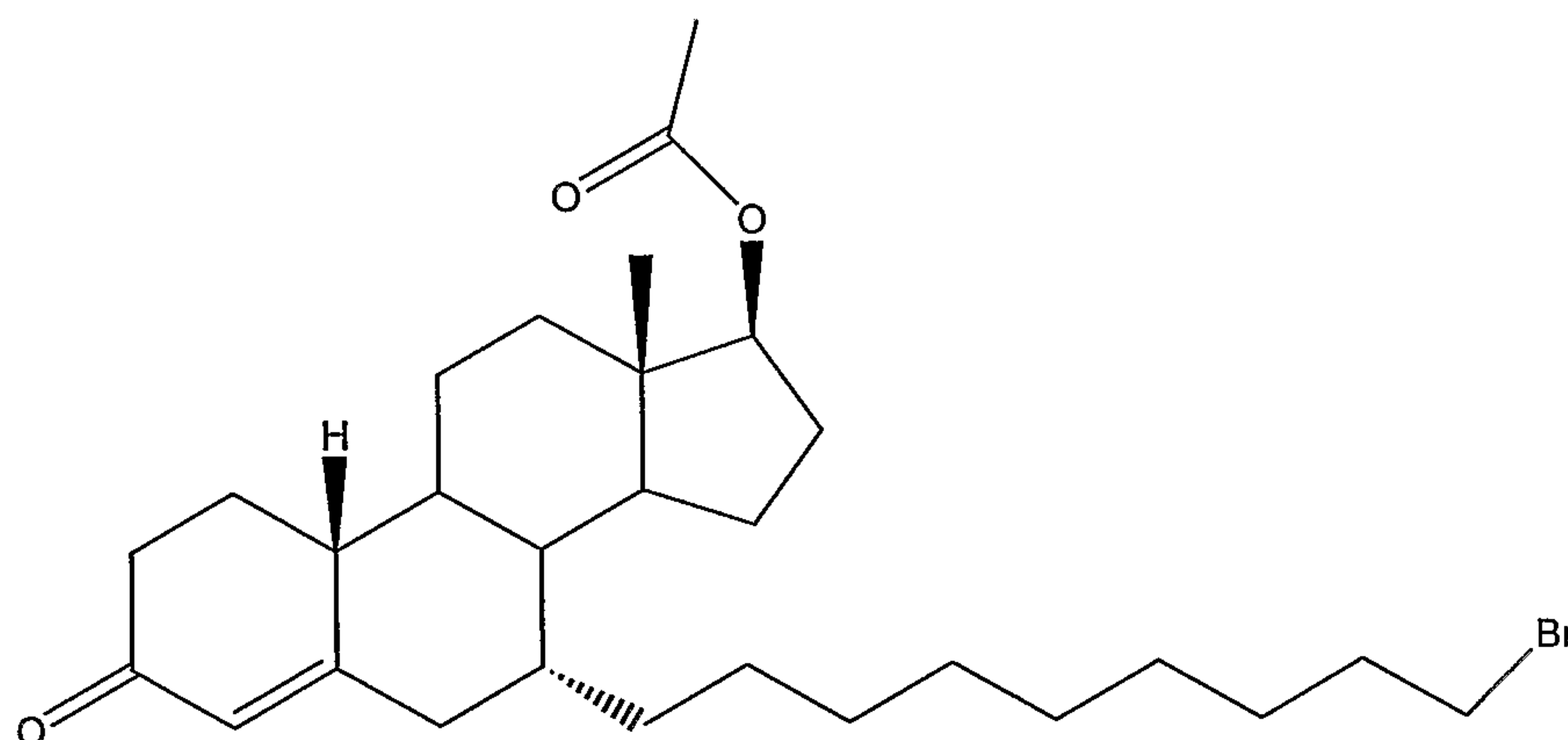


10

- c) quenching the first reaction mixture;

d) recovering compound 9295;

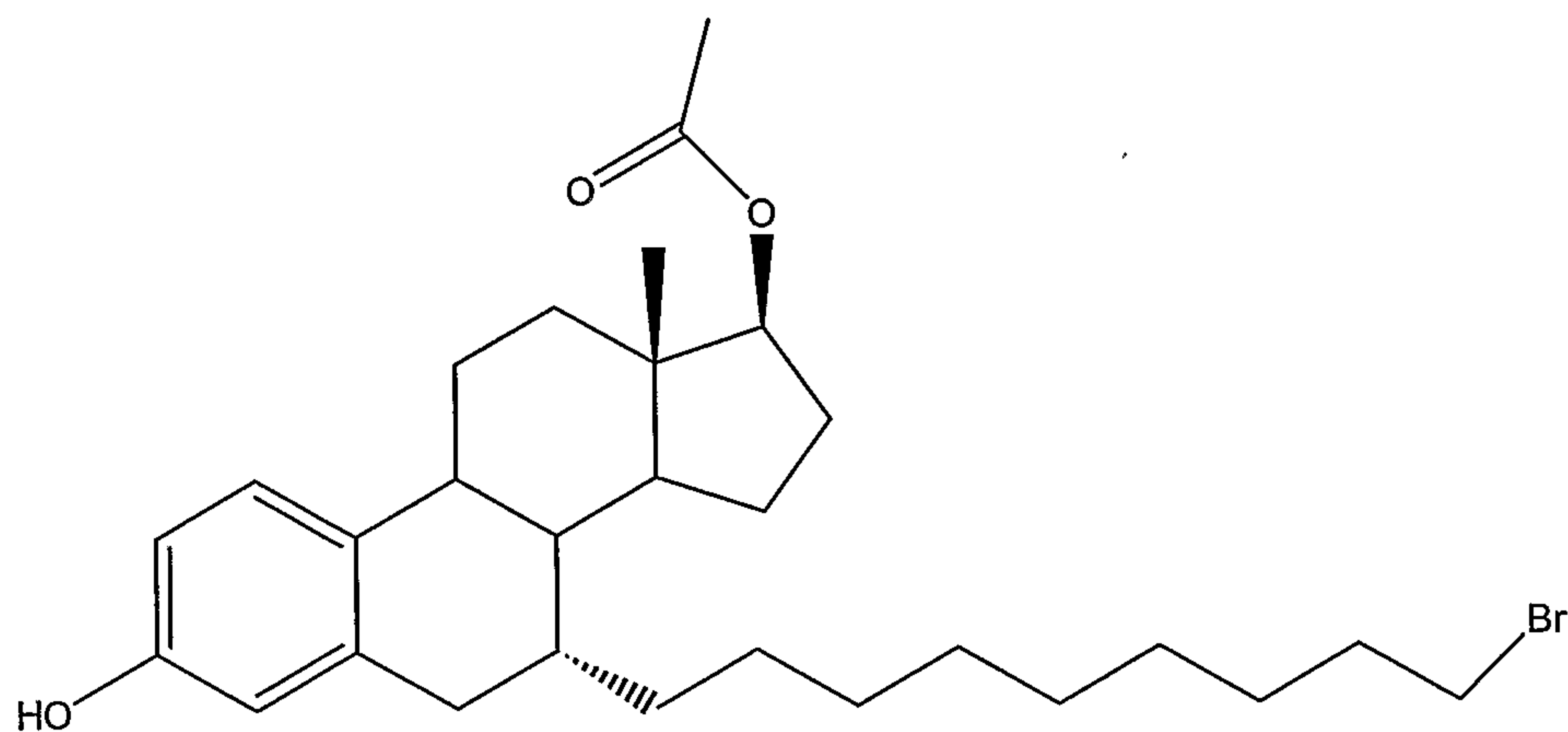
e) combining compound 9295 with acetonitrile and triphenylphosphine dibromide for a time sufficient to convert compound 9295 into a compound of formula 9341



5

9341;

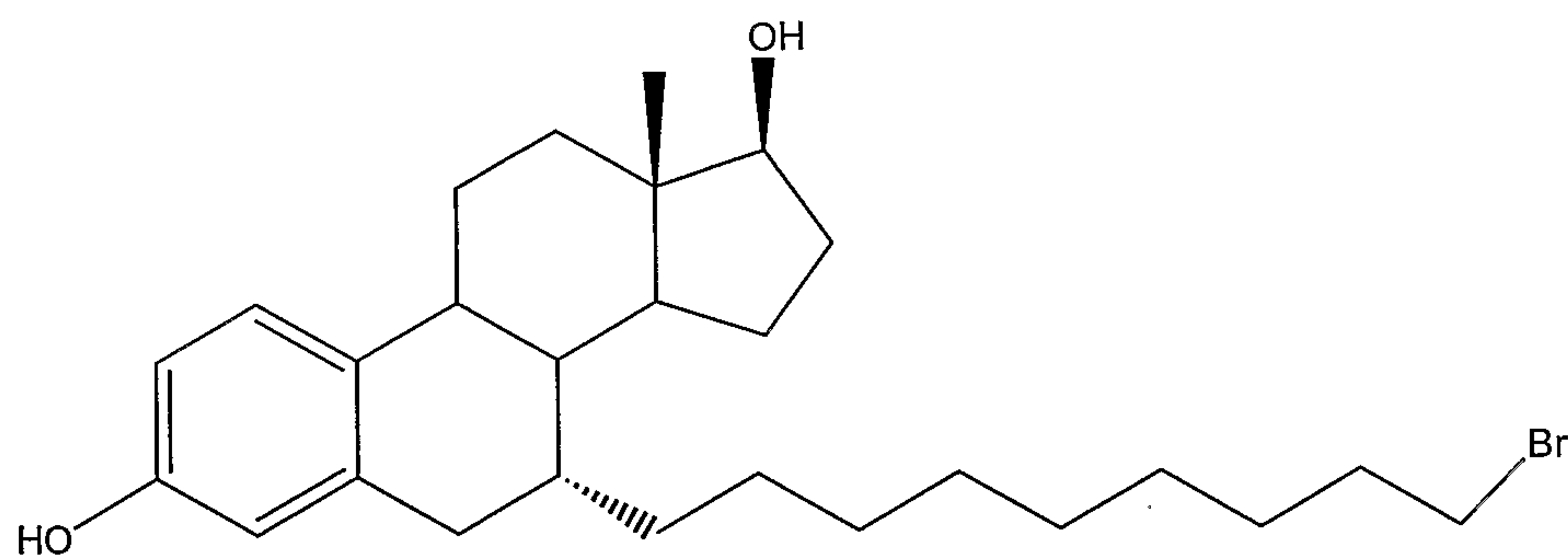
f) aromatizing the A ring of compound 9341 by reacting compound 9341 with a mixture of lithium bromide and copper bromide in acetonitrile to obtain a compound of formula 9342



10

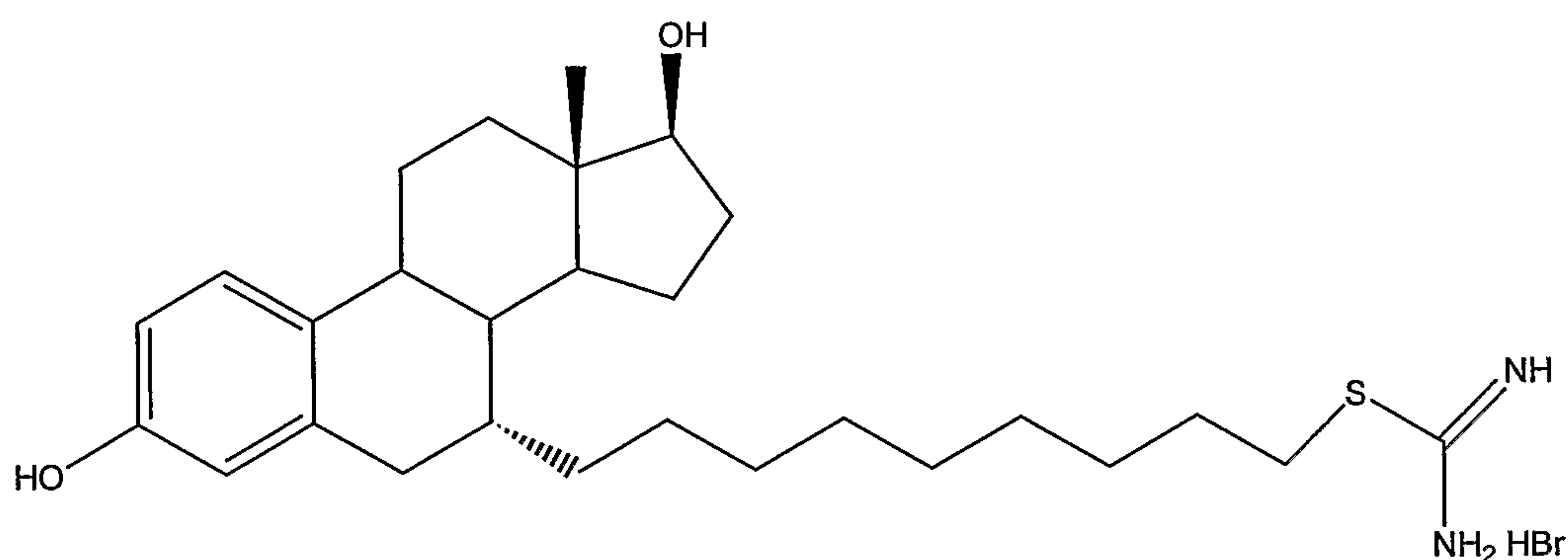
9342;

g) combining compound 9342 with C₁₋₆ alcohol and a mineral acid, at a temperature of about 50°C to about 70°C to obtain a compound of formula 9354



9354;

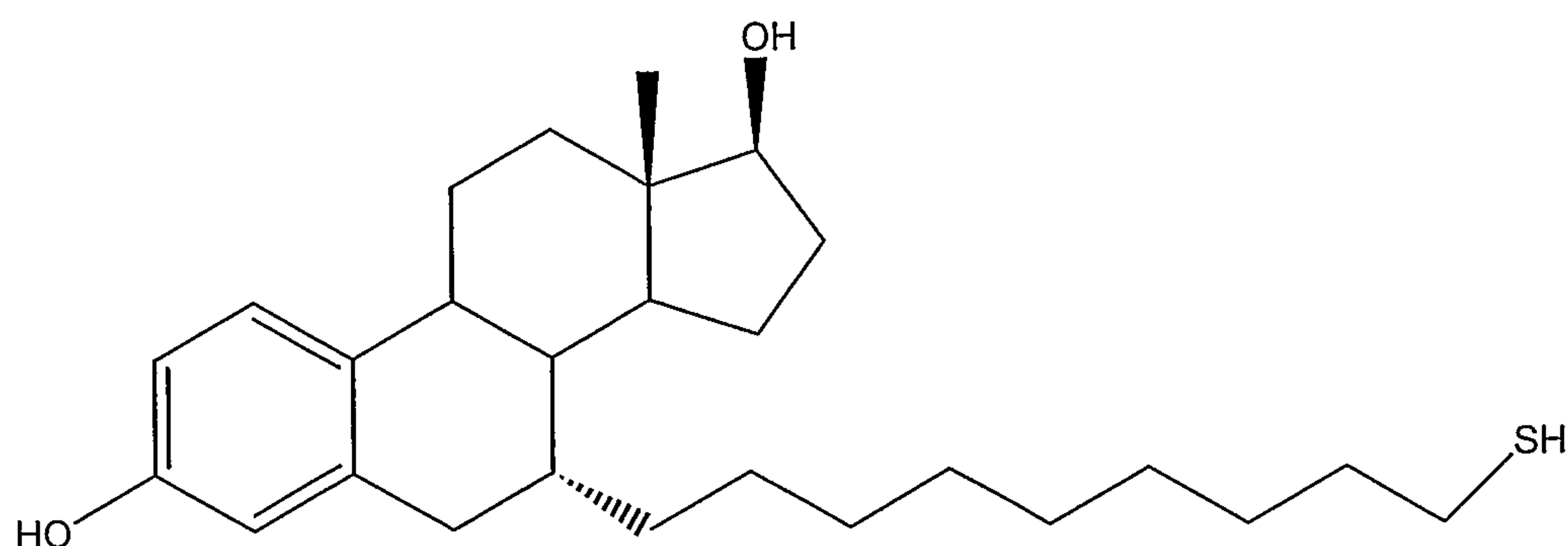
h) combining compound 9354 with a solvent selected from a C₁₋₆ aromatic hydrocarbon, a straight or branched C₁₋₄ alkyl amide and mixtures thereof and thiourea to
5 provide a compound of formula 9388



9388

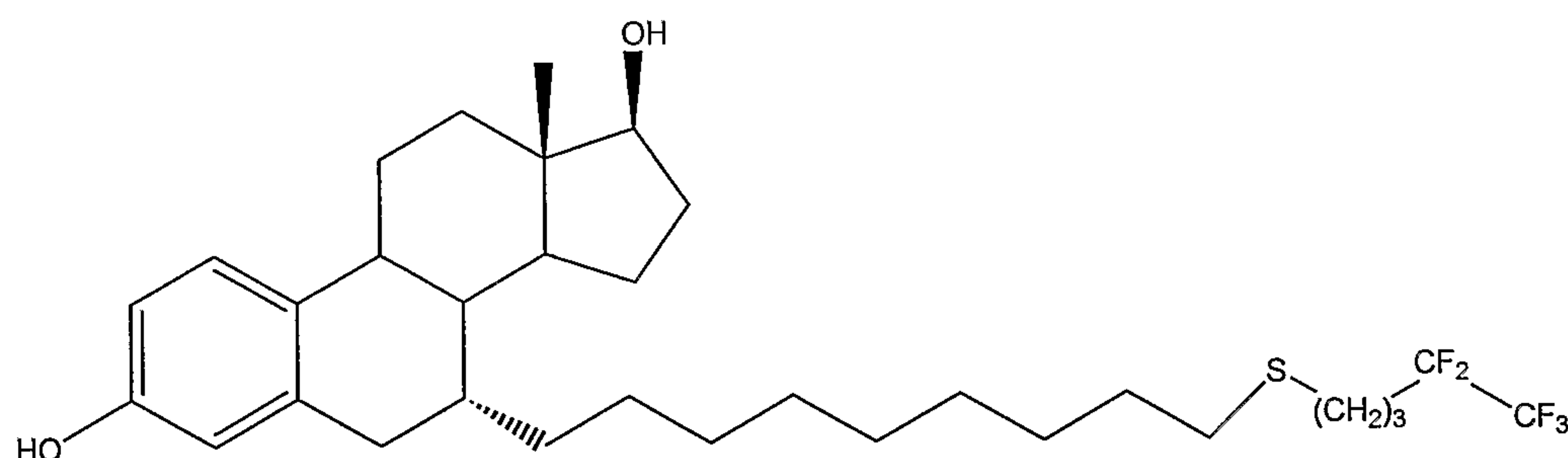
and recovering compound 9388;

i) combining compound 9388 with a base at ambient temperature to obtain a
10 compound of formula 9389



9389

j) combining compound 9389 with 4,4,5,5,5-pentafluoropentane-1-ol mesylate at an ambient temperature to provide a second reaction mixture and then combining the second reaction mixture with a base to obtain a compound of formula 9304



5

9304;

and

k) combining compound 9304 and a mixture of a C₁₋₄ alcohol and an etheral solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide fulvestant.

10

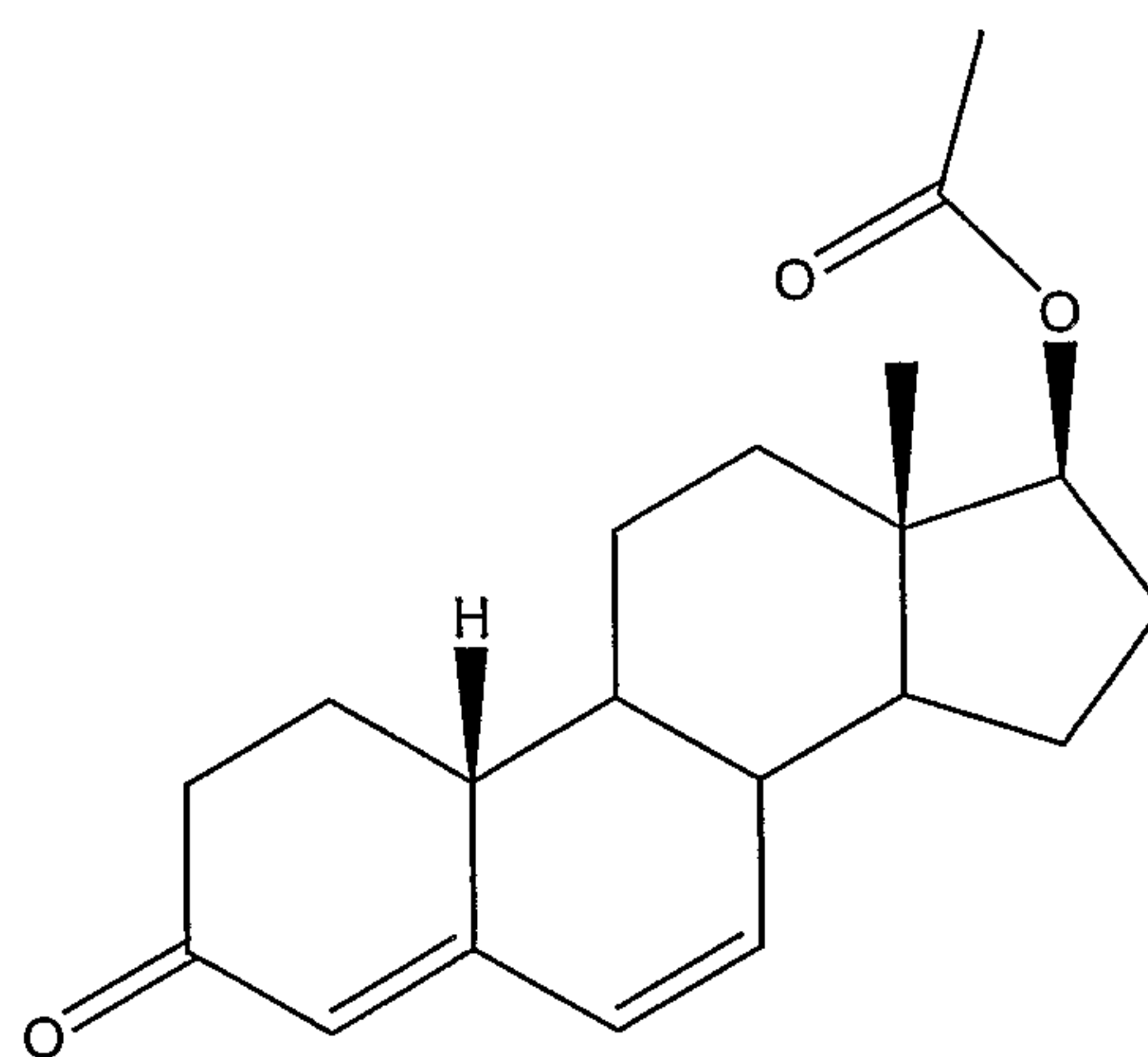
Fulvestrant can be recovered by any methods known in the art, such as evaporating the solvents, and can be further purified by crystallization from a C₁₋₆ aromatic hydrocarbon.

In one embodiment, the solution of the compound of formula 9318 is added to the solution of the compound of formula 9294 at a temperature of about -60°C to about 30°C.

15

Another aspect of the invention is a process for preparing fulvestrant comprising:

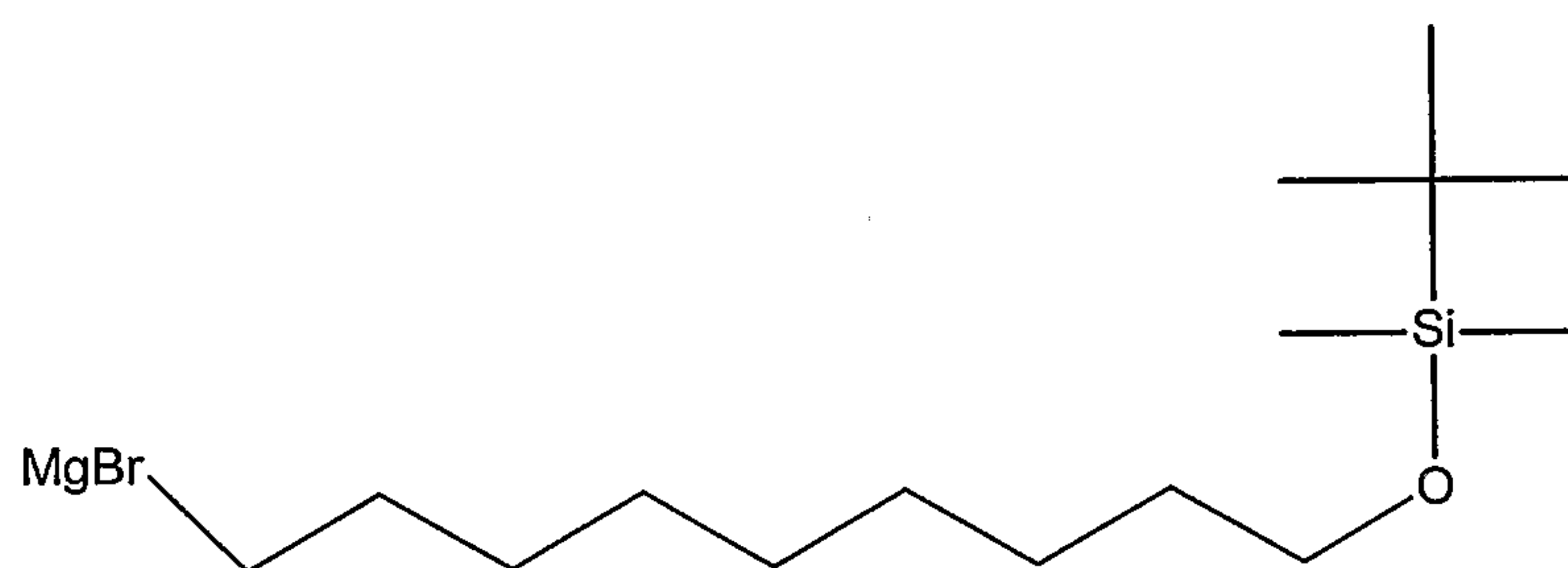
a) combining compound of formula 9294



9294

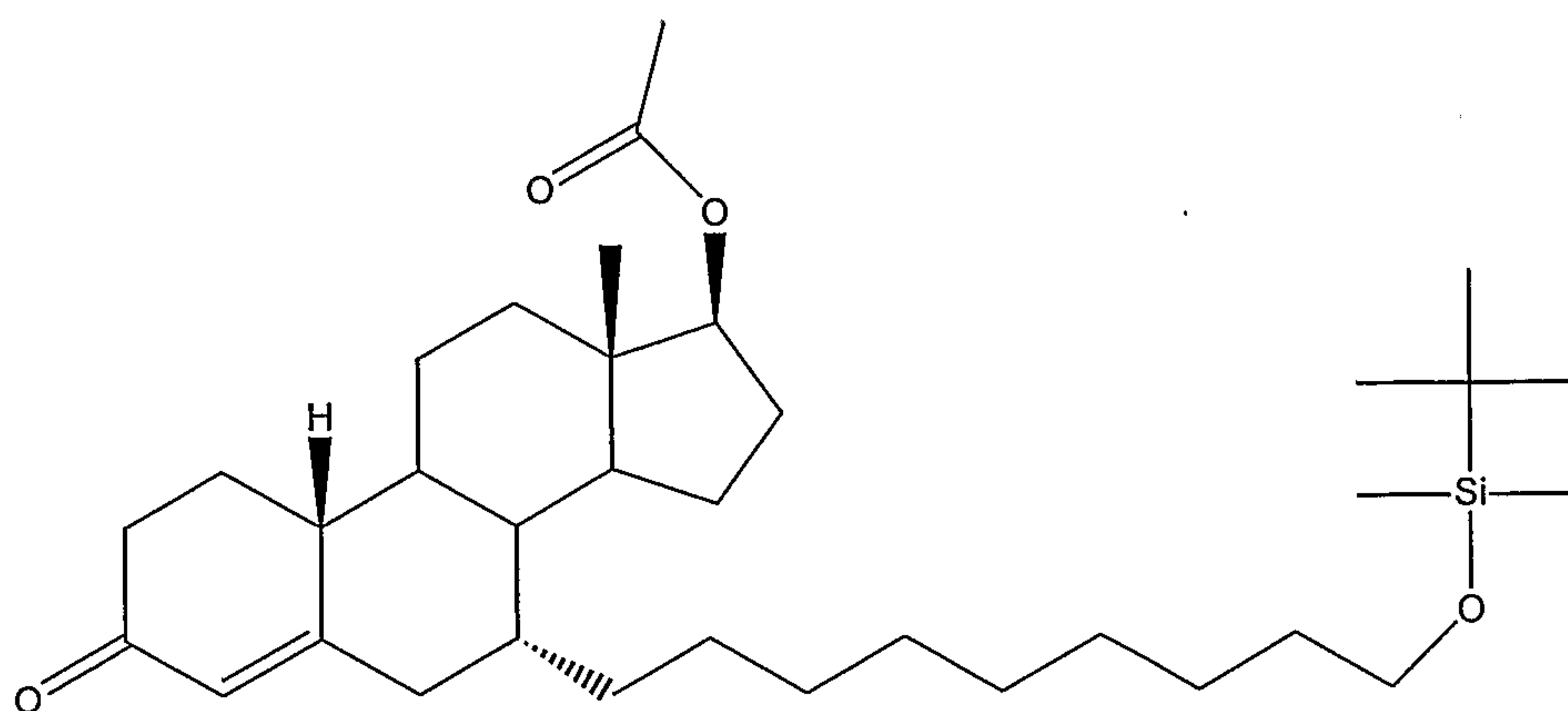
with an etheral solvent, to obtain a solution;

- b) adding to the solution of step a), in a drop-wise manner, a solution of the
5 compound of formula 9318



9318

in an etheral solvent to obtain a first reaction mixture comprising a compound of formula
9295;

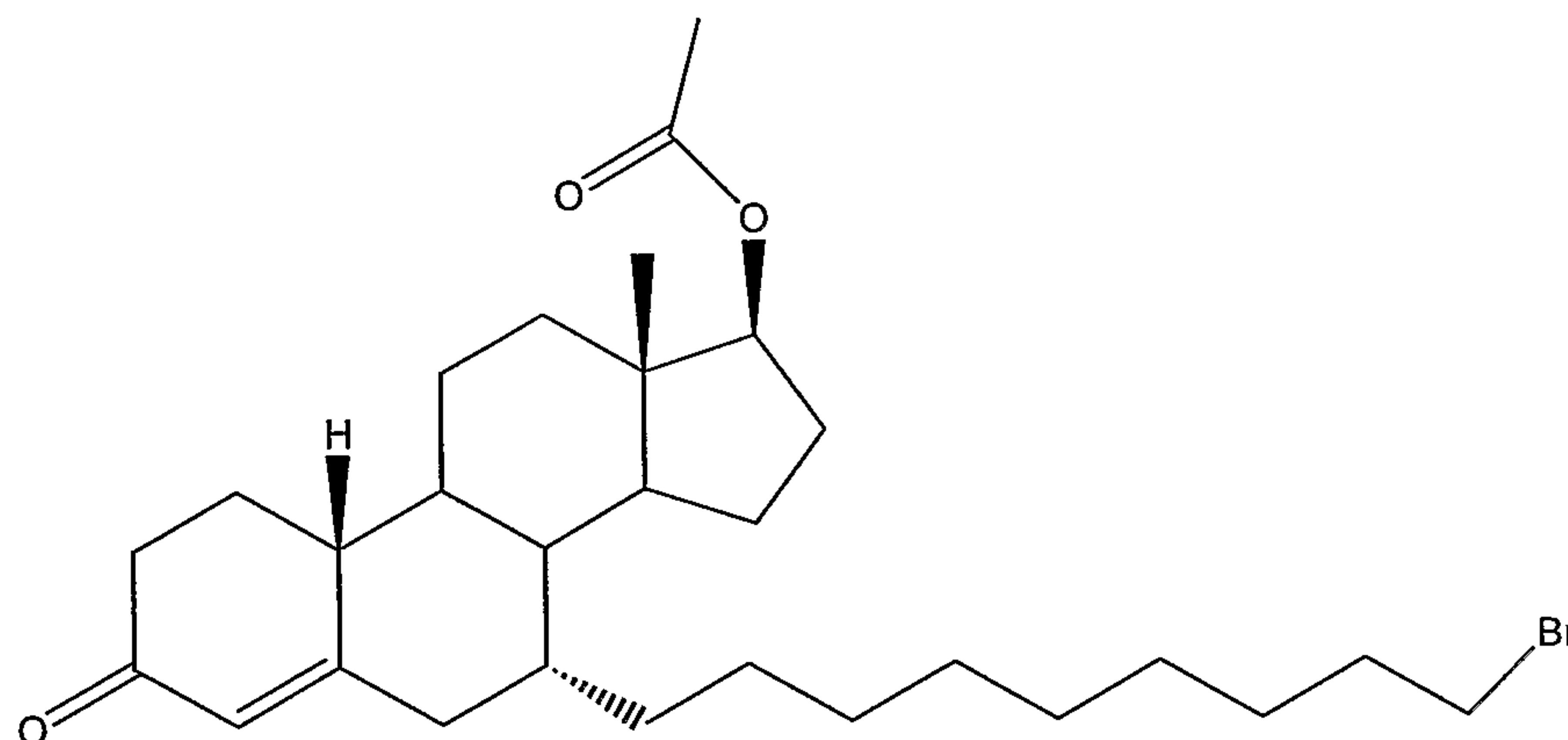


10

- c) quenching the first reaction mixture;

d) recovering compound 9295;

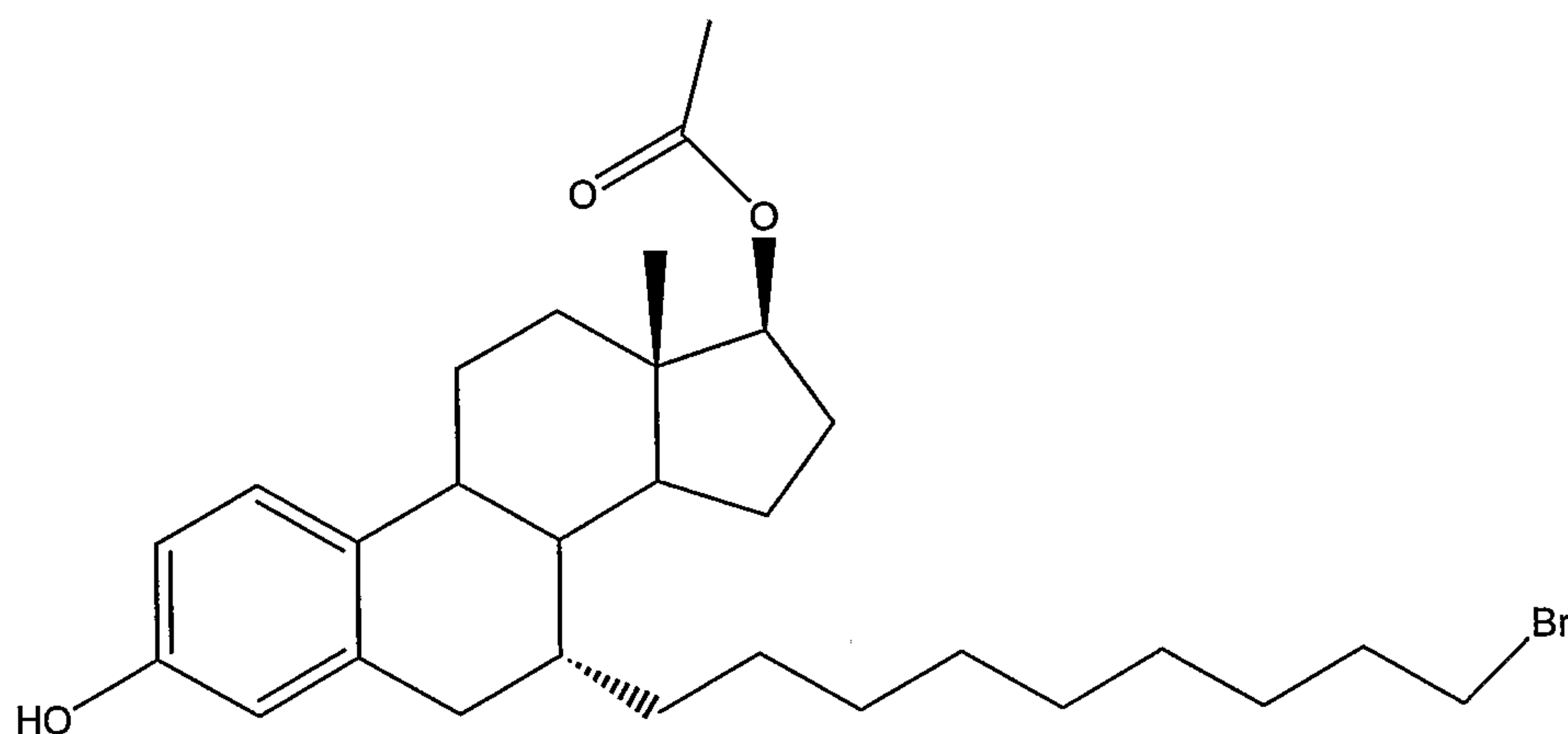
e) combining compound 9295 with acetonitrile and triphenylphosphine dibromide for a time sufficient to convert compound 9295 into a compound of formula 9341



5

9341;

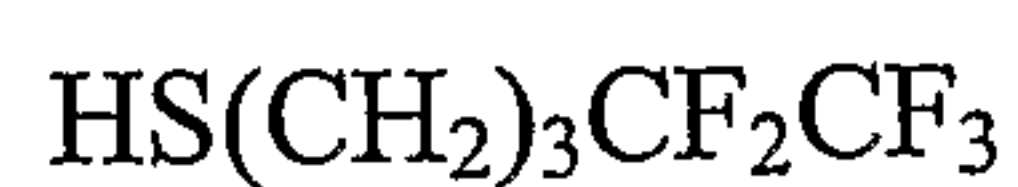
f) aromatizing the A ring of compound 9341 by reacting compound 9341 with a mixture of lithium bromide and copper bromide in acetonitrile to obtain a compound of formula 9342



10

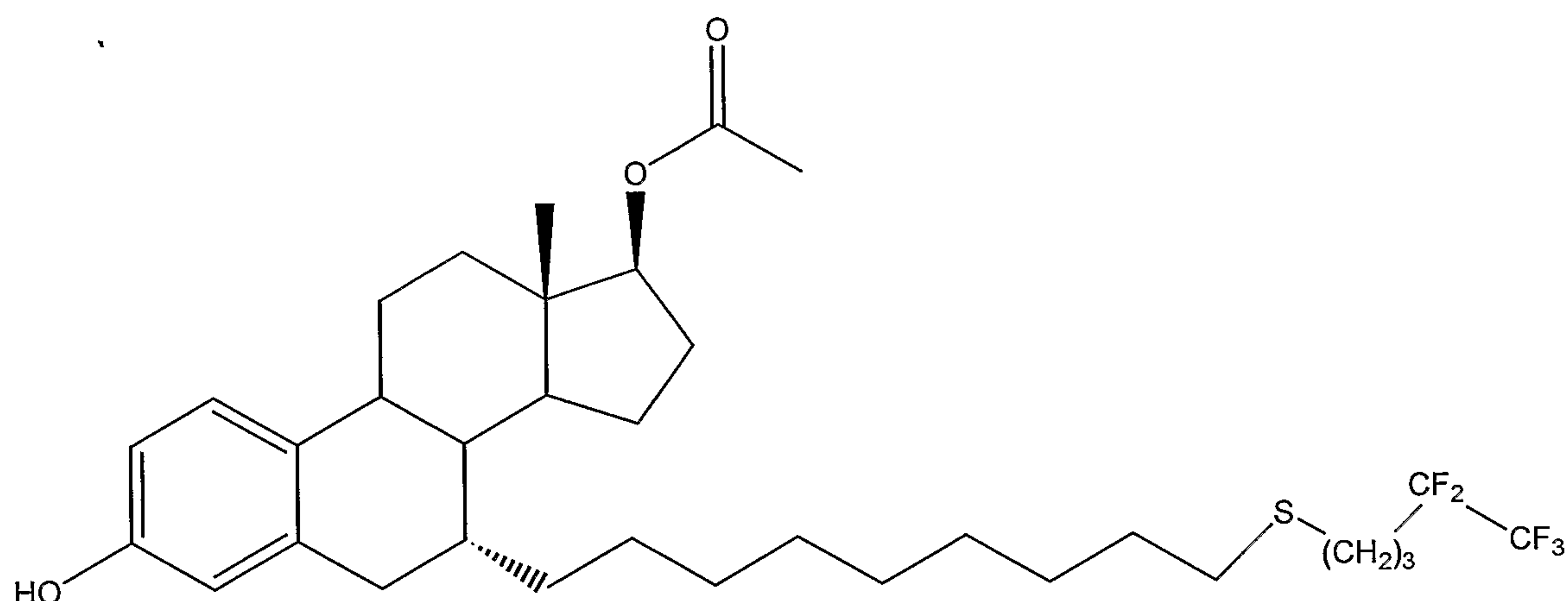
9342;

g) combining compound 9342 with a compound of formula 9383



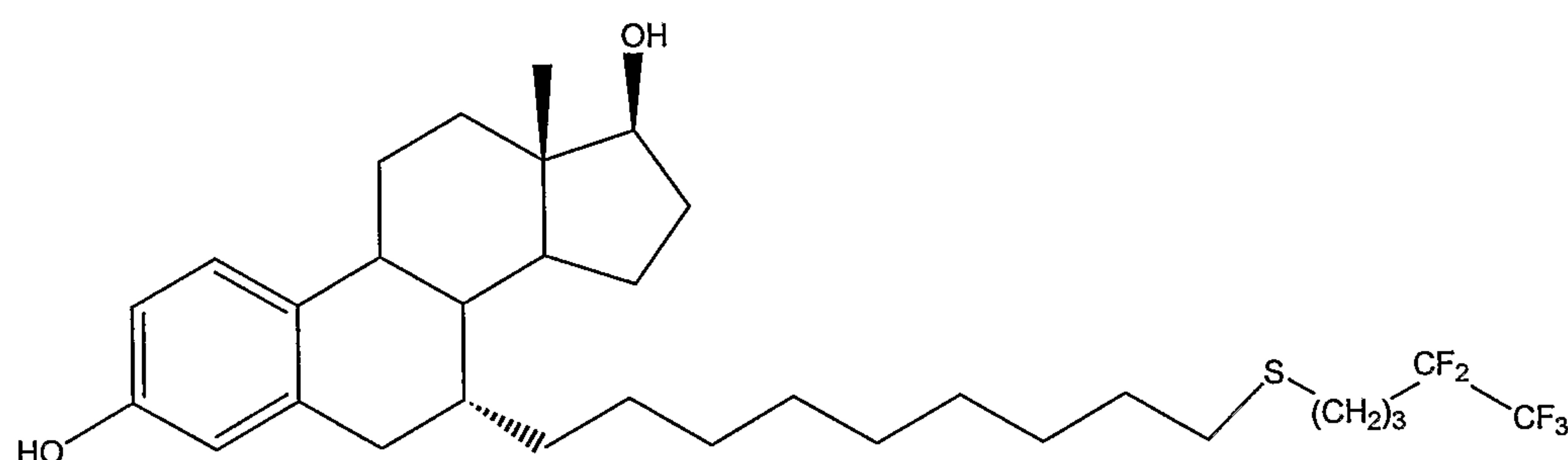
9383;

to provide a compound of formula 9363



9363;

h) combining at ambient temperature, compound 9363 and a C₁₋₄ alcohol with an alkali base to obtain compound 9304



9304;

and

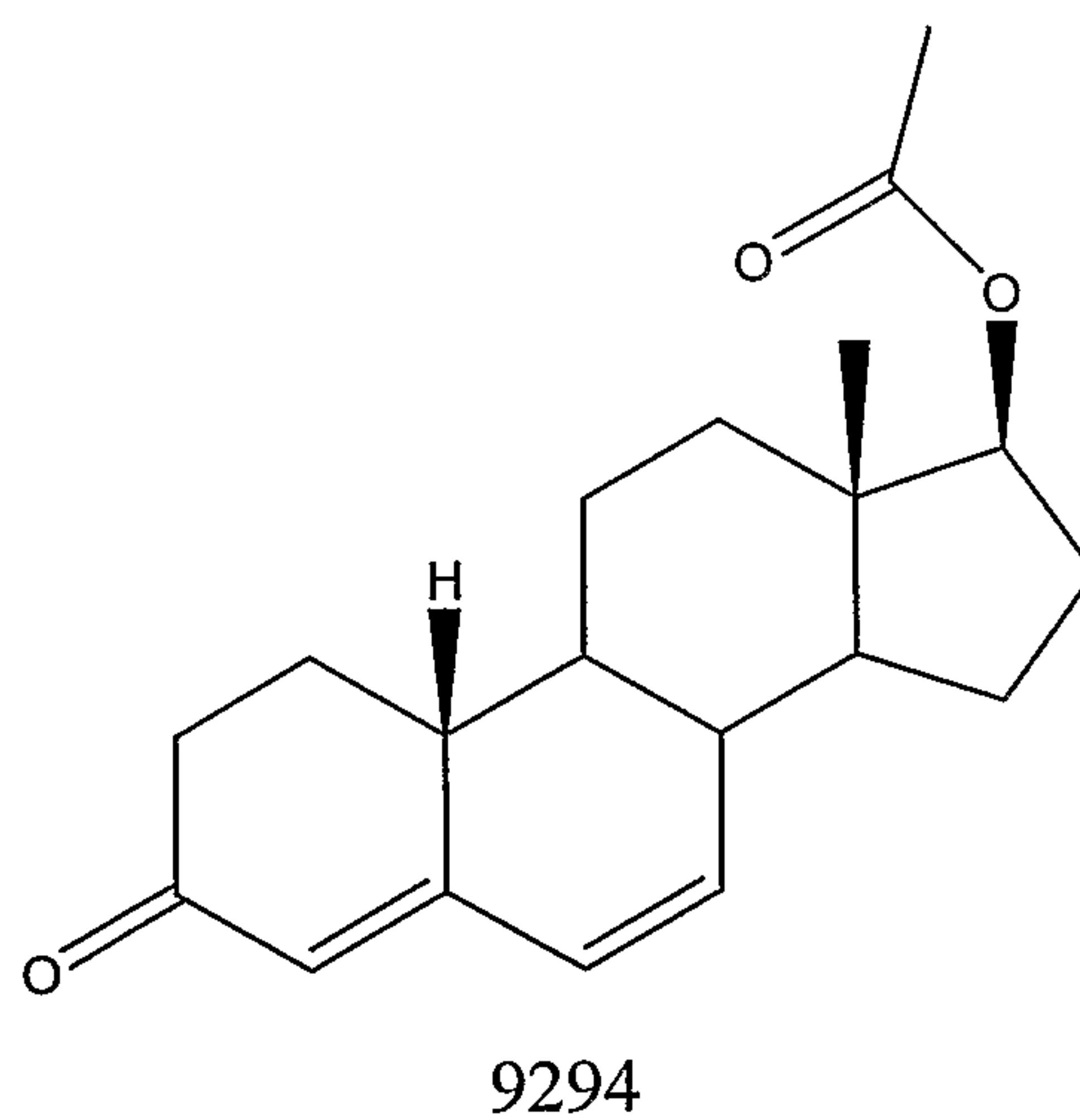
i) combining compound 9304 and a mixture of a C₁₋₄ alcohol and an ethereal solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide fulvestrant.

Fulvestrant can be recovered by any methods known in the art, such as evaporating the solvents, and can be further purified by crystallization from a C₁₋₆ aromatic hydrocarbon.

In one embodiment, the solution of the compound of formula 9318 is added to the solution of the compound of formula 9294 at a temperature of about -60°C to about 30°C.

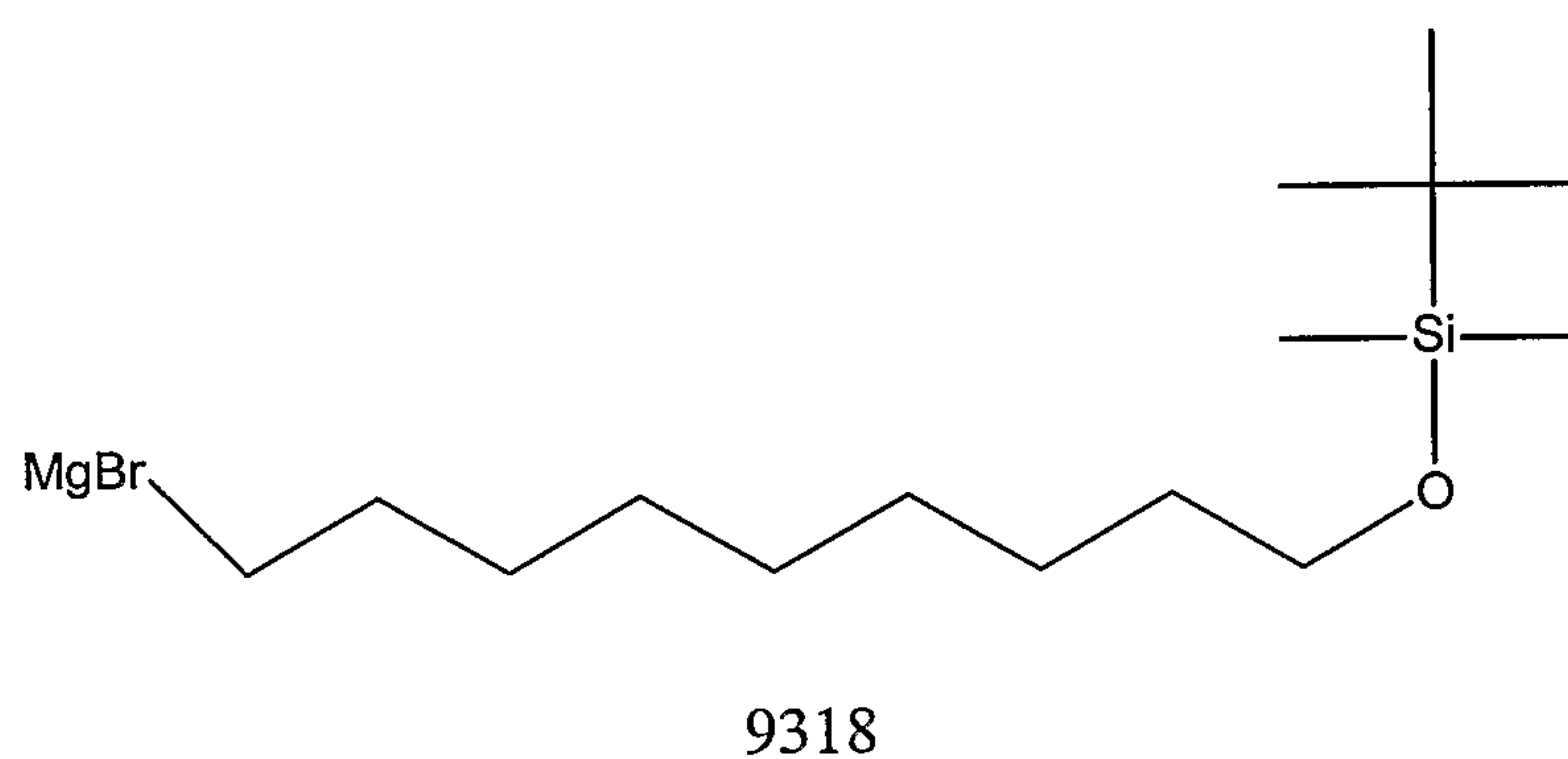
Another aspect of the invention is a process for preparing fulvestrant comprising

a) combining compound of formula 9294

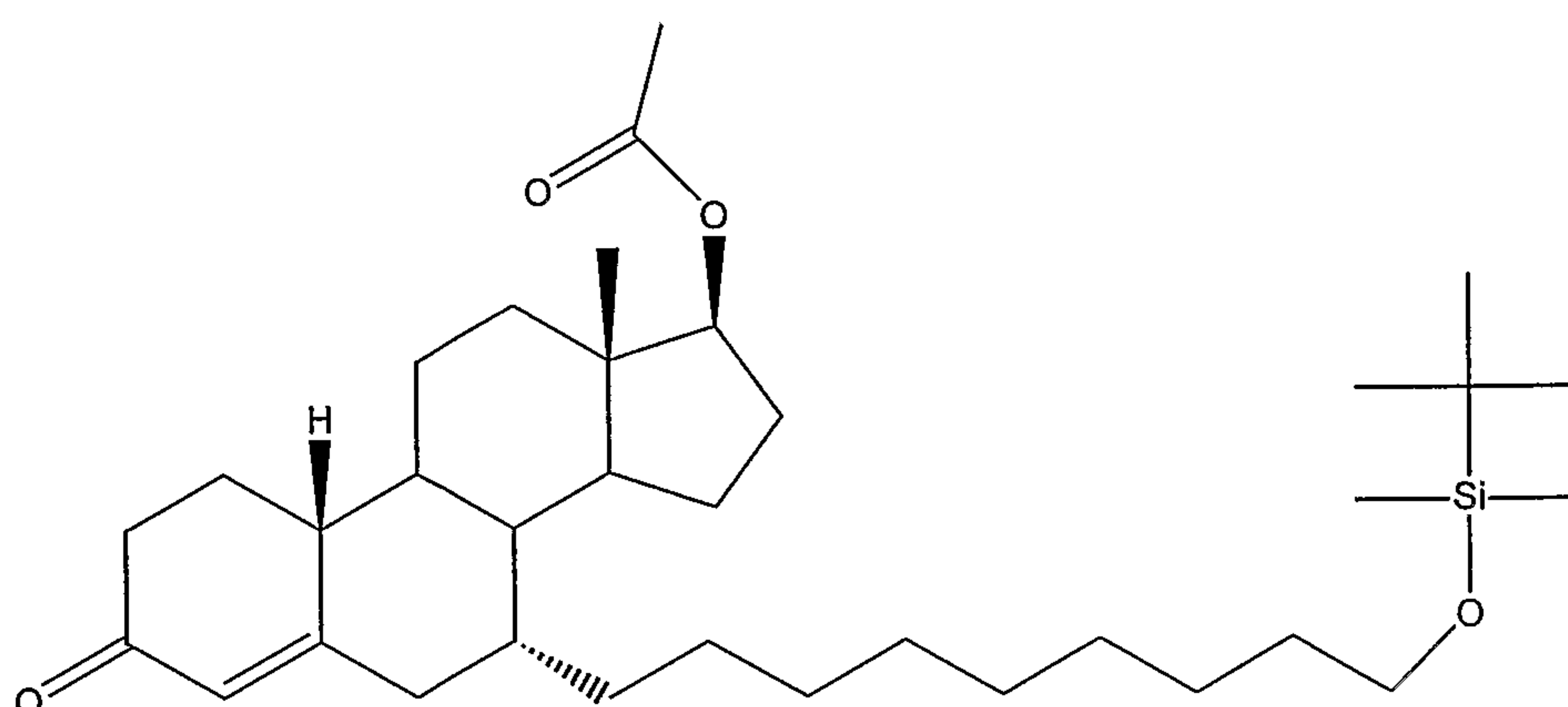


with an ethereal solvent, to obtain a solution;

5 b) adding to the solution of step a), in a drop-wise manner, a solution of the compound of formula 9318



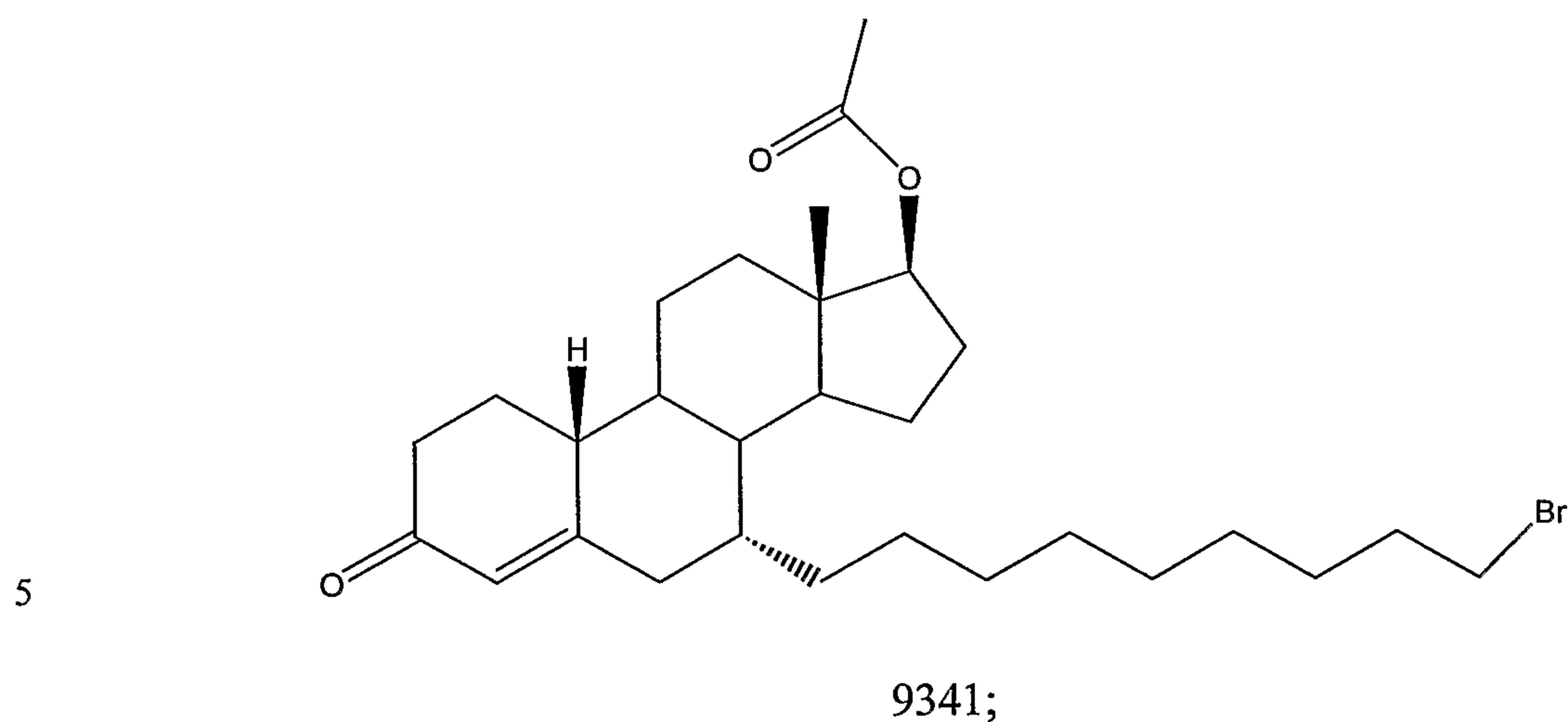
10 in an ethereal solvent to obtain a first reaction mixture comprising a compound of formula 9295;



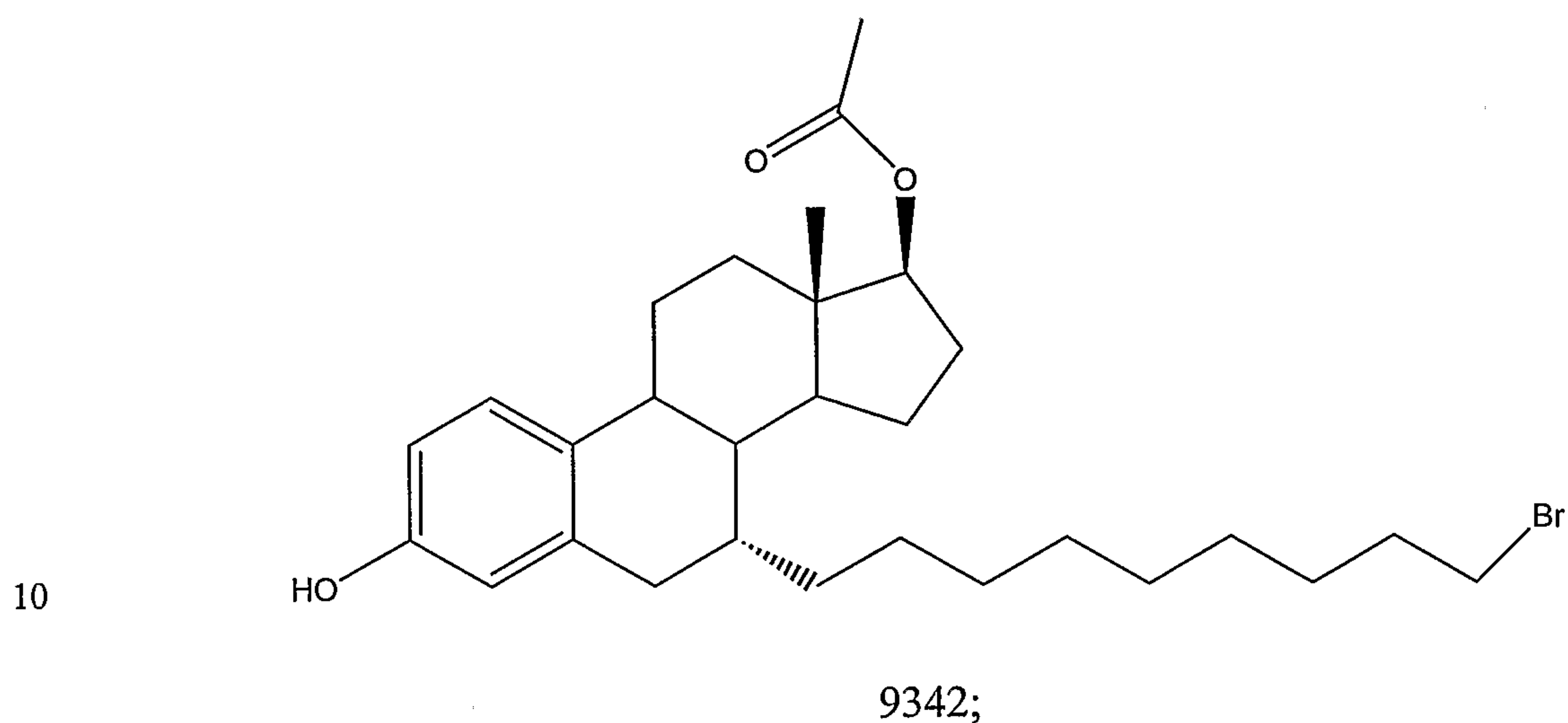
c) quenching the first reaction mixture;

d) recovering compound 9295;

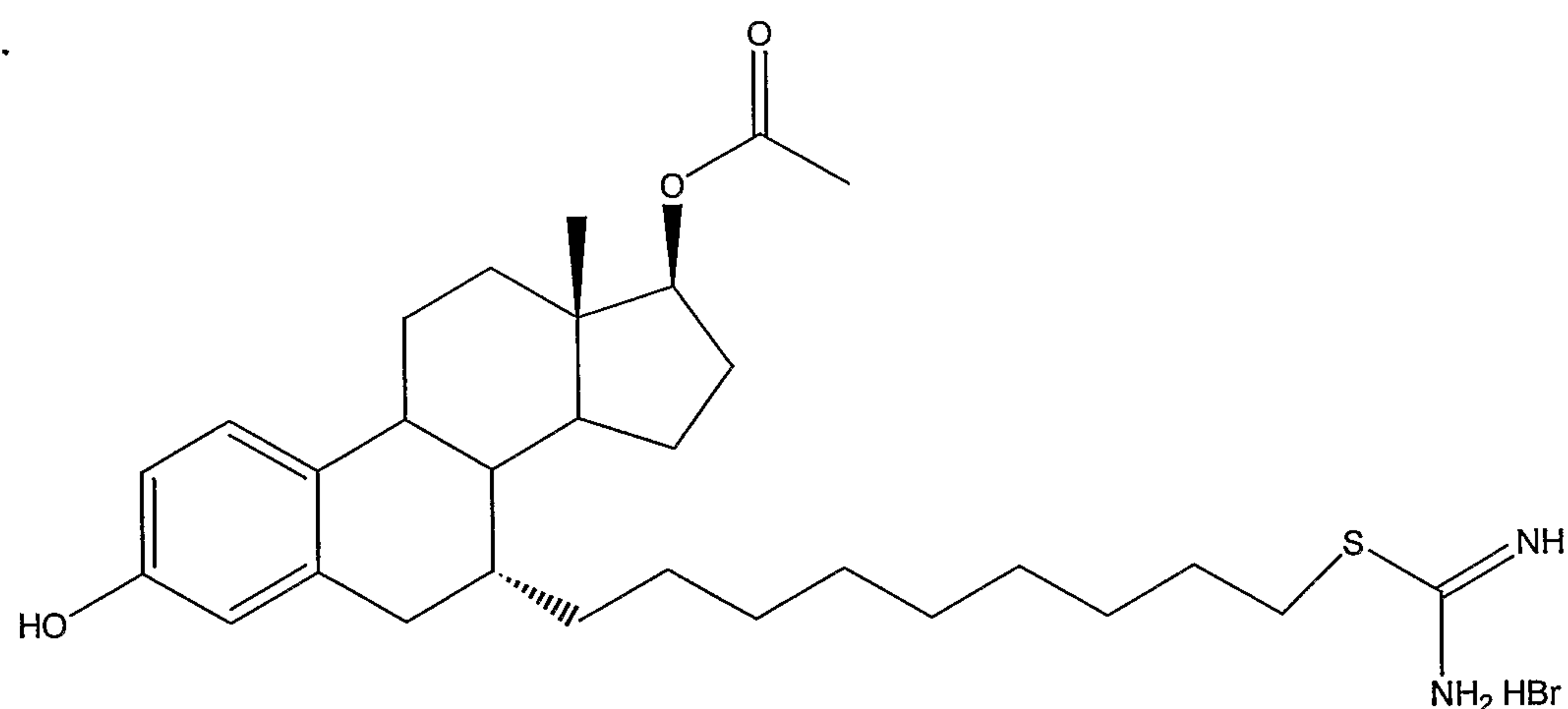
e) combining compound 9295 with acetonitrile and triphenylphosphine dibromide for a time sufficient to convert compound 9295 into a compound of formula 9341



f) aromatizing the A ring of compound 9341 by reacting compound 9341 with a mixture of lithium bromide and copper bromide in acetonitrile to obtain a compound of formula 9342



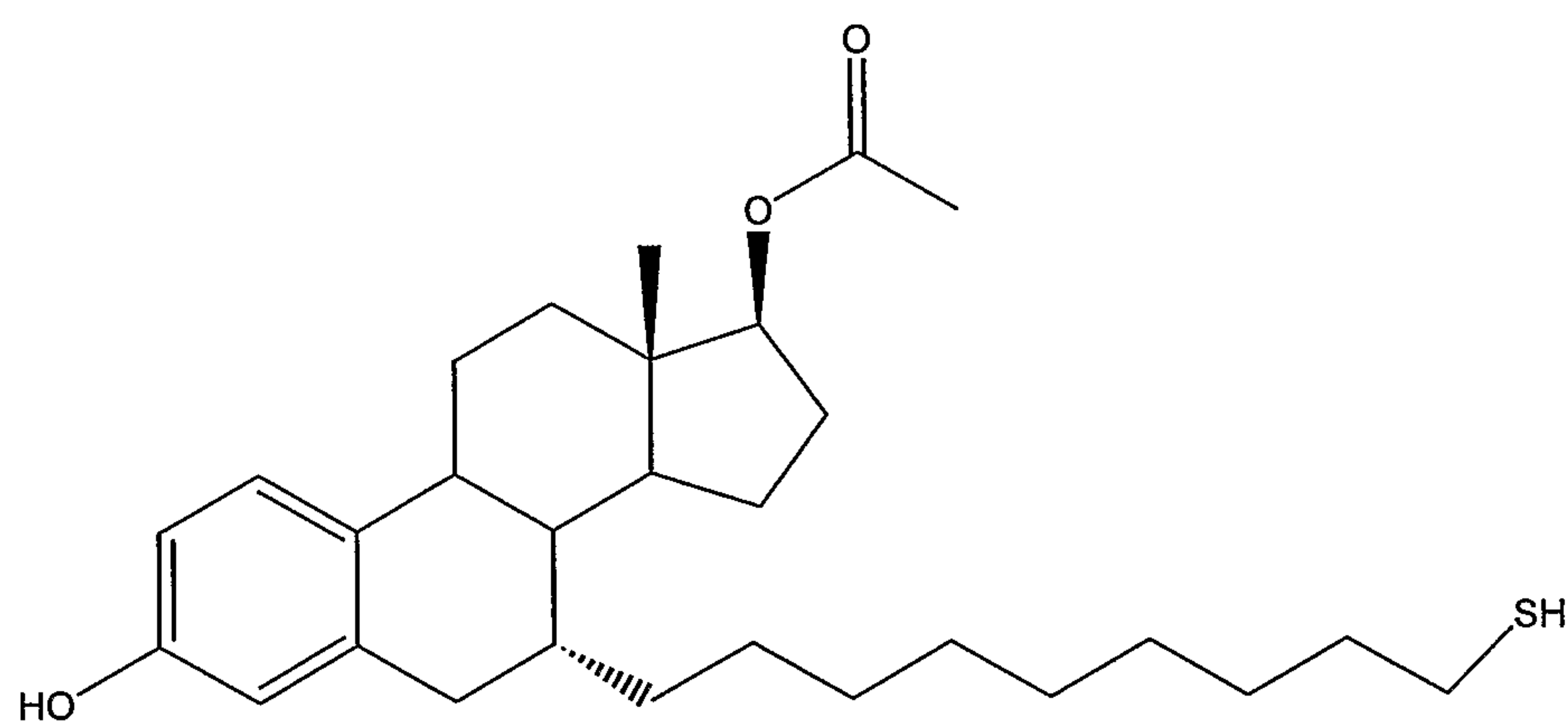
g) combining compound 9342 with with a solvent selected from a C₁₋₆ aromatic hydrocarbon, a straight or branched C₁₋₄ alkyl amide and mixtures thereof and thiourea to provide a compound of formula 9361



9361

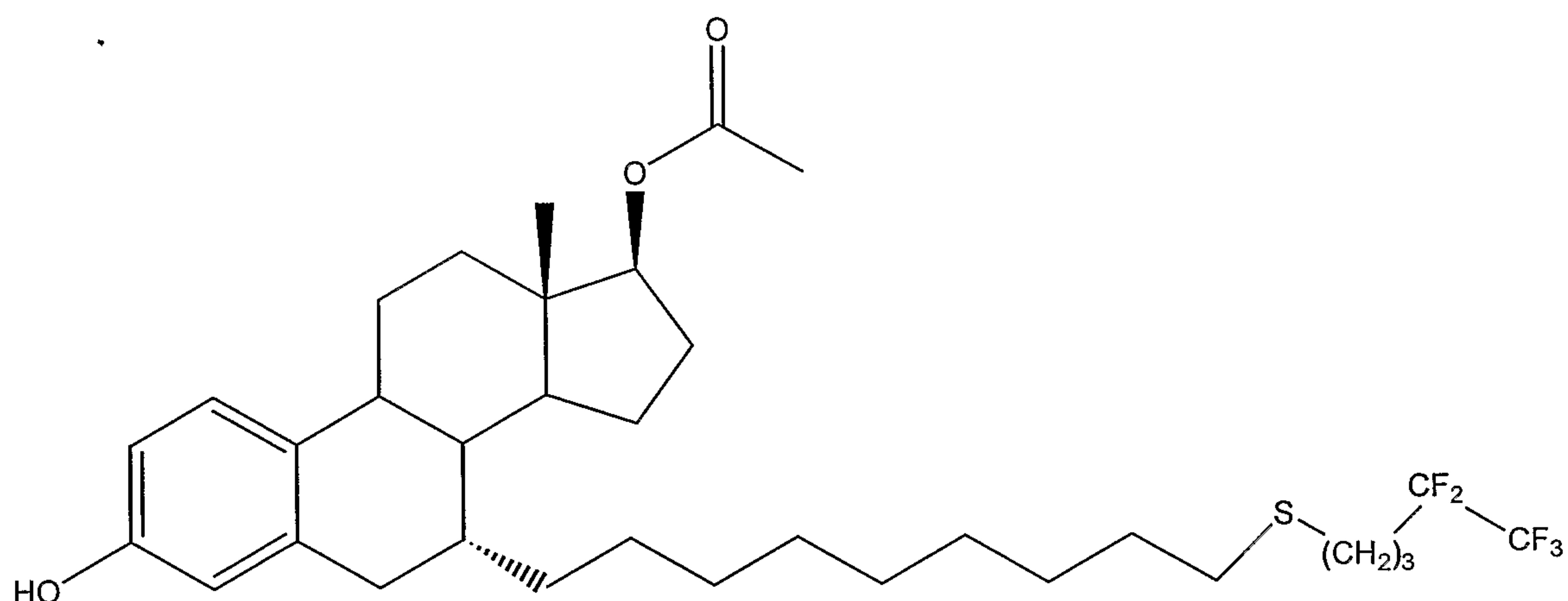
and recovering compound 9361.

- h) combining compound 9361 with a base at an ambient temperature to obtain a
5 compound of formula 9362



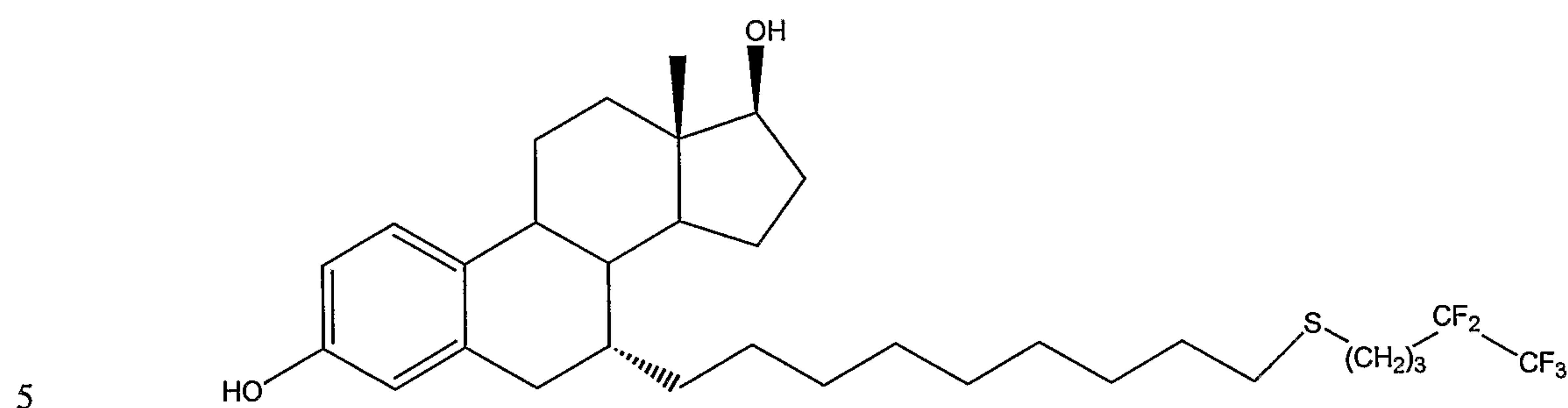
9362

- i) combining compound 9362 with 4,4,5,5,5-pentafluoropentane-1-ol mesylate
(compound 9360) at ambient temperature to provide a second reaction mixture followed
10 by combining the second reaction mixture with a base to obtain a compound of formula
9363



9363;

j) combining at ambient temperature compound 9363 and a C₁₋₄ alcohol with an alkali base to obtain a compound of formula 9304



9304;

and

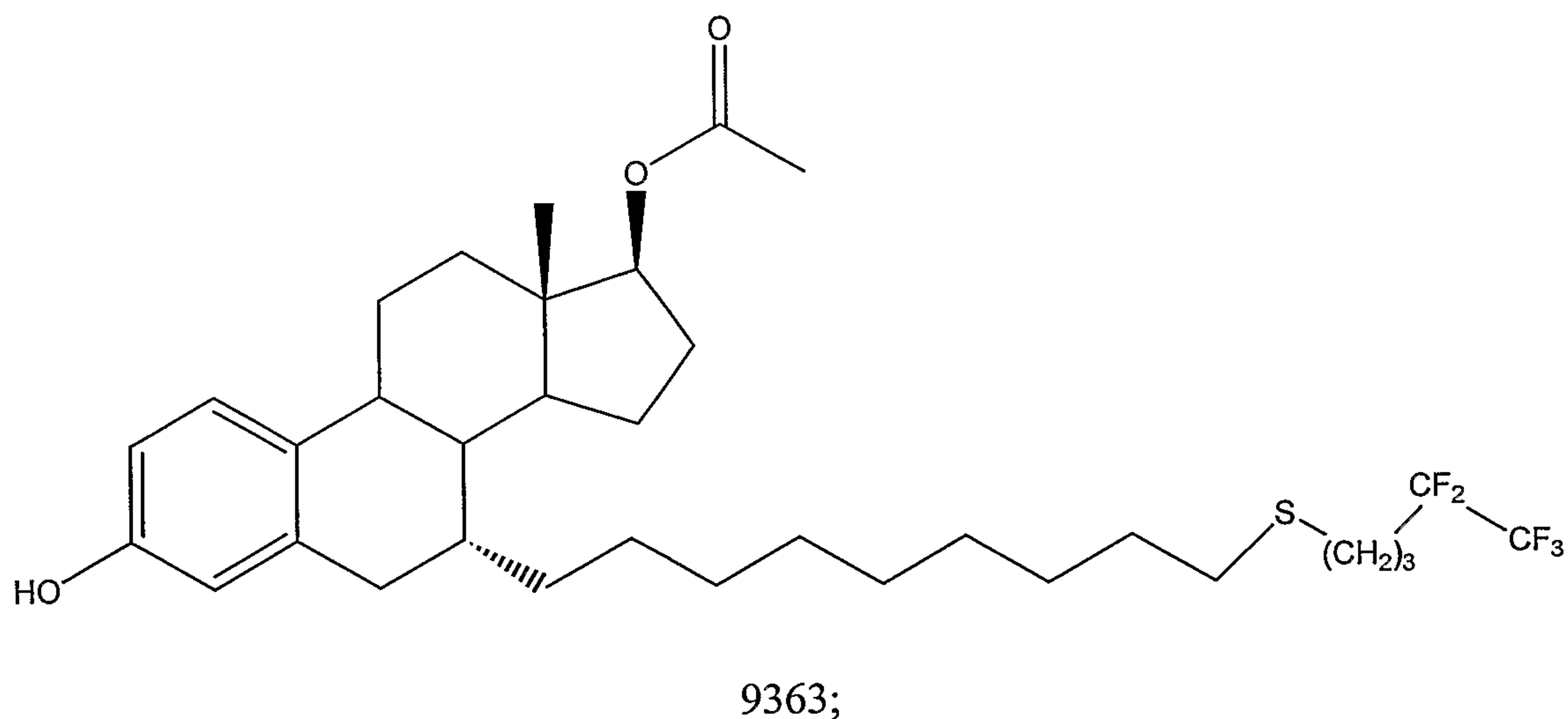
k) combining compound 9304 and a mixture of a C₁₋₄ alcohol and an etheral solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide fulvestrant.

Fulvestrant can be recovered by any methods known in the art, such as evaporating the solvents, and can be further purified by crystallization from a C₁₋₆ aromatic hydrocarbon.

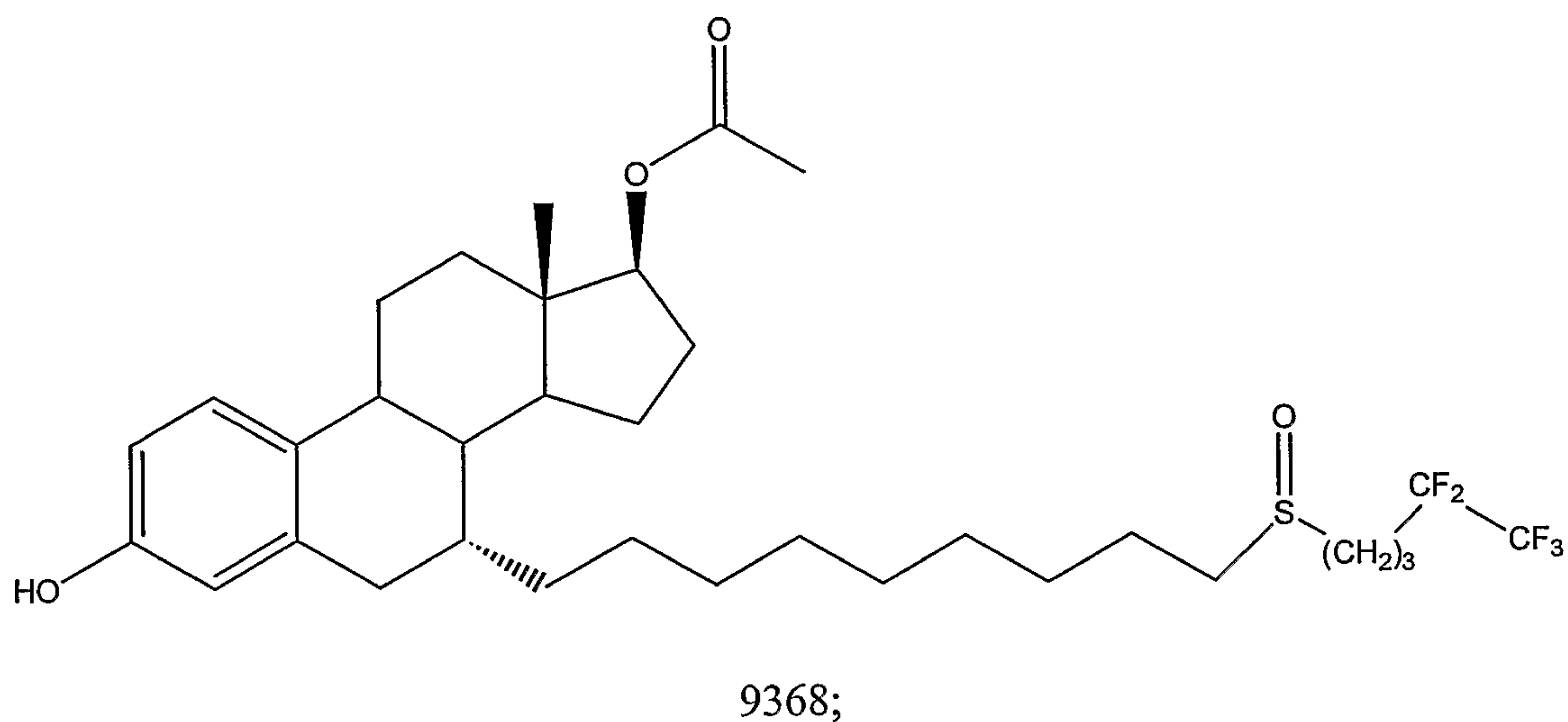
In one embodiment, the solution of the compound of formula 9318 is added to the solution of the compound of formula 9294 at a temperature of about -60°C to about 30°C.

Another aspect of the invention is a process for preparing fulvestrant comprising

a) reacting a compound of formula 9363



with a mixture of a C₁₋₄ alcohol and an etheral solvent with an aqueous solution of an
 5 oxidizing agent at a temperature of about 5°C for about 12 hours to provide a compound
 of formula 9368



and

10 b) combining at ambient temperature compound 9368 and a C₁₋₄ alcohol with an
 alkali base to obtain fulvestant.

This method is depicted schematically in FIG. 13.

The compound of formula 9363 can be made by any method of the invention.

EXAMPLES

Comparative Example repeating EP 138504

Following the method of Example 1 of EP 138504, to the Grignard reagent, Cp 9318, formed from 24.2 grams of 9-bromo-1-nonanol TBDMS (*i.e.*, 9-(dimethyl-
5 butylsiloxy)nonyl bromide), cooled to -30°C, were added 6.6 grams of copper (I) iodide.. After stirring for 10 minutes a solution of 10 grams of 17β hydroxy estra 4,6 diene 3 one acetate, Cp 9294 (*i.e.*, 6-dehydro-19-nortestosterone acetate), in tetrahydrofuran was added, and stirring continued for 90 minutes. After quenching with acetic acid, the
10 product 17β-hydroxy-7α-[9-[[1,1-dimethylethyl)dimethylsilyl]oxy]nonyl]-estr-4-en-3-oneacetate, Cp 9295, was examined by HPLC analysis and found to have a 7α/7β ratio of 2.3: 1.

Comparative Example repeating WO 02/32922

Following the method of Example 2 of WO 02/32922, the 7α/7β ratio obtained was 2.5: 1.

Example 1: Preparation of the Grignard reagent Cp 9318 (9-(dimethyl-tert-butylsilyloxy)nonyl magnesium bromide)

To a mixture of 100 g of 1-bromononanol, 33 g of imidazole and 250 g of dimethylformamide was added 70.2 g of tert-butyl-chlorodimethylsilane and the reaction mixture was stirred for 2 hours.

20 The mixture was diluted with 750 g of water and 220 g of toluene, and the phases separated. The aqueous phase was re-extracted with 90 g of toluene. The combined organic phases were washed with 100 g of water, and evaporated under vacuum at 80°. The residue of 9-bromo-1-nonanol TBDMS was dissolved in 500 g of anhydrous tetrahydrofuran.

25 In a 2 L flask fitted with stirrer, heating bath, condenser, nitrogen atmosphere, and thermometer 10.88 g of magnesium turnings and 100 g of tetrahydrofuran were charged and heated up to 45°.

A small amount of 9-bromo-1-nonanol TBDMS was added to initiate the reaction, and then the remaining solution was added dropwise at such a rate as to maintain the
30 reaction mixture at reflux.

When addition was finished the reaction mixture was refluxed for another hour, then cooled to about 40°C and filtered under nitrogen through a sintered glass in-line filter (to remove some residual magnesium) and diluted to about 1.15 L. The solution of reagent was kept at room temperature under nitrogen.

5 **Example 2: Preparation of Cp 9295 from Cp 9294 (depicted in Figure 1)**

10 10 grams of nandrolone acetate, Cp 9294 (6 dehydro 17 β hydroxy estra 4,6 diene 3 one acetate), was dissolved in 60 grams of tetrahydrofuran and 1.5 grams of copper (I) chloride added. The suspension was cooled under a nitrogen atmosphere to -20°C and 117 grams of a ca. 0.39M solution of the Grignard reagent, Cp 9318, formed from 9-
10 bromo-1-nonanol TBDMS (9-(dimethyl-tert-butyloxy)nonyl magnesium bromide) was added dropwise over 120 minutes. 10 grams of acetic acid was then added, and stirring continued for 30 minutes at room temperature. The flask was then opened to the atmosphere and a solution of 10 grams of ammonium chloride plus 15 grams of a 25% ammonium hydroxide solution in 73 grams of water was added and stirring was
15 continued for 2 hours. The phases were separated and the upper phase washed with a solution of 5 grams ammonium chloride in 37 grams of water. The upper phase was separated and the solvent was evaporated under reduced pressure to provide an oily residue which was dissolved in dichloromethane (100 grams) and further washed with 50 grams of water. The lower phase was separated and the solvent was evaporated under
20 reduced pressure to provide an oil (26.0 grams) containing 16.9 grams of 17 β -hydroxy-7 α -[9-[[1,1-dimethylethyl)dimethylsilyl]oxy]nonyl]-estr-4-en-3-one acetate, Cp 9295, by HPLC assay (93% of theoretical) having a 7 α / 7 β ratio of 12.1: 1.

The oil was further purified by chromatography using 200 grams of silica gel, eluting with 5% ethyl acetate in toluene. The main fraction, after evaporation of the
25 solvent, yielded Cp 9295 as an oil (16.8 grams) containing 15.9 grams of 17 β -hydroxy-7 α -[9-[[1,1-dimethylethyl)dimethylsilyl]oxy]nonyl]-estr-4-en-3-one acetate by HPLC assay (87.5%) having an 7-alpha / 7-beta ratio of 96.4 : 3.6. A later fraction (0.5 grams) contained mainly the 7- β isomer (7 α / 7 β ratio ca 1: 3).

The rate of adding 9-(dimethyl-tert-butyloxy)nonyl magnesium bromide, Cp
30 9318 was: 0.041 moles of 9-(dimethyl-tert-butyloxy)nonyl magnesium bromide were added to 0.032 moles of nandrolone acetate in 120 minutes. This translates into 1.28 mol equivalents in 120 minutes, or an average of ca. 0.011 mol equivalents per minute.

Example 3: Preparation of Cp 9295 from Cp 9294 (depicted in Figure 1)

10 grams of nandrolone acetate (6 dehydro 17 β hydroxy estro 4,6 diene 3 one acetate), Cp 9294, was dissolved in 54 grams of tetrahydrofuran and 1 gram of copper (I) chloride added. The suspension was cooled under nitrogen atmosphere to -20°C and 146
5 grams of a 0.346M solution of 9-(dimethyl-tert-butylsilyloxy)nonyl magnesium bromide, Cp 9318, (i.e., the Grignard reagent from 9-bromo-1-nonanol TBDMS) was added dropwise over 75 minutes. 10 grams of acetic acid was added and stirring was continued for 30 minutes at room temperature. The flask was then opened to the atmosphere and a solution of 10 grams of ammonium chloride plus 15 grams of a 25% ammonium
10 hydroxide solution in 73 grams of water was added and stirring was continued for 2 hours. The phases were separated and the upper phase was re-extracted with a solution of 5 grams ammonium chloride plus 0.5 grams of a 25% ammonium hydroxide solution in 37 grams of water. The upper phase was separated and the solvent was evaporated under reduced pressure to provide an oily residue that contained 16.2 grams of 17 β -hydroxy-7 α -
15 [9-[[1,1-dimethylethyl)dimethylsilyl]oxy]nonyl]-estr-4-en-3-one acetate, Cp 9295, by HPLC assay (89% of theoretical) having a 7 α / 7 β ratio of 9.2: 1

Example 4: Preparation of Cp 9295 from Cp 9294 (depicted in Figure 1)

5 grams of nandrolone acetate (6 dehydro 17 β hydroxy estro 4,6 diene 3 one acetate), Cp 9294, was dissolved in 60 grams of tetrahydrofuran and 0.5 grams of copper
20 (I) bromide added. The suspension was cooled under nitrogen atmosphere to -15°C and 90 grams of a ca. 0.39M solution of 9-(dimethyl-tert-butylsilyloxy)nonyl magnesium bromide, Cp 9318, (i.e., the Grignard reagent from 9-bromo-1-nonanol TBDMS) was added dropwise over 120 minutes. After another hour, 5.4 grams of acetic acid was
25 added and stirring continued for 60 minutes at room temperature. The flask was then opened to the atmosphere and a solution of 7 grams of ammonium chloride plus 10 grams of a 25% ammonium hydroxide solution in 50 grams of water was added and stirring was continued for 12 hours. The phases were separated and the upper phase washed with a solution of 2 grams ammonium chloride in 10 grams of water. The upper phase was then
30 separated and the solvent evaporated under reduced pressure to provide an oily residue that was dissolved in dichloromethane (100 grams) and further washed with 50 grams of water. The lower phase was separated and the solvent evaporated under reduced pressure to provide oil, Cp 9295, (18.0 grams) with a 7 α /7 β ratio of 7.1: 1 by HPLC.

Example 5: Preparation of Cp 9295 from Cp 9294 (depicted in Figure 1)

5 grams of nandrolone acetate (6 dehydro 17 β hydroxy estro 4,6 diene 3 one acetate, Cp 9294,) was dissolved in 50 grams of tetrahydrofuran and 2.5 grams of copper (I) iodide added. The suspension was cooled under nitrogen atmosphere to -20°C and 85 grams of a *ca.* 0.30M solution of 9-(dimethyl-tert-butylsilyloxy)nonyl magnesium bromide, Cp 9318, (*i.e.*, the Grignard reagent from 9-bromo-1-nonanol TBDMS) was added dropwise over 120 minutes while maintaining the temperature of the reaction mixture between -10°C and -20°C. After the addition of 60 grams of the Grignard reagent the reaction was shown by HPLC analysis to be incomplete, but to contain the product 17 β -hydroxy-7 α -[9-[[1,1-dimethylethyl)dimethylsilyl]oxy]nonyl]-estr-4-en-3-one acetate, Cp 9295, with a 7 α /7 β ratio of 8.0:1. After complete addition and another hour of stirring, 4.5 grams of acetic acid was added, and stirring continued for 30 minutes at room temperature. The flask was then opened to the atmosphere and a solution of 7.5 grams of ammonium chloride in 80 grams of water was added and stirring was continued for 12 hours. The phases were separated and the upper phase was washed with a solution of 2 grams ammonium chloride in 10 grams of water. The upper phase was separated and the solvent evaporated under reduced pressure to provide oil (13.9 grams) with a 7 α /7 β ratio of 7.7: 1 by HPLC.

Example 6: Preparation of Cp 9331 from Cp 9294 (depicted in Figure 3)

10 grams of nandrolone acetate (6 dehydro 17 β hydroxy estro 4,6 diene 3 one acetate), Cp 9294, are dissolved in 60 grams of tetrahydrofuran and 1.5 grams of copper (I) chloride are added. The suspension is cooled under nitrogen atmosphere to -20°C, and 117 grams of a *ca.* 0.39M solution of 9-[(4,4,5,5,5-pentafluoropentyl)thio]nonyl magnesium bromide, Cp 9330, are added dropwise over 120 minutes. 10 grams of acetic acid are then added, and stirring continued for 30 minutes at room temperature. The flask is then opened to the atmosphere and a solution of 10 grams of ammonium chloride plus 15 grams of a 25% ammonium hydroxide solution in 73 grams of water are added and stirring is continued for 2 hours. The phases are separated and the upper phase is washed with a solution of 5 grams ammonium chloride in 37 grams of water. The upper phase is then separated and the solvent evaporated to provide an oily residue which is dissolved in dichloromethane (100 grams) and is further washed with 50 grams of water. Evaporation of the lower phase gives an oil containing 17 β -hydroxy-7 α -[9-[(4,4,5,5,5-

pentafluoropentyl)thio]nonyl]-estr-4-en-3-one acetate, Cp 9331, with a 7 α /7 β ratio of 9.1 : 1 by HPLC assay.

Example 7: Preparation of Cp 9341 from Cp 9295 - direct synthesis (depicted in Figure 4)

5 190 grams of crude Cp 9295 (17 β -hydroxy-7 α -[9-[[1,1-dimethylethyl)dimethylsilyl]oxy]nonyl]-estr-4-en-3-one acetate), prepared from 75 grams of 6-dehydronandrolone acetate using conditions of Example 4, are dissolved in 100 grams of acetonitrile and added to a suspension at 10 - 12°C of triphenylphosphine dibromide (prepared by addition of 140 grams of bromine to 240 grams of
10 triphenylphosphine in 1200 grams of acetonitrile). The temperature is allowed to rise to ambient temperature and after 0.5 hours conversion into Cp 9341 is complete by HPLC. The suspension is diluted with 1000 grams of toluene, neutralised with ca. 112 grams of ammonium hydroxide solution 25%, and the phases are separated. The upper (organic) phase is washed with water (100 g) and then evaporated to an oily residue. The residue is
15 taken up in toluene and stirred at 5–10°C in order to precipitate most of the triphenylphosphine oxide by-product. The by-product is filtered off and rinsed with toluene and the filtrate purified by chromatography on silica gel (1250 grams) eluting with toluene. Weight of pure Cp 9341 obtained: 87 g.

Example 7: Preparation of Cp 9341 from Cp 9295 - indirect synthesis (depicted in Figure 8)

20 190 grams of crude Cp 9295 (17 β -hydroxy-7 α -[9-[[1,1-dimethylethyl)dimethylsilyl]oxy]nonyl]-estr-4-en-3-one acetate), prepared from 75 grams of 6-dehydronandrolone acetate (Cp 9294) using conditions of Example 4, are dissolved in 750 grams of methanol and cooled to between 5°C and 10°C under nitrogen. The
25 solution is treated with a solution of hydrochloric acid 32% (15 g) in water (45 g) and kept at 5°C to 10°C for 30 - 60 minutes. The reaction mixture is neutralised by charging a solution of ammonium hydroxide solution 25% (15 g) in distilled apyrogenic water (45 g) and evaporated under vacuum to an oily residue. The residue was dissolved in dichloromethane, extracted with water, and evaporated to an oily residue. Weight of
30 crude Cp 9297 obtained: ca. 150 g.

The oily residue is dissolved in dichloromethane (975 g) and triethylamine (60 g), cooled to between 0°C and 5°C, and treated at this temperature with methanesulfonyl

chloride (48 g). The temperature of the reaction mixture is brought to between 20°C - 25°C and the mixture is stirred at this temperature for 30 to 60 minutes.

With starting material absent, a solution of sodium chloride (75 g) in water (1125 g) is added and the mixture stirred for 2 - 3 hours at room temperature. The phases are separated and the lower (organic) phase again extracted with a solution of sodium chloride (75 g) in water (1125 g). The lower (organic) phase is evaporated at atmospheric pressure to an oily residue. Weight of crude Cp 9326 obtained: ca. 175 g.

The oily residue is dissolved in acetonitrile (375 g) and lithium bromide (41.2 g) added. The mixture is heated at 55 - 60°C for 1.5 - 2 hours, and then evaporated under vacuum to an oily residue. The residue is dissolved in toluene (650 g) and the solution stirred at 35 to 40°C with a solution of sodium chloride (75 g) in water (1125 g) for 0.5 hours. The phases are separated and the upper (organic) phase is washed with water (375 g) and then evaporated to an oily residue. Weight of crude Cp 9341 obtained: ca. 165 g.

If required, the product may be further purified by chromatography on silica gel (1120 grams) eluting with toluene. Weight of pure Cp 9341 obtained: 95 g.

Example 9: Preparation of Cp 9342 by aromatization of Cp 9341 (depicted in Figure 6)

37 grams of Cp 9341 and 6.15 grams of lithium bromide are dissolved in 629 grams of acetonitrile and 18.5 grams of copper (II) bromide added. The mixture was stirred at ambient temperature for 7 hours, and then diluted with a solution of 74 grams of ammonium chloride in 942 grams of water. The mixture is further diluted with 37 grams of ammonium hydroxide solution 25% and 185 grams of ethyl acetate and left overnight under agitation in an open flask. The phases are separated and the upper (organic) phase is evaporated to an oily residue, which is dissolved in 500 grams of dichloromethane and washed with 370 grams of water. The phases are separated and the lower (organic) phase is evaporated to an oily residue. Weight of Cp 9342 obtained: 36.5 g

Example 10: Preparation of Cp 9354 from Cp 9342 (depicted in Figure 7)

To 61.7 grams of Cp 9342 in 494 grams of methanol was added 123.4 grams of hydrobromic acid 48% and the mixture was heated at 60°C for 0.8 hours. The mixture was slowly cooled to 5°C and seeded with a crystal of Cp 9354. After 1 hour the suspension was filtered and the crystals rinsed with a cold mixture of 100 grams methanol and 30 grams of water. After drying under vacuum at 60°C to constant weight, 46 grams of Cp 9354 were obtained.

Example 11: Preparation of Cp 9360

A solution of 70.5 grams of 4,4,5,5,5-pentafluoropentane-1-ol in 1330 grams of dichloromethane was cooled under nitrogen and diluted with 59 grams of triethylamine followed by 54.5 grams of methanesulfonyl chloride. The solution was kept at 20°C for 2 hours and then diluted with 1000 grams of water and agitated overnight. Evaporation of the organic phase afforded 109 grams of Cp 9360.

Example 12: Preparation of Cp 9304 from Cp 9342 via Cp 9361, Cp 9362 and Cp 9363 (depicted in Figure 8 and part of Figure 10)

29 grams of Cp 9342 are heated at 80°C for 16 hours in 198 grams of toluene and 99 grams of isopropanol with 5.3 grams (1.25 equivalents) of thiourea. The reaction mixture is evaporated under vacuum to an oily residue which is Cp 9361 that is diluted with 250 grams of dimethylacetamide, followed by combining with 13.7 g of Cp 9360 (prepared in example 11) and treating at room temperature for 1 hour with 22.3 grams of sodium hydroxide solution 50% to give Cp 9363. Hydrolysis of the 17-acetate group is this carried out by treatment at room temperature for 1 hour with a solution of 5 grams of potassium hydroxide in 45 grams of methanol. The reaction mixture is diluted with water and extracted with a mixture of toluene and ethyl acetate (1:1). Evaporation of the extracts afforded 36 grams of crude Cp 9304.

The crude product was purified by chromatography on silica gel (290 grams) eluting with toluene/ethyl acetate (95:5) to give 21 grams of pure Cp 9304.

Example 13: Preparation of Cp 9304 from Cp 9342 (depicted in Figure 10)

40 grams of Cp 9360 (prepared according to Example 11) were heated at 80°C for 16 hours with 14.8 grams of thiourea and 345 grams of dimethylacetamide to give 400 grams of a 10% solution of Cp 9383.

To 90.7 grams of the 10% solution of Cp 9383 was added a solution of 18.5 grams of Cp 9342 in 76 grams of dimethylacetamide and the mixture was cooled to room temperature and treated with 9 grams of sodium hydroxide solution 50% for 0.6 hours. After neutralisation with 15 grams of acetic acid, the reaction mixture was then poured into water and extracted with toluene. Evaporation of the organic phase afforded 30 grams of Cp 9363.

30 grams of Cp 9363 were dissolved in 185 grams of methanol under nitrogen and the solution treated for 4 hours at room temperature with a solution of 9.25 grams of

potassium hydroxide in methanol. After neutralization with 13.9 grams of acetic acid the mixture was evaporated under vacuum, then dissolved in dichloromethane, extracted with water and evaporated to provide crude Cp 9304.

The crude product is purified by chromatography on silica gel eluting with toluene/ethyl acetate (95: 5) to provide purified Cp 9304.

Example 14: Preparation of Cp 9304 from Cp 9354 - indirect process (depicted in Figure 9)

A mixture of 10 grams of Cp 9354 and 1.91 grams of thiourea in 100 grams of dimethylacetamide (to give Cp 9388) was heated at 80°C for 16 hours, cooled to 20 / 25°C and treated with 5.3 grams of Cp 9360 (prepared as in example 10) followed by 5.05 grams of sodium hydroxide solution 50%. After 1 hour the reaction mixture was neutralised with 7.5 grams of acetic acid, diluted with water, and extracted with toluene/ethyl acetate (1: 1). Evaporation of the organic phase under vacuum gave an oily residue of Cp 9304.

The crude product is purified by chromatography on silica gel eluting with toluene / ethyl acetate (95: 5) to provide ourified Cp 9304.

Example 15: Preparation of Cp 9304 from Cp 9354 - direct process (depicted in Figure 11)

To a solution of 20.5 grams of Cp 9354 in 100 grams of dimethylacetamide was added 109 grams of a 10% solution of Cp 9383 (prepared from Cp 9382 from example 10), followed by 10.3 grams of sodium hydroxide solution 50%. After 1 hour the reaction mixture was neutralised with 15 grams of acetic acid, diluted with water, and extracted with toluene / ethyl acetate (1:1). Evaporation of the organic phase under vacuum gave 30 grams of Cp 9304. The crude product was purified by chromatography on silica gel (250 grams) eluting with toluene/ethyl acetate (95:5) to give 25.3 grams of pure Cp 9304.

Example 16: Preparation of fulvestrant (Cp 9305) from Cp 9363 - indirect process (depicted in Figure 12)

A solution of 40.5 grams of Cp 9363 in 320 grams tetrahydrofuran and 81 grams methanol was cooled to 5°C and treated with a warm solution of 27 grams sodium (meta) periodate in 183 grams water. The mixture was allowed to stand at room temperature overnight, concentrated under vacuum and then dissolved in dichloromethane, extracted with water and evaporated to give 40 grams of Cp 9368 (fulvestrant 17-acetate).

The oily residue of Cp 9368 (40 grams) was dissolved in 320 grams of methanol under nitrogen and treated for 3 hours at room temperature with a solution of 20 grams of potassium hydroxide in 128 grams methanol. After neutralisation with 30 grams of acetic acid, the reaction mixture was concentrated under vacuum and then dissolved in dichloromethane, extracted with water and evaporated. The oily residue was crystallised from 400 grams of toluene, then dried under vacuum to constant weight. 26.6 grams of fulvestrant were obtained.

Example 17: Preparation of fulvestrant (Cp 9305) from Cp 9304 - direct process (depicted in Figure 9)

A solution of 41 grams of Cp 9304 in 328 grams tetrahydrofuran and 82 grams methanol was cooled to 5°C and treated with a warm solution of 27 grams sodium (meta)periodate in 185 grams water. The mixture was allowed to stand at room temperature overnight, concentrated under vacuum and then dissolved in dichloromethane, extracted with water, evaporated, and crystallised from toluene to give 28 grams of Cp 9305 (fulvestrant). Further purification can be effected by recrystallisation from ethyl acetate.

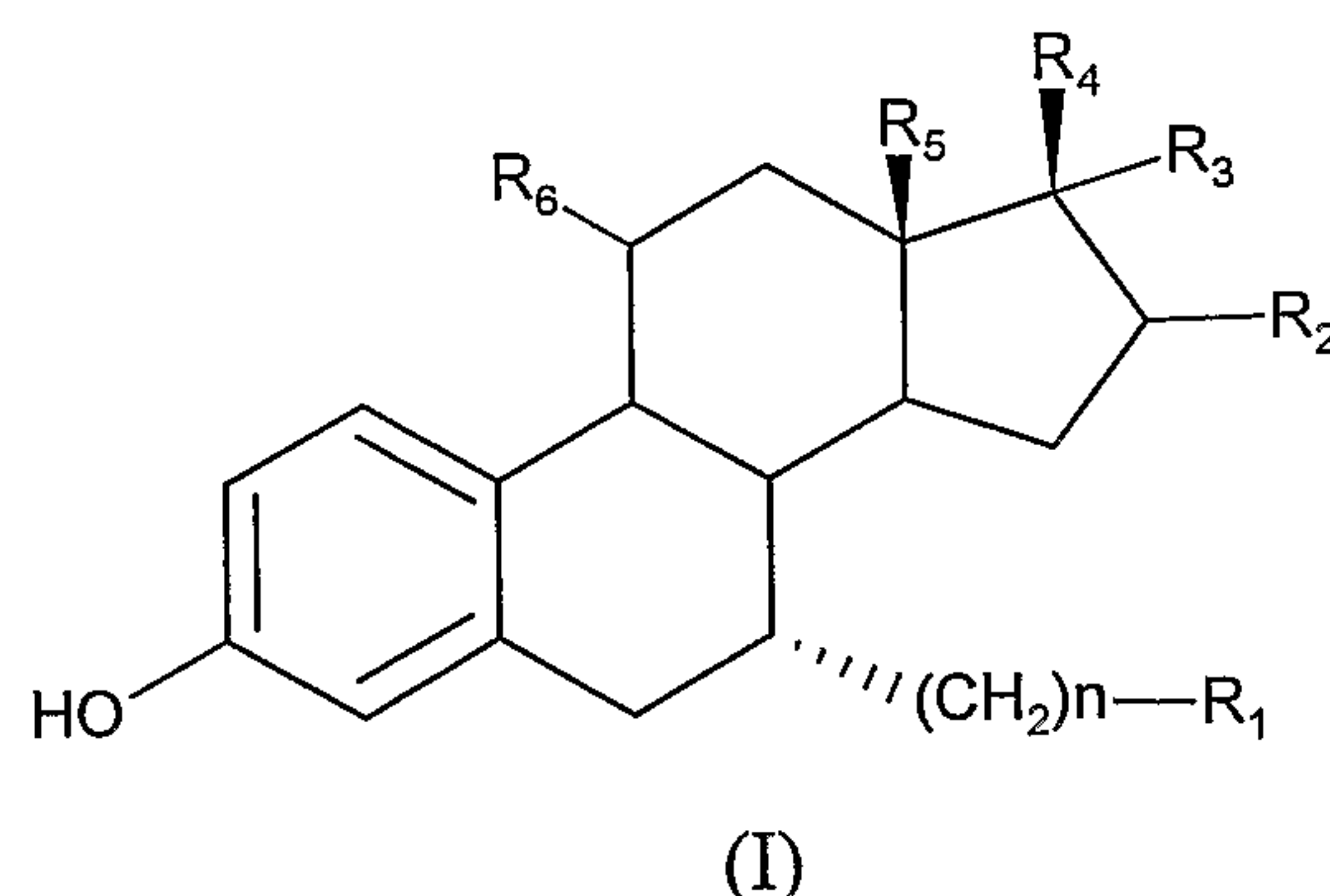
The present invention is not to be limited in scope by the specific embodiments disclosed in the examples which are intended as illustrations of a few aspects of the invention and any embodiments that are functionally equivalent are within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art and are intended to fall within the scope of the appended claims.

A number of references have been cited, the entire disclosure of which are incorporated herein by reference.

CLAIMS

WE CLAIM:

1. A compound of formula (I):



10 wherein

n is an integer ranging from 3 to 14,

R₁ is selected from the group consisting of Br, Cl, I, free base or a salt form of isothiuronium, or SH;

R₂ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo;

15 R₃ is either hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl, or C₂₋₆ alkynyl;

R₄ is either hydroxy, or a C₁₋₆ acyloxy;

R₅ is C₁₋₆ alkyl; and

R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo.

2. The compound of claim 1, wherein n is 9, R₁ is Br, R₂, R₃, and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl.

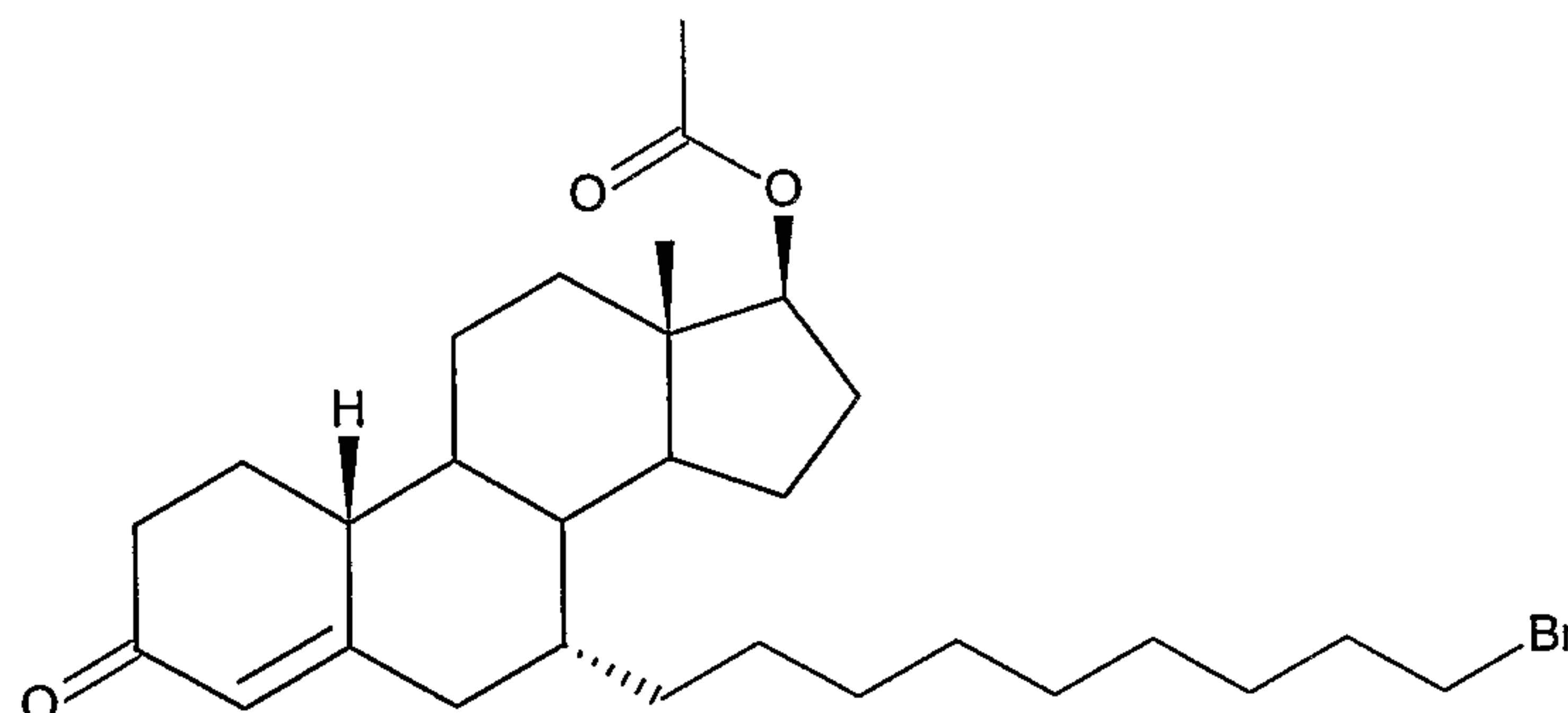
3. The compound of claim 1, wherein n is 9, R₁ is Br, R₂, R₃, and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

4. The compound of claim 1, wherein n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃, and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

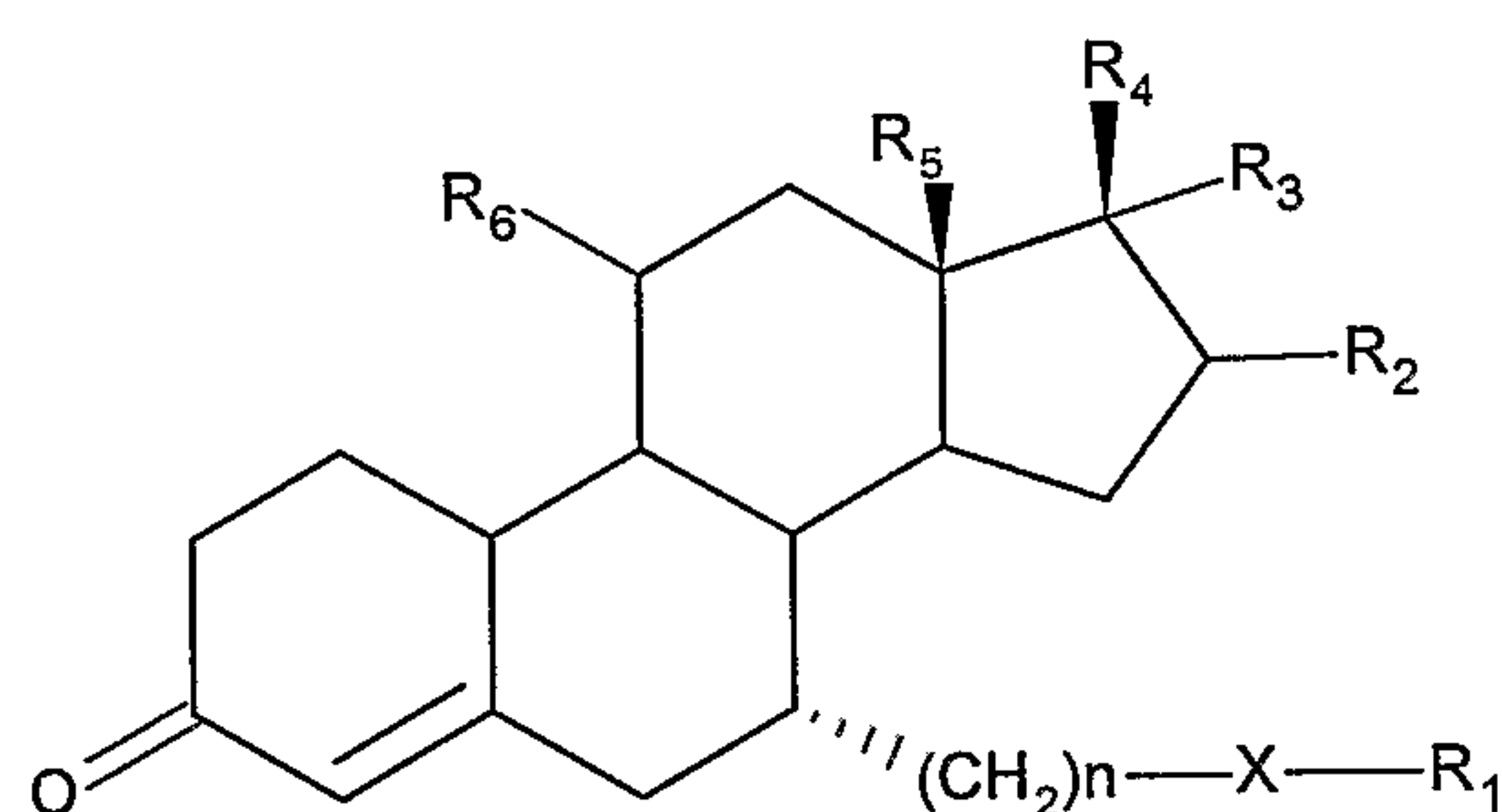
- 25 5. The compound of claim 1, wherein n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃, and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl.

6. The compound of claim 1, wherein n is 9, R₁ is SH, R₂, R₃, and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

7. The compound of claim 1, wherein n is 9, R₁ is SH, R₂, R₃, and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl.
8. A compound of formula



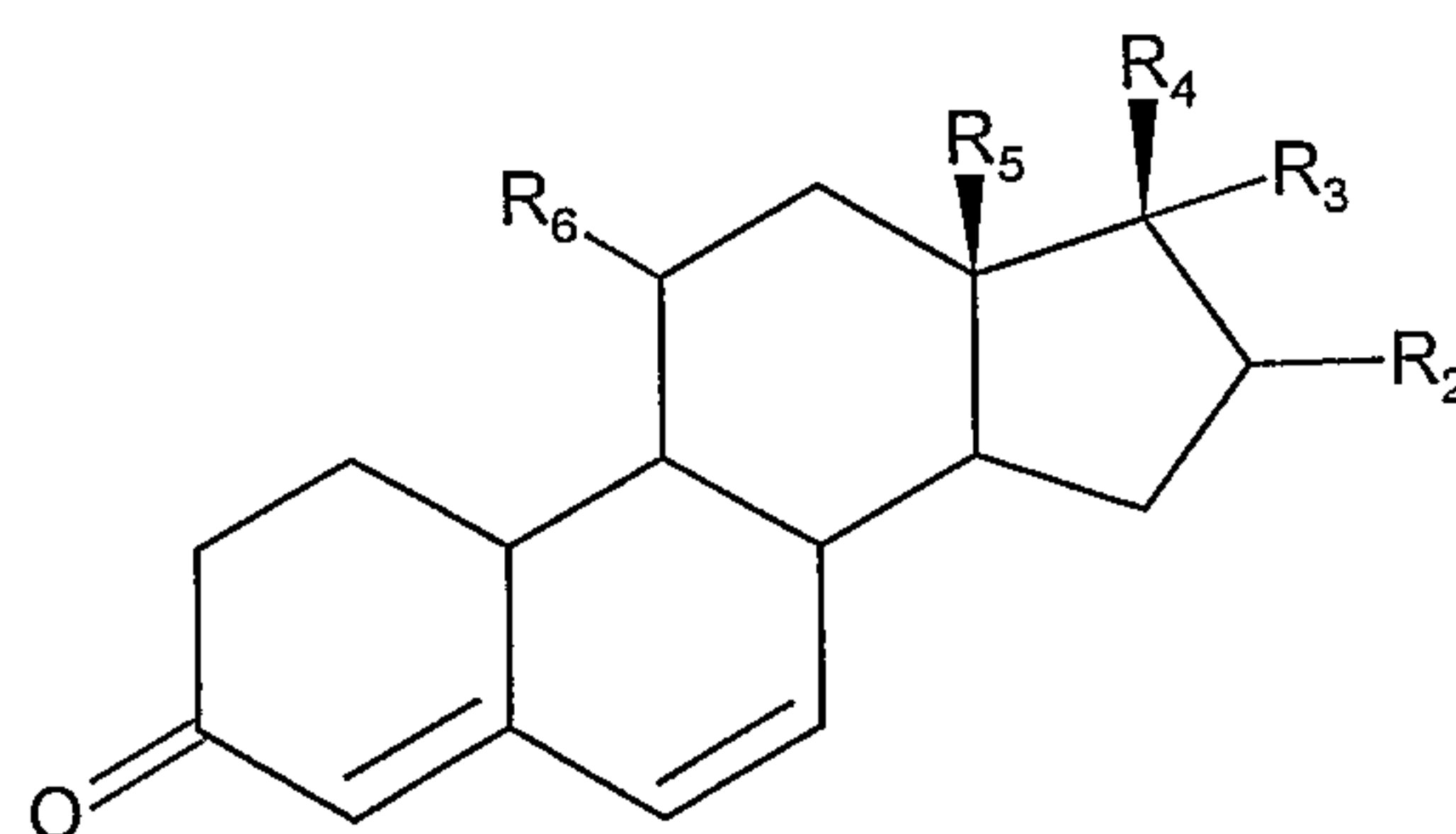
9. A process for preparing the compound of formula (II),



(II)

comprising:

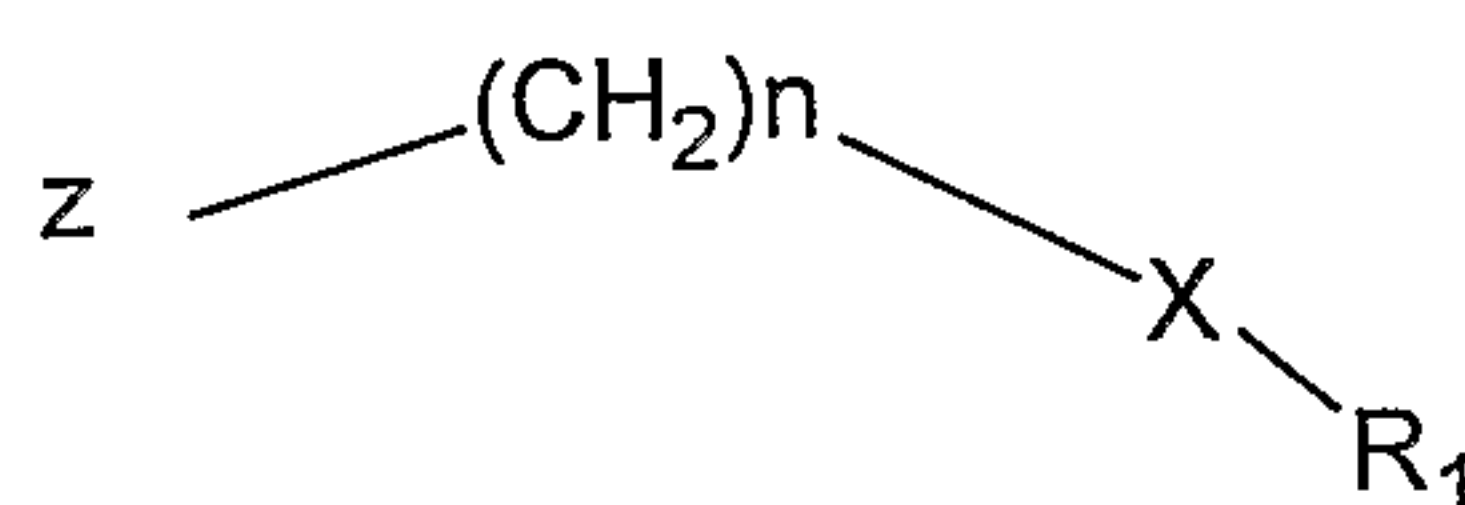
- c) combining a 19-nor-androsta-4,6-diene-3-one of formula (III)



(III)

- d) cooling the solution to a temperature of about -60°C to about 30°C;

- e) adding to the solution of step b), in a drop-wise manner, a solution of the compound of formula (IV)



f) (IV)

in an ethereal solvent to obtain a reaction mixture;

- f) quenching the reaction mixture; and
g) recovering the compound of formula (II);

wherein

n is an integer ranging from 3 to 14,

X is either O or S;

R₁ is a C₁₋₁₀ haloalkyl or a hydroxy protecting group;

R₂ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo;

R₃ is either hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl, or C₂₋₆ alkynyl;

R₄ is a C₁₋₆ acyloxy;

R₅ is C₁₋₆ alkyl; and

R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo; and

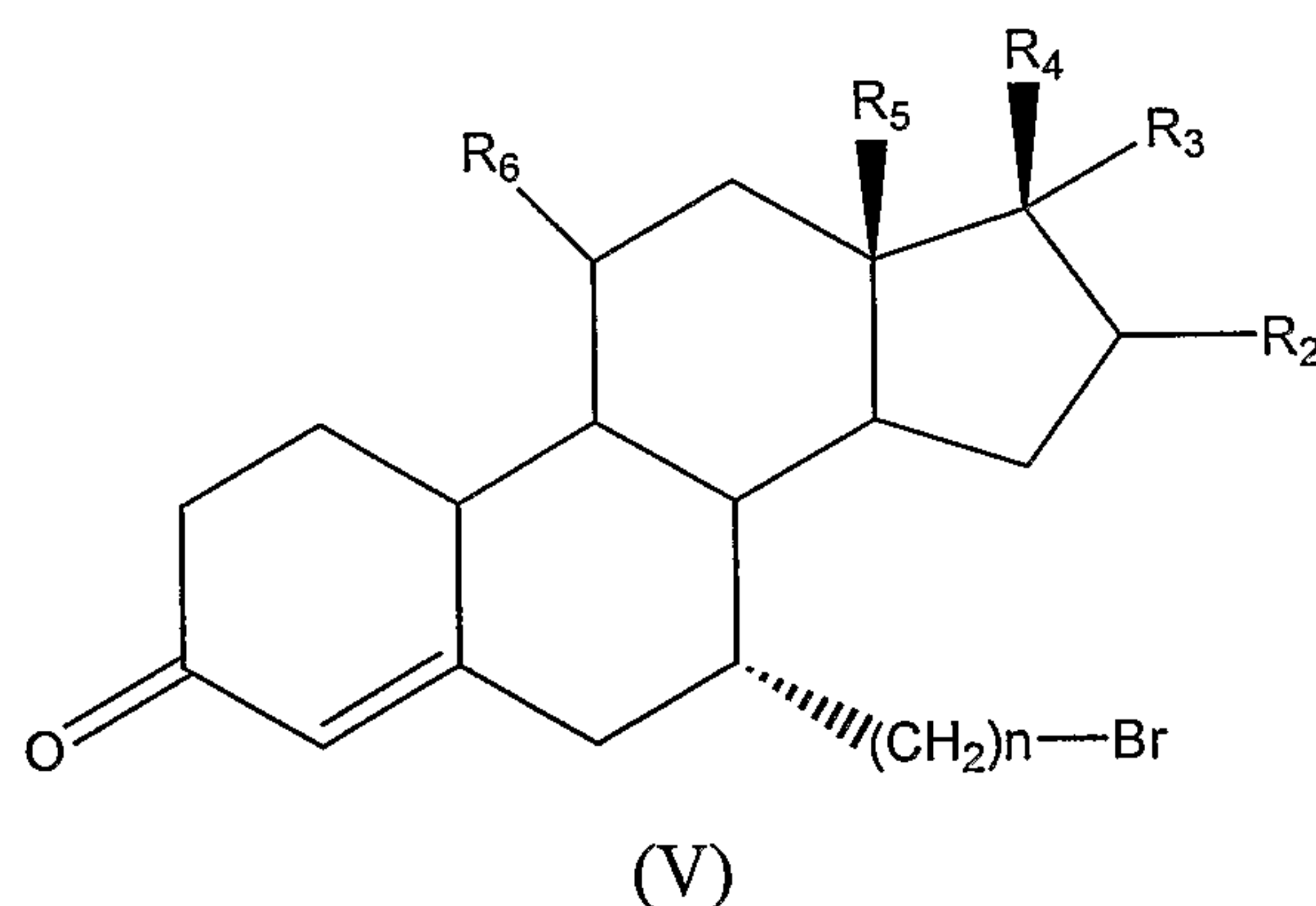
z is a metal halide of the formula R₇M, wherein

M is a metal atom; and

R₇ is a halogen atom.

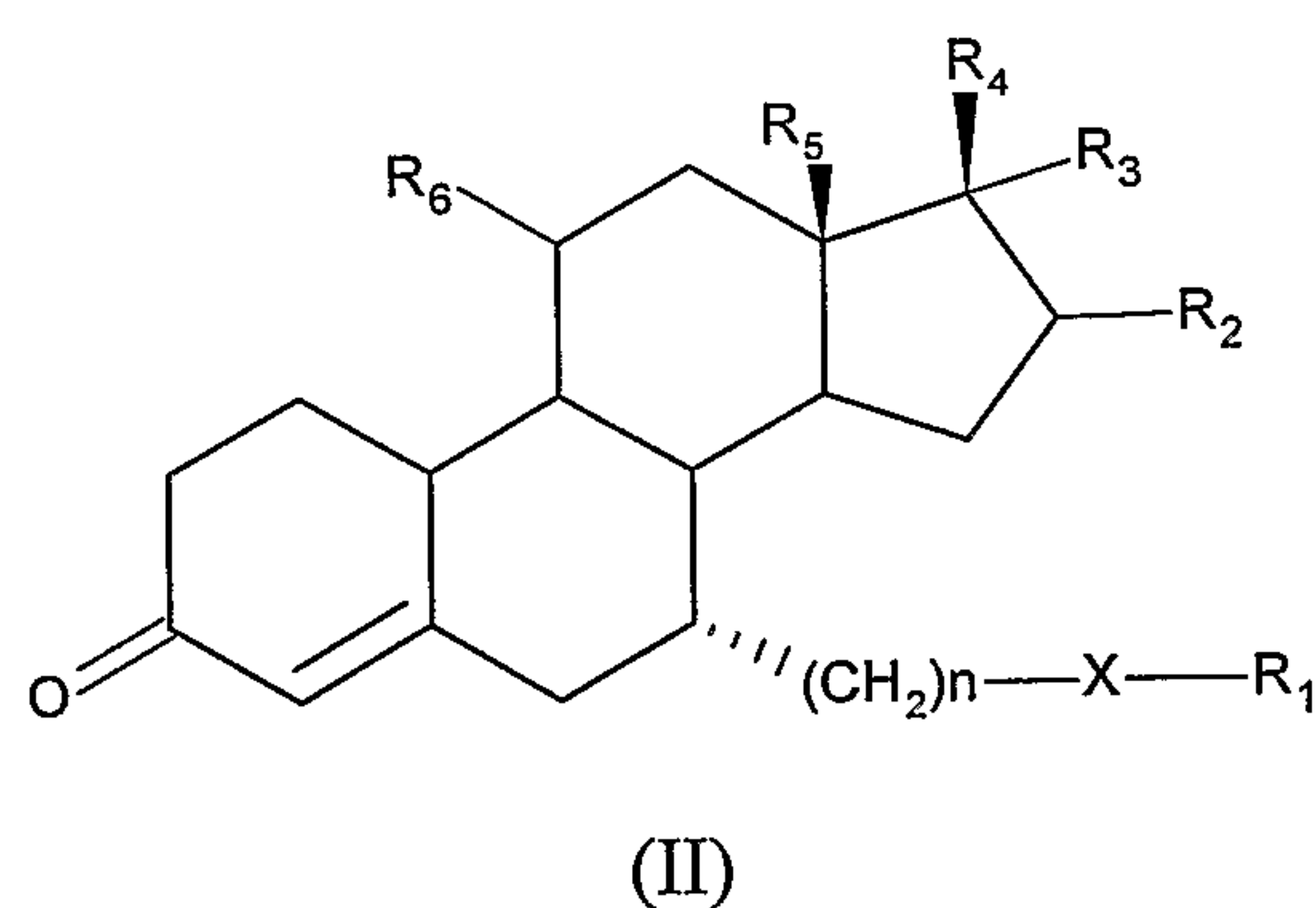
10. The process of claim 9, wherein n is 9, X is O, R₁ is tertbutyl-dimethylsilyl (TBDMS), R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.
11. The process of claim 9, wherein n is 5, X is O, R₁ is TBDMS, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.
12. The process of claim 9, wherein n is 9, X is S, R₁ is $-(\text{CH}_2)_3\text{CF}_2\text{CF}_3$, R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.
13. The process of claim 9, wherein M is a metal atom selected from the group consisting of magnesium, zinc, aluminum, copper, copper-lithium and titanium.
14. The process of claim 13, wherein M is magnesium.

15. The process of claim 9, wherein R₇ is selected from the group consisting of Cl, Br and I.
16. The process of claim 15, wherein R₇ is Br.
17. The process of claim 14, wherein a copper catalyst is a combined in step a) with the
5 19-nor-androsta-4,6-diene-3-one of formula (III) and the ethereal solvent.
18. The process of claim 17, wherein said copper catalyst is in the form of Cu(I)Y, wherein Y is Cl, Br or I.
19. The process of claim 18, wherein said copper catalyst is Cu(I)Cl.
20. The process of claim 9, wherein the compound of formula (II) obtained in step e)
10 has a ratio of 7 α -to 7 β -epimer of about 2.5:1 to about 12.1:1.
21. The process of claim 20, wherein the compound of formula (II) obtained in step e) has a ratio of 7 α -to 7 β -epimer of about 12.1:1.
22. The process of claim 9, wherein the ethereal solvent in step a) is selected from the group consisting of: diethyl ether, THF and glyme.
- 15 23. The process of claim 22, wherein said ethereal solvent is THF.
24. The process of claim 9, wherein the solution of step b) is cooled to a temperature of about -20°C to about -10°C.
25. The process of claim 9, wherein the reaction mixture in step d) is quenched by one of the reagents selected from the group consisting of: NH₄Cl, HCl, water, acetic
20 acid and a mixture of NH₄Cl with NH₄OH.
26. The process of claim 25, wherein the reaction mixture is quenched with acetic acid.
27. The process of claim 9, further comprising converting the compound of formula (II) obtained in step e) to fulvestrant.
28. A process for preparing the compound of formula (V),



comprising combining a compound of formula (II)

5



10 with acetonitrile and triphenylphosphine dibromide for a sufficient amount of time
for conversion into the compound of formula (V);
wherein

n is an integer ranging from 3 to 14,

X is O;

15 R₁ is a hydroxy protecting group;

R₂ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo;

R₃ is either hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl, or C₂₋₆ alkynyl;

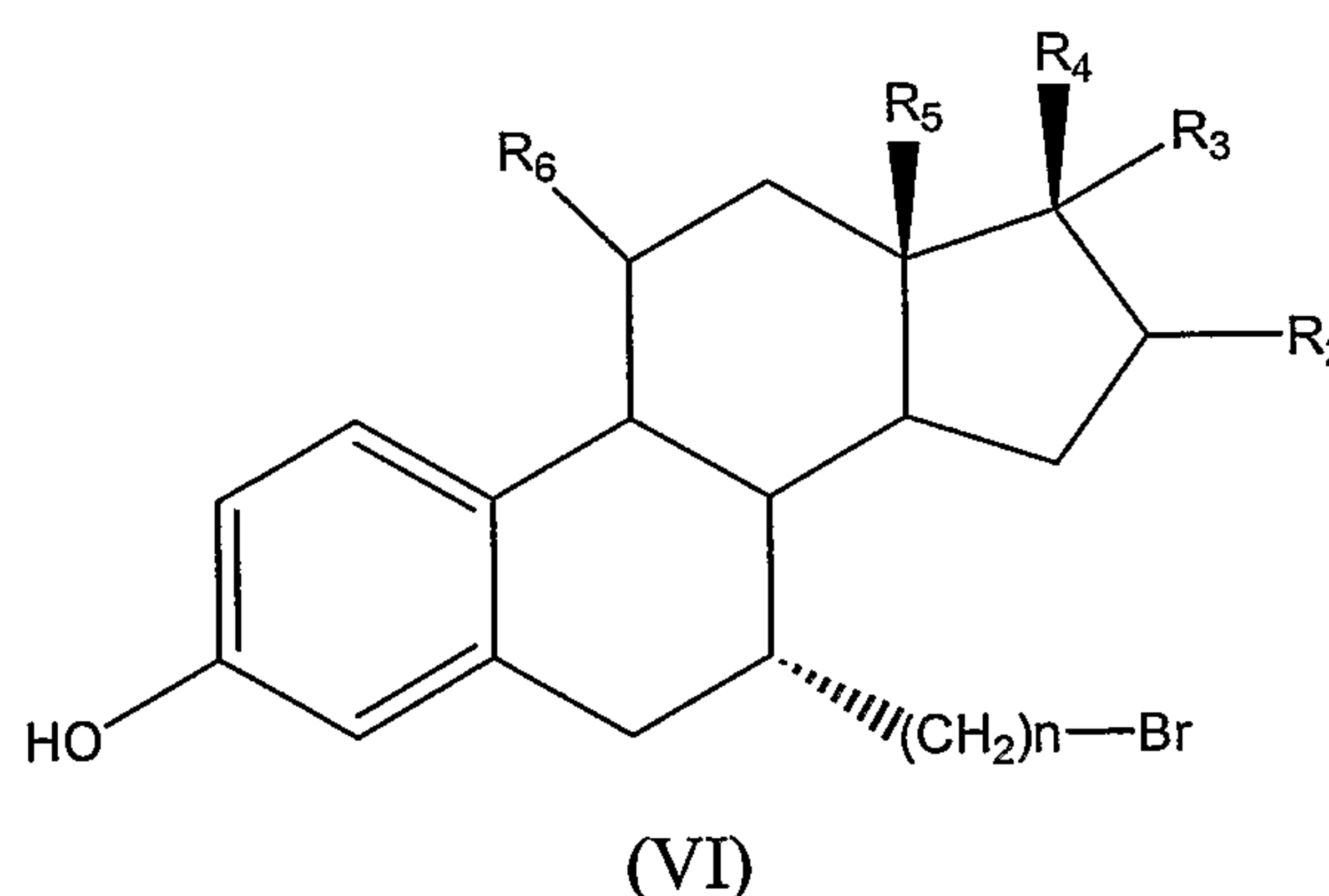
R₄ is a C₁₋₆ acyloxy;

R₅ is C₁₋₆ alkyl; and

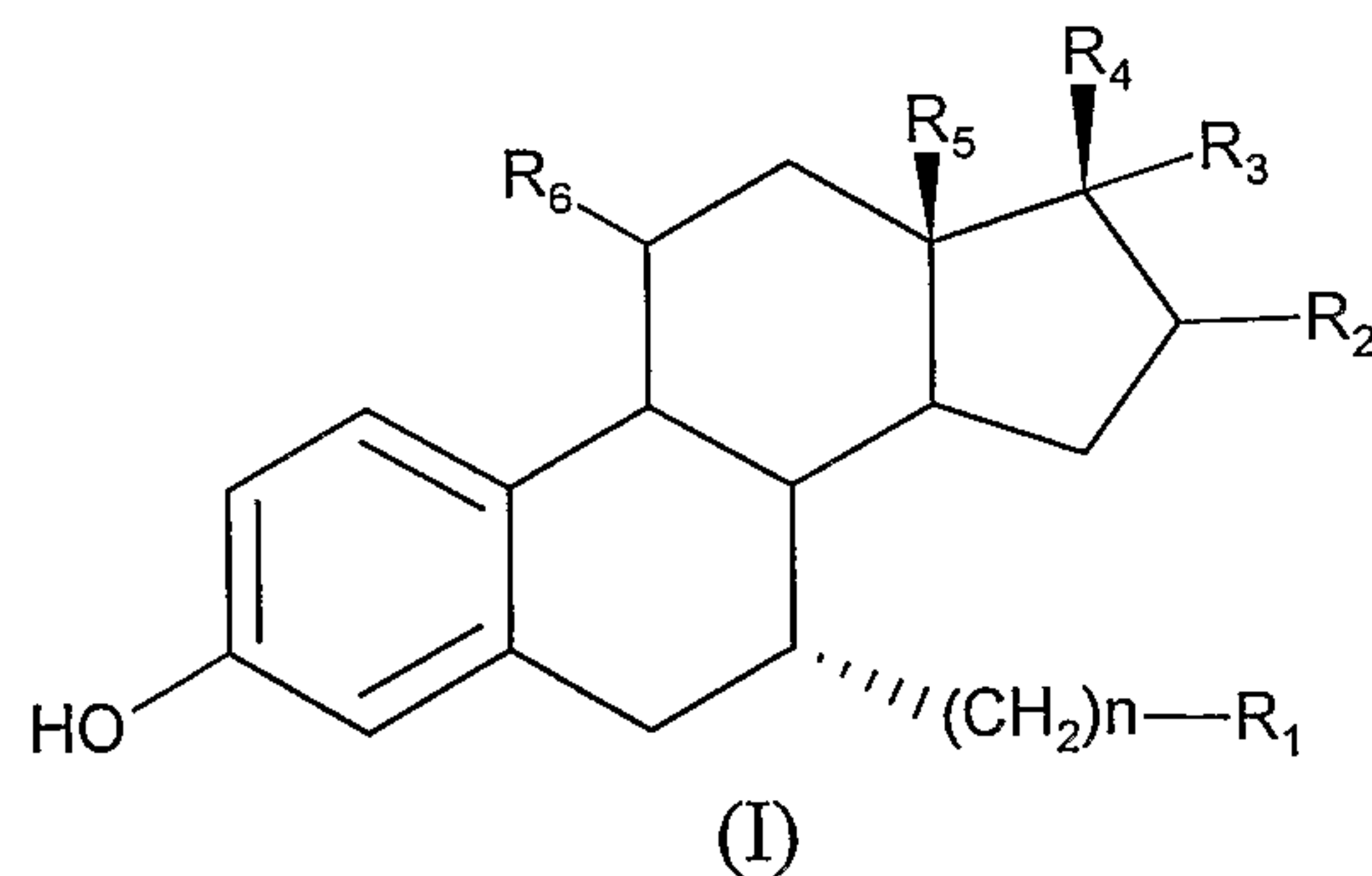
20 R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo.

29. The process of claim 28, wherein n is 9, R₁ is tertbutyl-dimethylsilyl (TBDMS), R₂,
R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

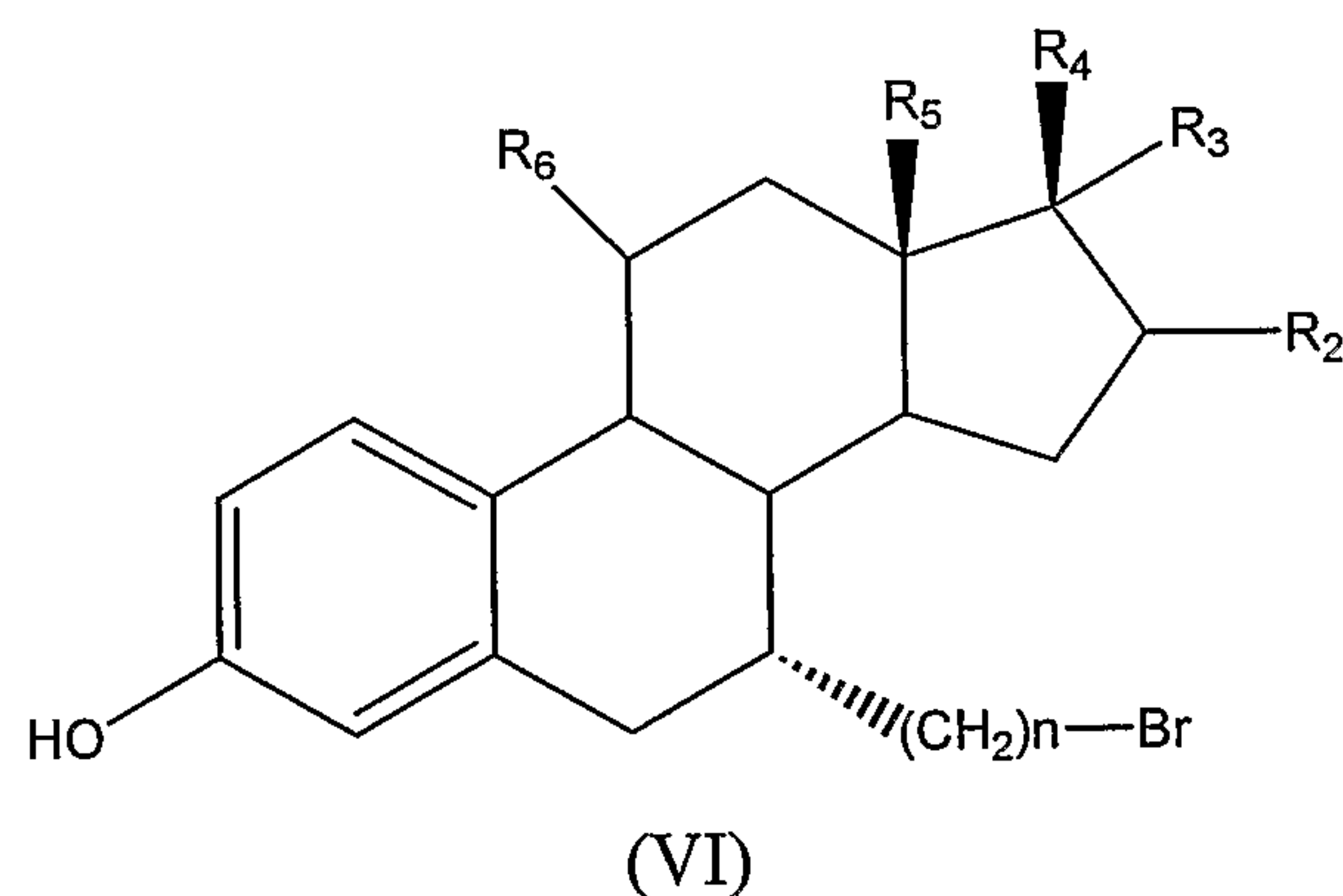
30. The process of claim 28, wherein the compound of formula (II) is combined with the acetonitrile and triphenylphosphine dibromide at a temperature of about 10°C to about 12°C.
31. The process of claim 28, further comprising converting the obtained product to
5 fulvestrant.
32. A process for preparing the compound of formula (VI)



- 10 wherein R_4 is hydroxy, comprising
combining the compound of formula (VI), wherein R_4 is a C_{1-6} acyloxy, with a C_{1-6}
alcohol and mineral acid, at a temperature of about 50°C to about 70°C;
wherein
- n is an integer ranging from 3 to 14,
- 15 R_2 is either hydrogen, C_{1-6} alkyl, hydroxyl, protected hydroxy, or halo;
 R_3 is either hydrogen, C_{1-6} alkyl, C_{2-6} alkenyl, or C_{2-6} alkynyl;
 R_5 is C_{1-6} alkyl; and
 R_6 is either hydrogen, C_{1-6} alkyl, hydroxyl, protected hydroxy, or halo.
33. The process of claim 32, wherein R_2 , R_3 and R_6 are hydrogens, and R_5 is methyl.
- 20 34. The process of claim 32, wherein the mineral acid is HBr.
35. The process of claim 32, wherein the temperature is about 60°C.
36. The process of claim 32, further comprising converting the obtained product to
fulvestrant.
37. A process for preparing the compound of the formula (I)



comprising combining the compound of formula (VI)



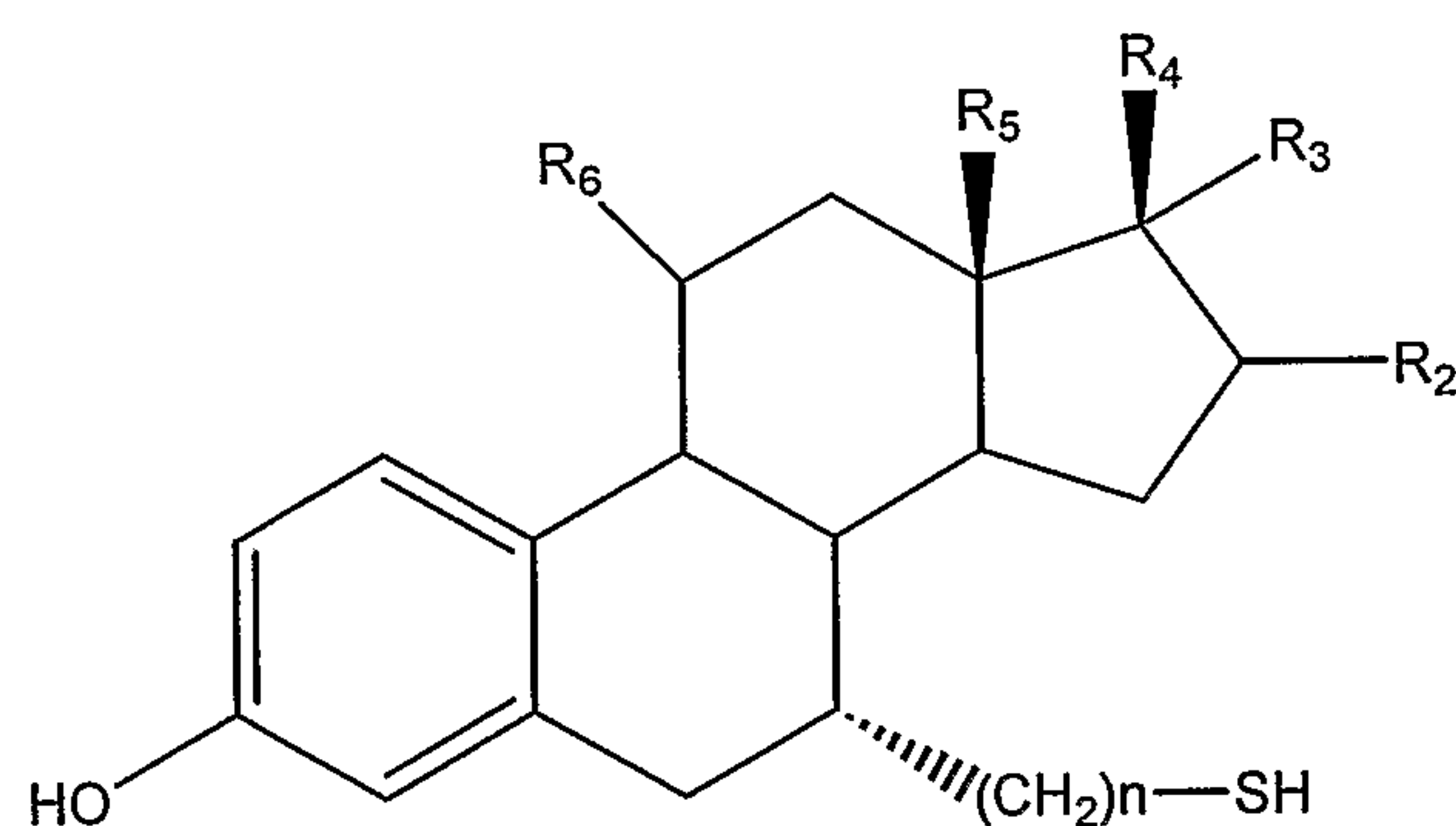
with a solvent selected from a C₁₋₆ aromatic hydrocarbon, a straight or branched C₁₋₄ alcohol, a C₁₋₄ alkyl amide and mixtures thereof and thiourea; and recovering the compound of formula (I) wherein

- 15 n is an integer ranging from 3 to 14,
 R₁ is a free base or a salt form of isothiuronium;
 R₂ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo;
 R₃ is either hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl, or C₂₋₆ alkynyl;
 R₄ is either hydroxy or C₁₋₆ acyloxy;
 20 R₅ is C₁₋₆ alkyl; and
 R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo.

38. The process of claim 37, wherein n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

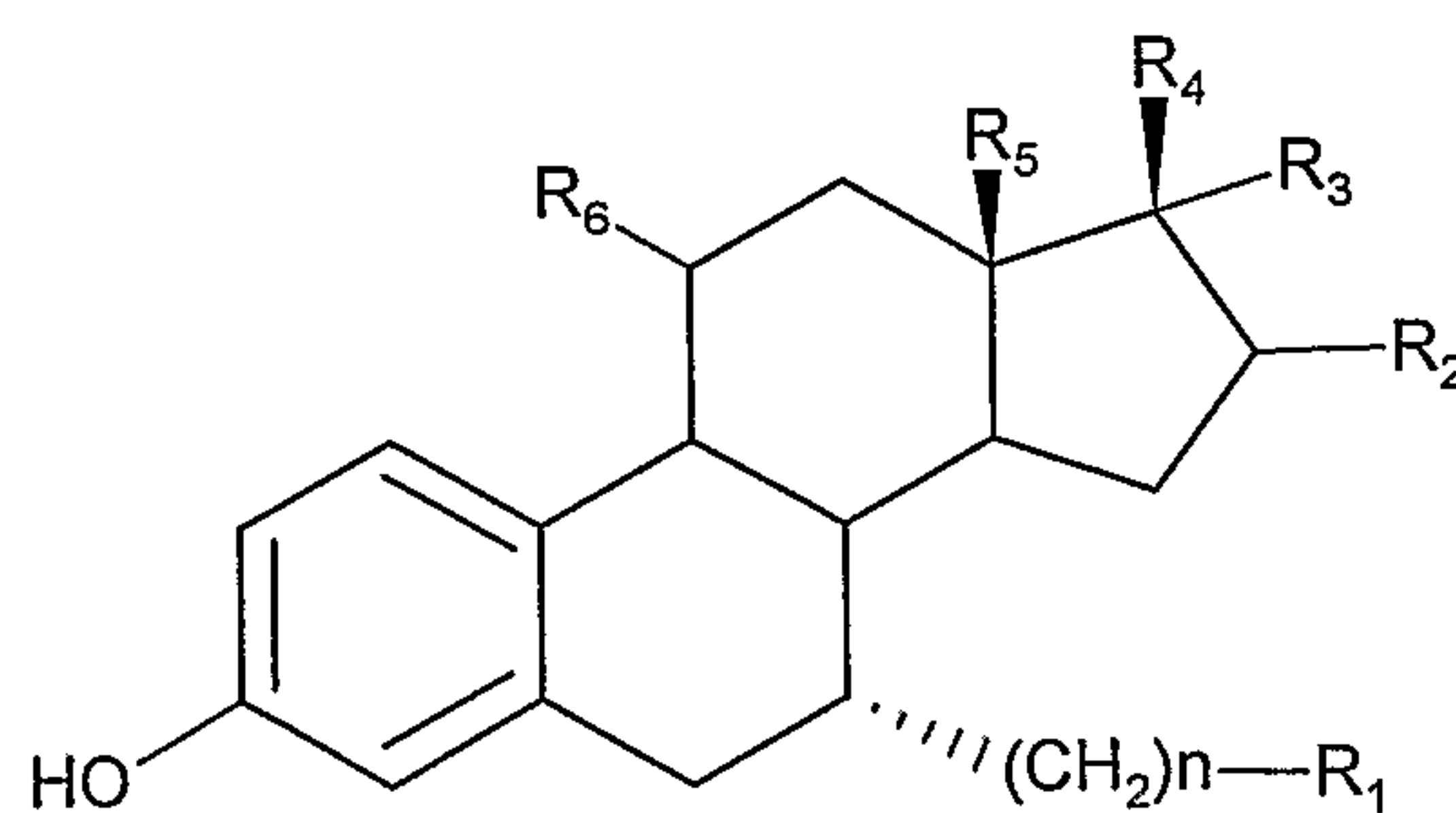
39. The process of claim 37, wherein n is 9, R₁ is a hydrobromide salt of isothiuronium, R₂, R₃ and R₆ are hydrogens, R₄ is hydroxy and R₅ is methyl.

40. The process of claim 37, wherein the solvent is selected from the group consisting of toluene, xylene, benzene, methanol, ethanol, propanol, isopropanol, butanol, dimethylacetamide and mixtures thereof.
41. The process of claim 37, wherein the solvent is a mixture of toluene and isopropanol or dimethylacetamide.
42. The process of any one of claims 38 and 39, further comprising converting the obtained product to fulvestrant.
43. A process for preparing the compound of the formula (VII)



(VII)

comprising combining compound of the formula (I)



(I)

with a base in the presence of an apolar protic organic solvent at ambient temperature;

wherein

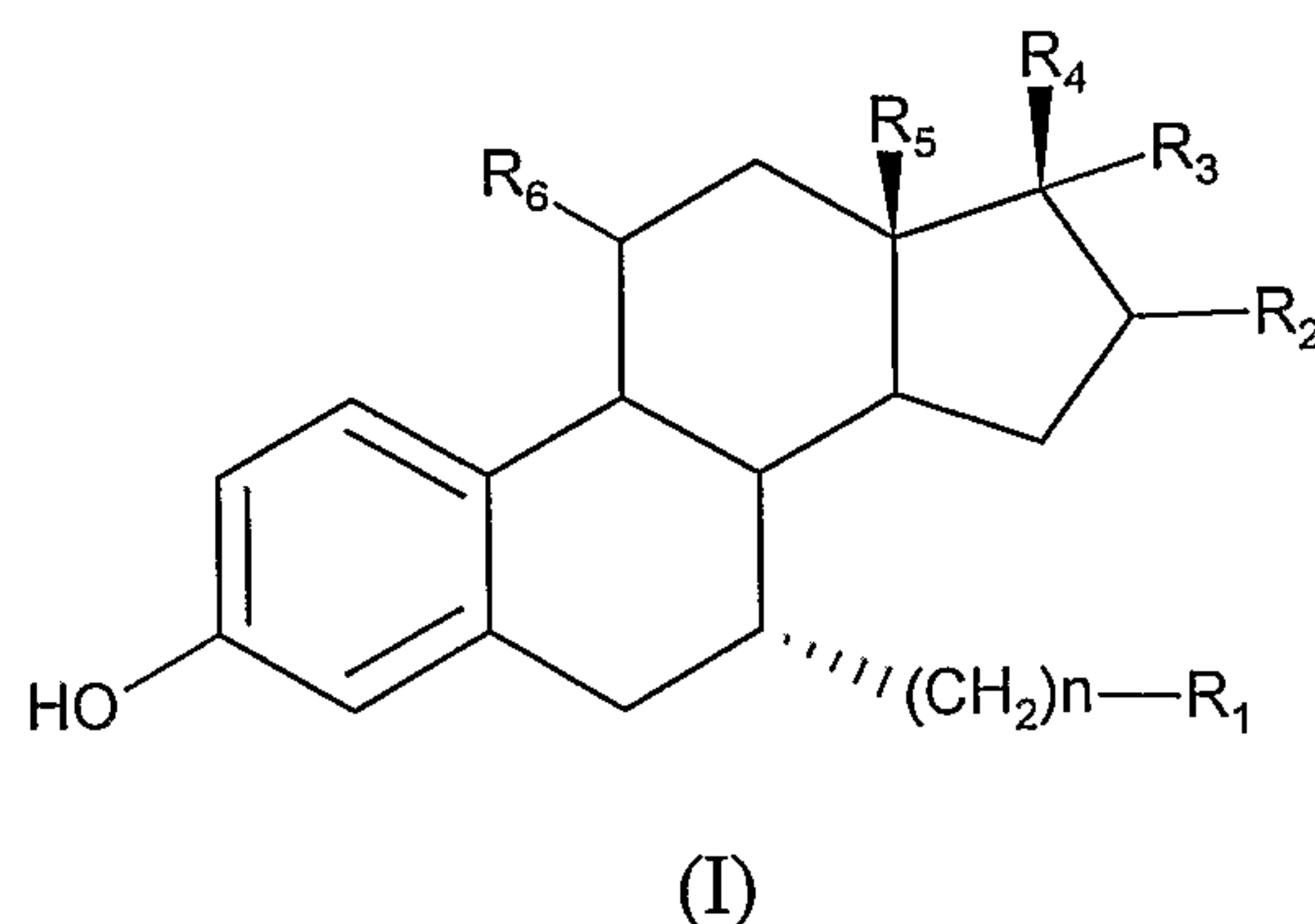
n is an integer ranging from 3 to 14,

R_1 is a free base or a salt form of isothiuronium;

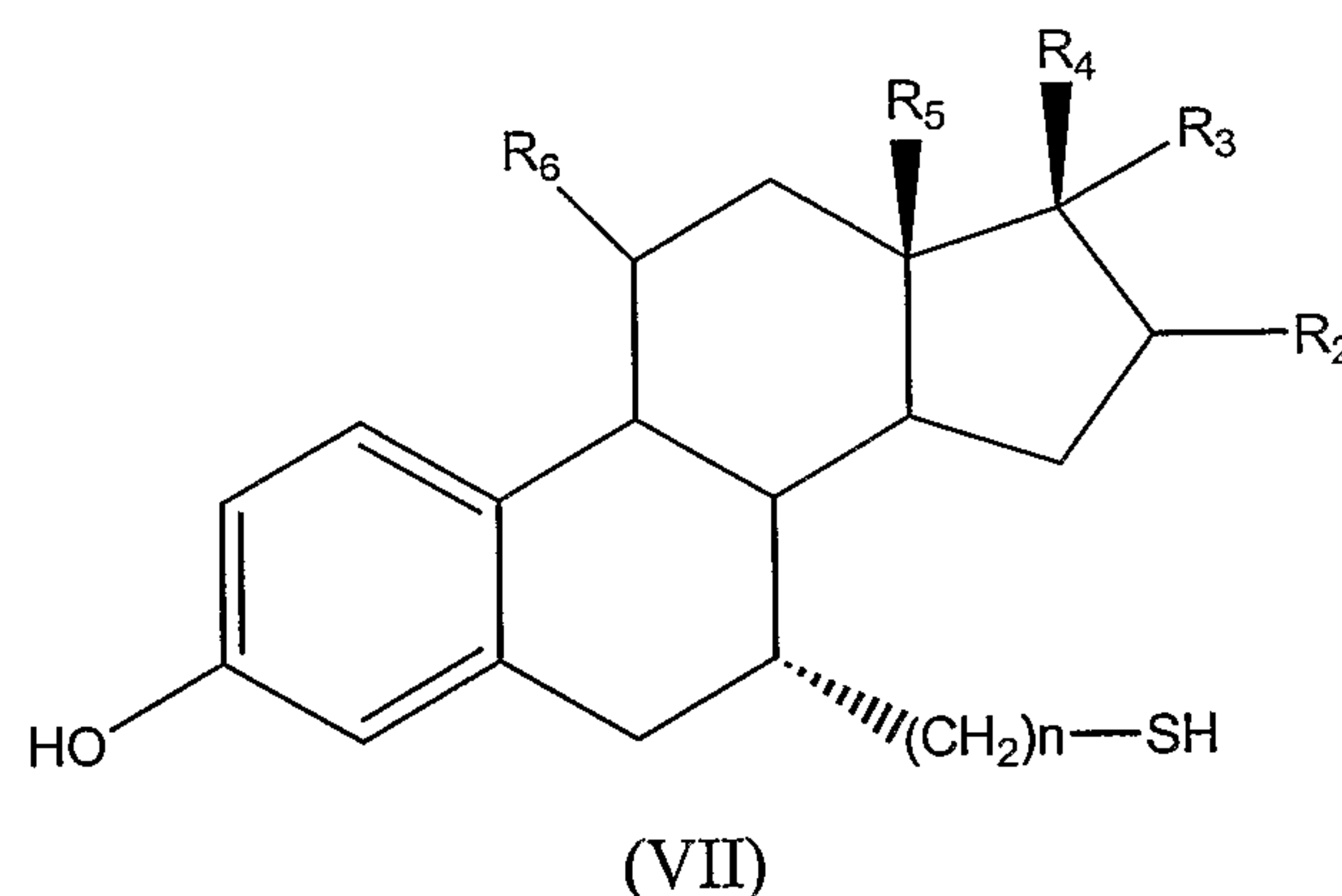
R_2 is either hydrogen, C_{1-6} alkyl, hydroxyl, protected hydroxy, or halo;

R_3 is either hydrogen, C_{1-6} alkyl, C_{2-6} alkenyl, or C_{2-6} alkynyl;
 R_4 is either hydroxy or C_{1-6} acyloxy;
 R_5 is C_{1-6} alkyl; and
 R_6 is either hydrogen, C_{1-6} alkyl, hydroxyl, protected hydroxy, or halo.

- 5 44. The process of claim 43, wherein n is 9, R_1 is a hydrobromide salt of isothiuronium, R_2 , R_3 and R_6 are hydrogens, R_4 is acetyloxy and R_5 is methyl.
45. The process of claim 43, wherein n is 9, R_1 is a hydrobromide salt of isothiuronium, R_2 , R_3 and R_6 are hydrogens, R_4 is hydroxy and R_5 is methyl.
46. The process of claim 43, wherein the base is an alkali metal base.
- 10 47. The process of claim 43, wherein the base is NaOH.
48. The process of claim 43, wherein the aprotic polar organic solvent is dimethylacetamide or acetonitrile.
49. The process of claim 48, wherein said aprotic polar organic solvent is dimethylacetamide.
- 15 50. The process of any one of claims 44 and 45 further comprising converting the obtained product to fulvestrant.
51. A process for preparing the compound of the formula (I)



comprising combining the compound of formula (VII)



with 4,4,5,5,5-pentafluoropentane-1-ol mesylate at an ambient temperature;
 5 combining the obtained reaction mixture with a base in the presence of an organic solvent; and recovering the compound of the formula (I);
 wherein

n is an integer ranging from 3 to 14,

R₁ is -S-(CH₂)₃CF₂CF₃

10 R₂ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo;

R₃ is either hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl, or C₂₋₆ alkynyl;

R₄ is either hydroxy or C₁₋₆ acyloxy;

R₅ is C₁₋₆ alkyl; and

R₆ is either hydrogen, C₁₋₆ alkyl, hydroxyl, protected hydroxy, or halo.

15 52. The process of claim 51, wherein n is 9, R₂, R₃ and R₆ are hydrogens, R₄ is a acetyloxy and R₅ is methyl.

53. The process of claim 51, wherein n is 9, R₂, R₃ and R₆ are hydrogens, R₄ is acetyloxy and R₅ is methyl.

54. The process of claim 51, wherein the base is an alkali metal base.

20 55. The process of claim 51, wherein the base is KOH.

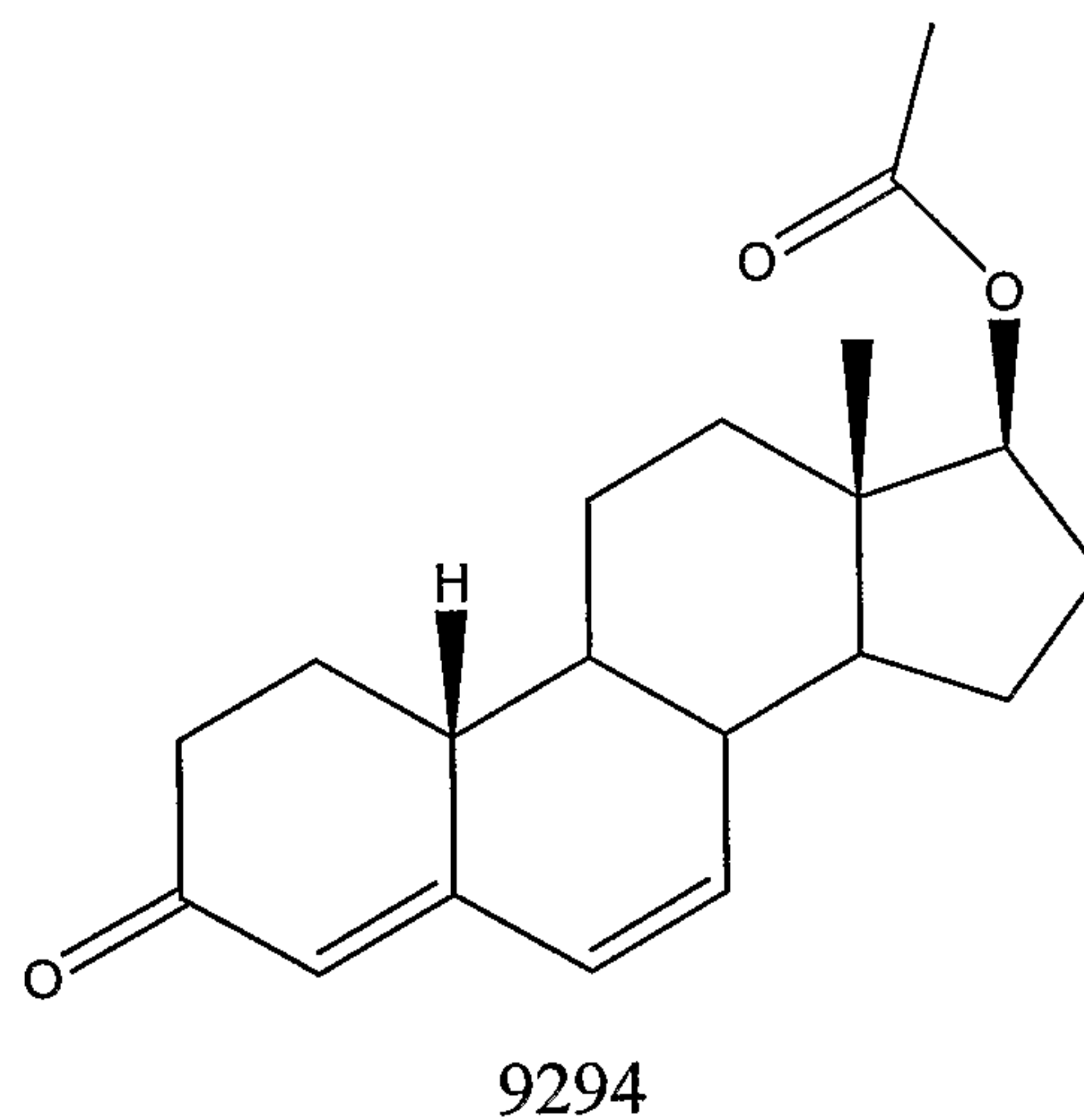
56. The process of claim 51, wherein the organic solvent is a C₁₋₆ alcohol.

57. The process of claim 51, wherein the organic solvent is methanol.

58. The process of any one of claims 52 and 53, further comprising converting the obtained product to fulvestrant.

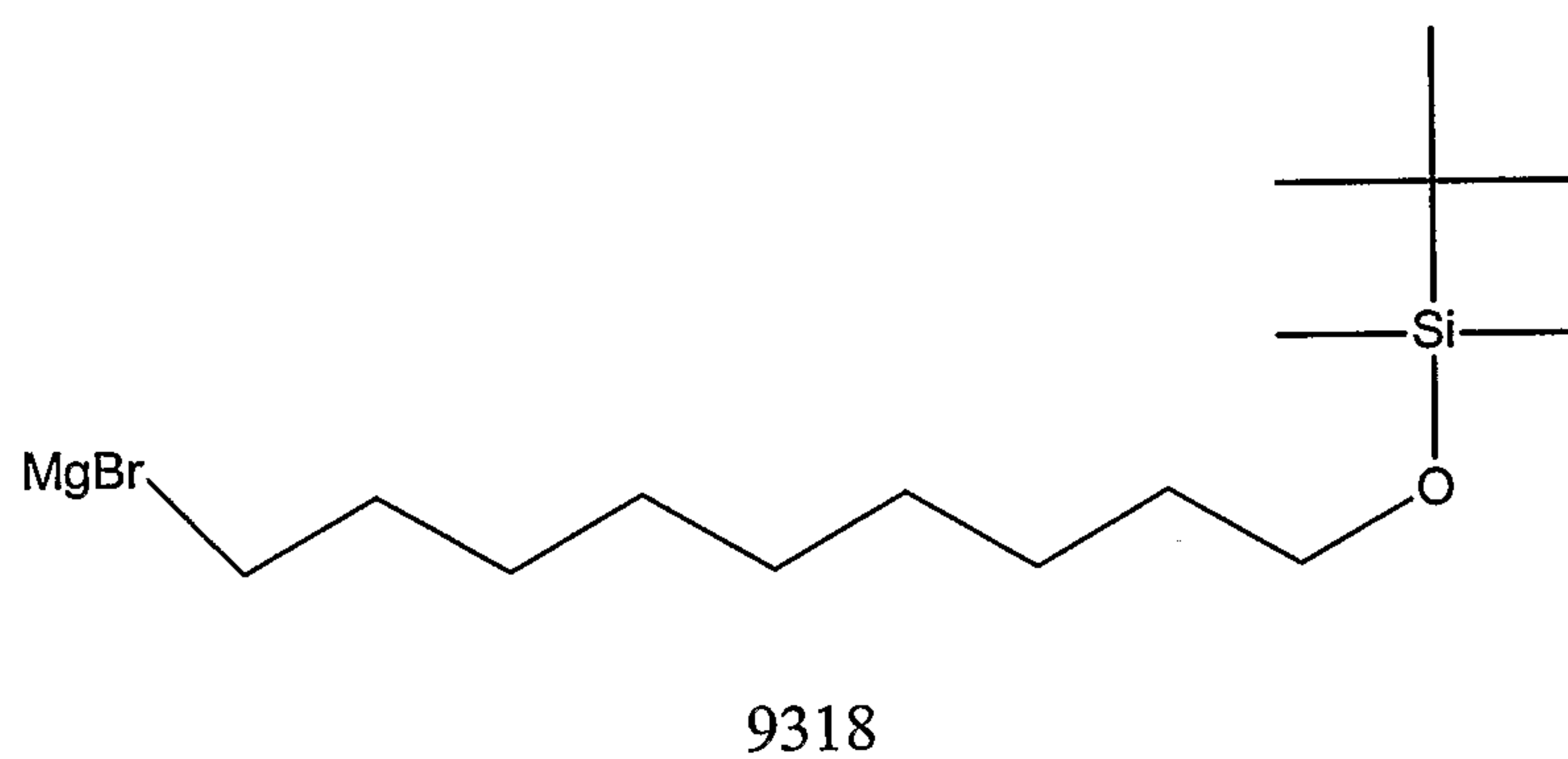
59. A process for preparing fulvestrant comprising:

a) combining compound of formula 9294

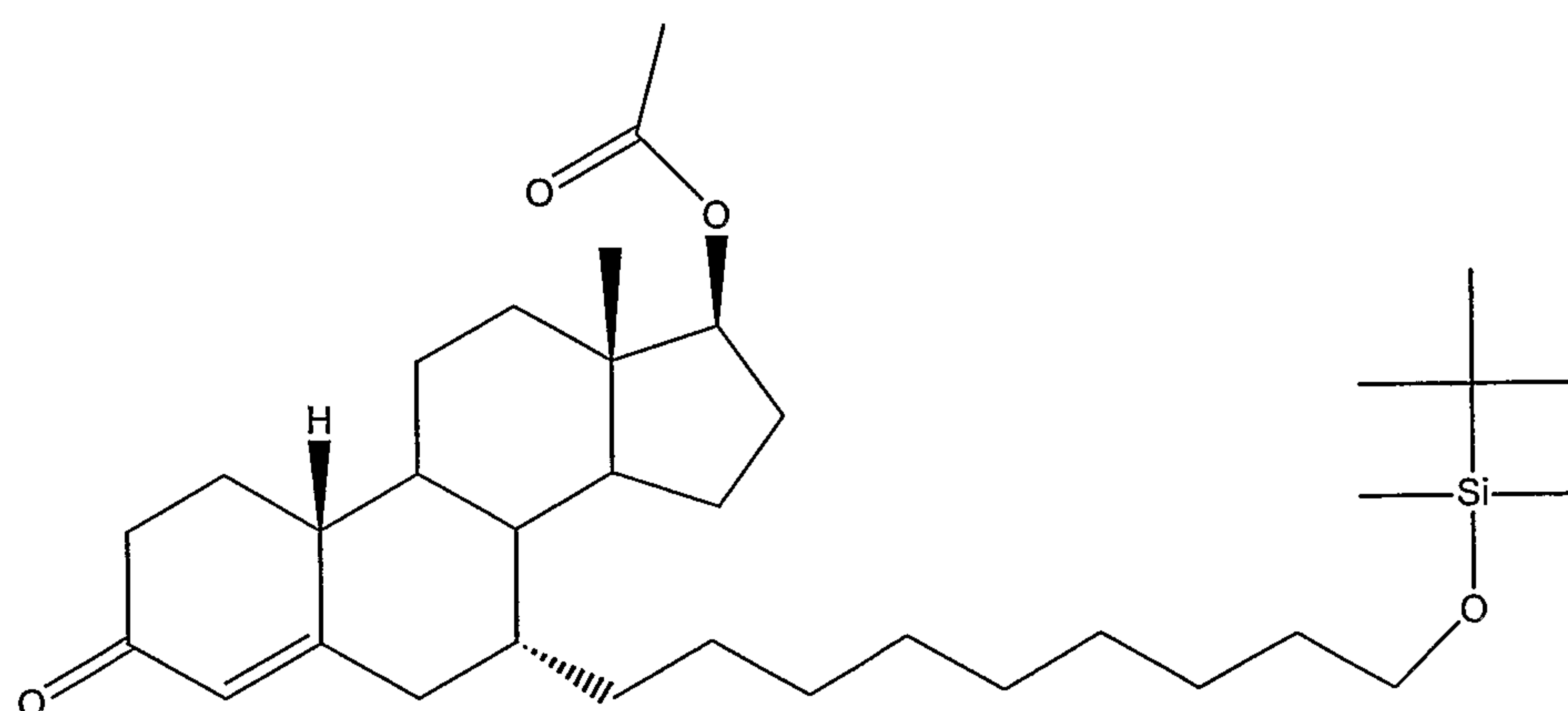


5 with an etheral solvent, to obtain a solution;

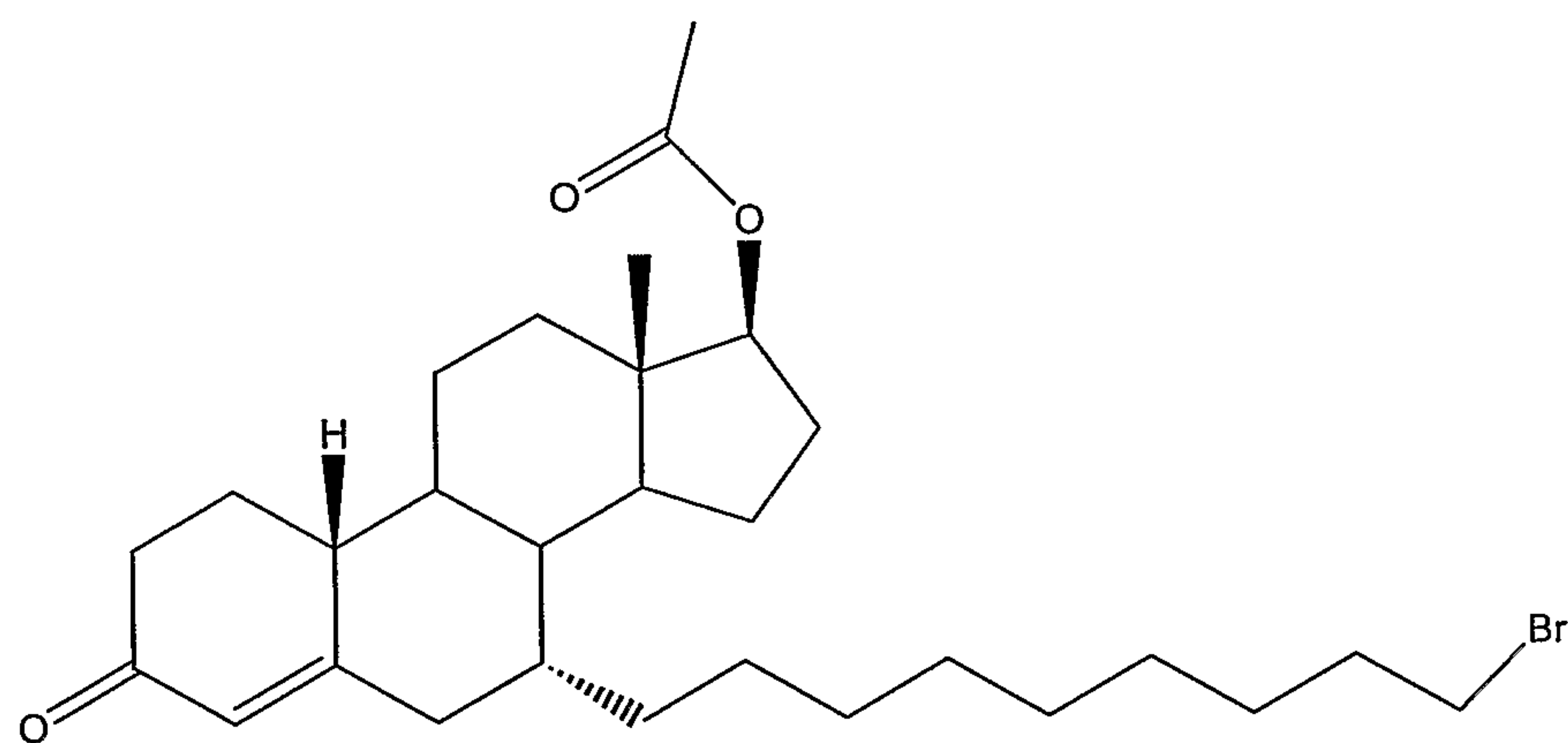
b) adding to the solution of step a), in a drop-wise manner, a solution of the compound of formula 9318



10 in an etheral solvent to obtain a first reaction mixture comprising a compound of formula 9295;

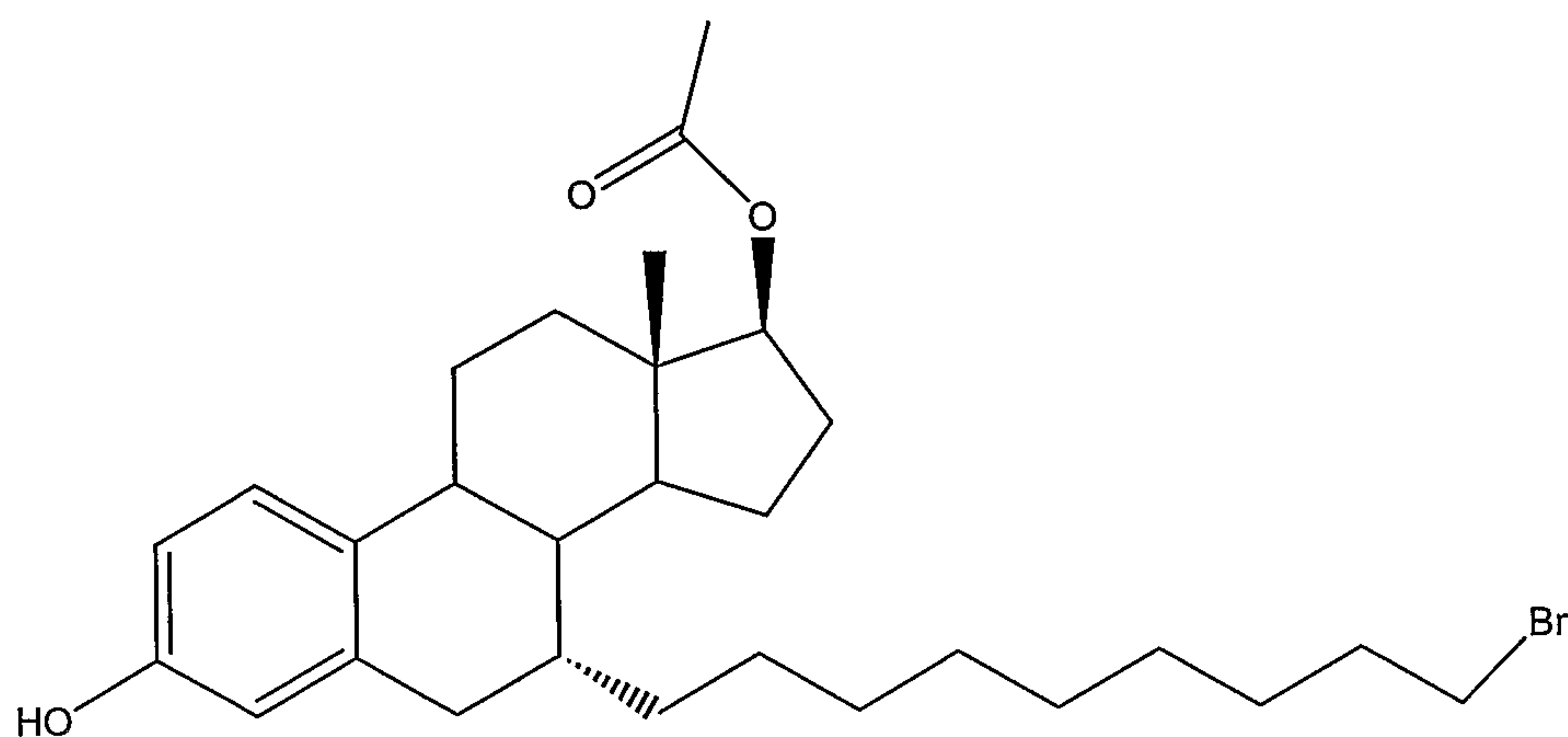


- c) quenching the first reaction mixture;
- d) recovering compound 9295;
- e) combining compound 9295 with acetonitrile and triphenylphosphine dibromide for a time sufficient to convert compound 9295 into a compound of formula 9341



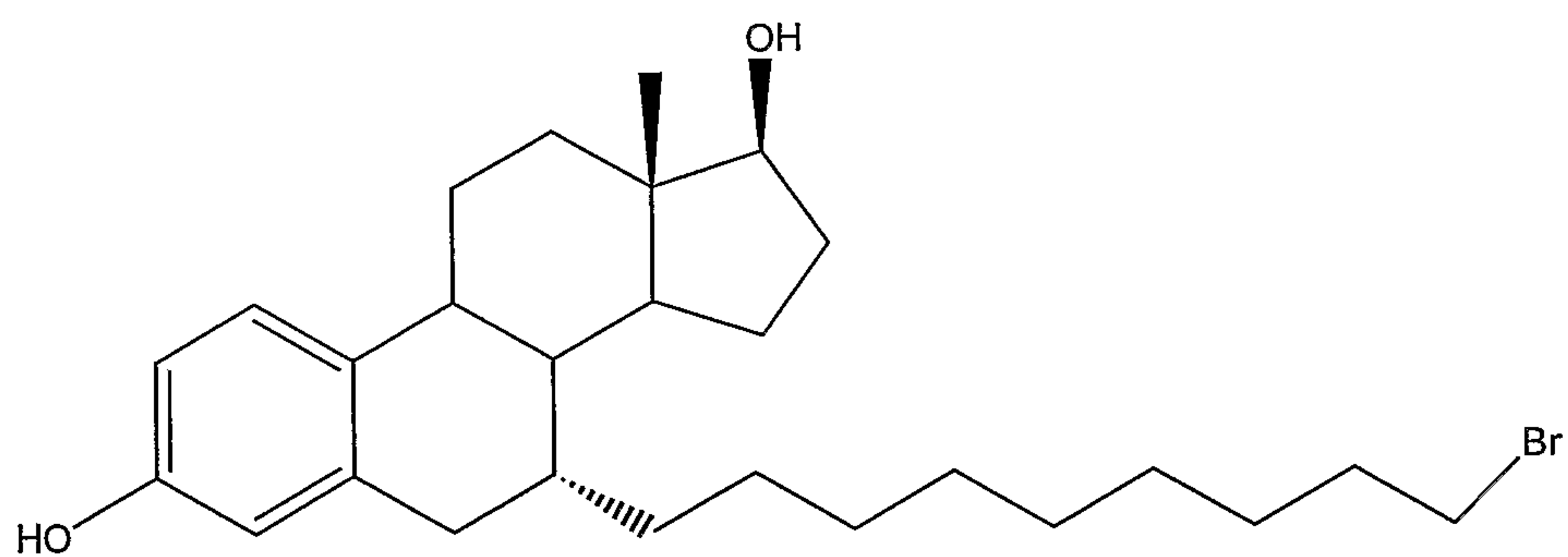
9341;

- f) aromatizing the A ring of compound 9341 by reacting compound 9341 with a mixture of lithium bromide and copper bromide in acetonitrile to obtain a compound of formula 9342



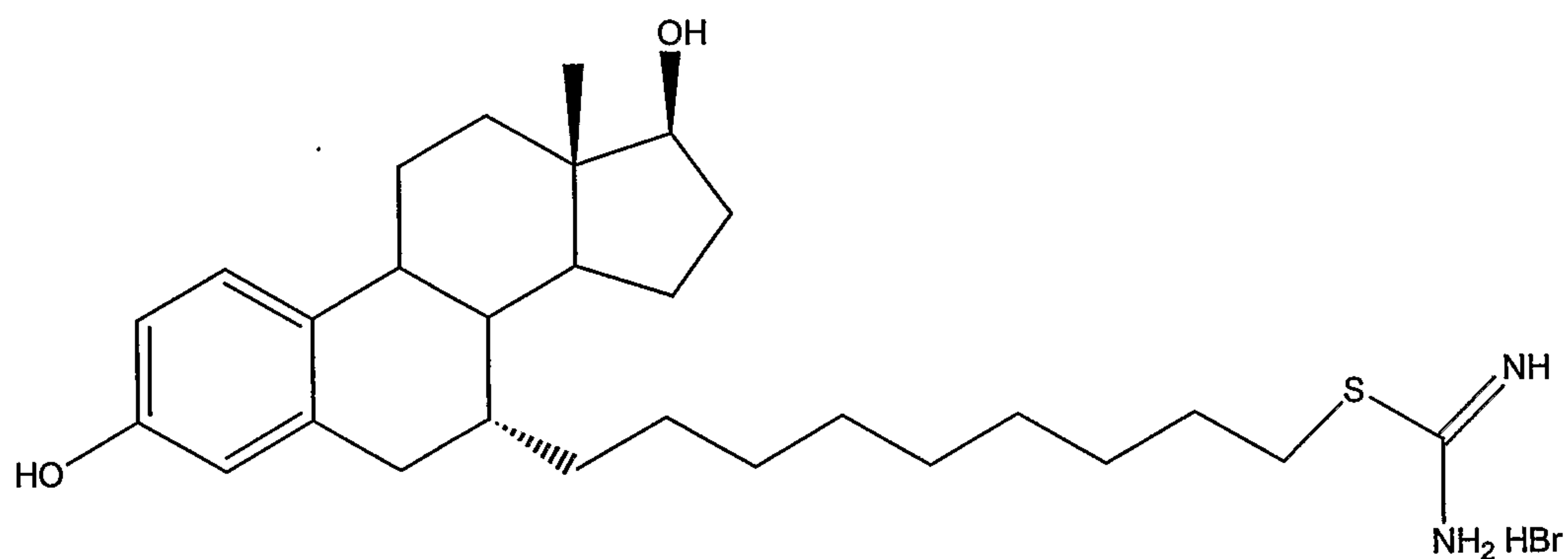
9342;

- g) combining compound 9342 with C₁₋₆ alcohol and a mineral acid, at a temperature of about 50°C to about 70°C to obtain a compound of formula 9354



9354;

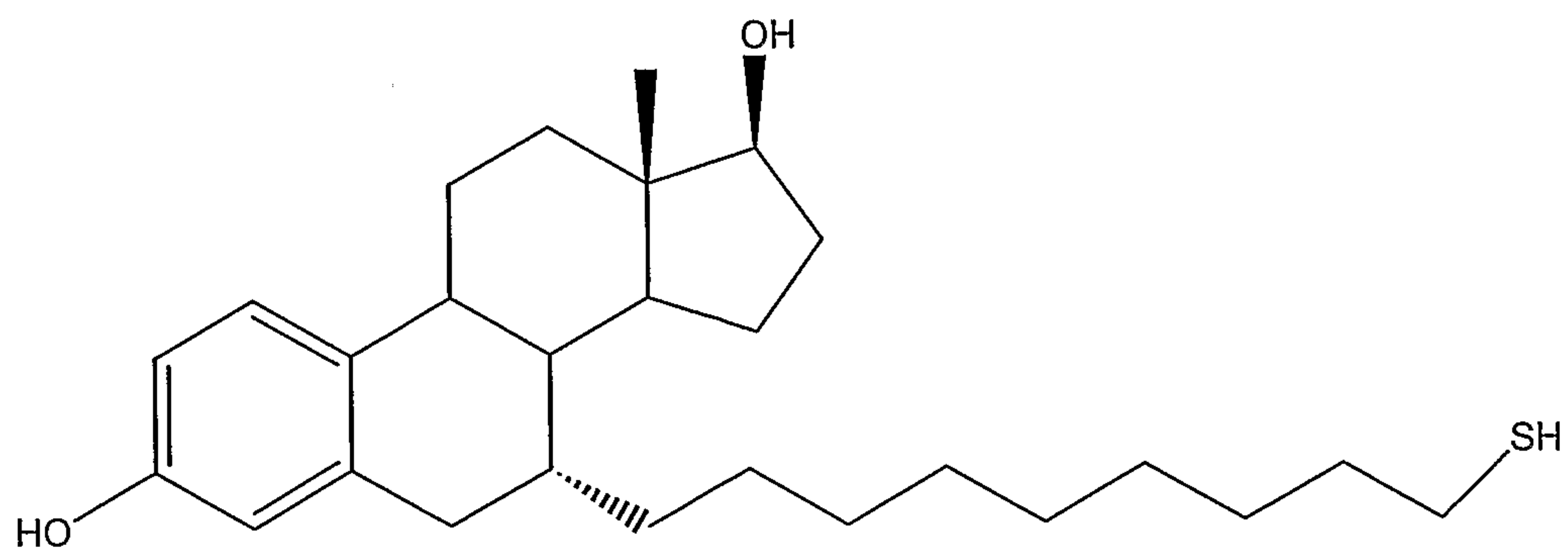
- h) combining compound 9354 with a solvent selected from a C₁₋₆ aromatic hydrocarbon, a straight or branched C₁₋₄ alkyl amide and mixtures thereof and thiourea to
 5 provide a compound of formula 9388



9388

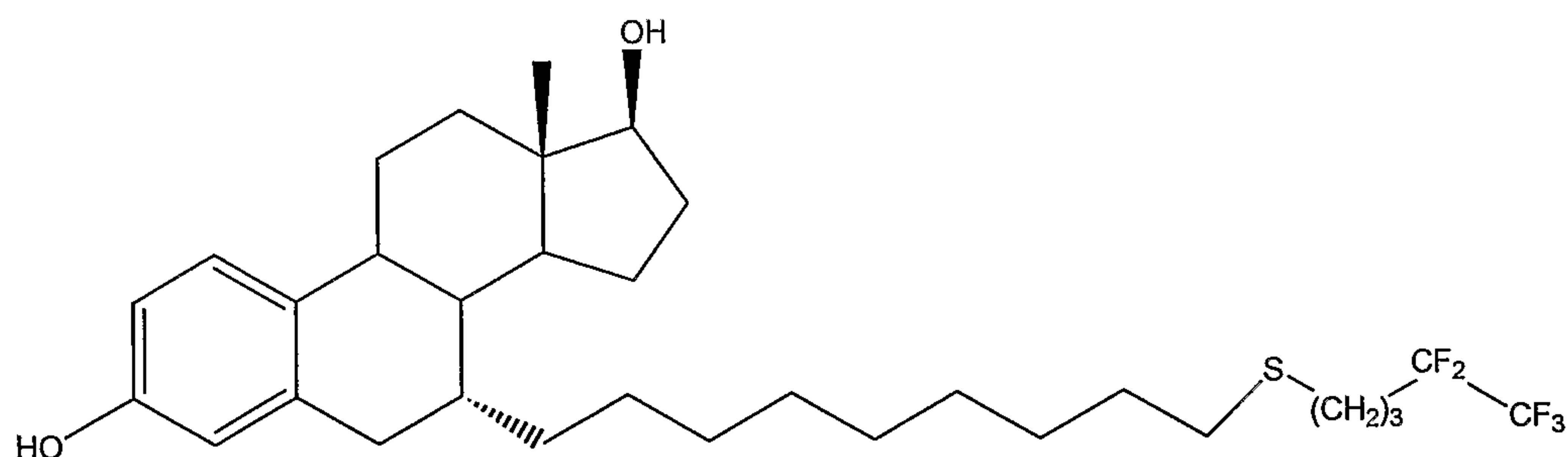
and recovering compound 9388;

- i) combining compound 9388 with a base at ambient temperature to obtain a
 10 compound of formula 9389



9389

j). combining compound 9389 with 4,4,5,5,5-pentafluoropentane-1-ol mesylate at an ambient temperature to provide a second reaction mixture and then combining the second reaction mixture with a base to obtain a compound of formula 9304



5

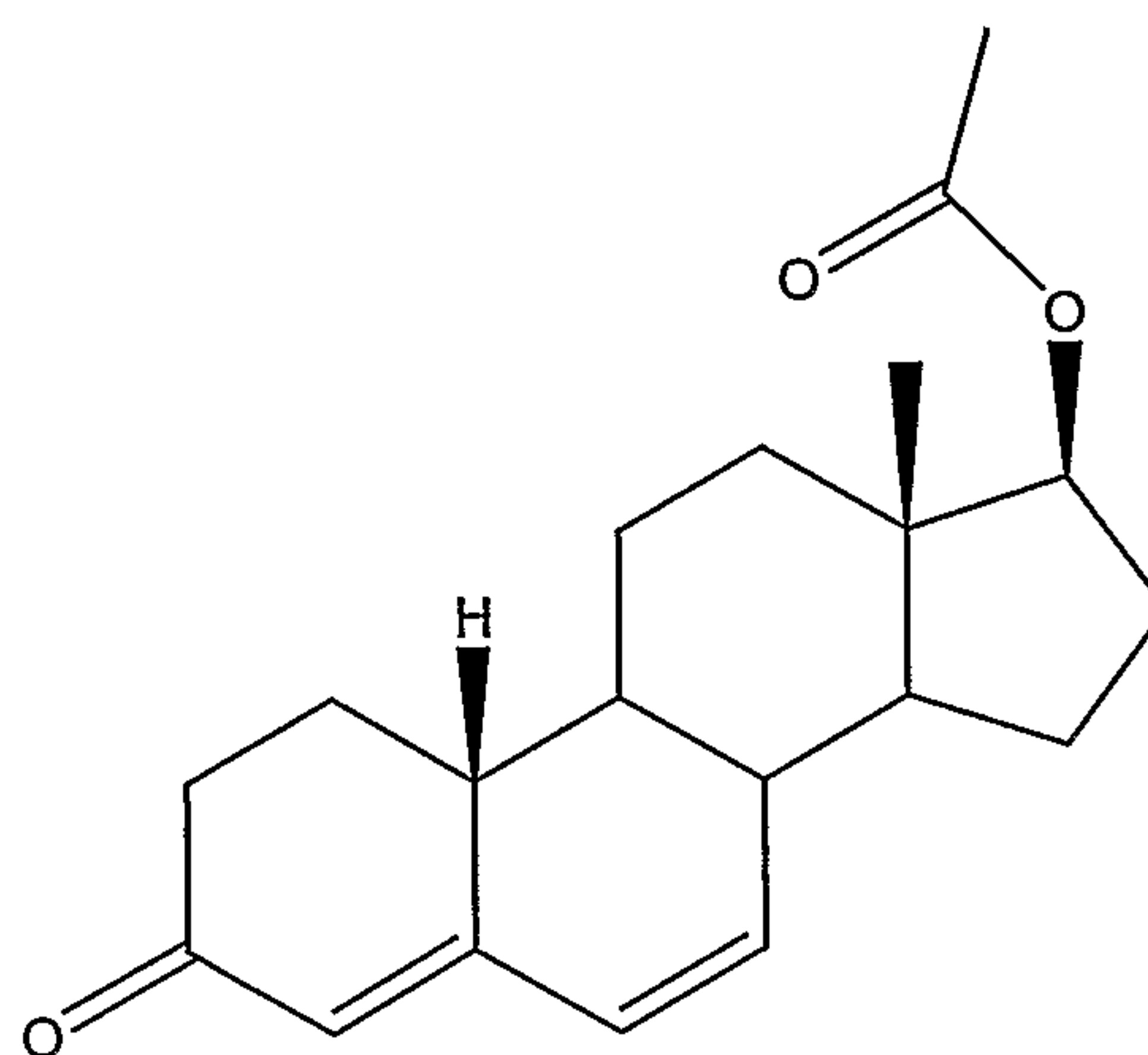
9304;

and

k) combining compound 9304 and a mixture of a C₁₋₄ alcohol and an etheral solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide fulvestant.

10 60. A process for preparing fulvestrant comprising:

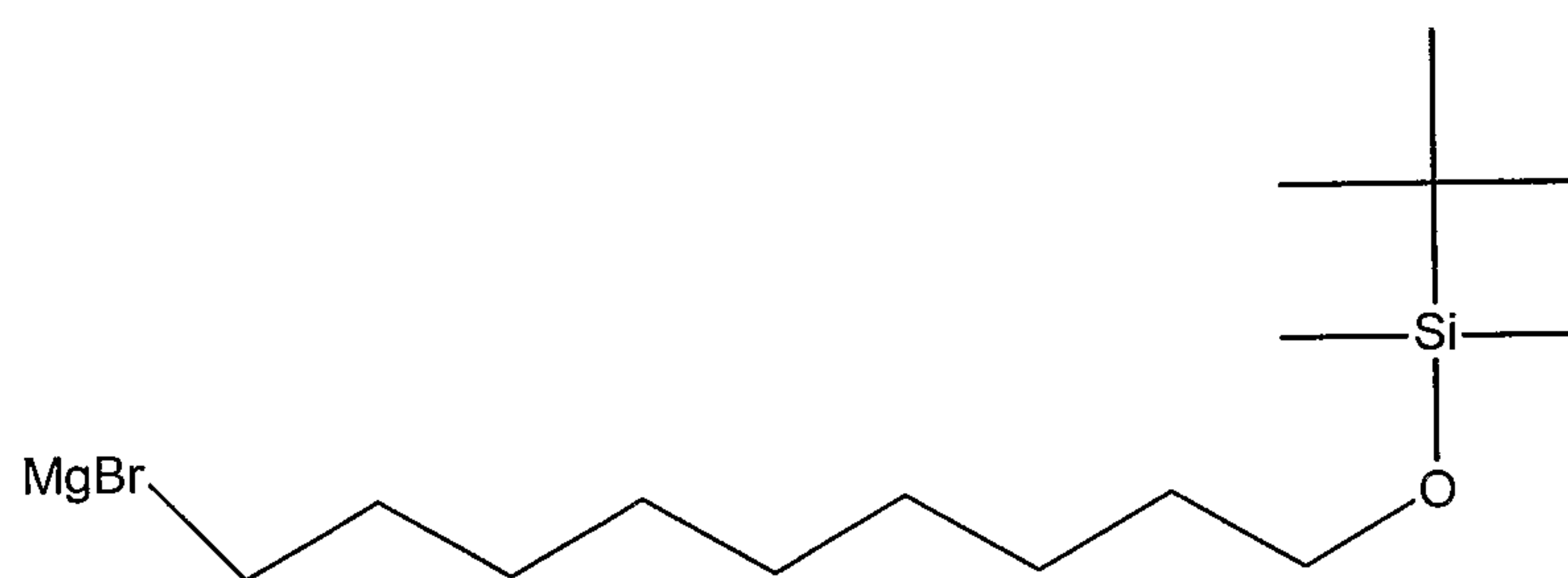
a) combining compound of formula 9294



9294

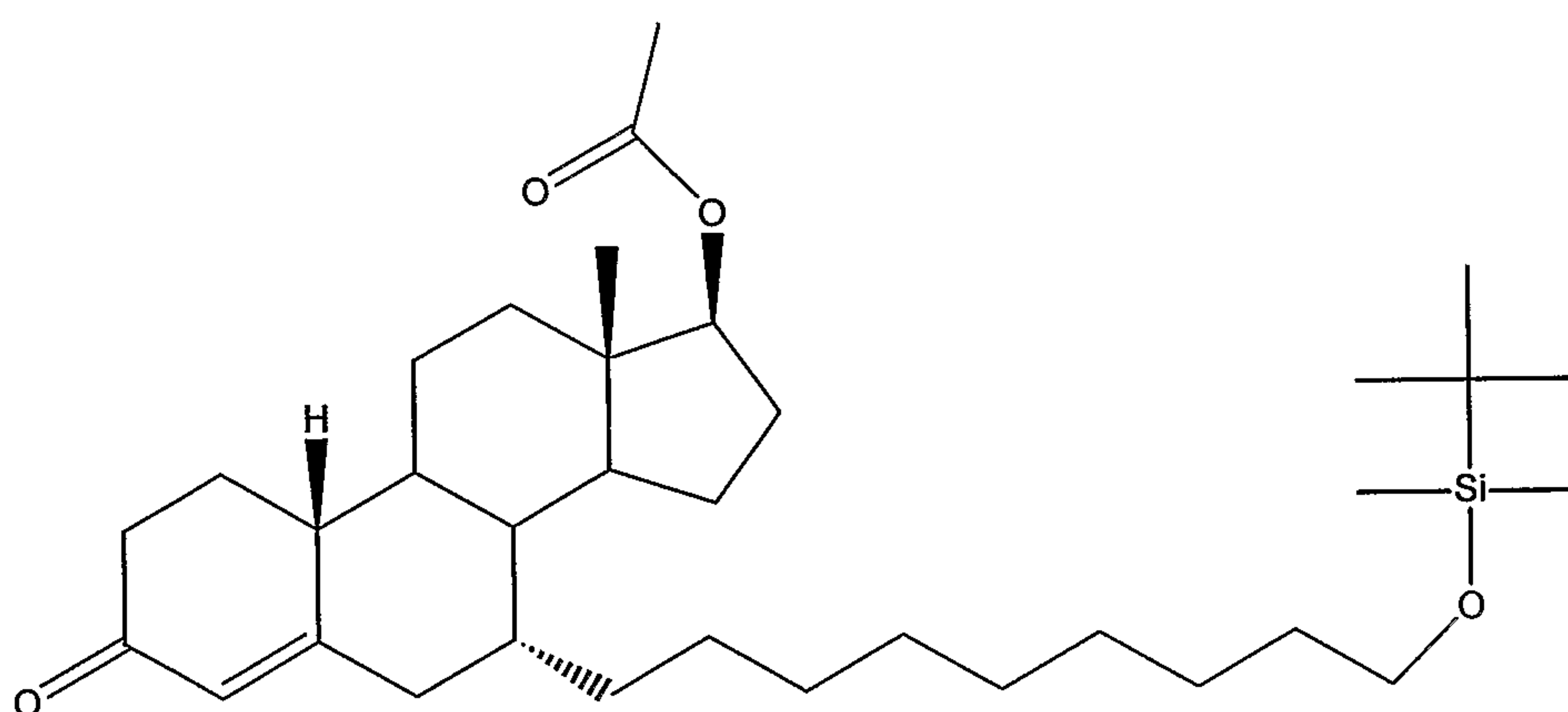
with an etheral solvent, to obtain a solution;

15 b) adding to the solution of step a), in a drop-wise manner, a solution of the compound of formula 9318



9318

in an etheral solvent to obtain a first reaction mixture comprising a compound of formula 9295;

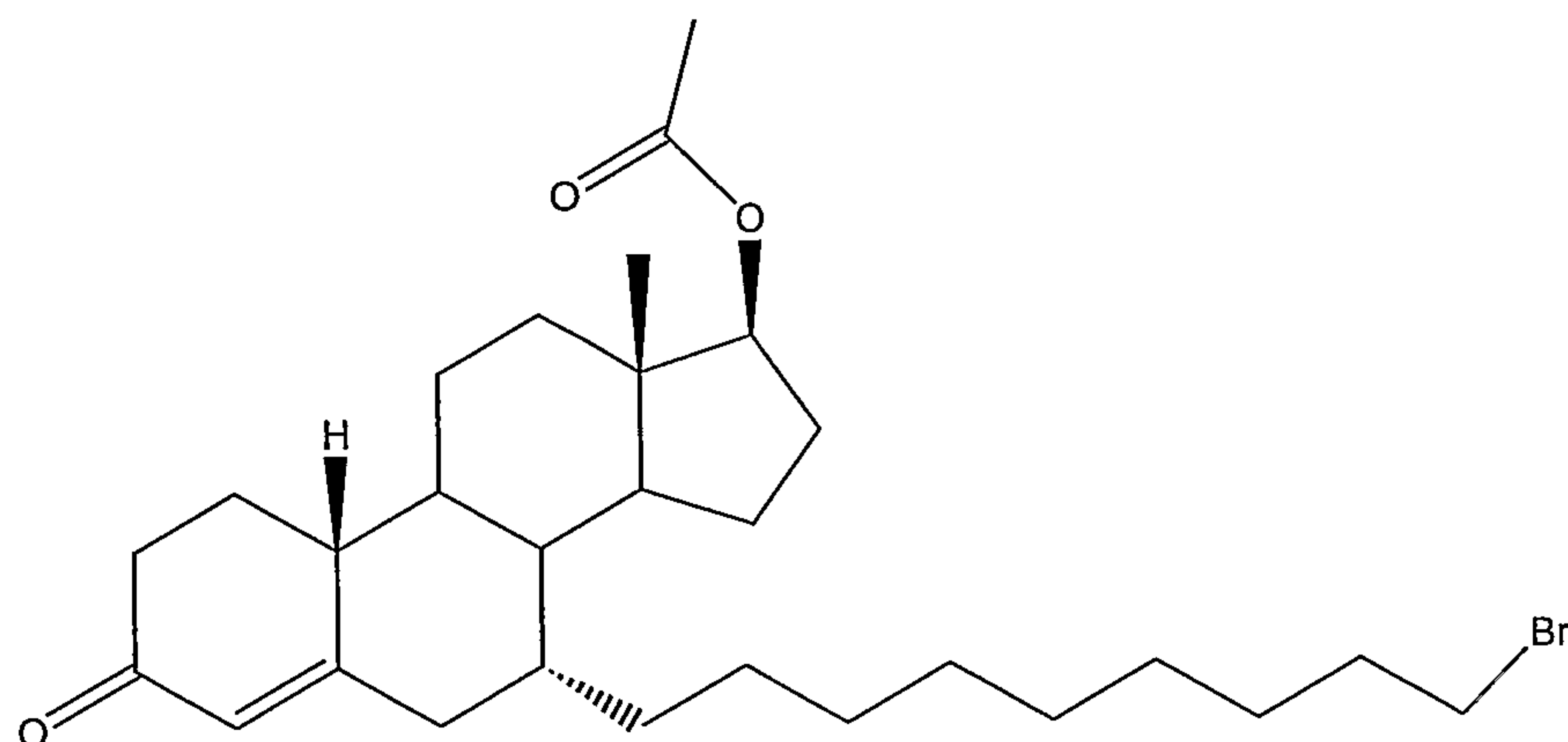


5

c) quenching the first reaction mixture;

d) recovering compound 9295;

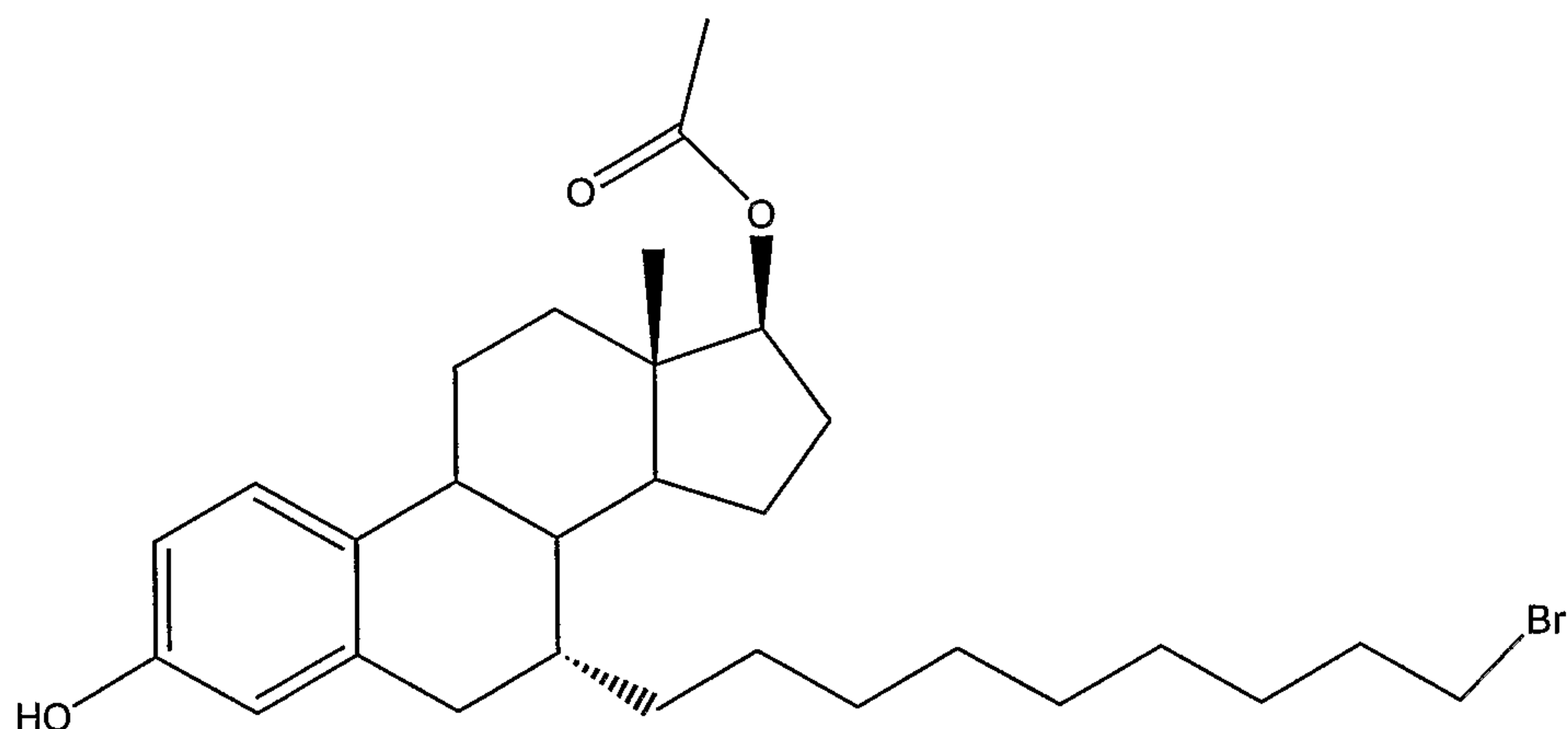
e) combining compound 9295 with acetonitrile and triphenylphosphine dibromide for a time sufficient to convert compound 9295 into a compound of formula 9341



10

9341;

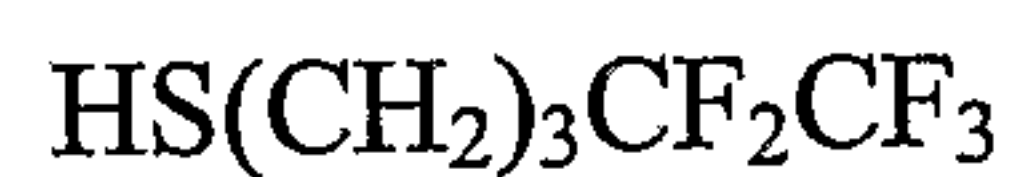
f) aromatizing the A ring of compound 9341 by reacting compound 9341 with a mixture of lithium bromide and copper bromide in acetonitrile to obtain a compound of formula 9342



5

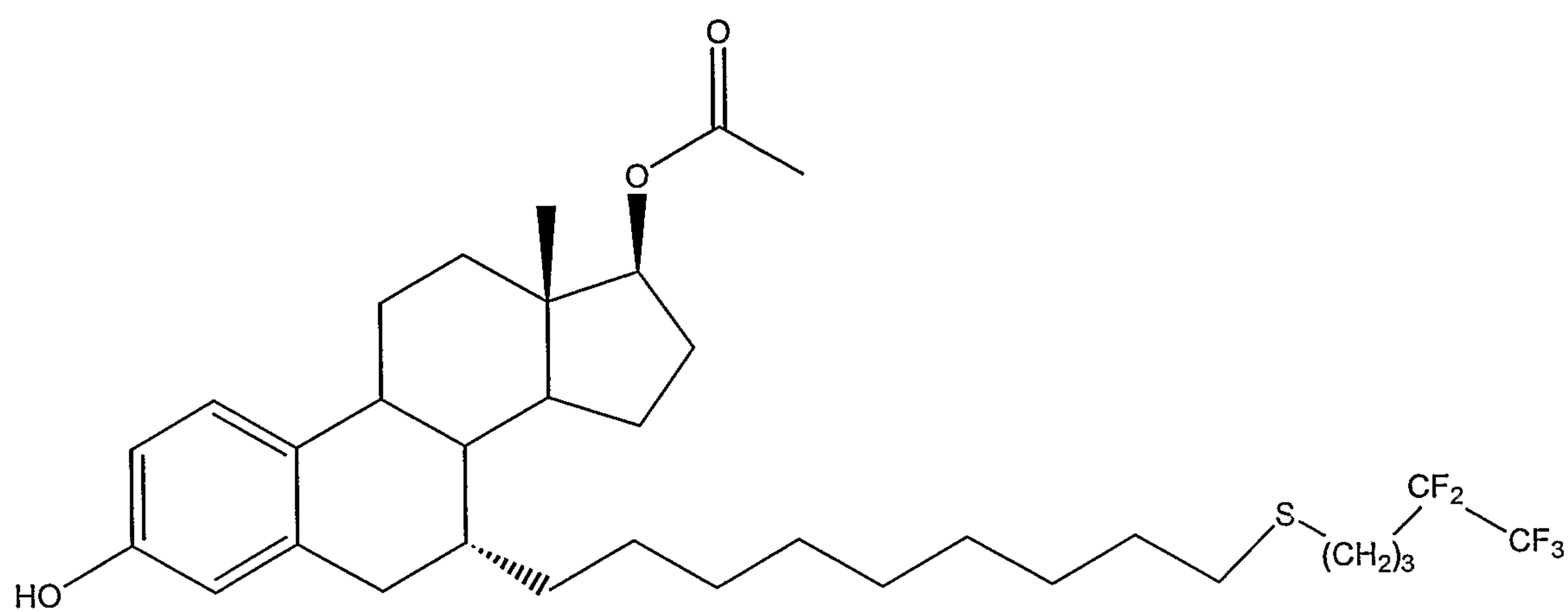
9342;

g) combining compound 9342 with a compound of formula 9383



9383;

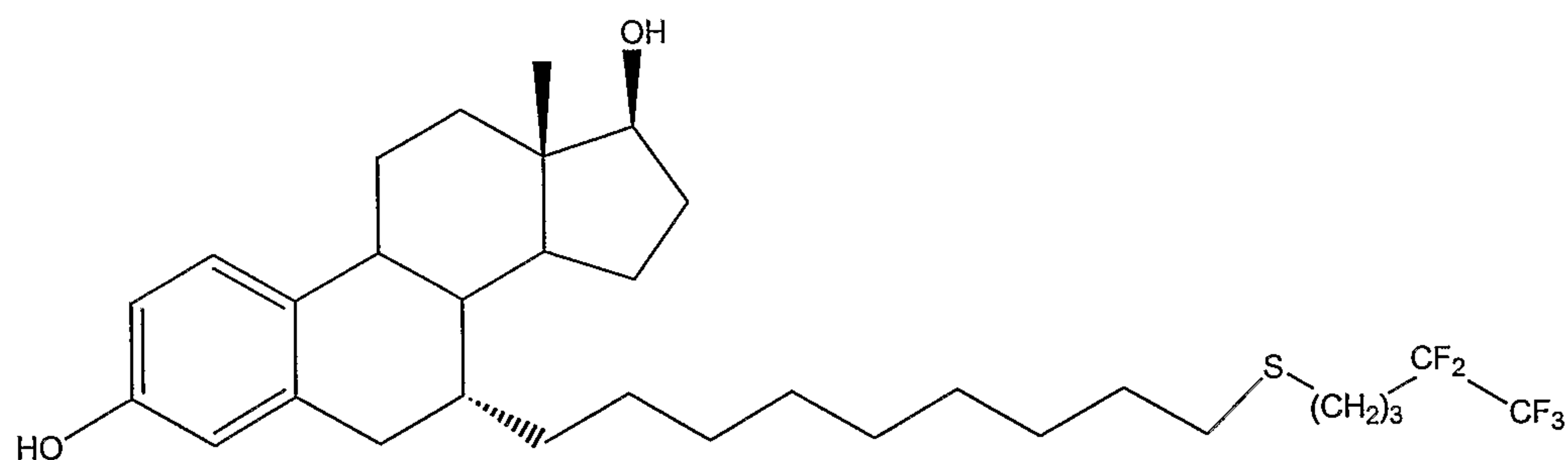
to provide a compound of formula 9363



10

9363;

h) combining at ambient temperature, compound 9363 and a C₁₋₄ alcohol with an alkali base to obtain compound 9304



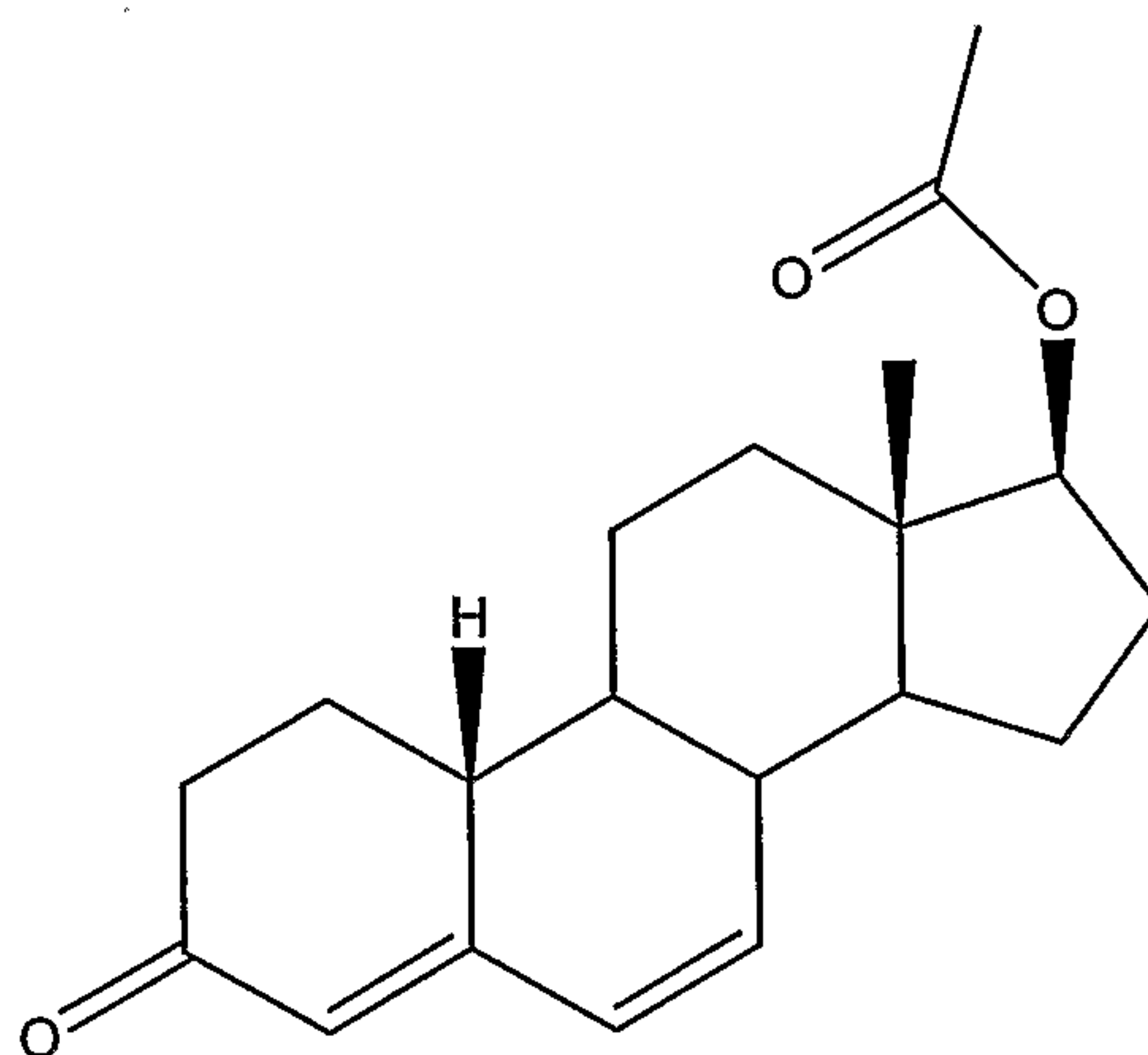
9304;

and

- 5 i) combining compound 9304 and a mixture of a C₁₋₄ alcohol and an ethereal solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide fulvestant.

61. A process for preparing fulvestrant comprising

- a) combining compound of formula 9294

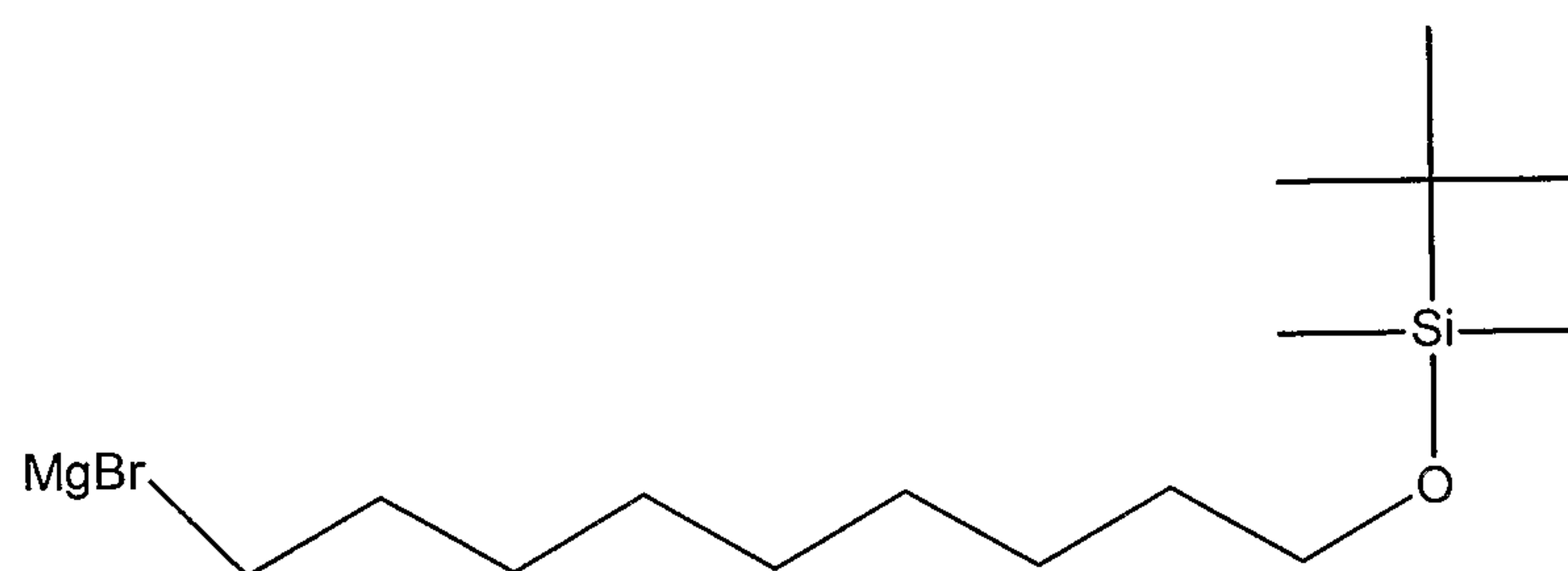


9294

10

with an ethereal solvent, to obtain a solution;

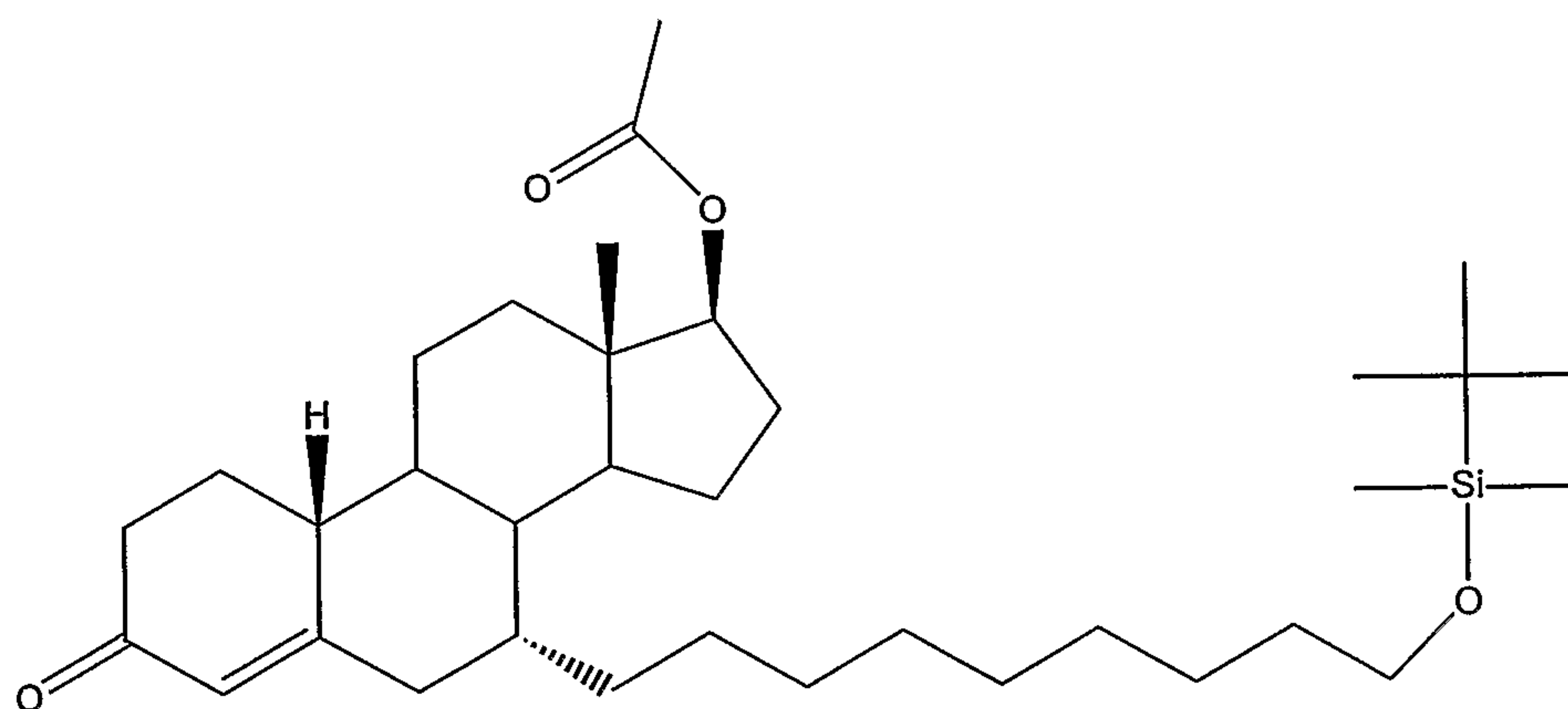
- b) adding to the solution of step a), in a drop-wise manner, a solution of the compound of formula 9318



9318

in an ethereal solvent to obtain a first reaction mixture comprising a compound of formula 9295;

5

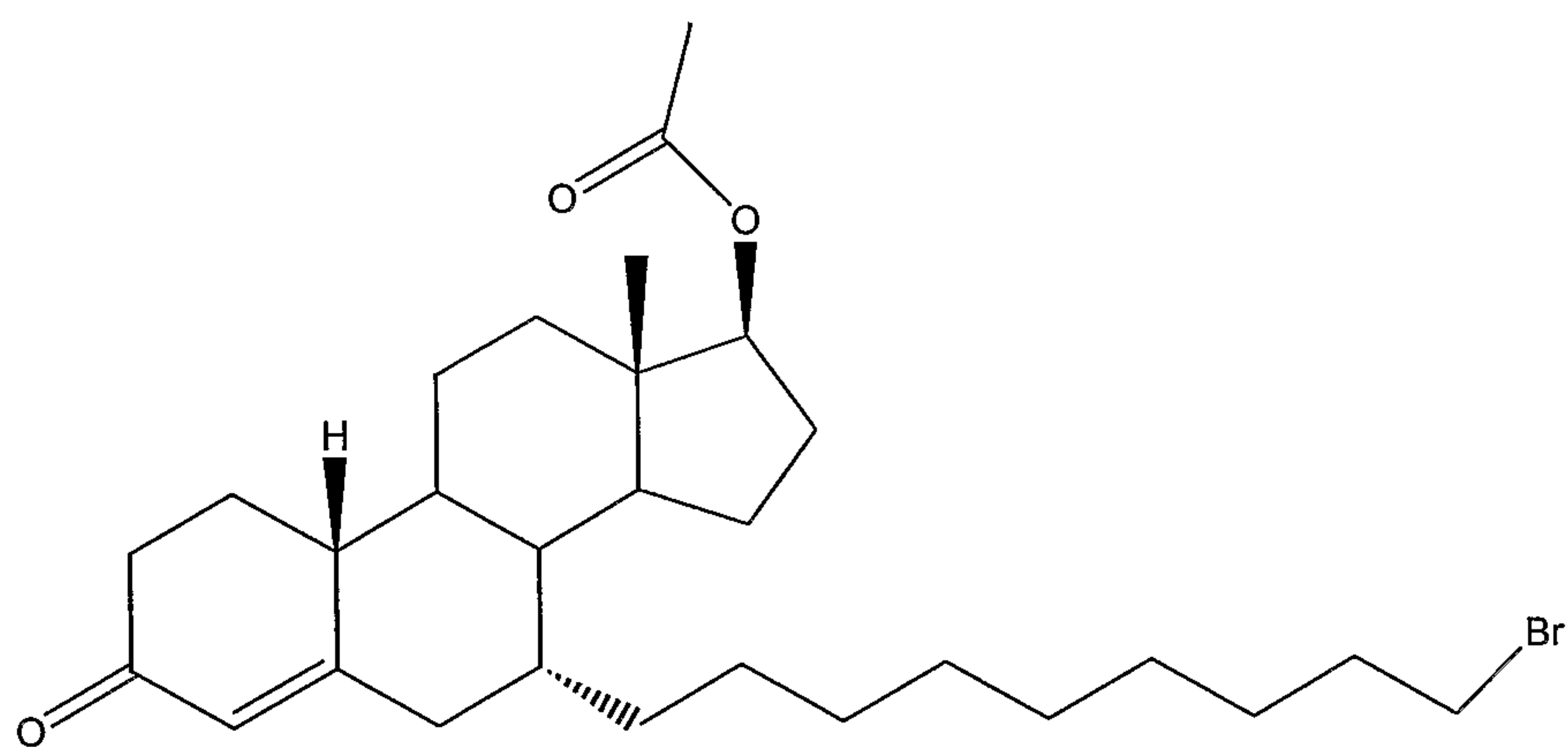


c) quenching the first reaction mixture;

d) recovering compound 9295;

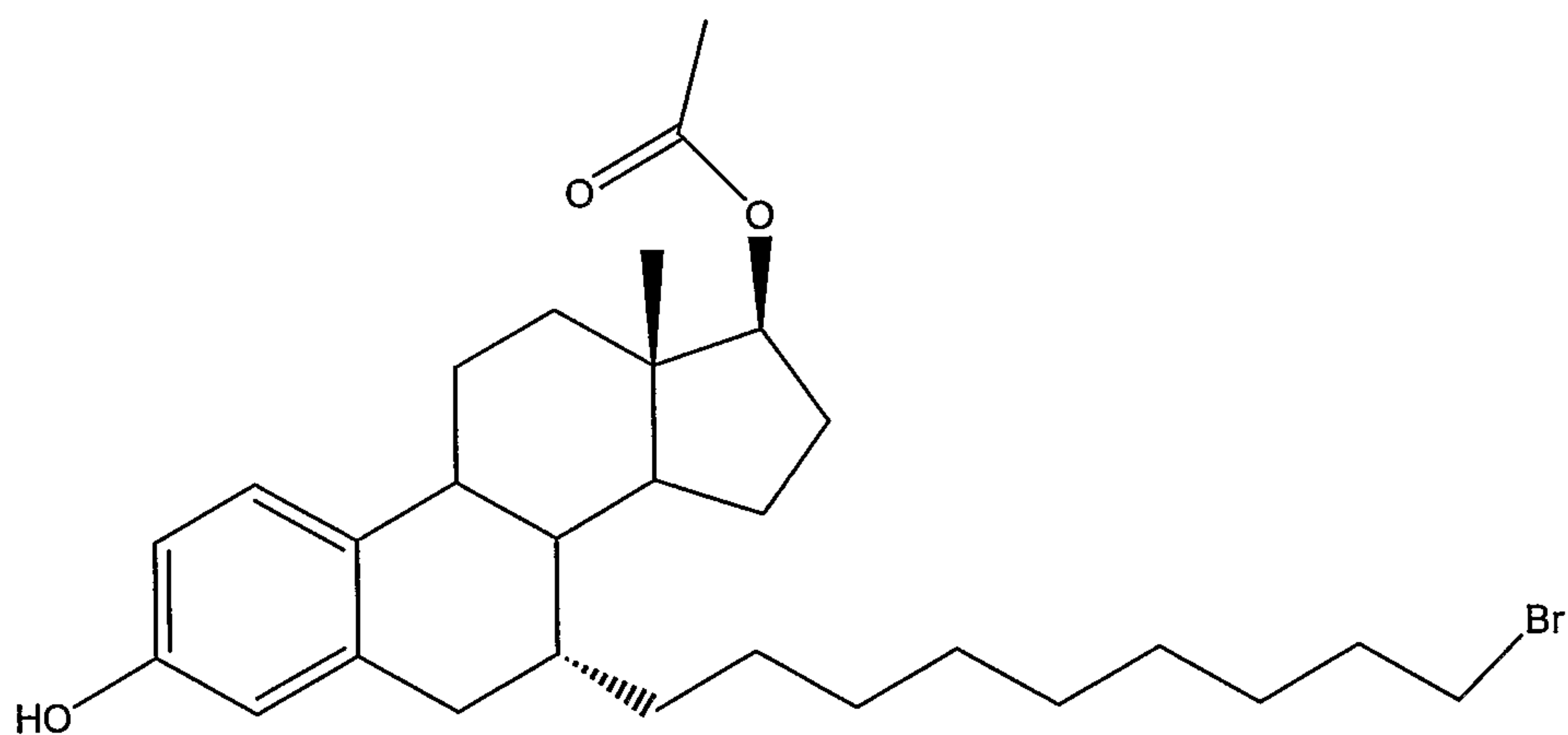
10

e) combining compound 9295 with acetonitrile and triphenylphosphine dibromide for a time sufficient to convert compound 9295 into a compound of formula 9341



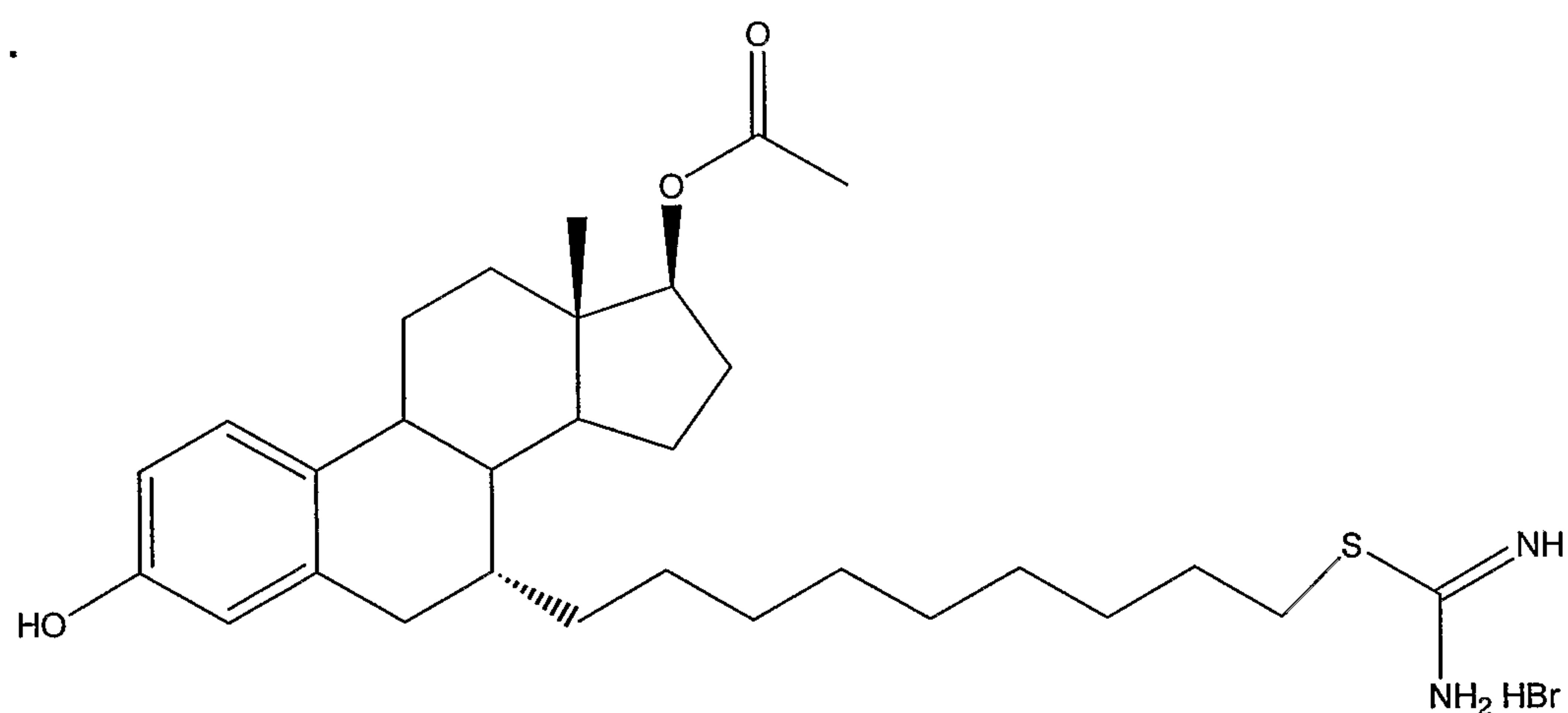
9341;

f) aromatizing the A ring of compound 9341 by reacting compound 9341 with a mixture of lithium bromide and copper bromide in acetonitrile to obtain a compound of
5 formula 9342



9342;

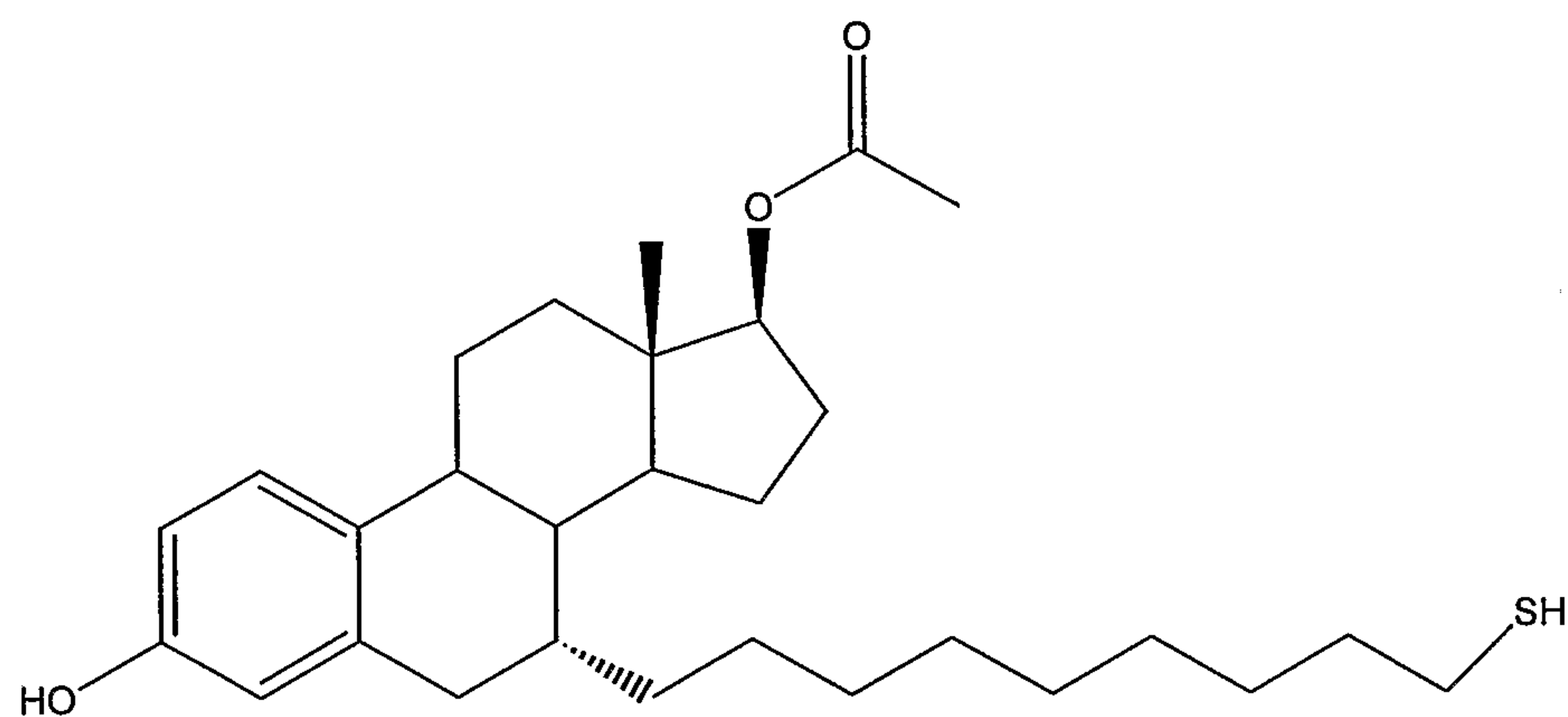
g) combining compound 9342 with with a solvent selected from a C₁₋₆ aromatic hydrocarbon, a straight or branched C₁₋₄ alkyl amide and mixtures thereof and thiourea to
10 provide a compound of formula 9361



9361

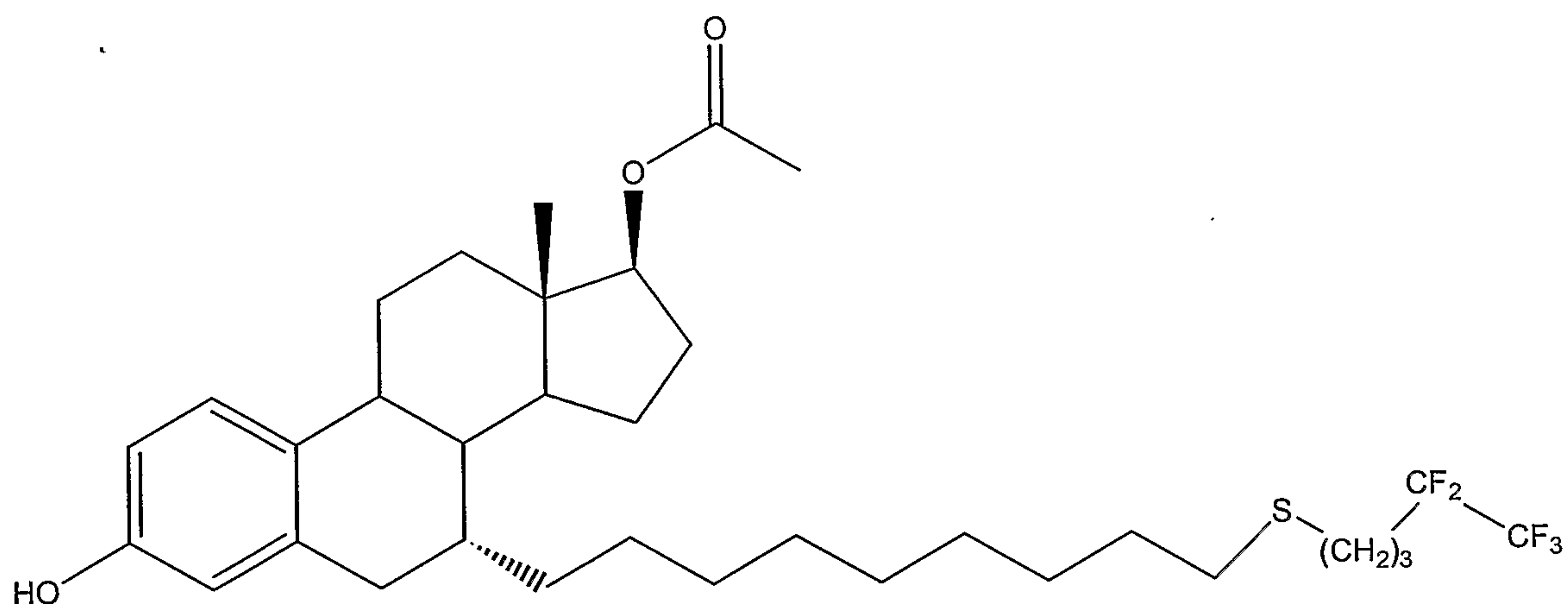
and recovering compound 9361.

- h) combining compound 9361 with a base at an ambient temperature to obtain a
5 compound of formula 9362



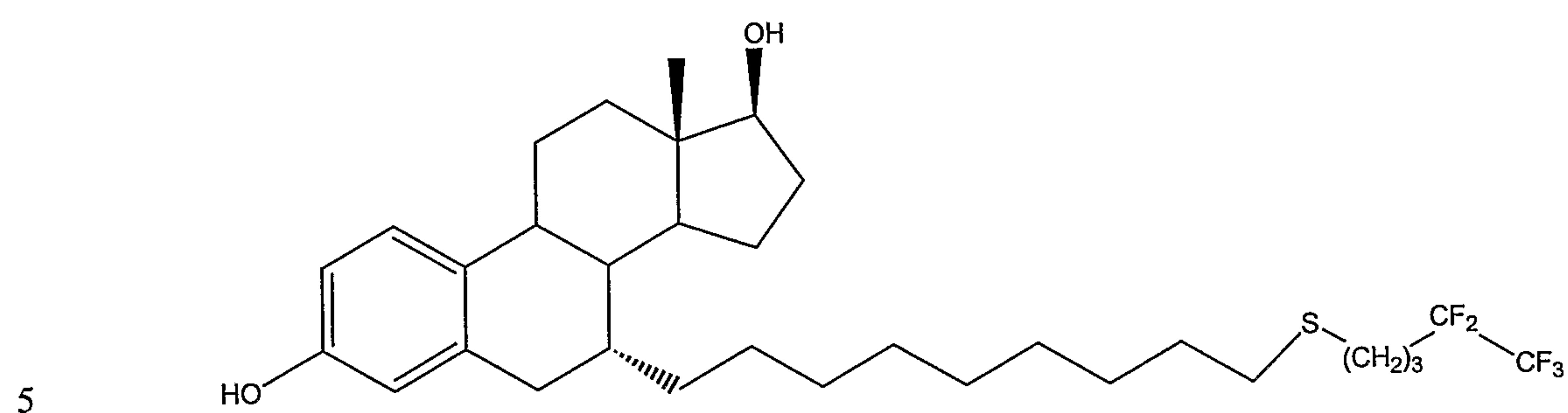
9362

- i) combining compound 9362 with 4,4,5,5,5-pentafluoropentane-1-ol mesylate at
ambient temperature to provide a second reaction mixture followed by combining the
10 second reaction mixture with a base to obtain a compound of formula 9363



9363;

j) combining at ambient temperature compound 9363 and a C₁₋₄ alcohol with an alkali base to obtain a compound of formula 9304



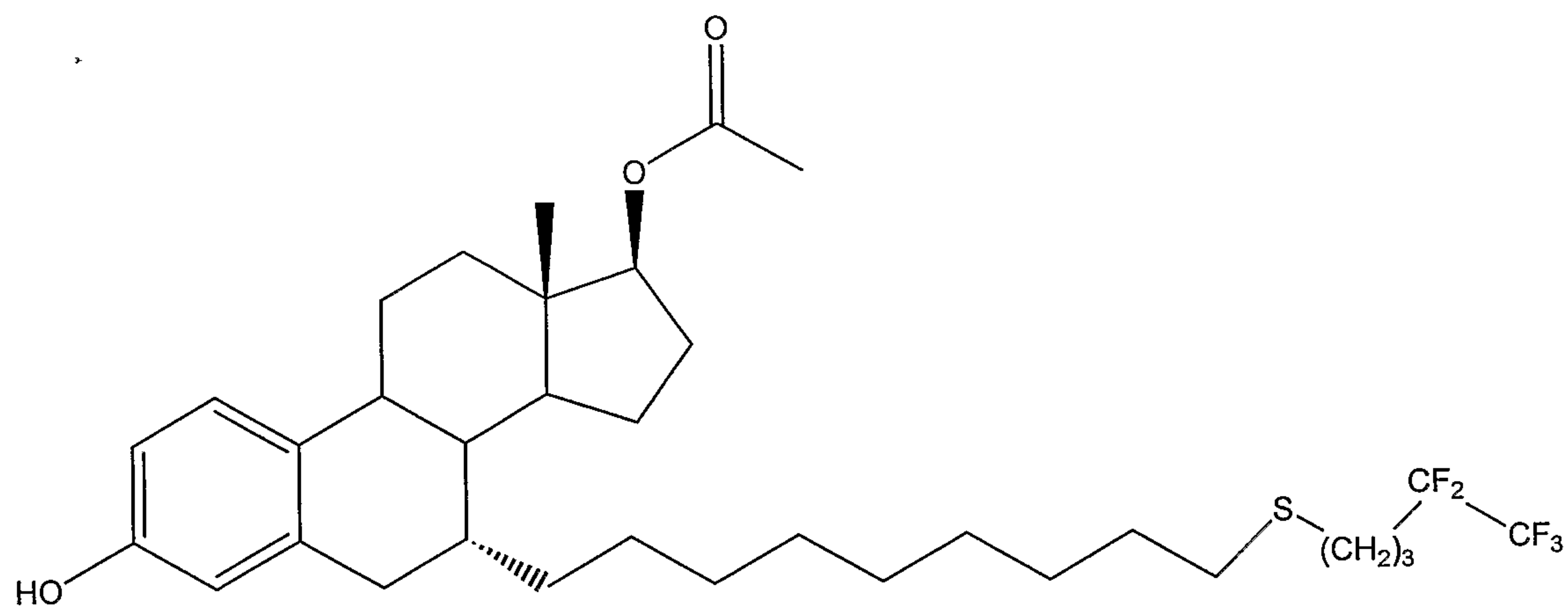
9304;

and

k) combining compound 9304 and a mixture of a C₁₋₄ alcohol and an etheral solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide fulvestant.

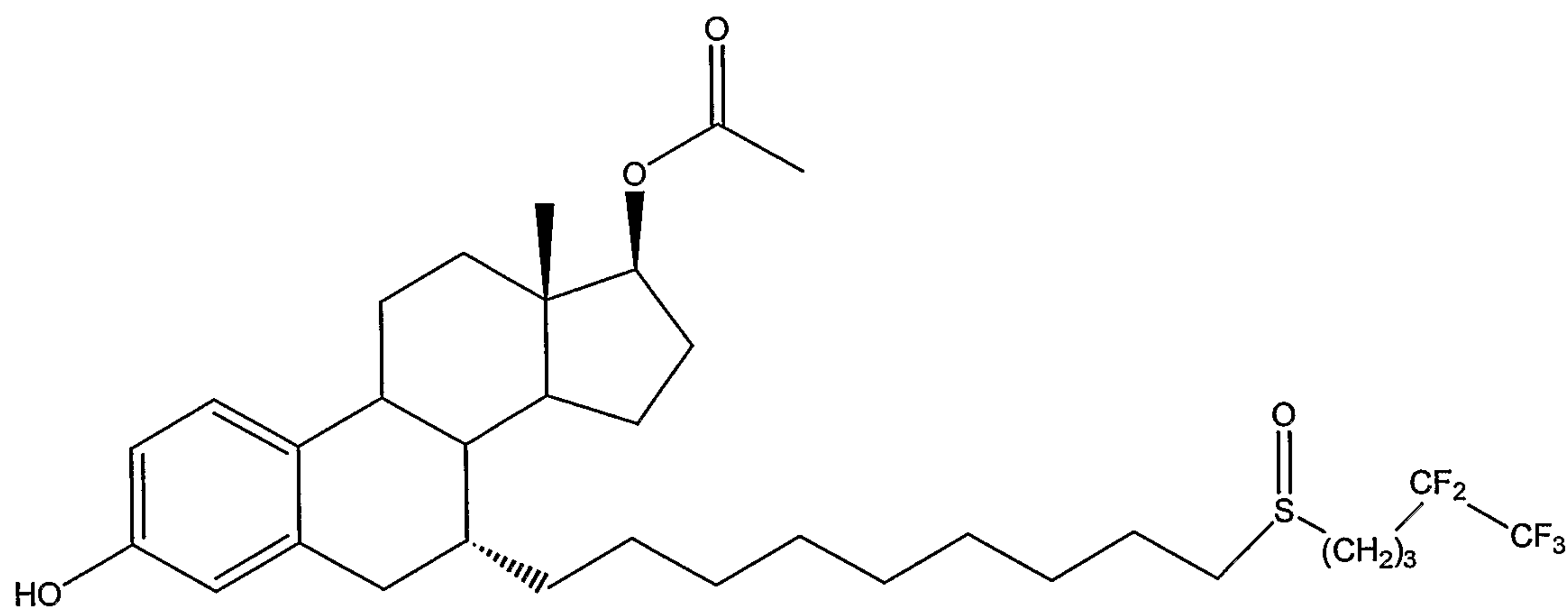
62. A process for preparing fulvestrant comprising

a) reacting a compound of formula 9363



9363;

with a mixture of a C₁₋₄ alcohol and an etheral solvent with an aqueous solution of an oxidizing agent at a temperature of about 5°C for about 12 hours to provide a compound
 5 of formula 9368



9368;

and

b) combining at ambient temperature compound 9368 and a C₁₋₄ alcohol with an
 10 alkali base to obtain fulvestant.

1/13

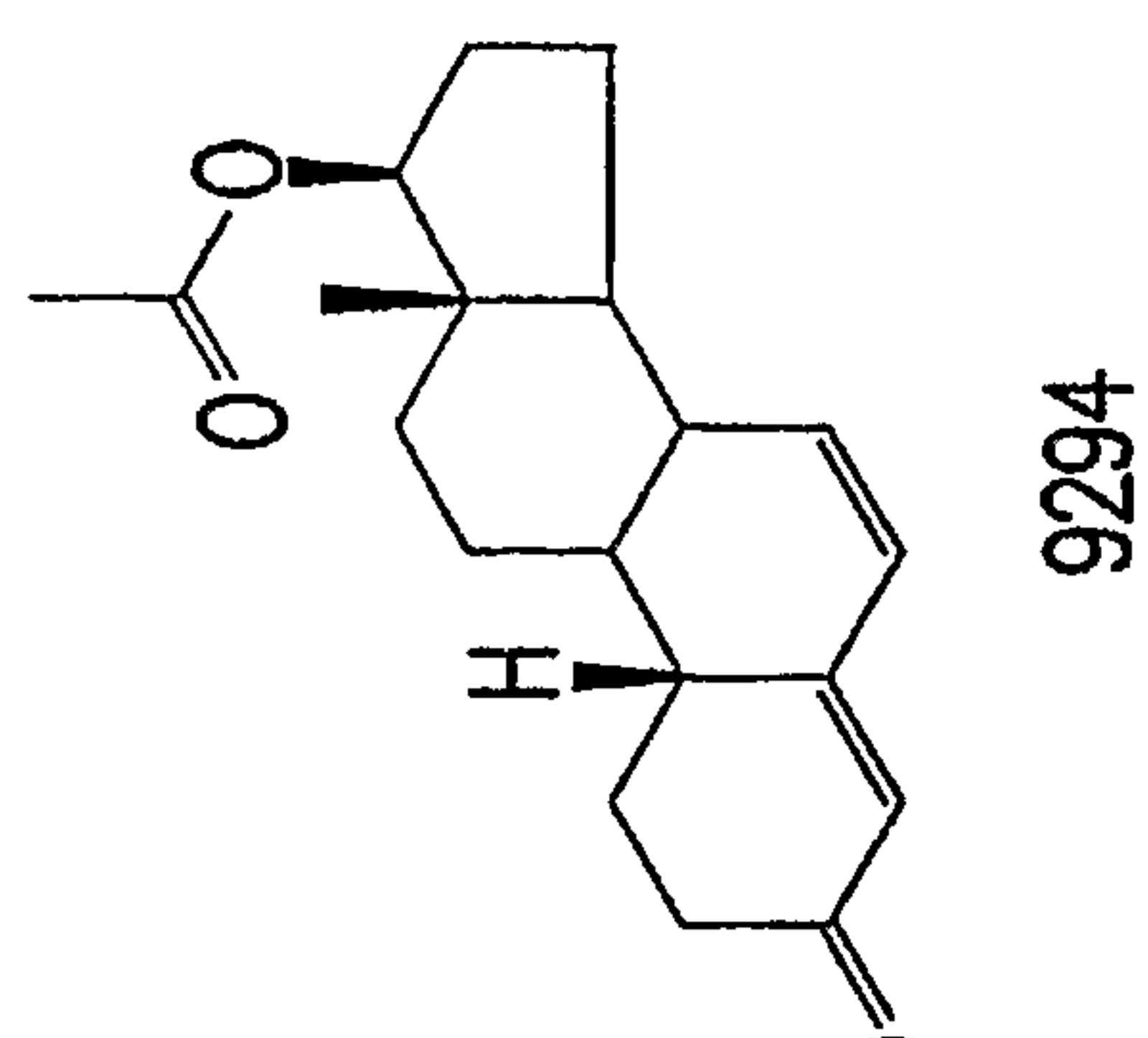
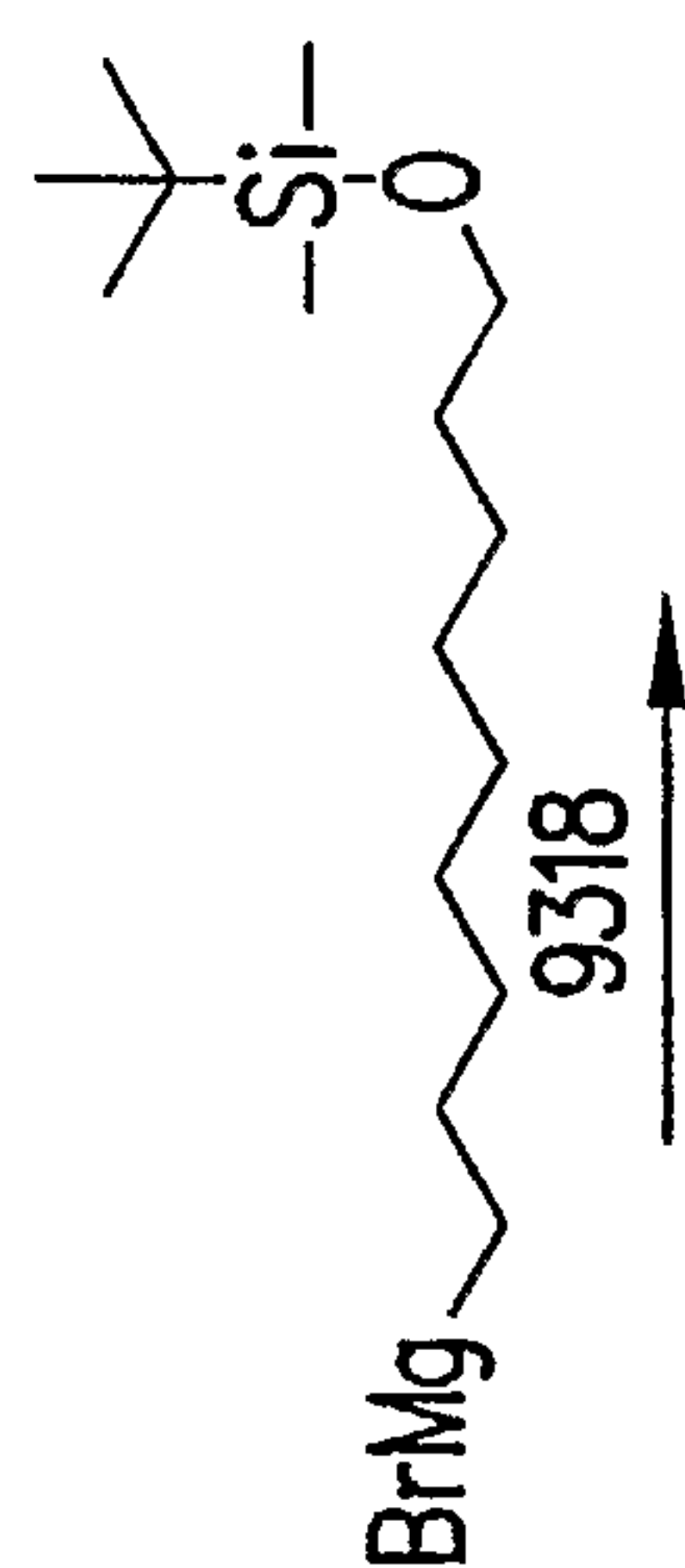
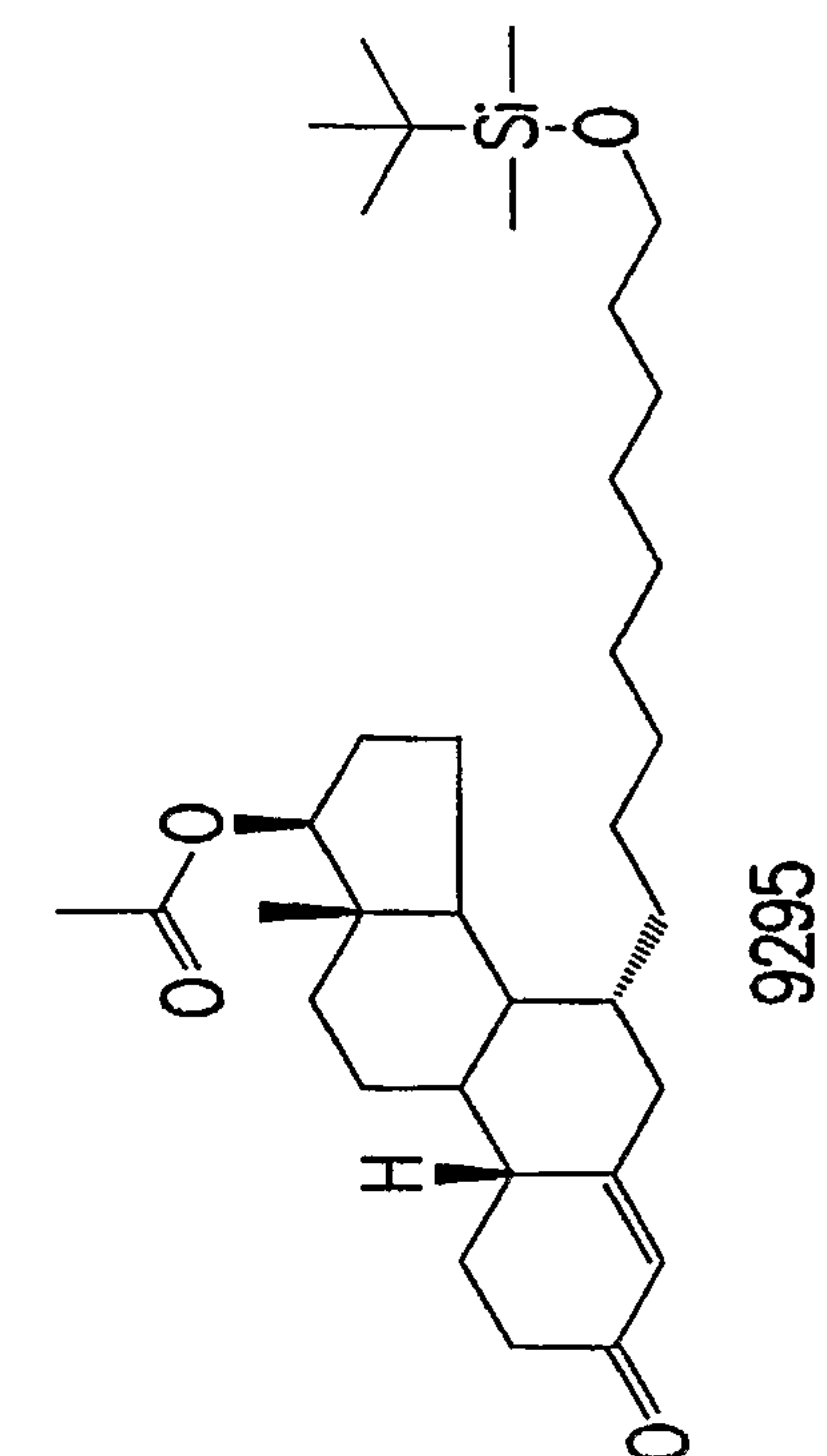


FIG. 1

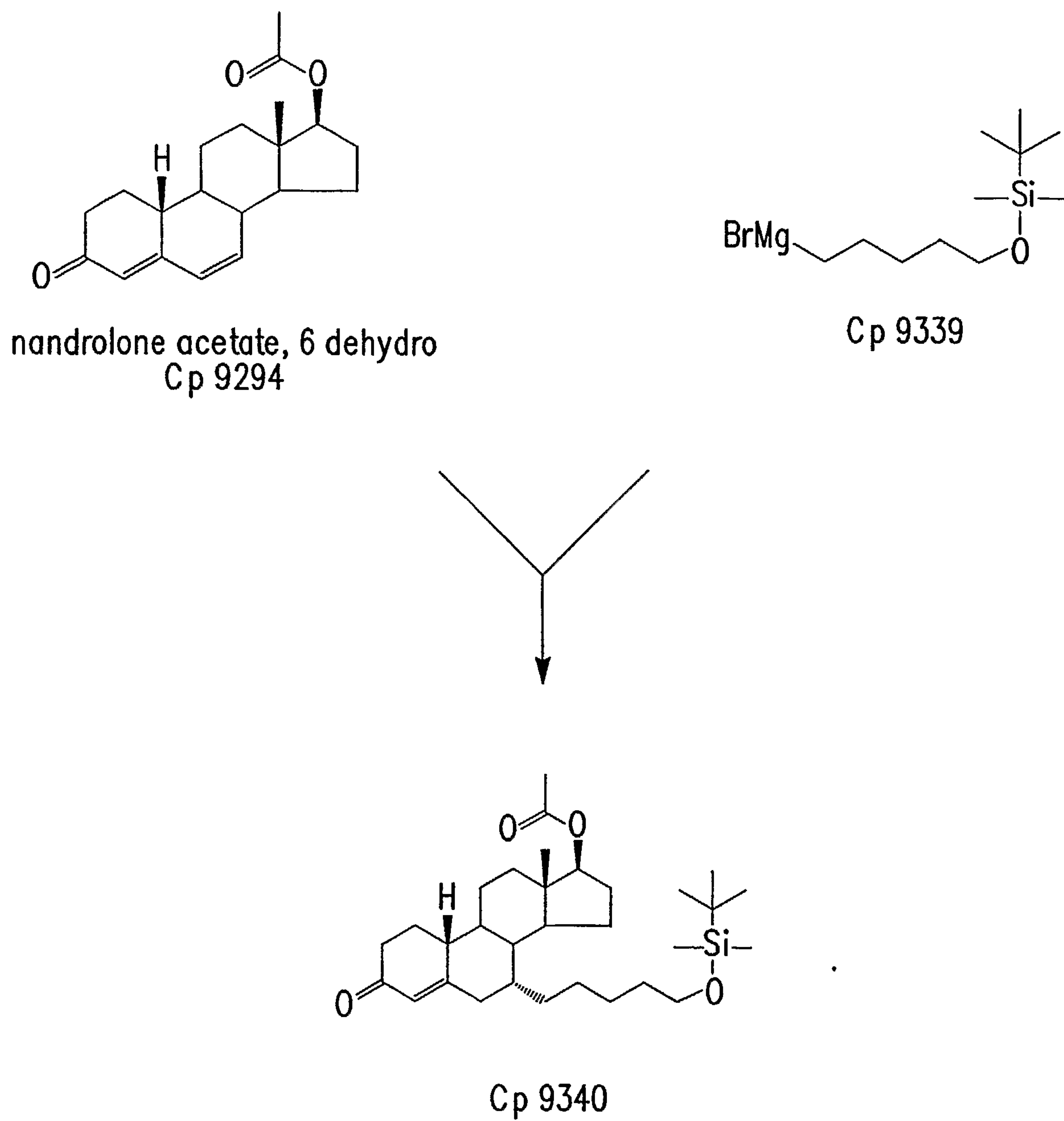


FIG.2

3/13

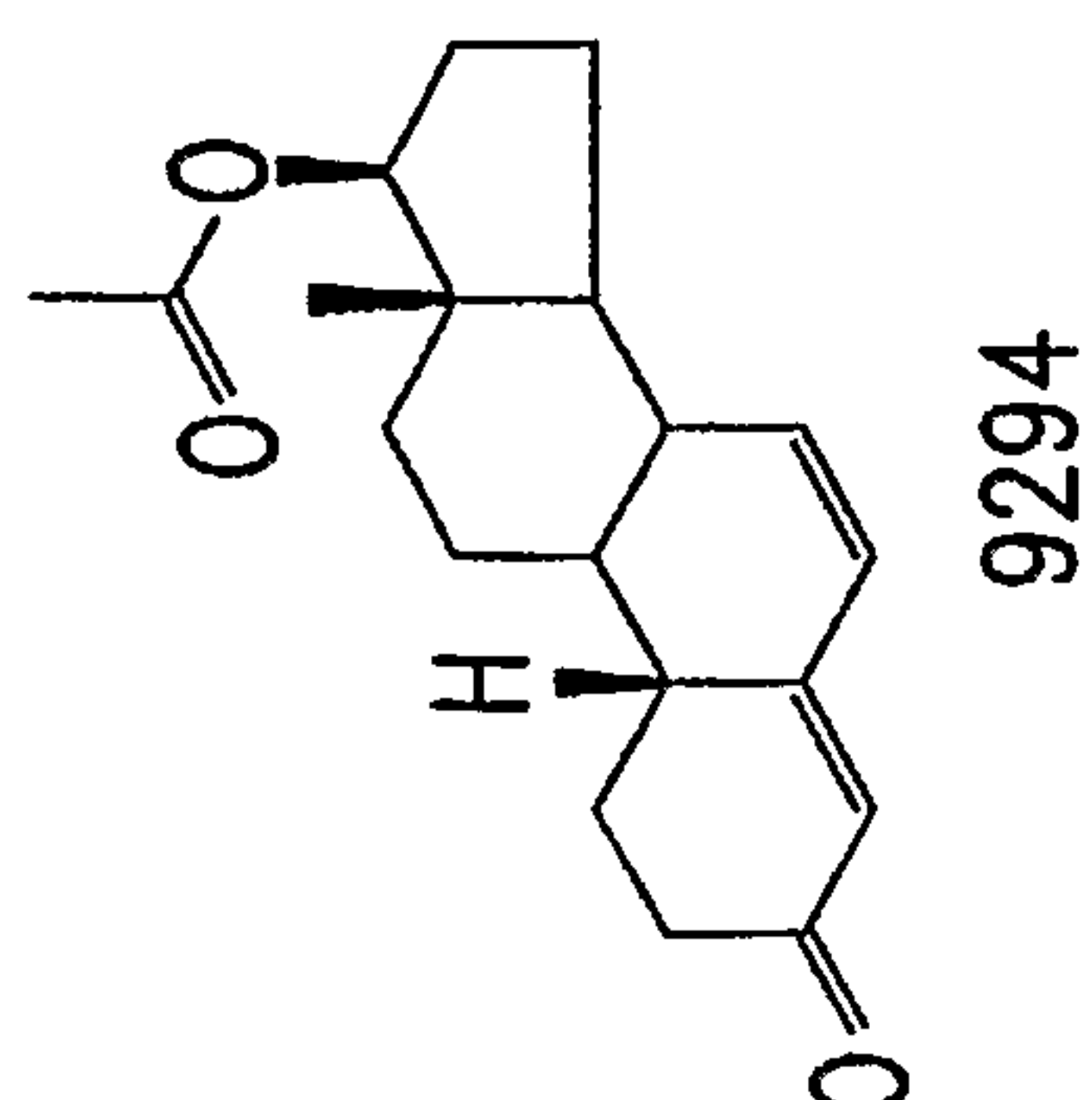
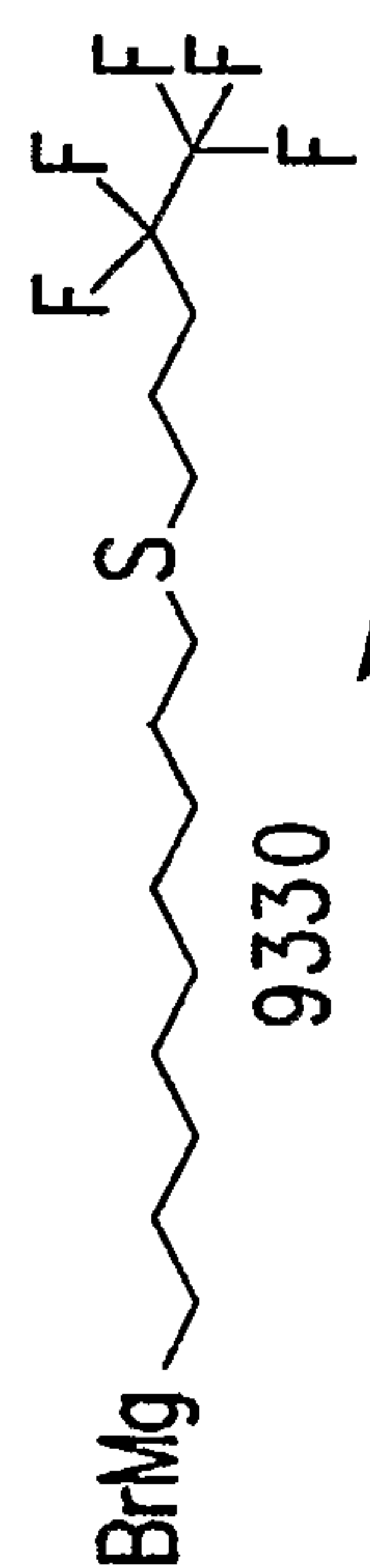
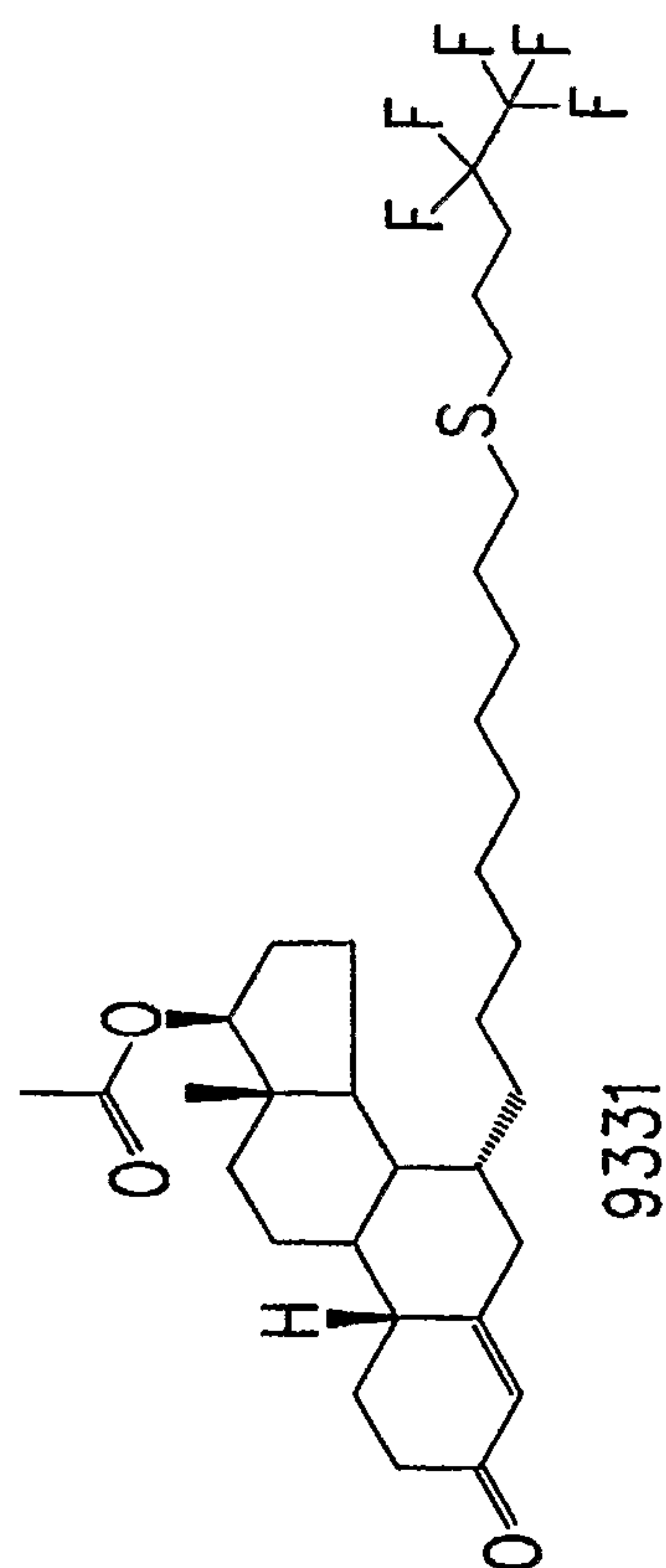


FIG.3

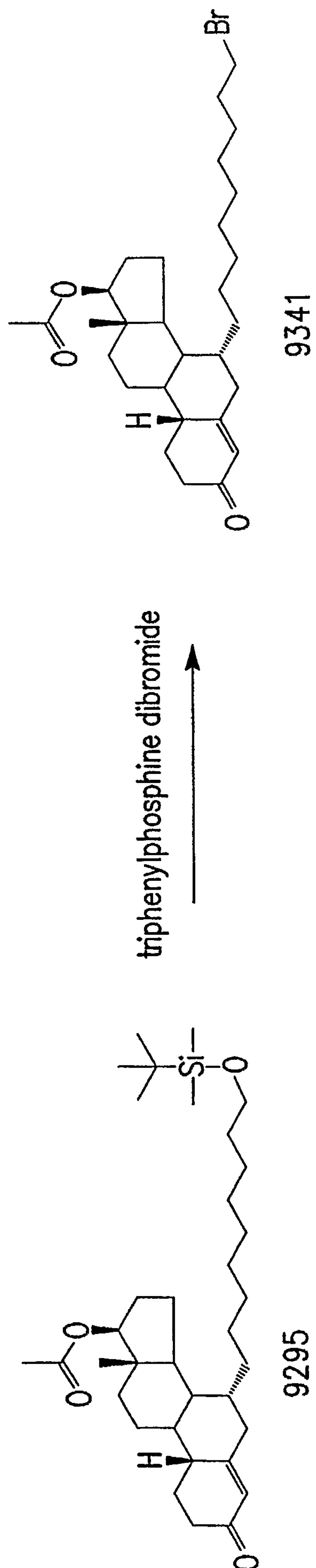


FIG.4

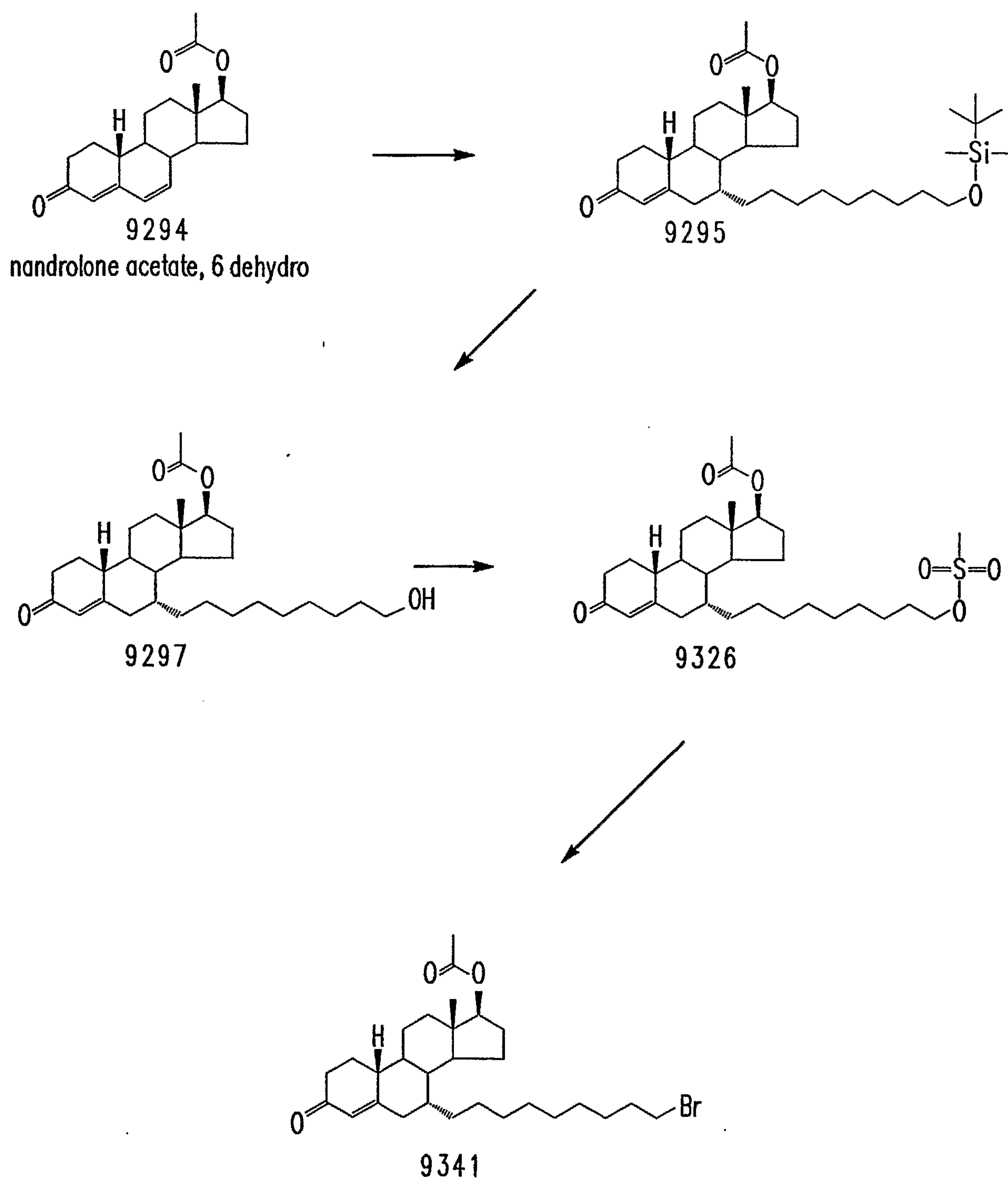


FIG.5

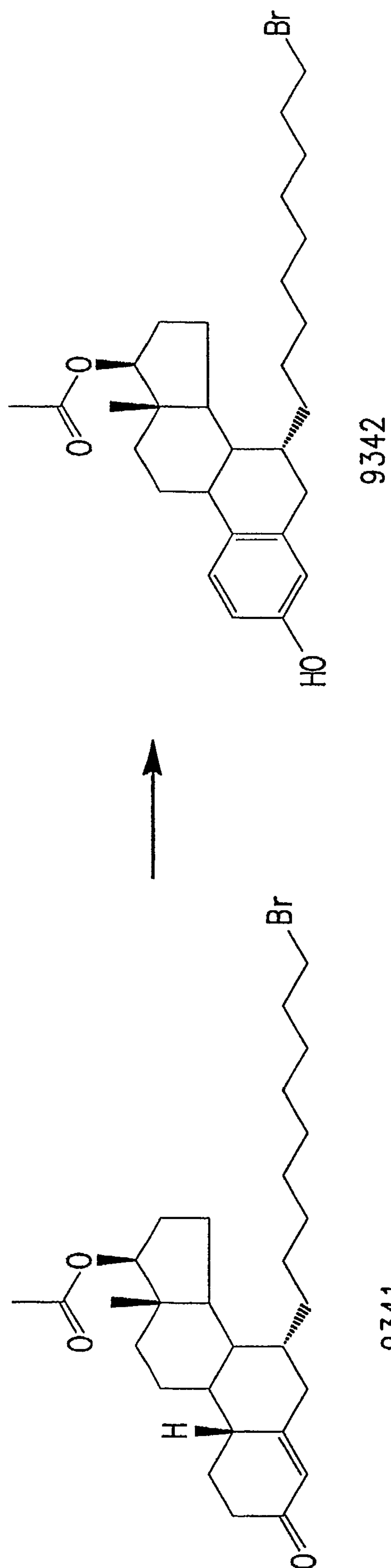


FIG. 6

7/13

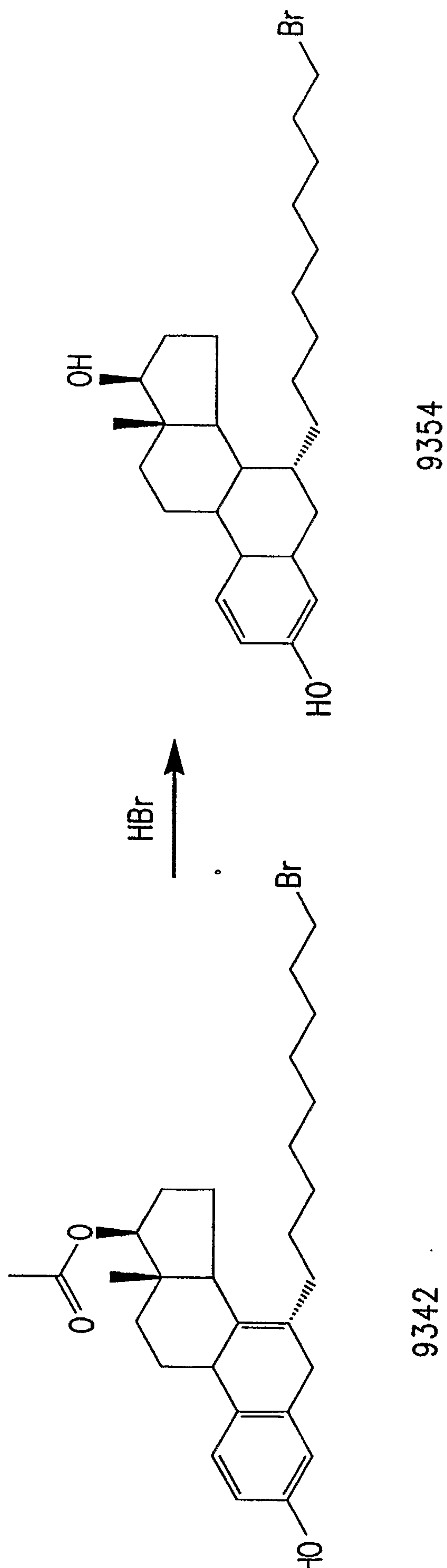
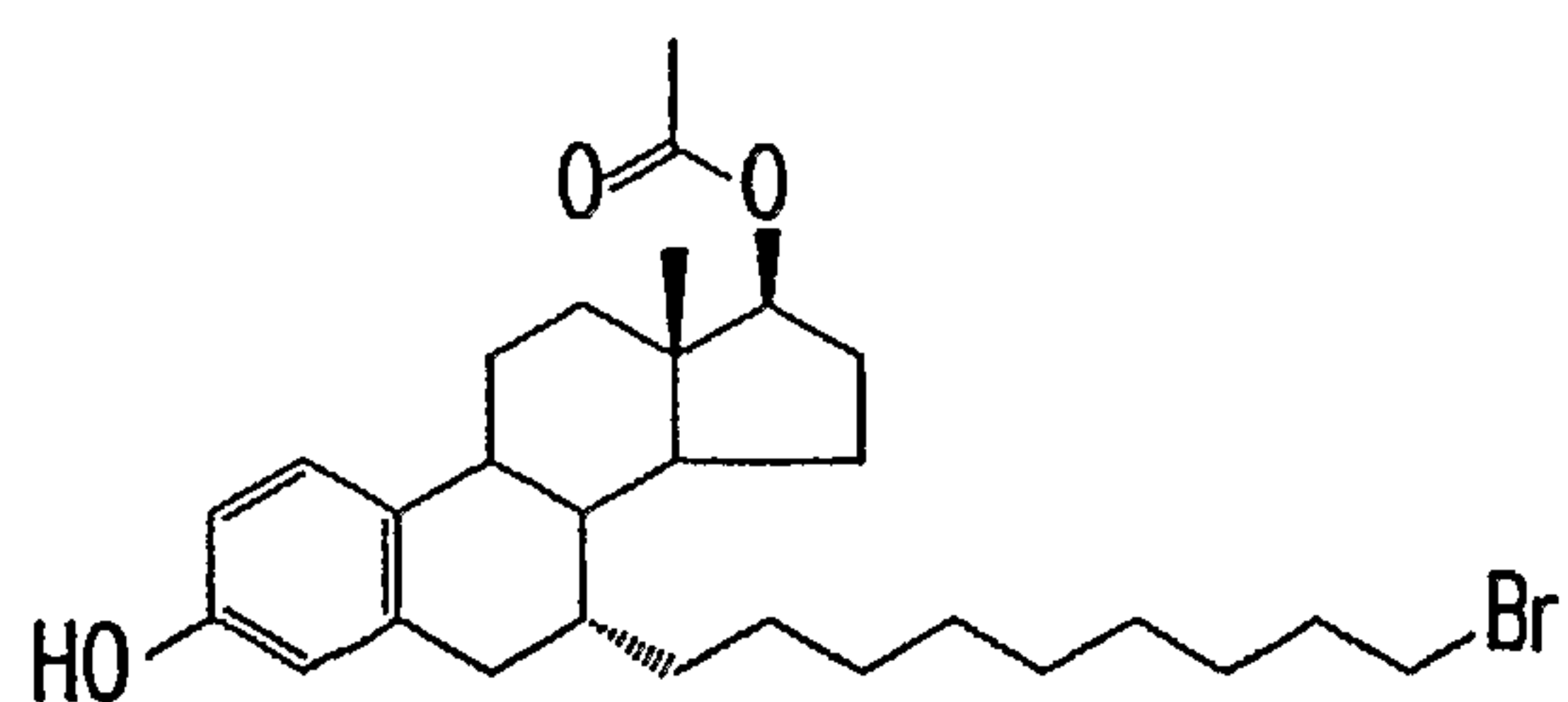
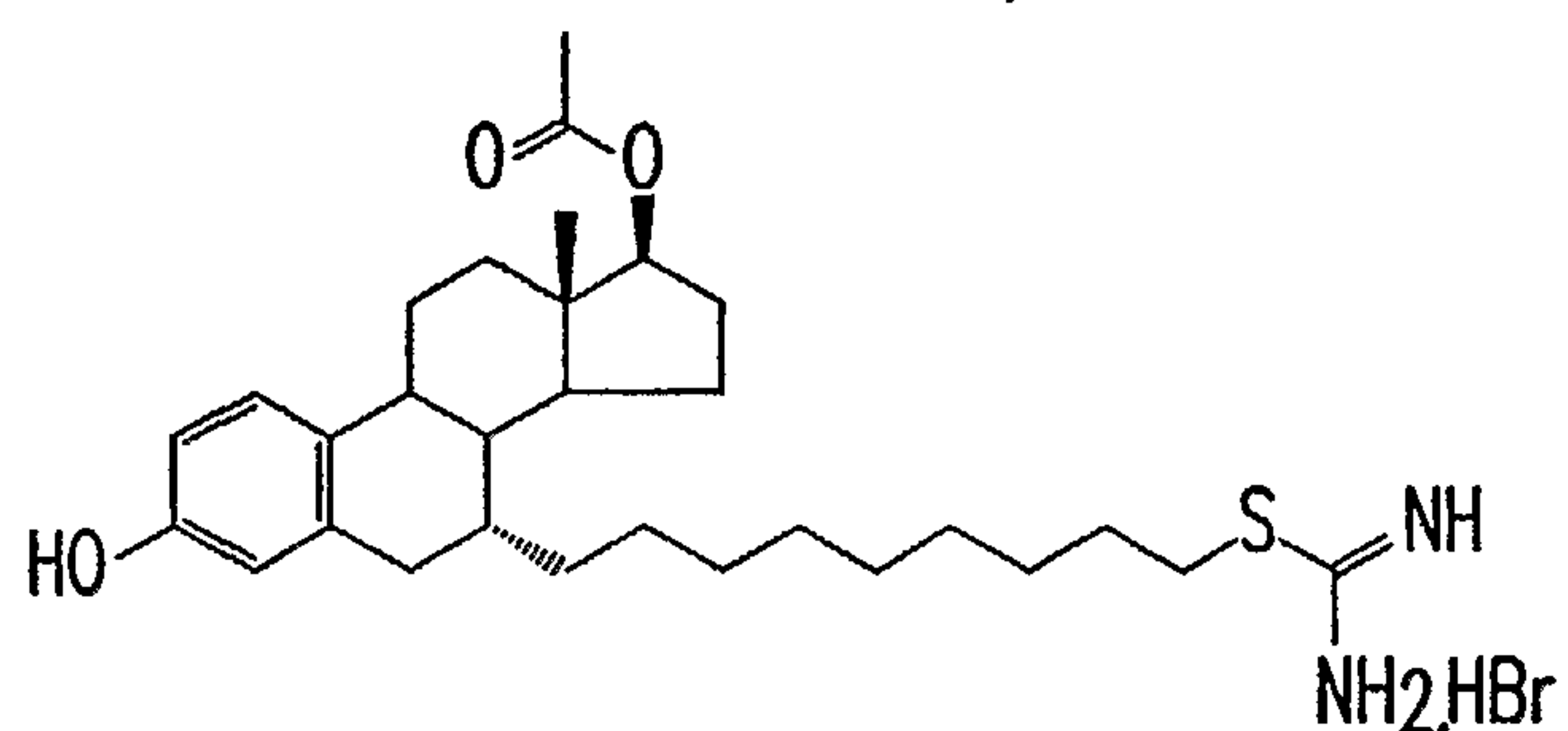


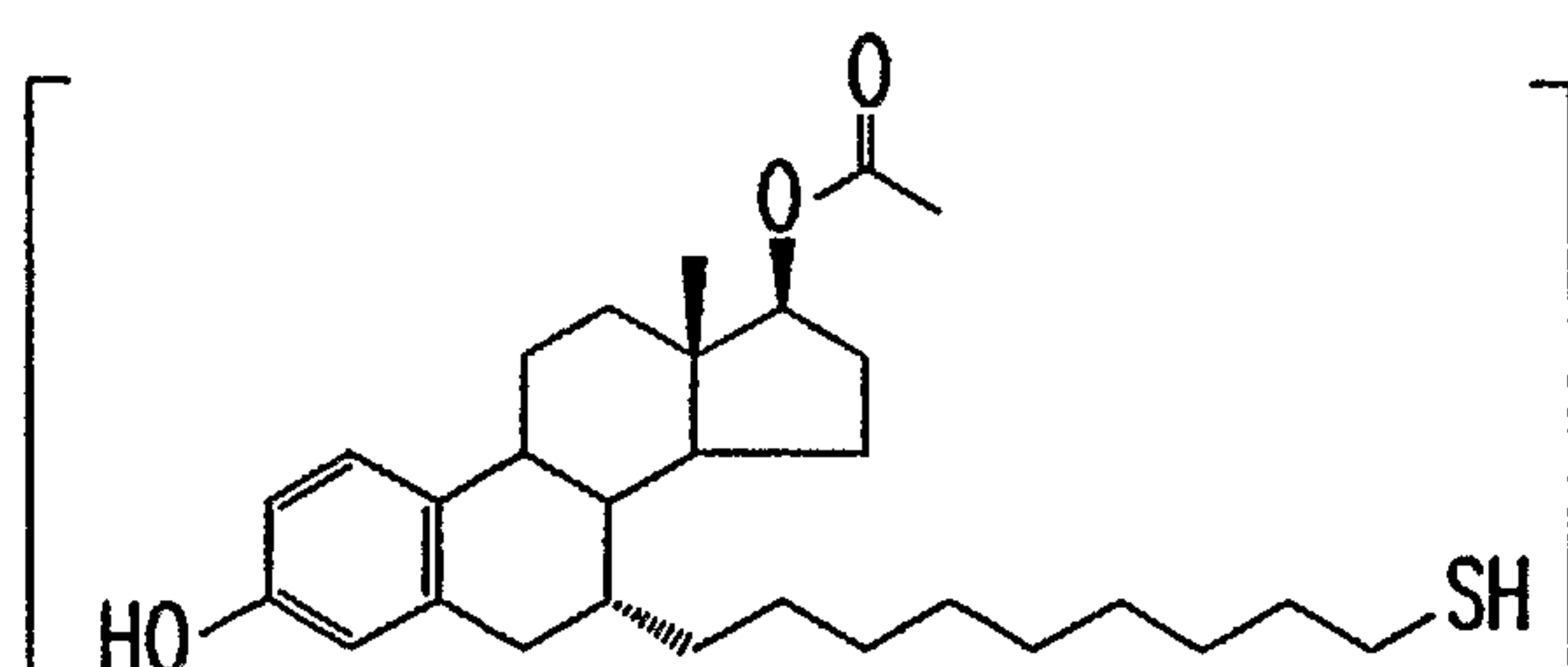
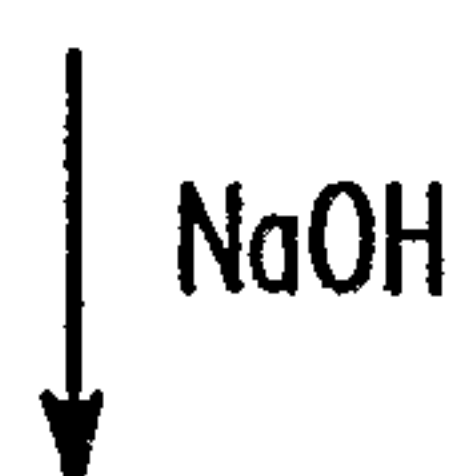
FIG. 7



9342



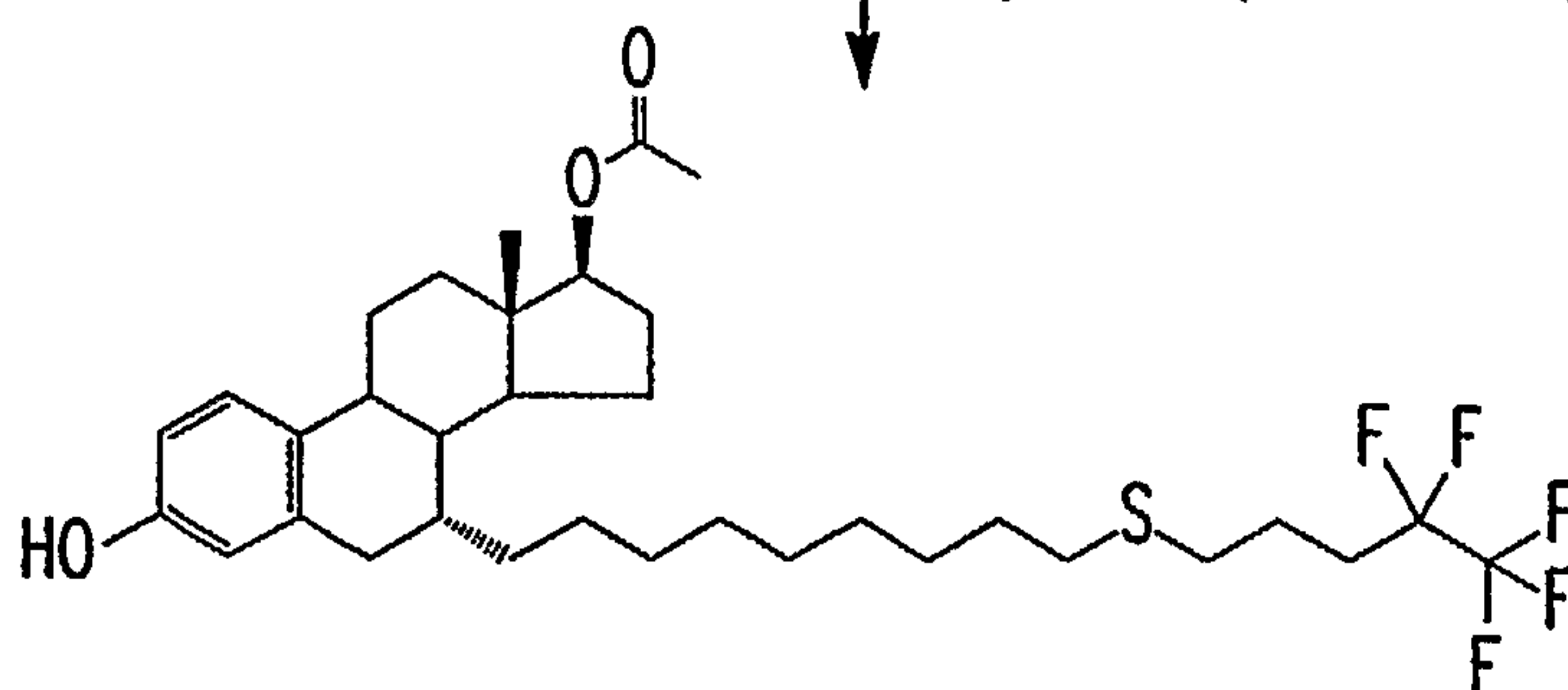
9361



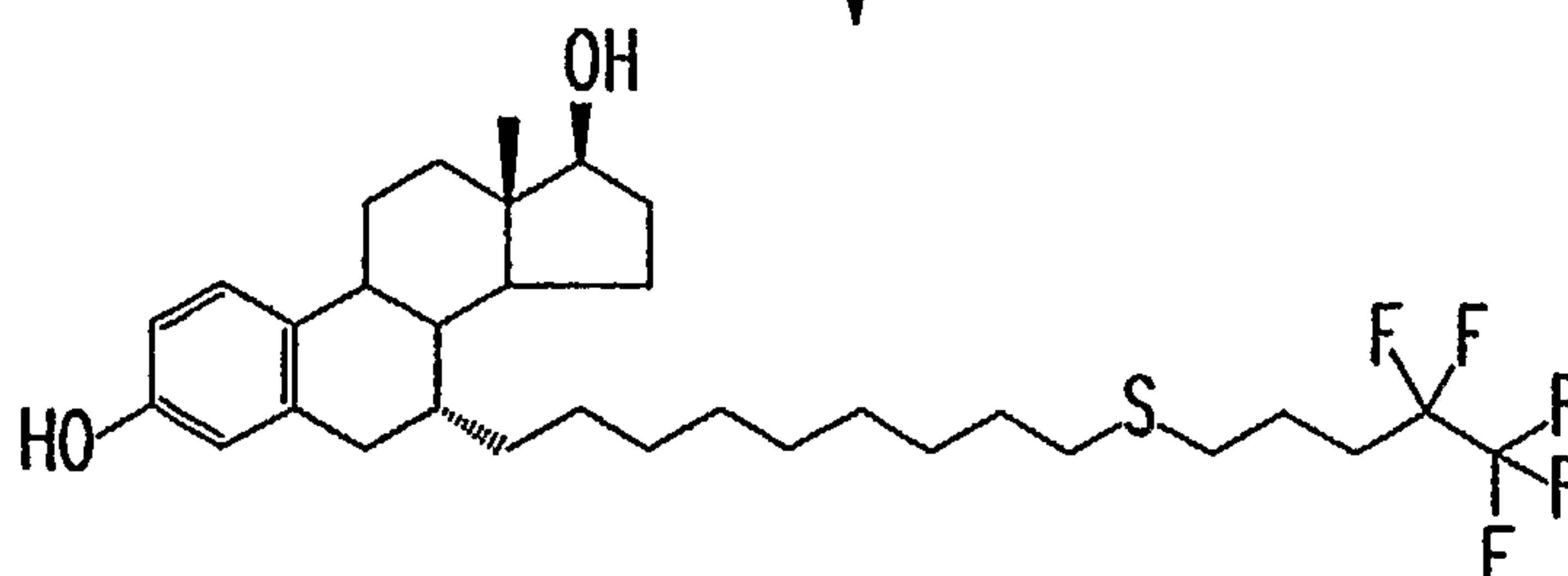
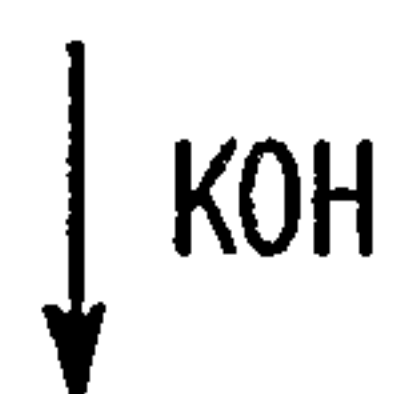
9362



Cp 9360 (4,4,5,5,5-pentafluoropentane 1-ol-mesylate)



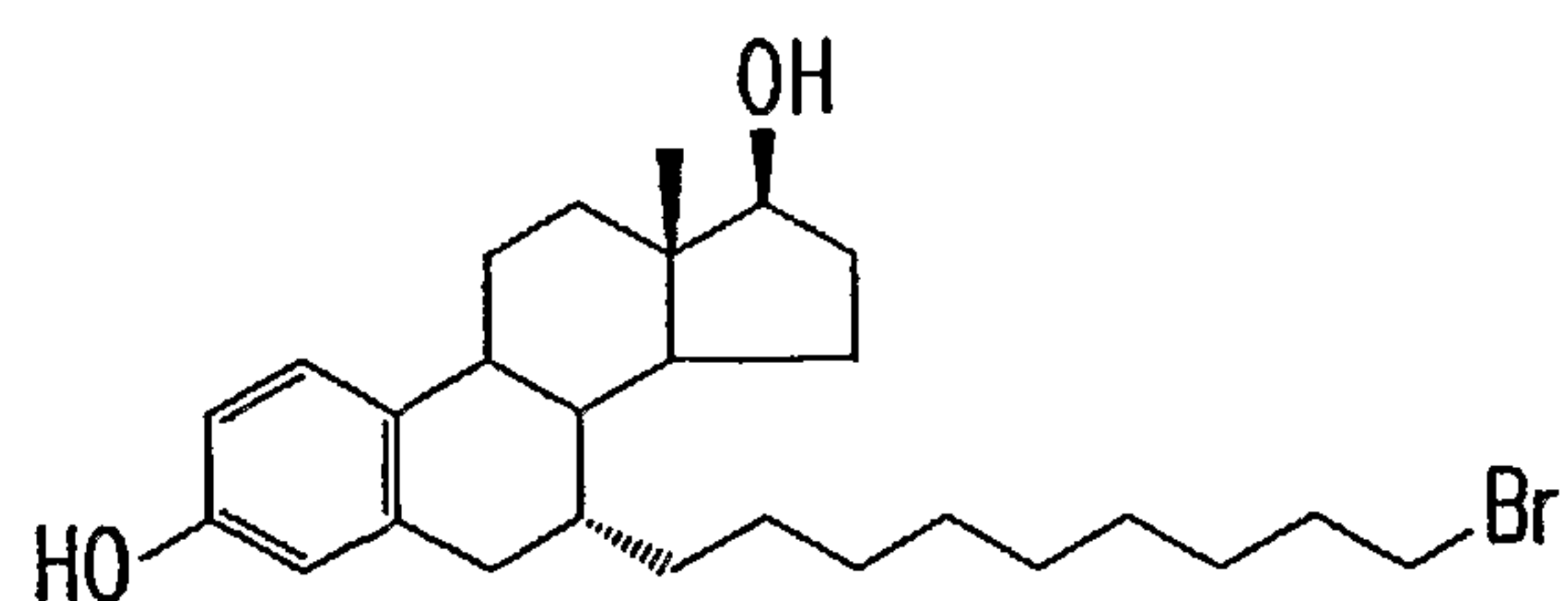
9363



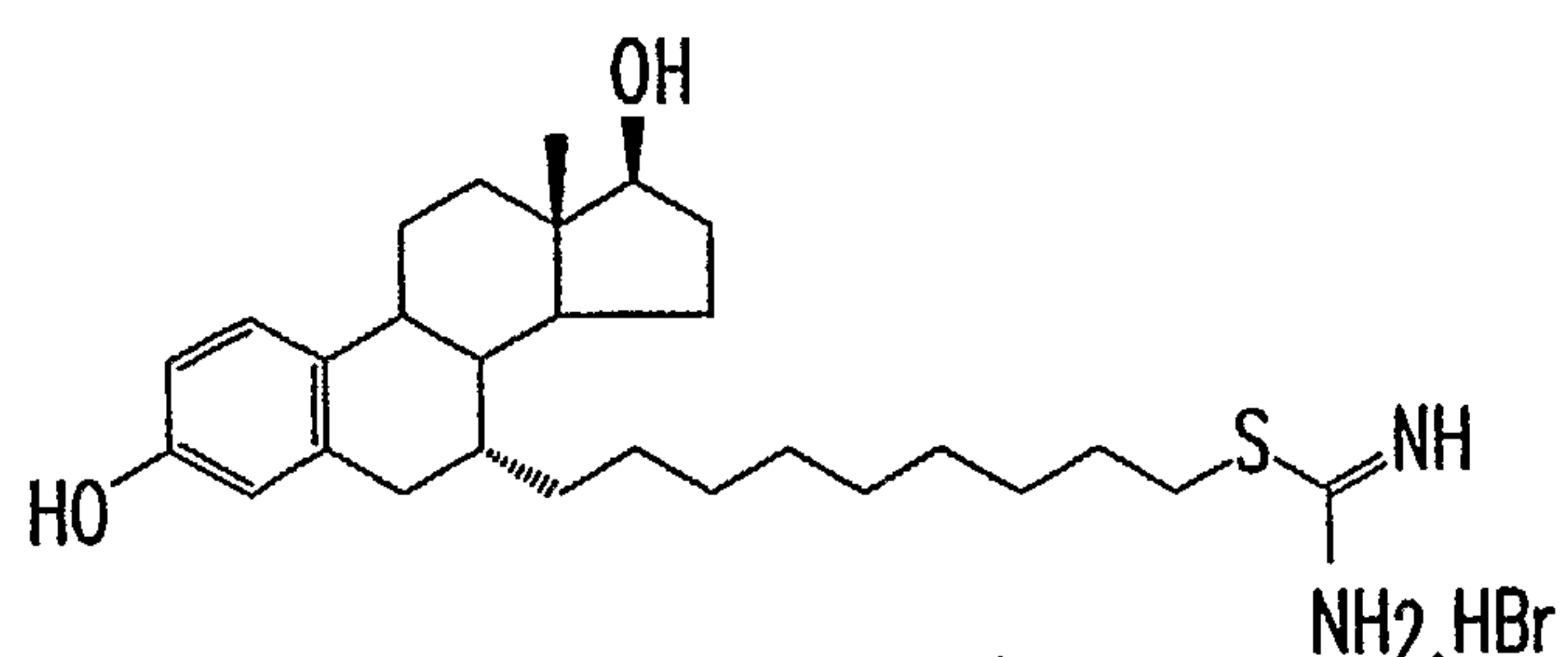
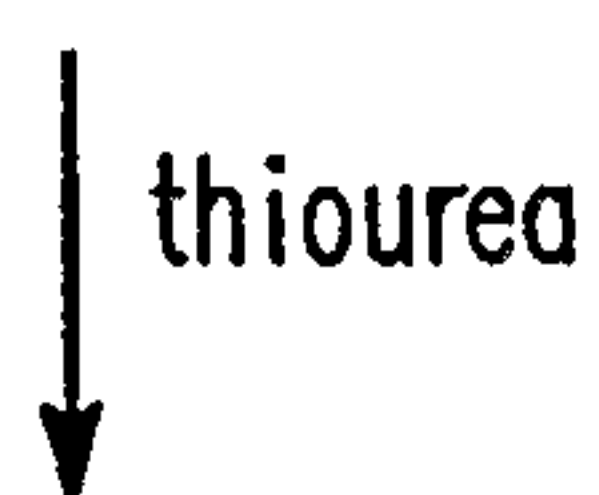
9304

↓ oxidise
fulvestrant (9305)

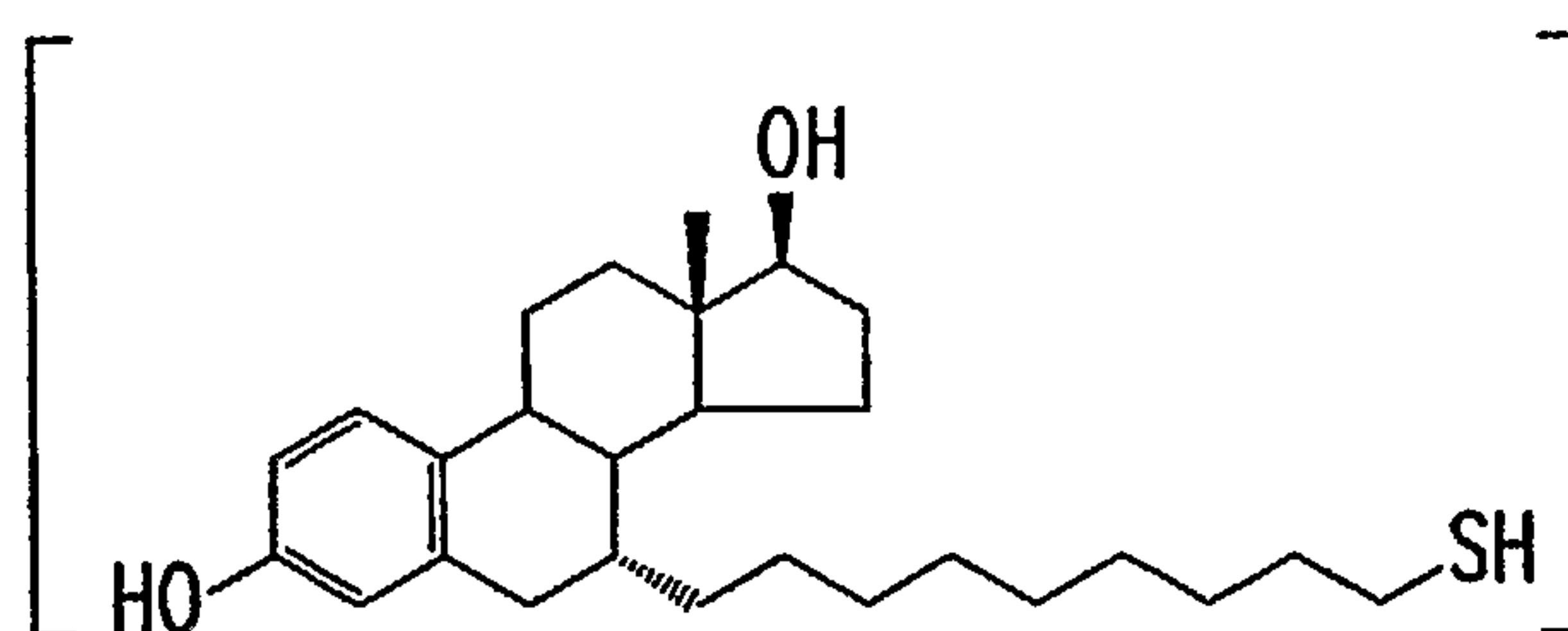
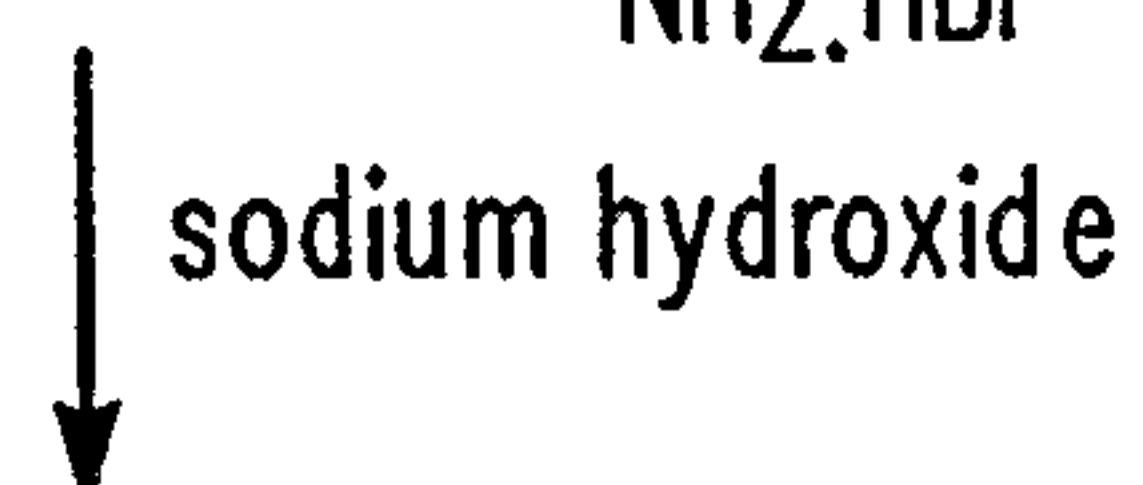
FIG. 8
SUBSTITUTE SHEET (RULE 26)



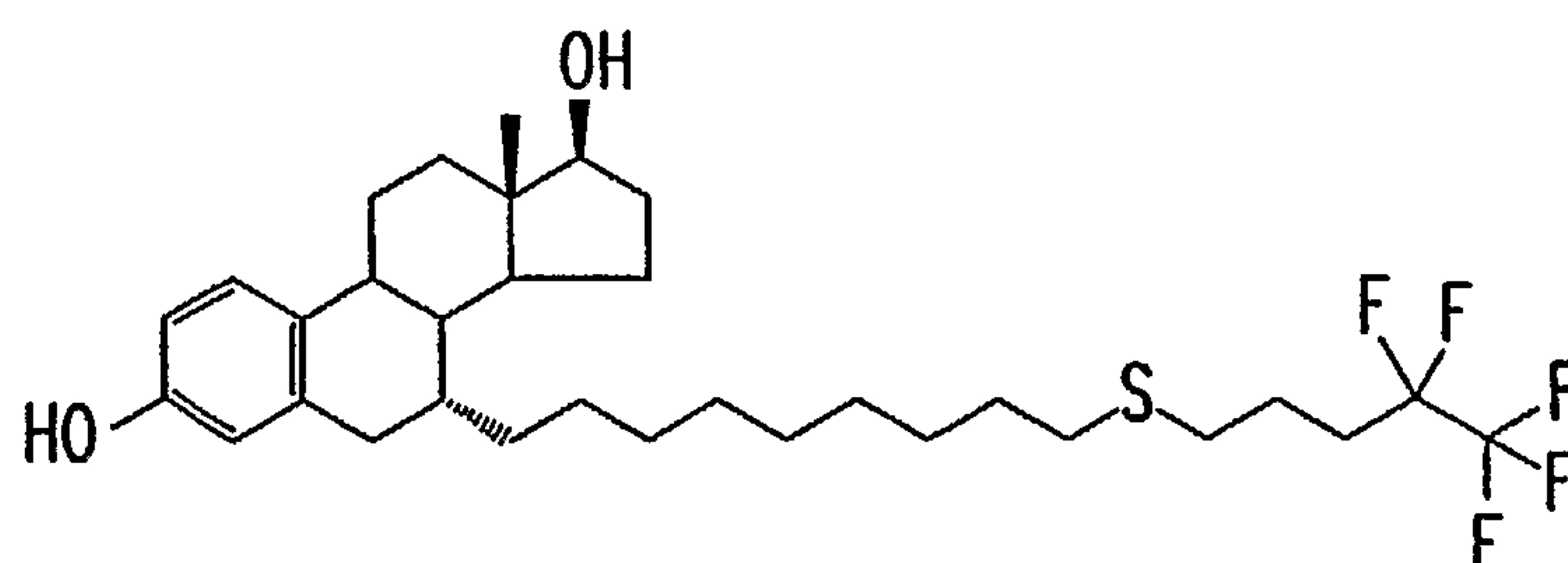
9354



9388



9389



9304

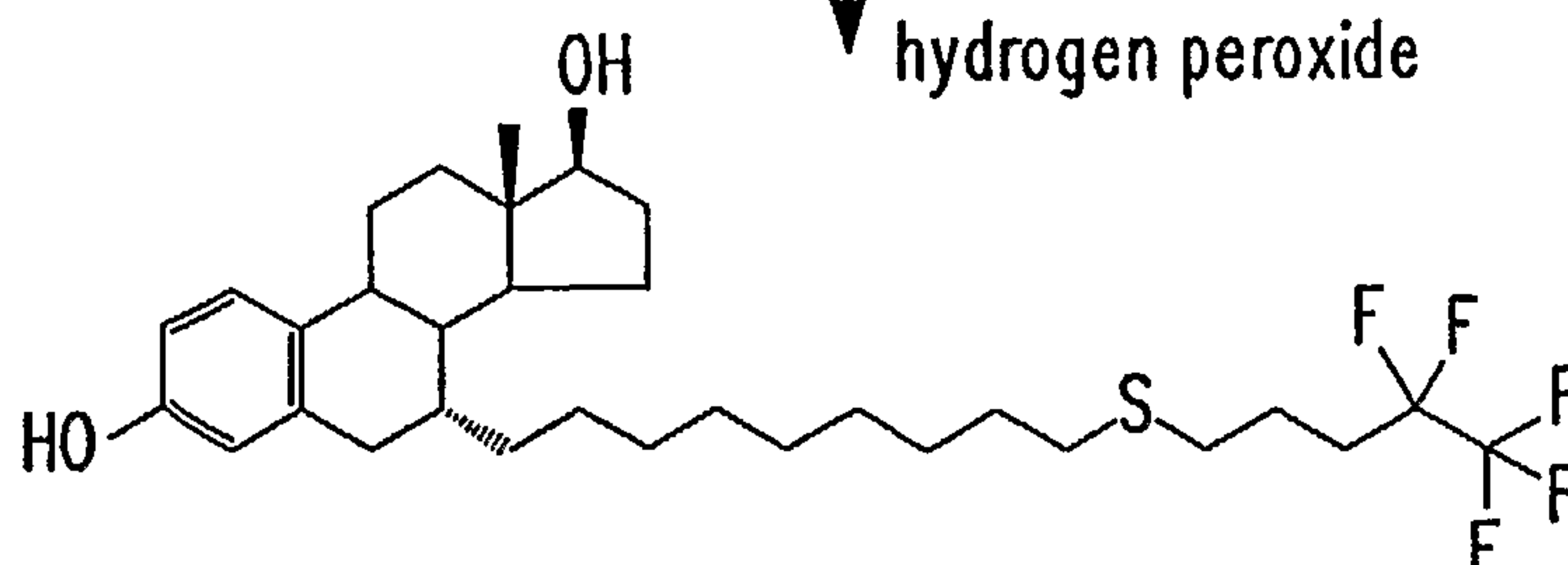
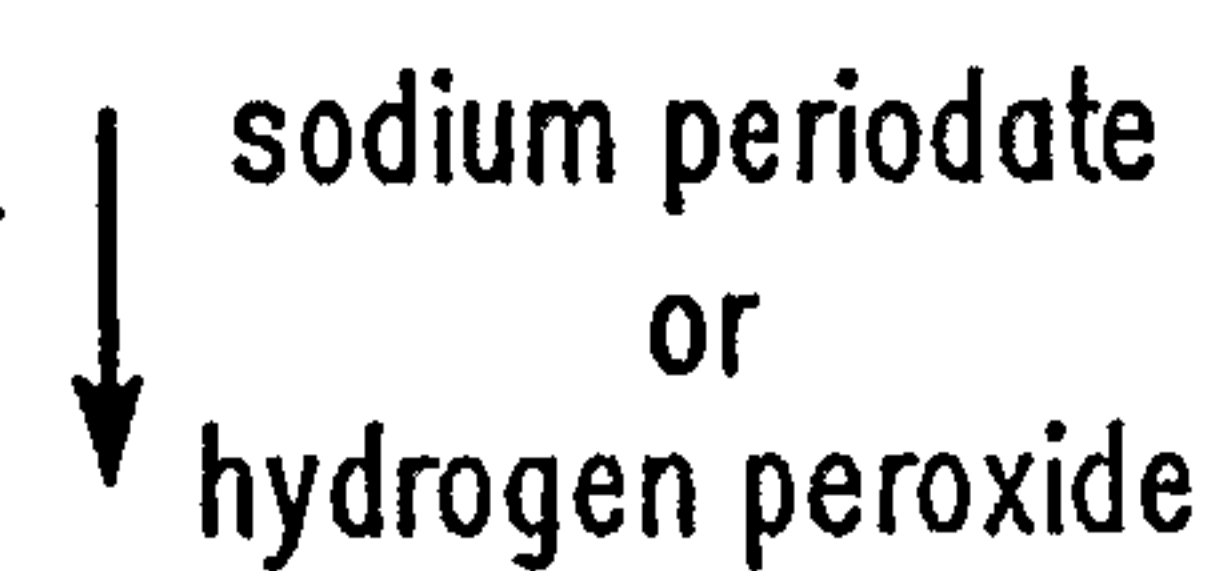
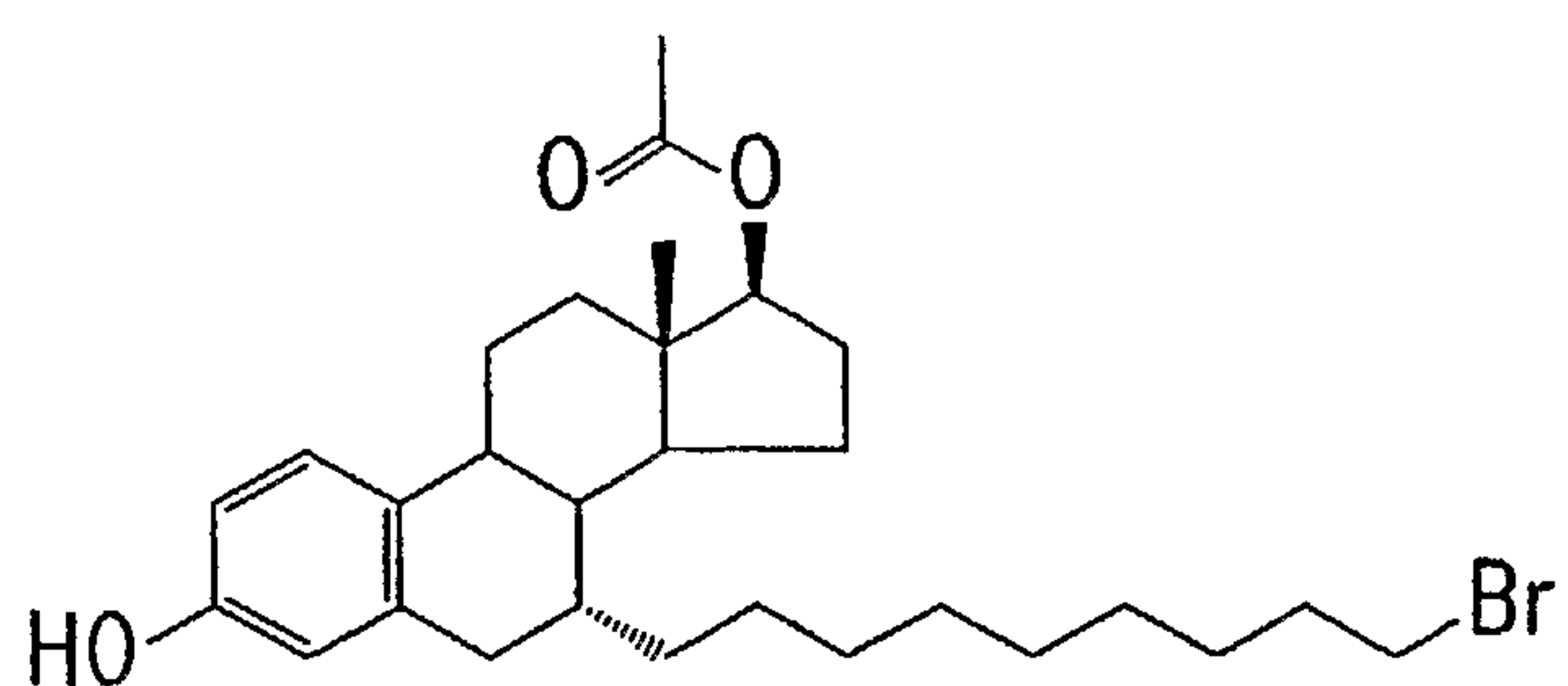
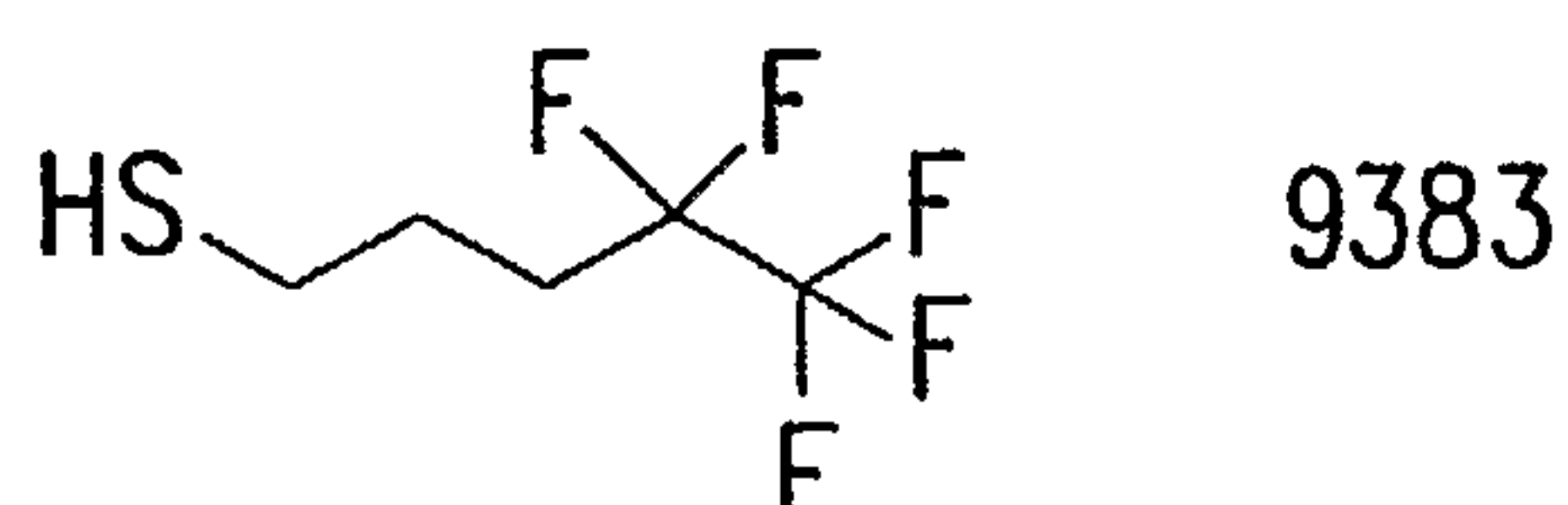
fulvestrant
9305

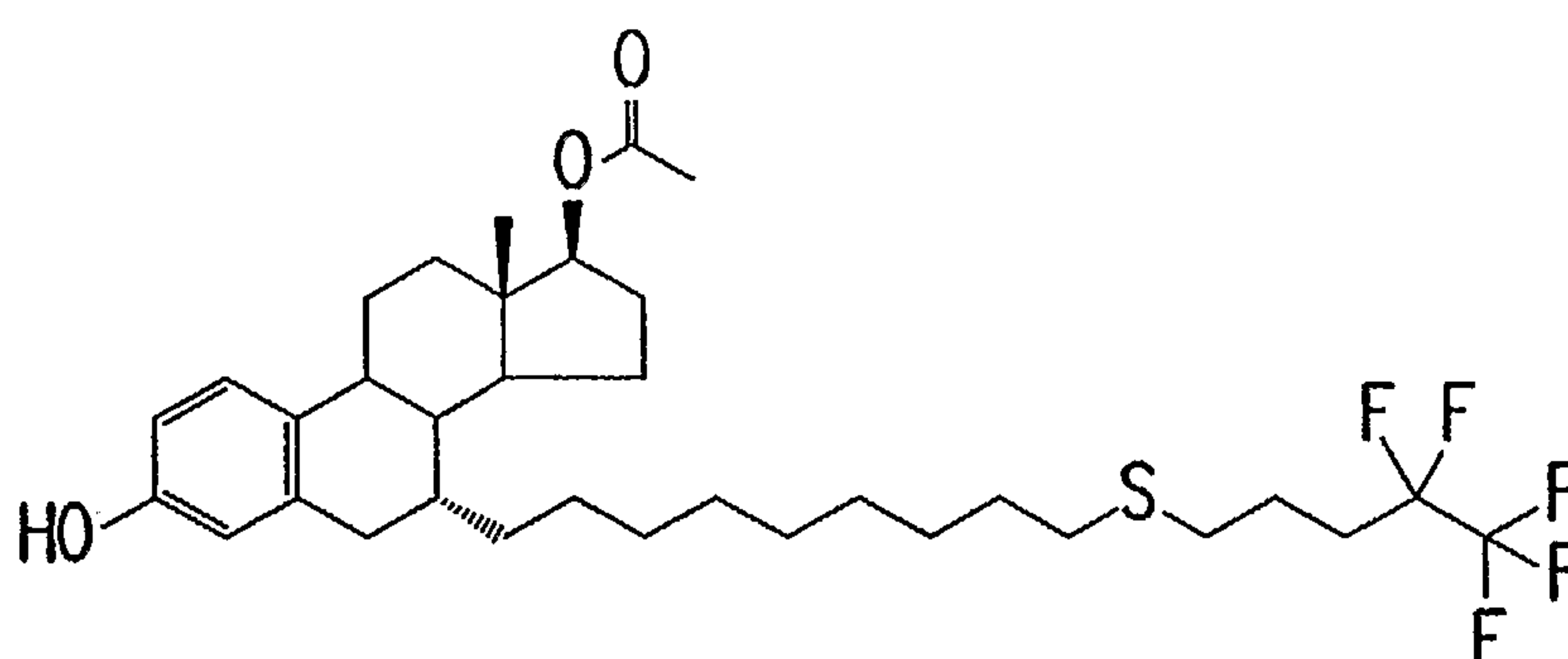
FIG. 9
SUBSTITUTE SHEET (RULE 26)



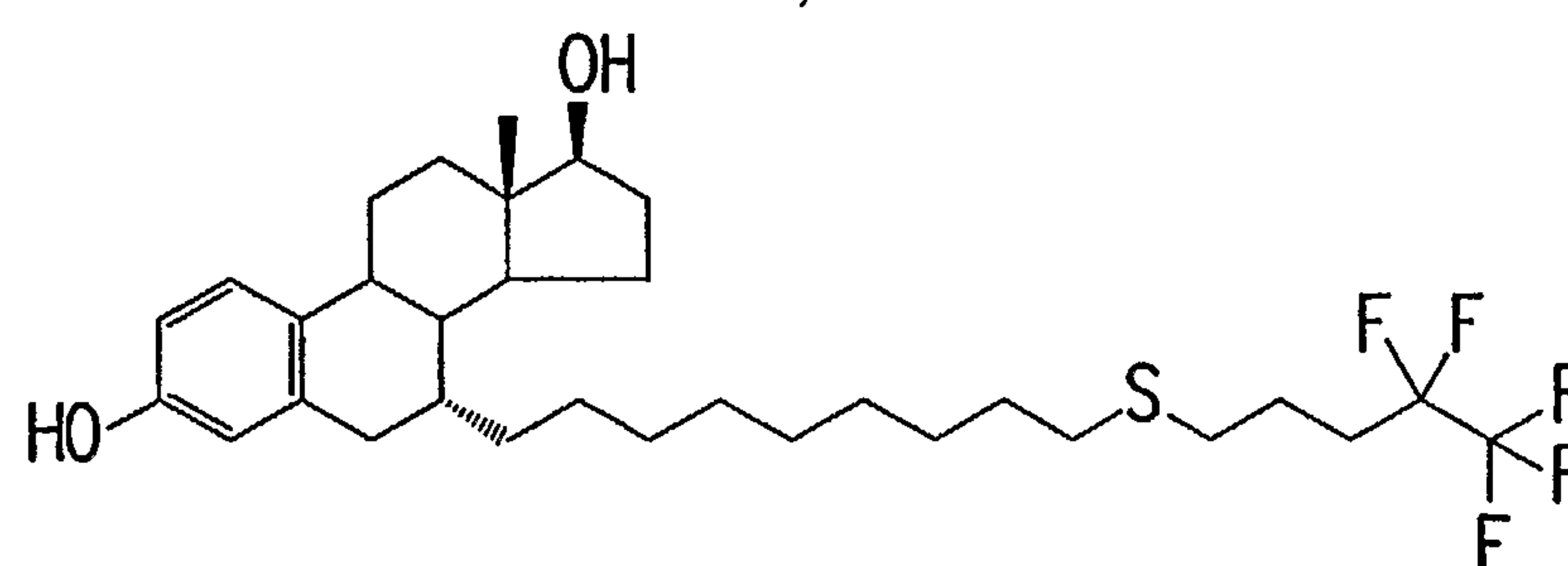
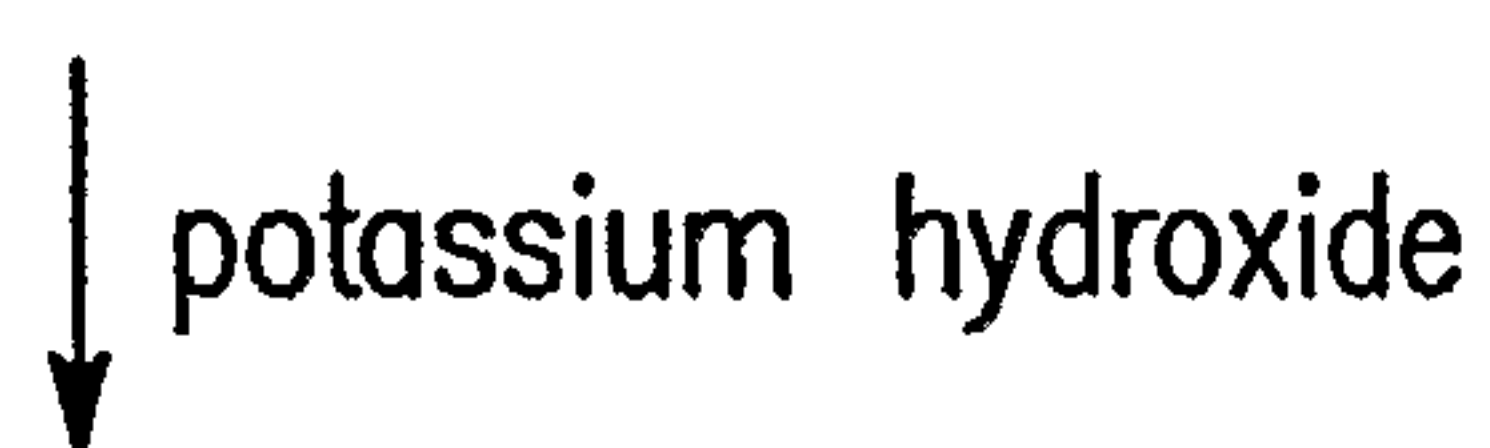
9342



9383



9363



9304

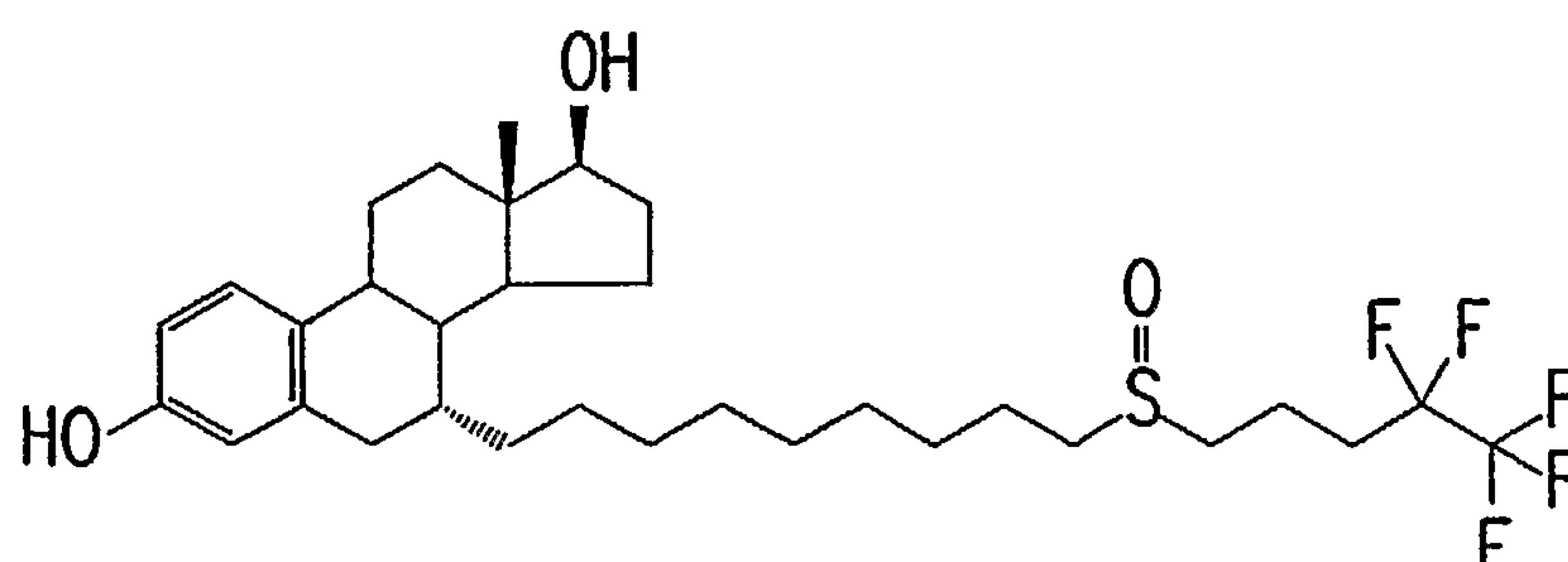
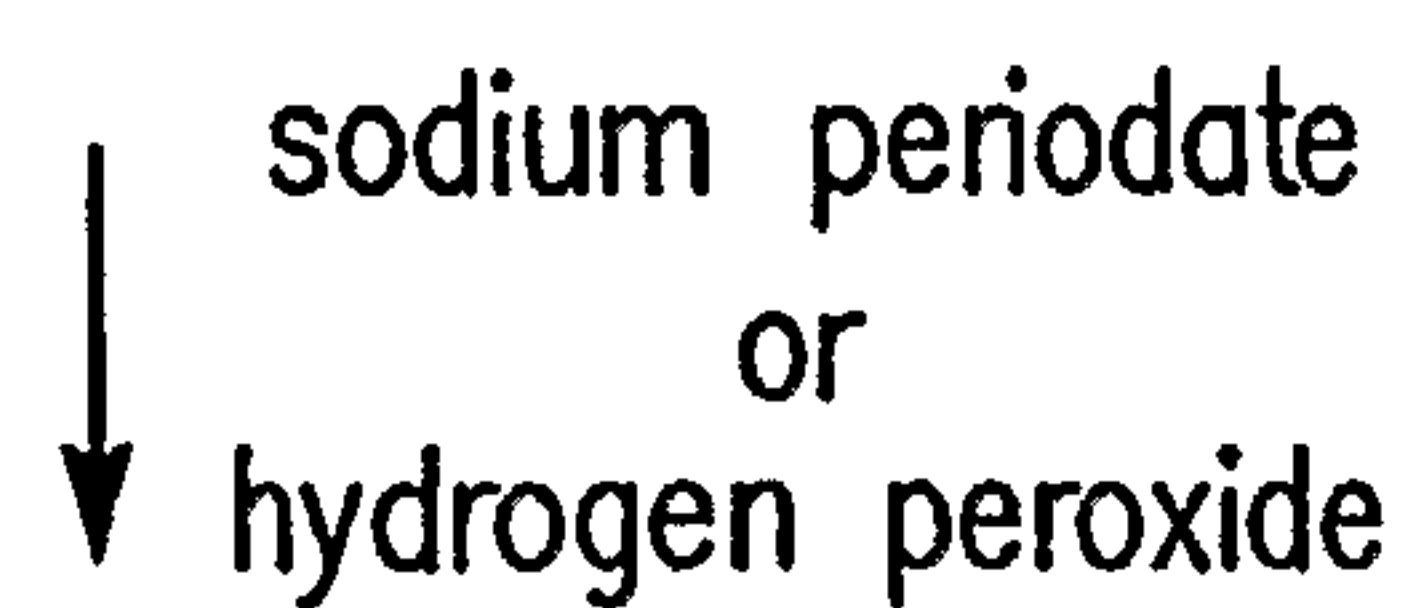
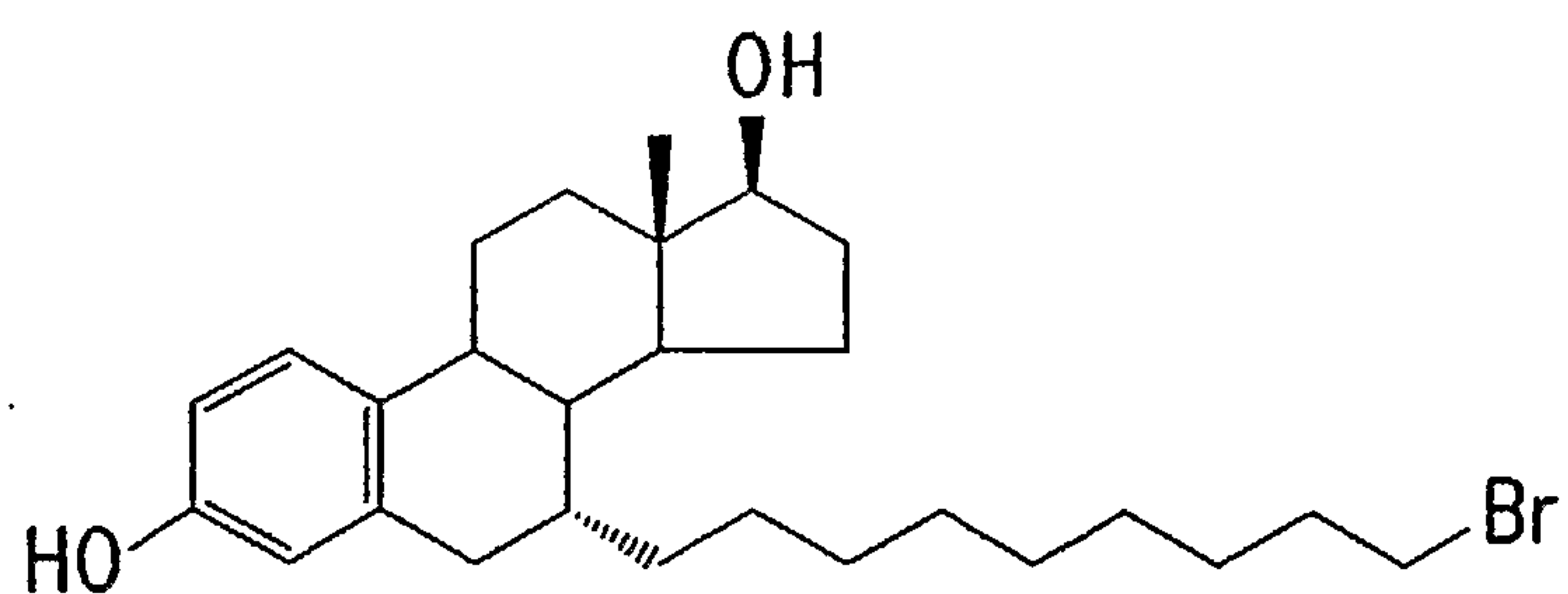
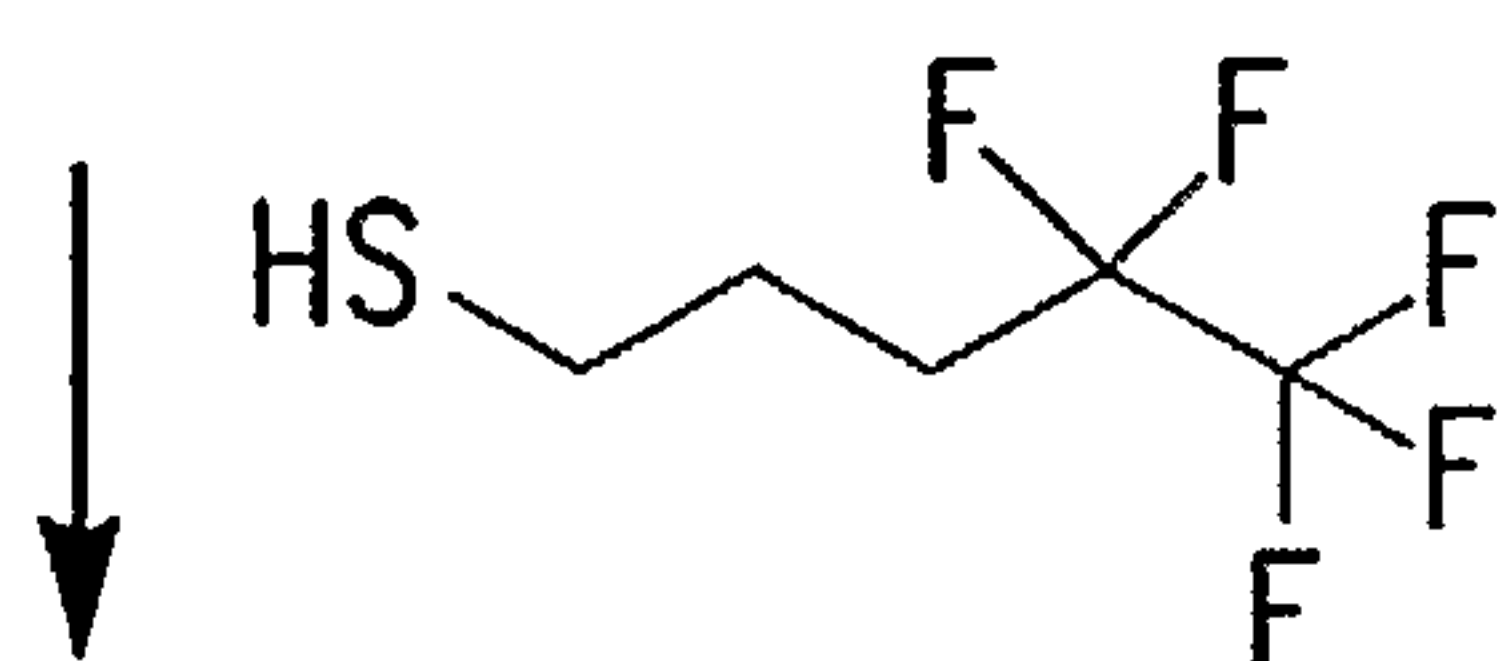
fulvestrant
9305

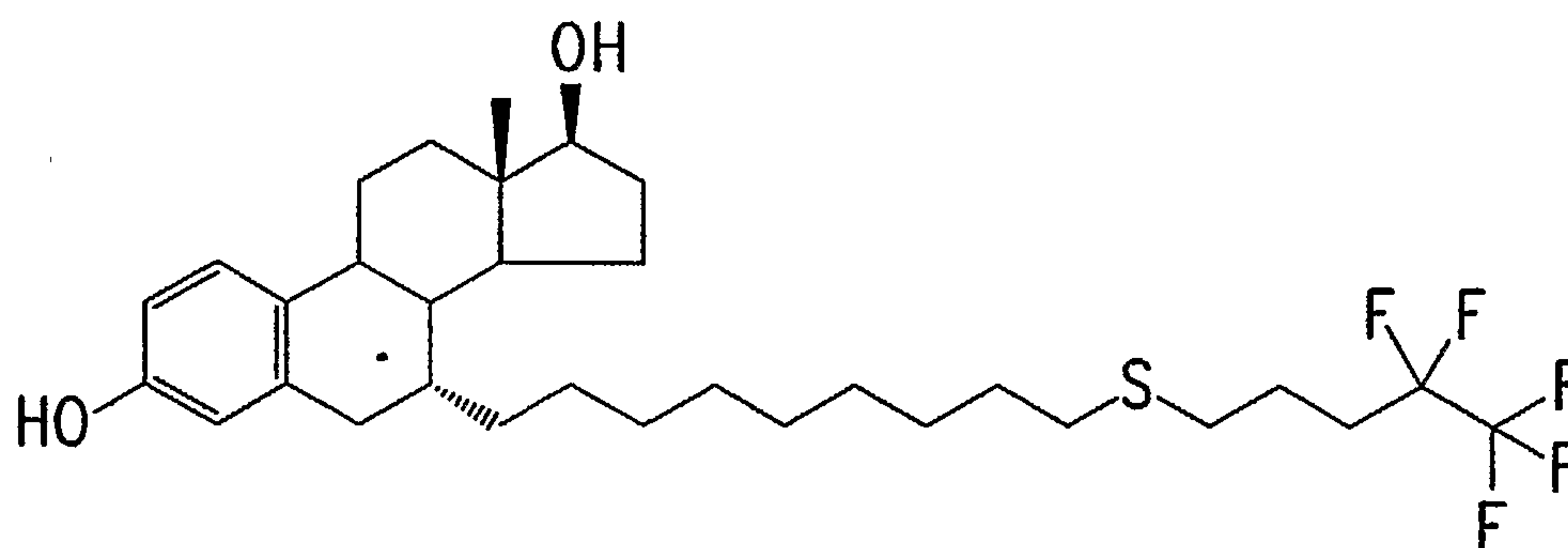
FIG. 10
SUBSTITUTE SHEET (RULE 26)



9354



9383



9304

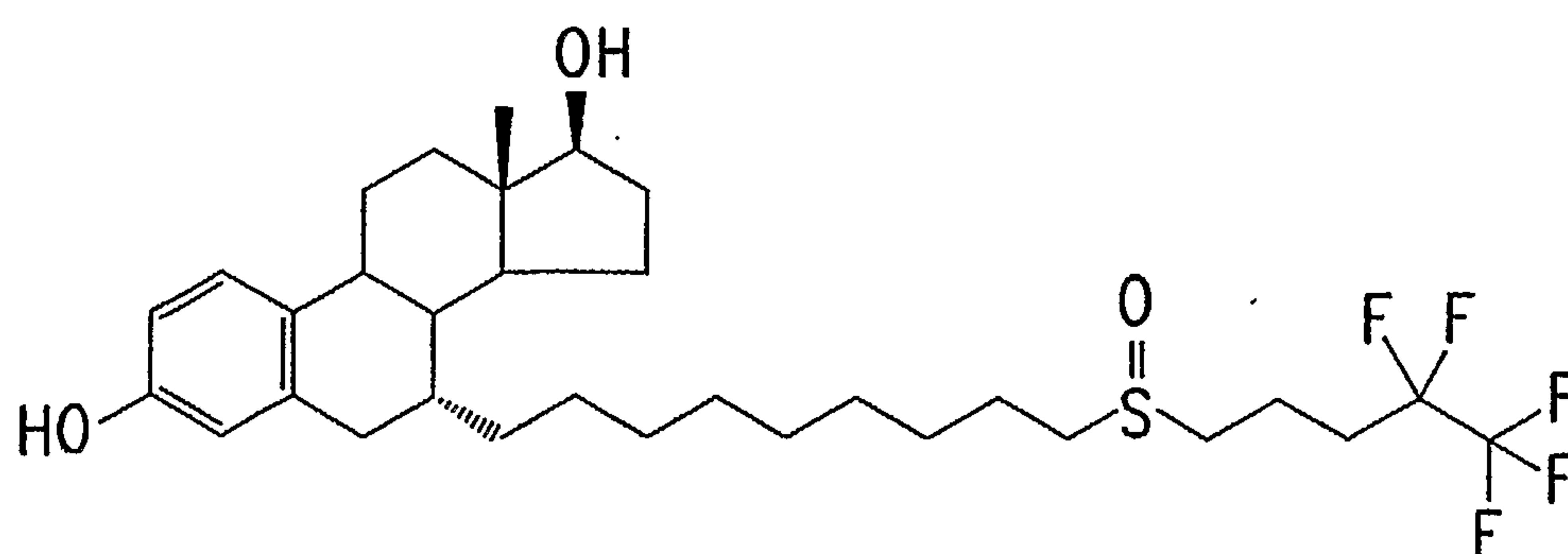
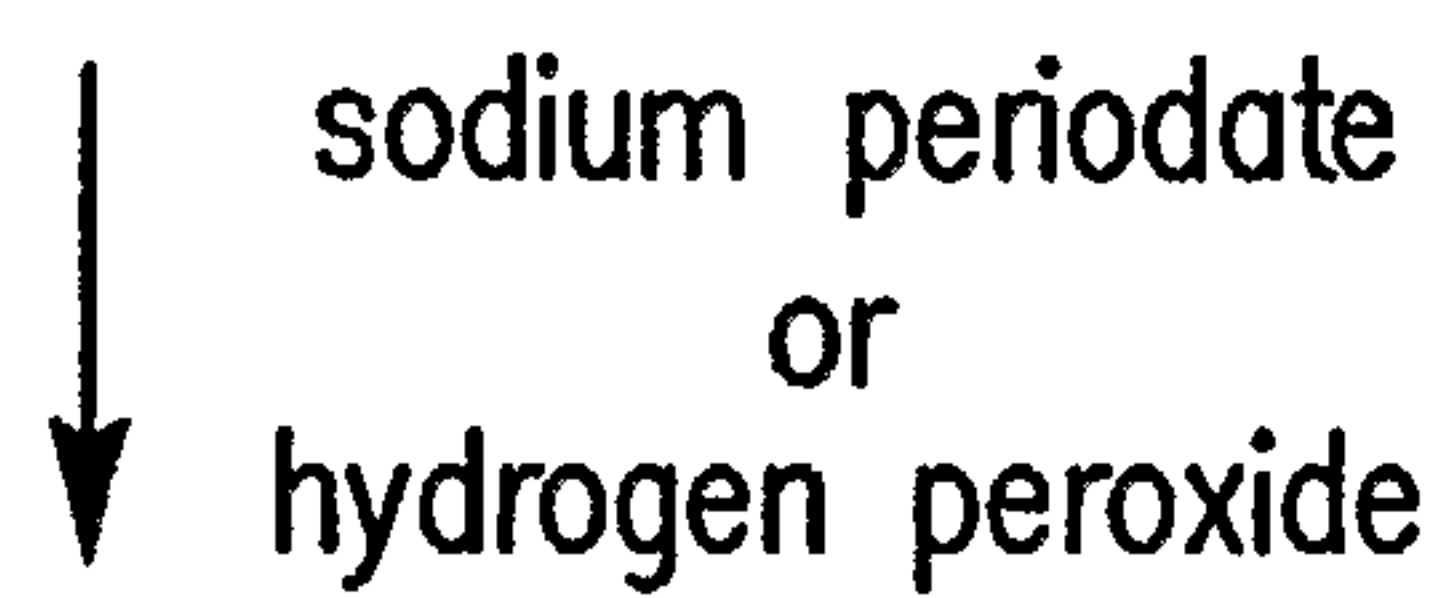
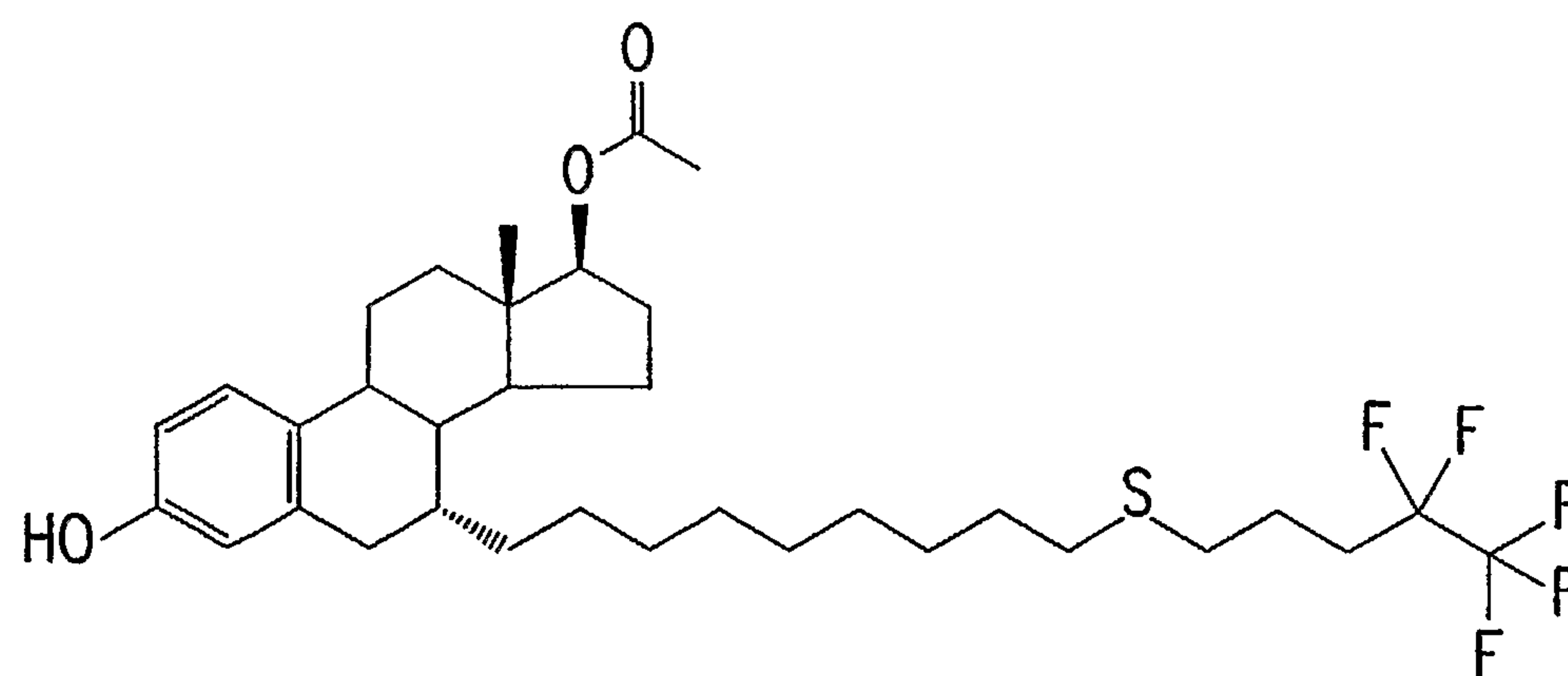
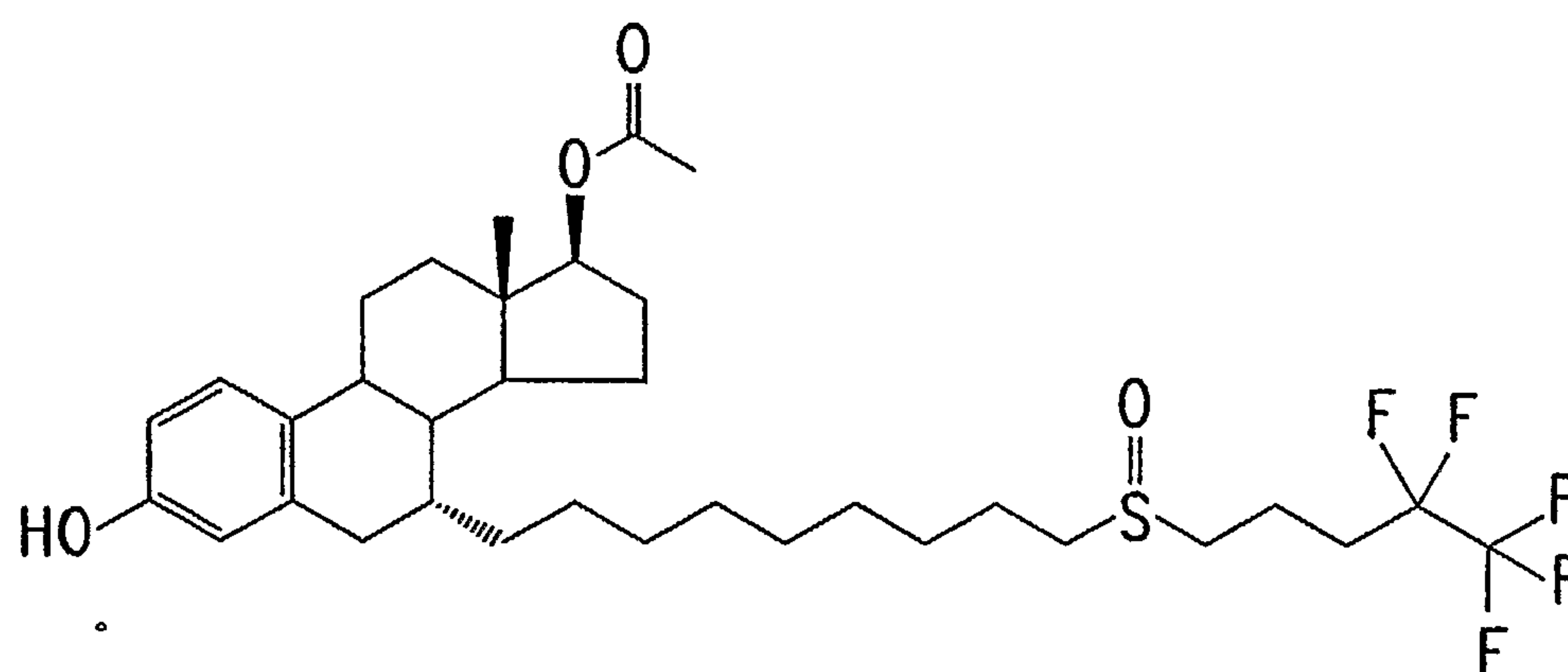
fulvestrant
9305

FIG. 11
SUBSTITUTE SHEET (RULE 26)



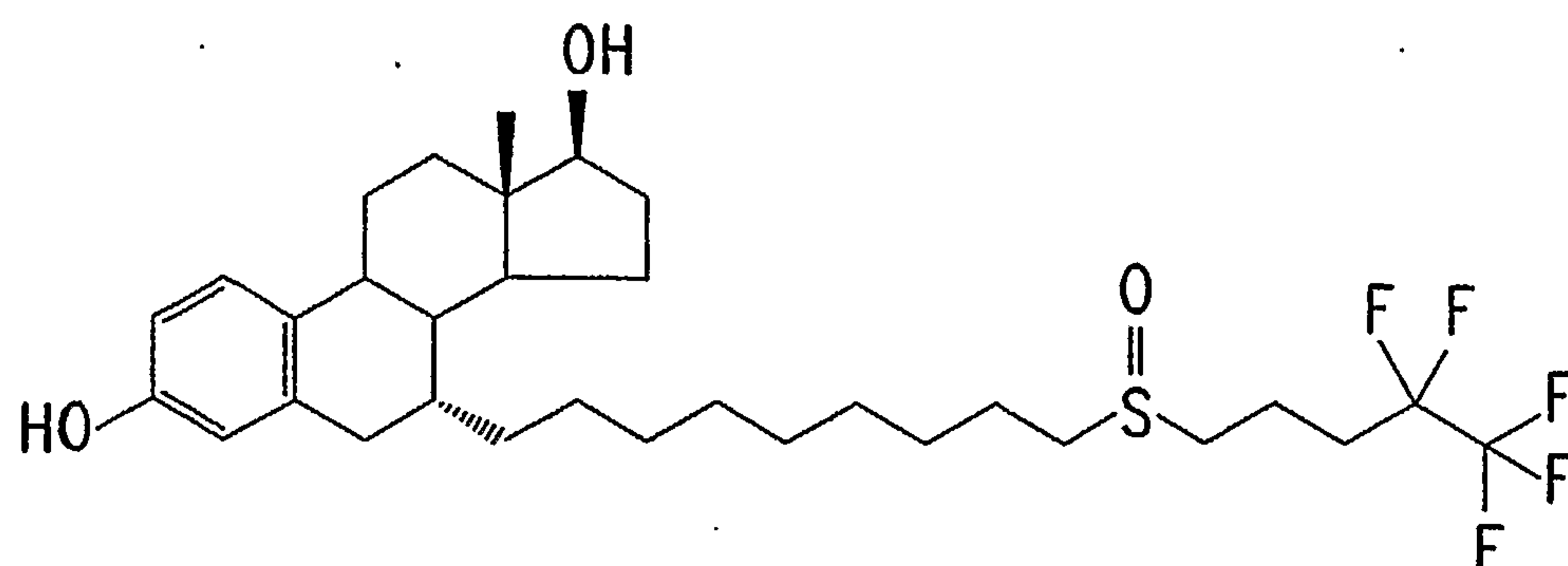
9363

oxidation



9368

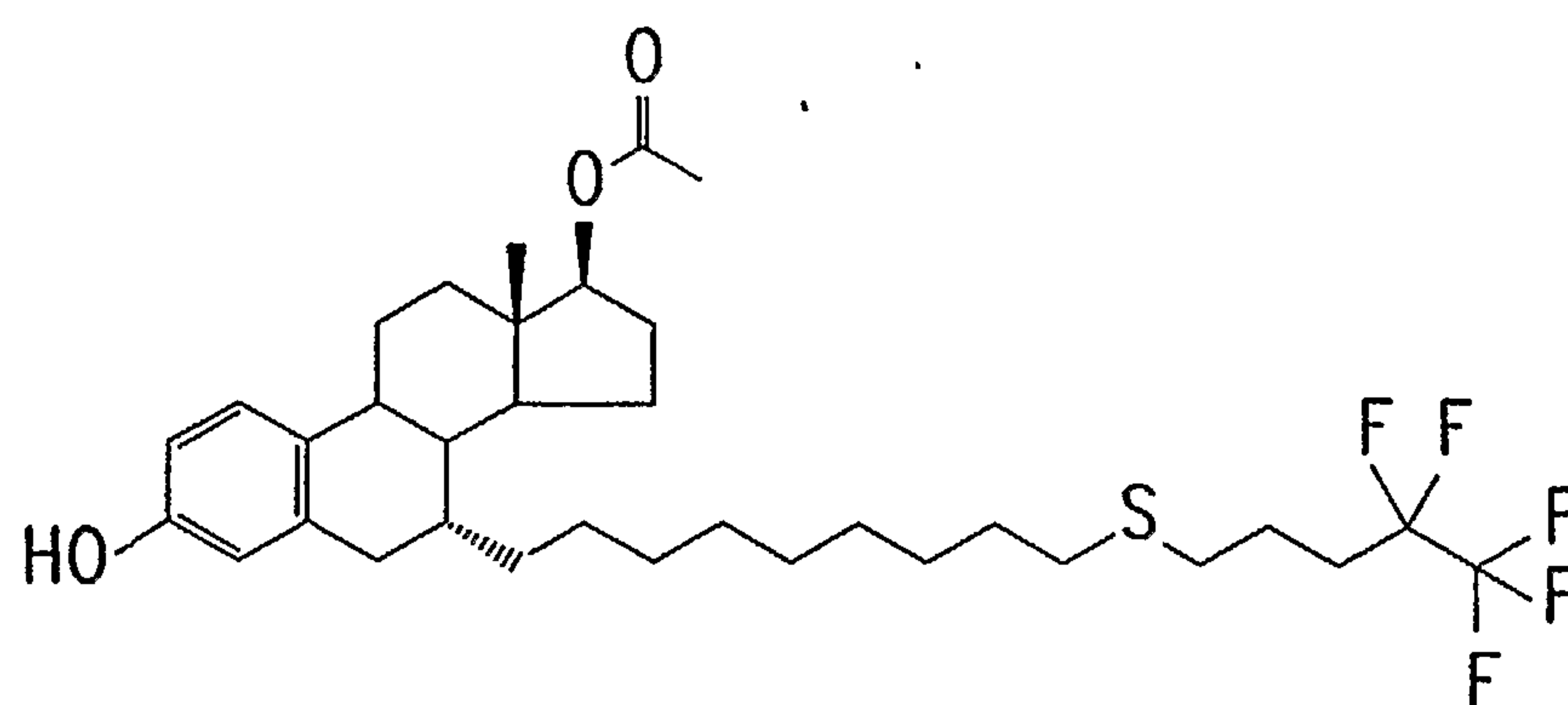
hydrolysis



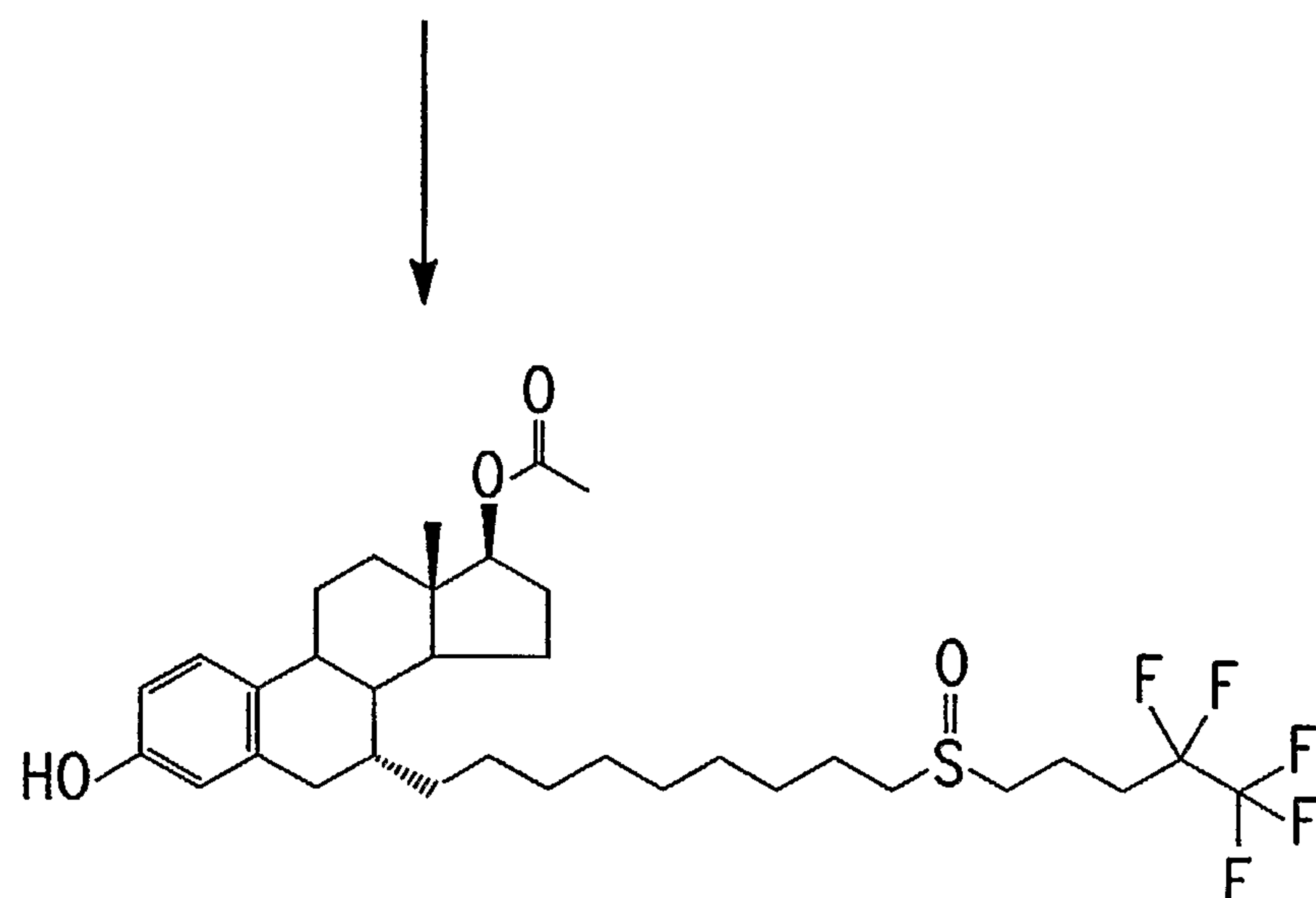
9305

FIG. 12

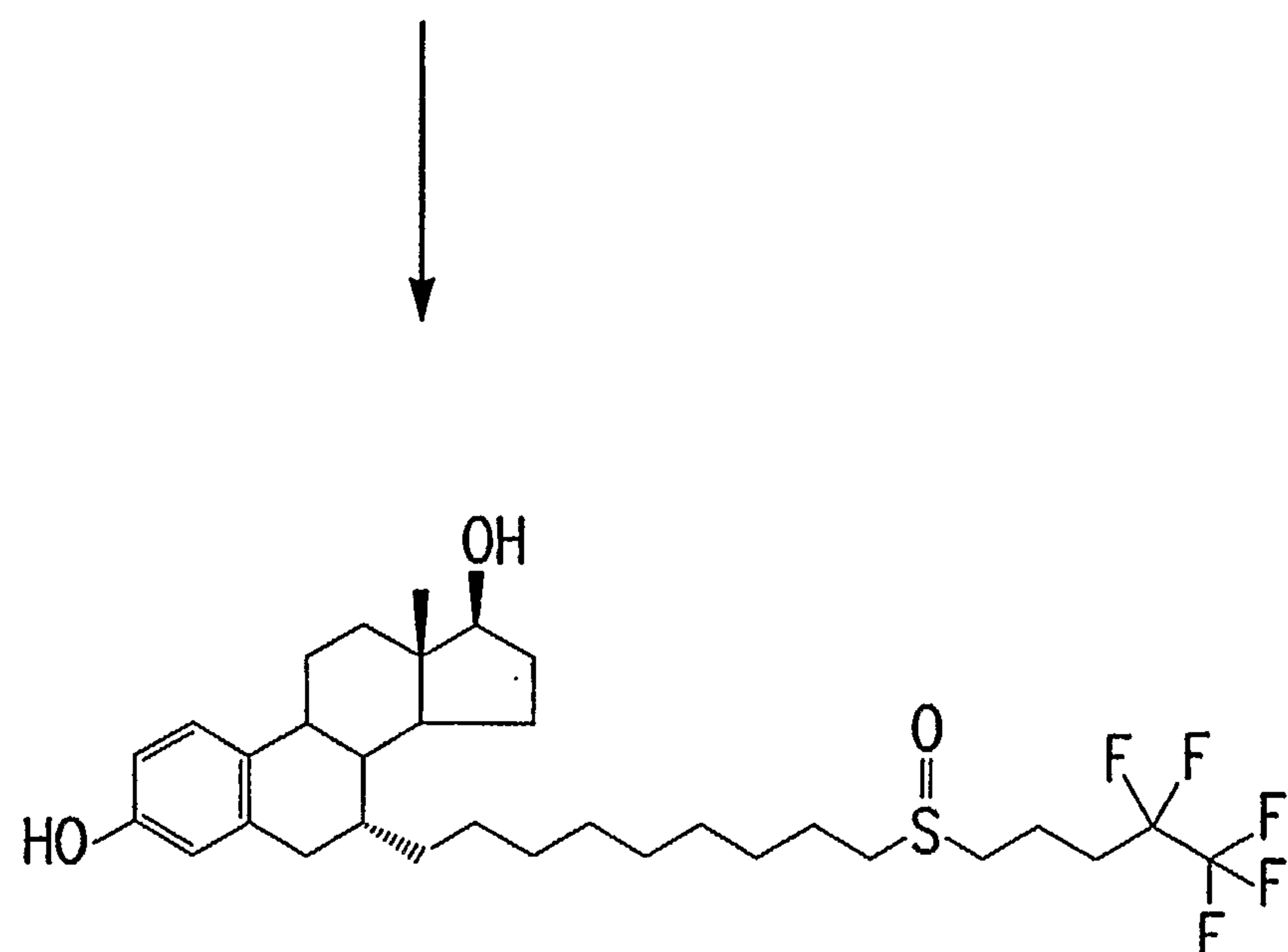
SUBSTITUTE SHEET (RULE 26)



9363

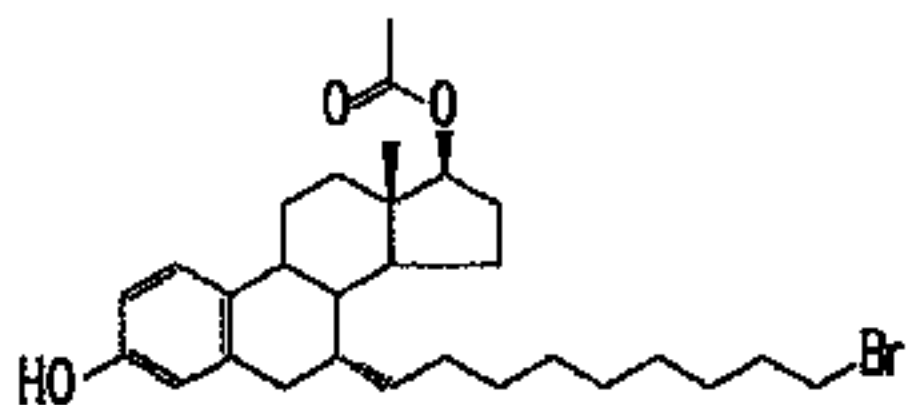


9368

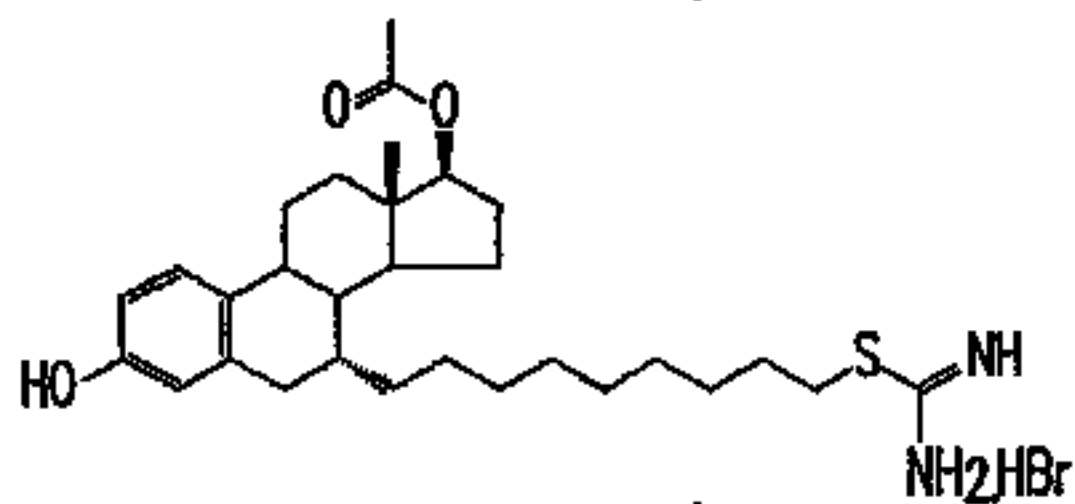


9305

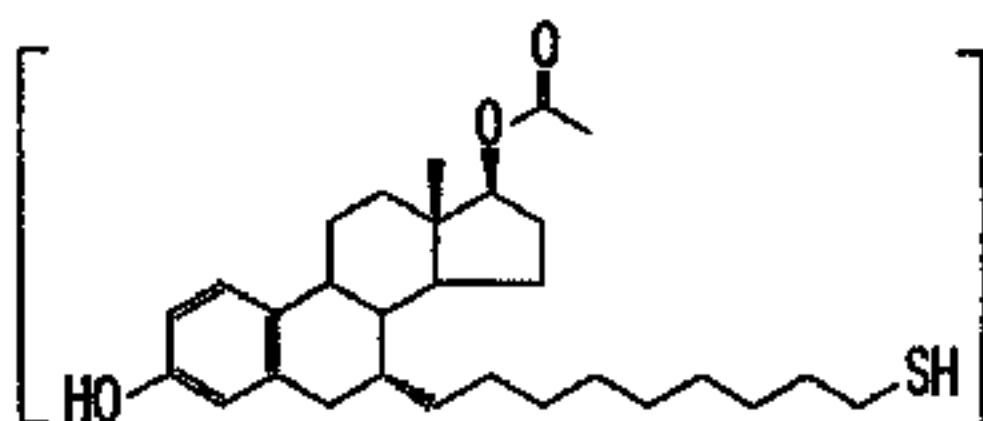
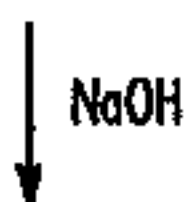
FIG. 13
SUBSTITUTE SHEET (RULE 26)



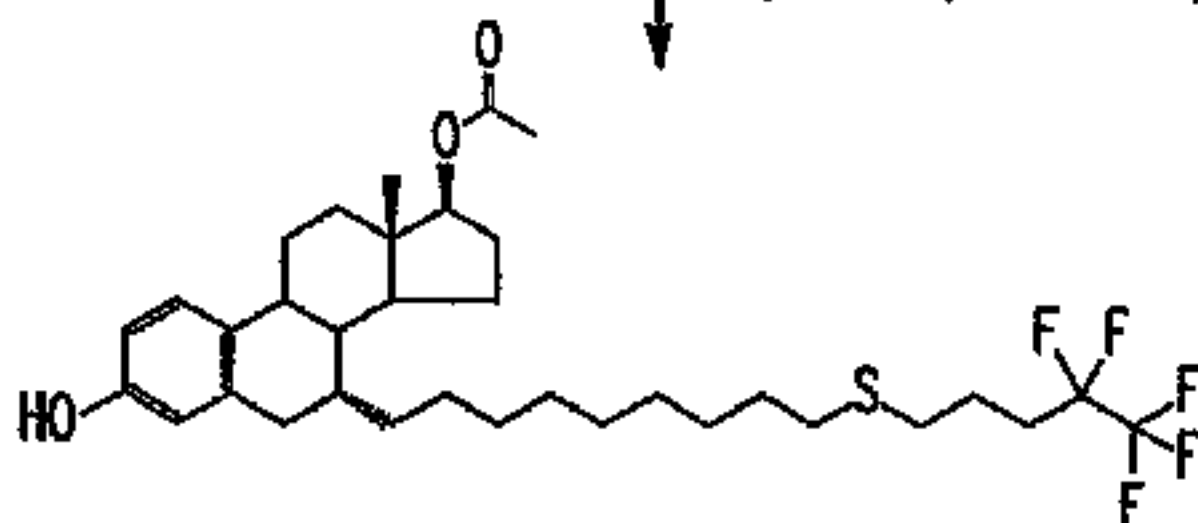
9342



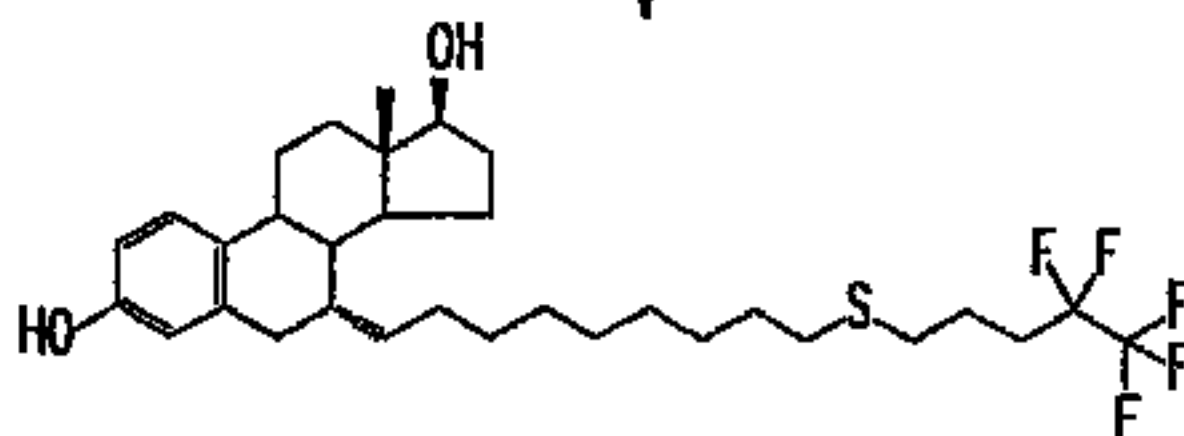
9361



9362



9363



9304



fulvestrant (9305)