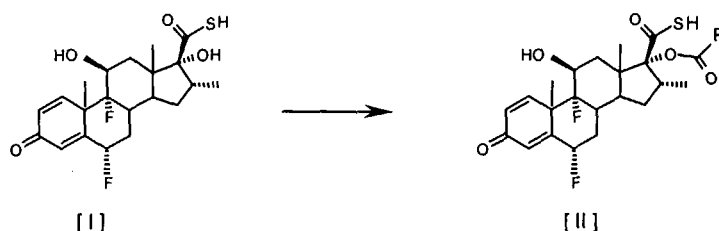


PROCESS FOR THE ESTERIFICATION OF A CARBOTHIOIC ACID

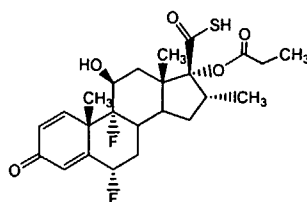
The present invention relates generally to a process for the esterification of a carbothioic acid, particularly but not exclusively in the preparation of fluticasone propionate; and to the use of certain intermediates.

In one aspect, the present invention relates to an improved process for the esterification of the C-17 hydroxyl group of 6 α ,9 α -difluoro-11 β ,17 α -dihydroxy-16 α -methyl-3-oxoandrosta-1,4-diene-17 β -carbothioic acid, compound of formula [I], comprising treating this intermediate with a slight excess of an acyl chloride of general formula R-COCl, where R represents, -CH₂CH₃, -CH₂CH₂CH₃ or -CH(CH₃)₂, in the presence of an appropriate tertiary amine, in an inert solvent, at a temperature between 5°C and -20°C, to obtain selectively the 17 α -acyl derivative of formula [II].



This invention provides an esterification process which is simpler and more economically efficient than those disclosed in the prior art because it suppresses one of the two chemical reactions described in those processes. Another feature of the process of this invention is that it yields 17 α -esters of high purity.

More particularly, this invention relates to an improved process for the preparation of 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-17 α -propionyloxy-3-oxoandrosta-1,4-diene-17 β -carbothioic acid, compound of formula [III] which is an intermediate in the synthesis of fluticasone propionate, an active ingredient used as an anti-inflammatory steroid, effective for the treatment of inflammatory diseases such as asthma and chronic obstructive pulmonary disease.

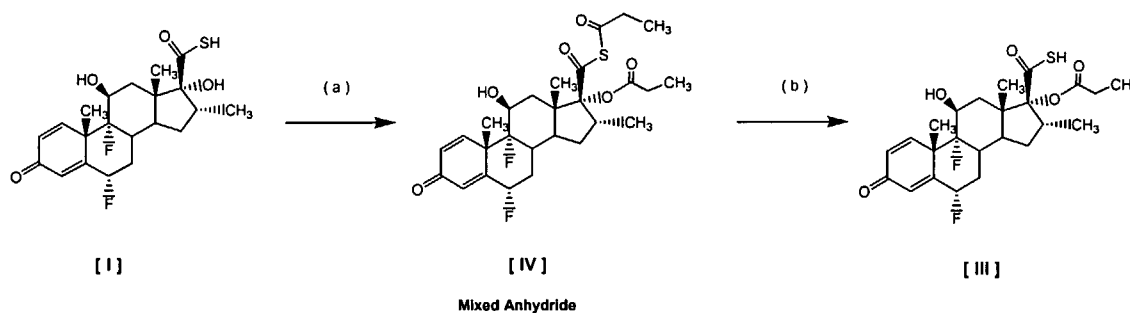


[III]

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US patent 4,335,121, British patents GB 2,088,877, GB 2,137,206, US patent 4,578,221 and J. Med. Chem., 1994, 37, 3717-3729, describe the 17 α -propionylation of compound [I], to obtain the fluticasone propionate intermediate [III], through the two chemical steps illustrated below, via the mixed anhydride compound [IV].

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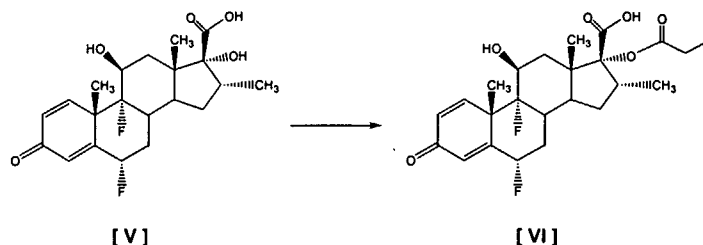
In the first step (a), the mixed anhydride [IV] is prepared with an excess of at least 2 moles of propionyl chloride per mol of compound [I], in the presence of triethylamine and using dichloromethane as solvent. Upon conclusion of the propionylation reaction, the reaction mixture is worked-up and a buff solid is obtained. In the second step (b), this solid is dissolved in acetone and treated with diethylamine, to convert the mixed anhydride to compound [III]. Once the aminolysis reaction is complete, the reaction mixture is worked up to isolate compound [III].

25

International patent application WO 03/066654 claims the preparation of intermediate [III] by: (a) reacting compound [I] with at least 1.3 moles of an activated derivative of propionic acid per mol of compound [I], and removal of the sulphur linked moiety from any compound of formula [IV] with an organic primary or secondary amine such as diethanolamine or N-methylpiperazine.

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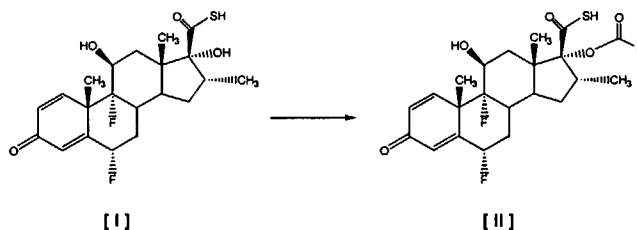
Patent application WO 01/62722 discloses the 17 α -esterification of the hydroxyacid compound [V] with an alkanoyl halide, in presence of a base, and particularly describes the preparation of the 17 α -propionate compound of formula [VI]



by: (a) reacting the hydroxyacid of formula [V] with 2.3 moles of propionyl chloride per mol of compound [V], using triethylamine as base, and (b) *in situ* reacting the compound obtained in (a) with diethylamine.

All of the 17 α -acylation procedures described in the prior art, either for the carbothioic acid [I] or the related carboxylic acid [V], use an excess of the acylating agent to ensure completion of the 17 α -acylation, thus requiring aminolysis, with an adequate primary or secondary amine, of any mixed anhydride formed.

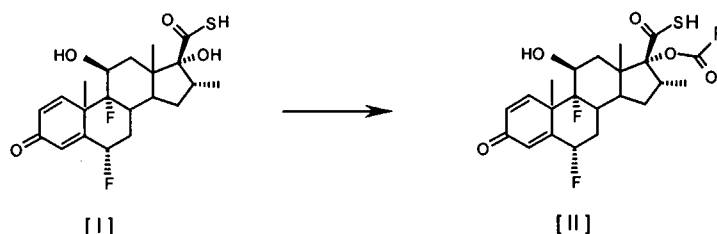
We have now found that the transformation of the carbothioic acid compound [I] into the compounds of general formula [II], can selectively take place directly, with negligible formation of the correspondent mixed anhydride, under conditions herein described below. By following the process of the present invention, the intermediate 6 α ,9 α -difluoro-11 β ,17 α -dihydroxy-16 α -methyl-3-oxoandrosta-1,4-diene-17 β -carbothioic acid, compound [I], is directly converted to compounds of general formula [II]



by reaction with a slight excess of the corresponding acyl chloride, in an inert solvent, in the presence of an appropriate tertiary amine.

The particular advantage of the present invention over those of the prior art is that compounds of general formula [II] are obtained directly from compound [I], without the need to perform the aminolysis of the corresponding mixed anhydride. Additionally, under the aminolysis conditions described in the prior art, the chemical stability of carbothioic acid derivatives such as compound [III] is limited therefore, the simplified process of this invention, by eliminating the aminolysis reaction, affords 17 α -esters of higher purity.

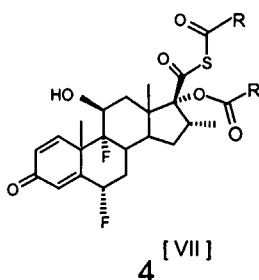
According to the present invention, there is provided a process for preparing compounds of formula [II]



by esterification of the C-17 hydroxyl group of 6 α ,9 α -difluoro-11 β ,17 α -dihydroxy-16 α -methyl-3-oxoandrosta-1,4-diene-17 β -carbothioic acid, compound of formula [I], which process comprises treating compound [I] with a slight excess of an acyl chloride of general formula R-COCl, where R represents -CH₂CH₃, -CH₂CH₂CH₃ or -CH(CH₃)₂, in an inert solvent, in the presence of a tertiary amine. Preferably, the process is carried out at a temperature of from 5°C to -20°C.

The invention also provides the use of compounds of formula [II] when made according to the process of the invention for the preparation of therapeutically useful medicaments.

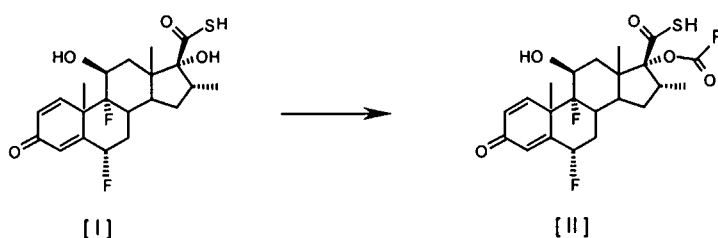
The present invention provides an improved and simplified process for the selective 17 α -esterification of the compound [I], forming negligible amounts of mixed anhydrides of general formula [VII]



in which R represents $-\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CH}_2\text{CH}_3$ or $-\text{CH}(\text{CH}_3)_2$, without the need to perform the aminolysis reaction of the corresponding mixed anhydrides.

- 5 The process comprises the reaction of compound [I], 6 α ,9 α -difluoro-11 β ,17 α -dihydroxy-16 α -methyl-3-oxoandrosta-1,4-diene-17 β -carbothioic acid, with a slight excess of an acyl chloride of general formula $\text{R}-\text{COCl}$, in which R represents $-\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CH}_2\text{CH}_3$ or $-\text{CH}(\text{CH}_3)_2$, in the presence of an appropriate organic tertiary amine, in an inert solvent, to yield the compounds of general formula [II]

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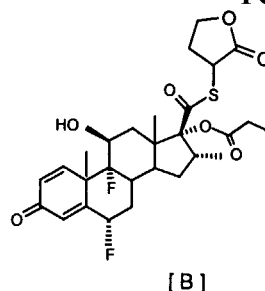
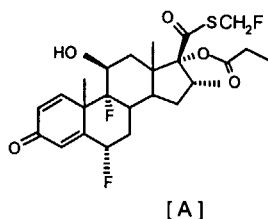
in which R represents $-\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CH}_2\text{CH}_3$ or $-\text{CH}(\text{CH}_3)_2$.

A particularly preferred embodiment of the present invention is to provide an improved process for the preparation of 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-17 α -propionyloxy-3-oxoandrosta-1,4-diene-17 β -carbothioic acid, compound of formula [III], comprising of reacting 6 α ,9 α -difluoro-11 β ,17 α -dihydroxy-16 α -methyl-3-oxoandrosta-1,4-diene-17 β -carbothioic acid [II] with a slight excess of propionyl chloride, in the presence of an appropriate tertiary amine, in an inert solvent.

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- 25 The compound of formula [III] is a known intermediate useful in the preparation of anti-inflammatory steroids such as fluticasone propionate of formula [A] (described in US 4 335 121), highly effective in the treatment of inflammatory diseases like asthma and chronic obstructive pulmonary disease (COPD), and in the preparation of the related 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-3-oxo-17 α -propionyloxy-androsta-1,4-diene-17 β -carbothioic acid S-(2-oxo-tetrahydro-furan-3-yl) ester of formula [B] (described in the application WO 97/24365), possessing a useful anti-inflammatory activity and having little or no systemic activity.

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Accordingly, the invention also provides a process for preparing fluticasone propionate which process comprises preparing 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-17 α -propionyloxy-3-oxoandrosta-1,4-diene-17 β -carbothioic acid according to the process of the invention and converting the said compound to fluticasone propionate.

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There is also provided a process for the preparation of 6 α -9 α -difluoro-11 β -hydroxy-16 α -methyl-3-oxo-17 α -propionyloxy-androsta-1,4-diene-17 β -carbothioic acid S-(2-oxo-tetrahydrofuran-3-yl) ester which process comprises preparing 6 α , 9 α -difluoro -

15 11 β - hydroxy-16 α - methyl -17 α - propionyloxy - 3 - oxoandrosta - 1,4-diene -17 β - carbothioic acid according to the process of the invention and converting said compound to the said S-ester.

15

The present invention provides an advantageous process for the preparation of

20 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-17 α -propionyloxy-3-oxoandrosta-1,4-diene-17 β -carbothioic acid, compound of formula [III] comprising of treating the compound [I], 6 α ,9 α -difluoro-11 β ,17 α -dihydroxy-16 α -methyl-3-oxoandrosta-1,4-diene-17 β -carbothioic acid, with a slight excess of propionyl chloride, in the presence of an appropriate tertiary amine, in an inert solvent, at a temperature between 5°C and

25 -20°C.

25

The acyl chloride of general formula R-COCl is preferably used in the process of the present invention in a molar ratio of from 1.0 to 1.2 moles of acyl chloride per mol of starting compound [I], preferably in an amount within this range.

30

Inert solvents for the 17 α -acylation process of the present invention include acetone, tetrahydrofuran, dimethylacetamide, dichloromethane, ethyl acetate, 2-pentanone, 3-pentanone, 4-methyl-2-pentanone and 2-butanone. Acetone is the preferred solvent.

Appropriate tertiary amines to carry out the selective 17 α -propionylation include pyridine, 2-picoline 3-picoline, 4-picoline, N-methylimidazole, and N-methylpyrrolidine.

- 5 The 17 α -acylation reaction of the invention is preferably performed at a temperature of from 5°C to –20°C.

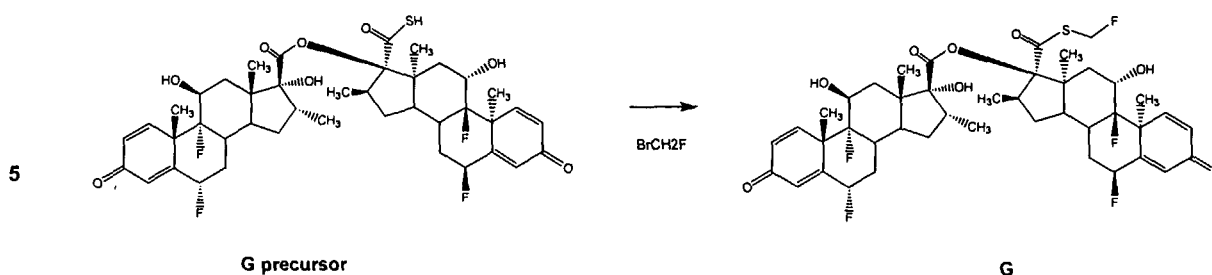
The use of the tertiary amines defined above as adequate for the process of the patent, present advantages over other bases previously described in the prior art such as triethylamine, tripropylamine, ethyldiisopropylamine, N,N-dimethylaniline,
10 N,N-dimethylcyclohexylamine, inorganic carbonates such as e.g. sodium hydrogen carbonate, potassium carbonate and sodium carbonate. When using these bases the formation of high levels of the mixed anhydride compound [IV] or incomplete consumption of compound [I] or the formation of high levels of impurities as is the case when sodium hydrogen carbonate is avoided.

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Under the preferred conditions of the process of the present invention, 17 α -esterification goes to completion with 1.0 to 1.2 moles of propionyl chloride per mole of compound [I], in the presence of pyridine, and the levels of mixed anhydride formed during the reaction are below 3% (in area, by HPLC). With these low levels of
20 mixed anhydride, the aminolysis reaction is not required and compound [III] is isolated with a high degree of purity, on work-up of the propionylation reaction.

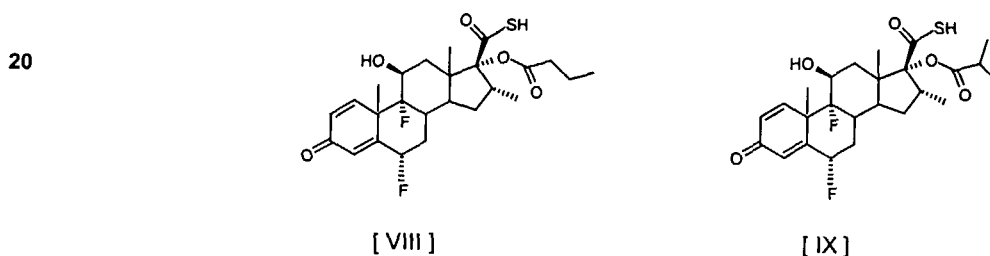
Under the conditions described in the prior art when compound [III] is prepared via the mixed anhydride, partial degradation of compound [III] may occur during the
25 aminolysis reaction. This degradation is especially problematic when prolonged reaction times take place, which is to be expected on an industrial scale. Under the conditions disclosed in the present invention this *in situ* degradation of compound [III] is avoided.

30 We have found that by following the prior art a precursor (G precursor) to an impurity (impurity G) is formed.



With the process of the present invention, dimer G, which is difficult to remove from the final product, fluticasone propionate, by recrystallization when at levels higher than 0.5%, is formed at levels below 0.3%. Hence, repeated recrystallizations to
 10 obtain material of the required purity, which if carried out significantly reduces the overall yield, are avoided.

Another embodiment of this invention is to provide an improved process for the
 15 preparation of the compounds 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-17 α -butyryloxy-3-oxoandrosta-1,4-diene-17 β -carbothioic acid, compound of formula [VIII] and 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-17 α -isobutyryloxy-3-oxoandrosta-1,4-diene-17 β -carbothioic acid of formula [IX].



25 Compounds of formula [VIII] and [IX] are directly prepared from compound [I] by reaction with a slight excess of the corresponding acyl chloride, without the need to perform an aminolysis reaction of the corresponding mixed anhydrides.

According to a preferred aspect of the present invention, esterification of
 30 compound [I] to obtain compound [VIII], is performed with 1.0 to 1.2 moles of butyryl chloride, in acetone, in the presence of pyridine, at a temperature between 5°C and -20°C, preferably between 5°C and 0°C. The esterification of compound [I] to obtain compound [IX] is preferably performed with 1.0 to 1.2 moles of isobutyryl chloride, in acetone, in the presence of pyridine, at a temperature between 5°C and -
 35 20°C, preferably between 5°C and 0°C.

The following examples illustrate the invention and certain preferred embodiments and are exempt of limitative character of the scope of the invention.

Example 1: Preparation of 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-17 α -propionyloxy-3-oxoandrosta-1,4-diene-17 β -carbothioic acid

A suspension of compound [I] (10 g, 0.024 moles) in acetone (175 ml) is cooled to -20°C and treated with pyridine (30 ml) and propionyl chloride (2.3 ml, 0.026 moles), while maintaining the temperature between -20°C and -15°C . The mixture is stirred at $-20^{\circ}\text{C}/-15^{\circ}\text{C}$ until completion of reaction. A second addition of propionyl chloride (0.02 ml) can be carried out if necessary to complete the reaction. Compound [III] is precipitated by addition of water (240 ml) and concentrated hydrochloric acid (30 ml). The suspension is stirred for 2 hours at a temperature between 0°C and 5°C , filtered, and the wet cake washed with cold water until neutral pH. The solid is dried at a temperature below 40°C , under vacuum, to give the title compound as a white to off white solid (10.04 g; 88%; Purity, area % by HPLC: 96.1%).

Example 2: Preparation of 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-17 α -isobutyryloxy-3-oxoandrosta-1,4-diene-17 β -carbothioic acid

Isobutyryl chloride (0.28 ml, 0.0027 moles) is slowly added to a mixture of acetone (17.5 ml), compound [I] (1 g, 0.0024 moles) and pyridine (3 ml), at temperatures between 5°C and 0°C , and the mixture is stirred at that temperature range until consumption of compound [I]. Upon completion of the reaction the title compound is precipitated by addition of water (24 ml) and concentrated hydrochloric acid (3 ml). The suspension is stirred for 1 to 2 hours, at a temperature between 0°C and 5°C , filtered, and the wet cake washed with cold water until neutral pH. The wet solid is dried at a temperature lower than 40°C , under vacuum, to yield the title compound as a white to off white solid (1.09 g; 93%; Purity, area % by HPLC: 94.8%).

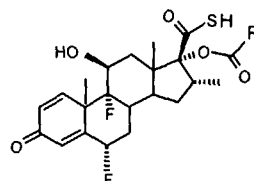
Example 3: Preparation of 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-17 α -propionyloxy-3-oxoandrosta-1,4-diene-17 β -carbothioic acid

A suspension of compound [I] (1 g, 0.0024 moles) in acetone (17 ml) is cooled to a temperature between -20°C and -15°C . N-methylimidazole (2.9 ml) and propionyl chloride (0.23 ml, 0.0026 moles) are sequentially added to the solution, maintaining

the temperature between -20°C and -15°C . Upon completion of the reaction, compound [III] is precipitated by addition of water (24 ml) and concentrated hydrochloric acid (3 ml). The suspension is stirred for 2 hours at ca. 0°C , filtered, and the wet cake washed with cold water until neutral pH. The wet solid is dried at a temperature below 40°C , under vacuum, to give the title compound as a white to off white solid (1.0 g; 88%; Purity, area % by HPLC: 96.8%).

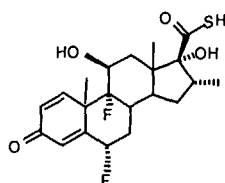
CLAIMS:

1. A process for preparing compounds of formula [II]



[II]

- by esterification of the C-17 hydroxyl group of 6 α ,9 α -difluoro-11 β ,17 α -dihydroxy-16 α -methyl-3-oxoandrosta-1,4-diene-17 β -carbothioic acid, the compound of formula [I], which process comprises treating compound [I] with a slight excess of an acyl chloride of general formula R-COCl, where R represents -CH₂CH₃, -CH₂CH₂CH₃ or -CH(CH₃)₂, in an inert solvent, in the presence of a tertiary amine.



[I]

2. A process according to claim 1 wherein the process is carried out at a temperature of from 5°C to -20°C.
3. A process according to claim 1 or 2 characterized in that the amount of the acyl chloride to be used is between 1.0 mol to 1.2 moles of acyl chloride per mol of compound [I].
4. A process according to claim 1, 2 or 3 where the acyl chloride of general formula R-COCl is propionyl chloride, R representing -CH₂CH₃.
5. A process according to claim 1, 2, 3 or 4 where the tertiary amine is pyridine, 2-picoline, 3-picoline, 4-picoline, N-methylimidazole, and N-methylpyrrolidine, preferably pyridine, 3-picoline, 4-picoline, N-methylimidazole, and N-methylpyrrolidine.

6. A process according to any preceding claim wherein the tertiary amine is pyridine.

7. A process according to any preceding claim wherein the inert solvent is
5 acetone.

8. A process according to any one of claims 1 to 6 wherein pyridine is used as tertiary amine and the inert solvent is acetone, tetrahydrofuran, dimethylacetamide, dichloromethane, ethyl acetate, 2-pentanone, 3-pentanone, 4-methyl-2-pentanone or
10 2-butanone, preferably acetone.

9. A process according to any preceding claim wherein the reaction is performed at a temperature of from -15°C to -20°C .

10. A process according to any preceding claim wherein the acyl chloride of general formula R-COCl is butyryl chloride, R representing $-\text{CH}_2\text{CH}_2\text{CH}_3$, characterized in that compound [I] is treated with 1.0 to 1.2 moles of butyryl chloride per mol of compound [I], in the presence of pyridine, in acetone, at a temperature of from 5°C to -20°C , preferably from 5°C to 0°C .

11. A process according to any one of claims 1 to 9 wherein the acyl chloride of general formula R-COCl is isobutyryl chloride, R representing $-\text{CH}(\text{CH}_3)_2$, characterized in that compound [I] is treated with 1.0 to 1.2 moles of isobutyryl chloride per mol of compound [I], in the presence of pyridine, in acetone, at a
25 temperature of from 5°C to -20°C , preferably from 5°C to 0°C .

12. A process for preparing fluticasone propionate which process comprises preparing $6\alpha,9\alpha$ -difluoro- 11β -hydroxy- 16α -methyl- 17α -propionyloxy-3-oxoandrost-1,4-diene- 17β -carbothioic acid according to the process of any preceding claim, and
30 converting said compound to fluticasone propionate.

13. A process for the preparation of 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-3-oxo-17 α -propionyloxy-androsta-1,4-diene-17 β -carbothioic acid S-(2-oxo-tetrahydrofuran-3-yl) ester which process comprises preparing 6 α ,9 α -difluoro-11 β -hydroxy-16 α -methyl-3-oxo-17 α -propionyloxy-3-oxoandrosta-1,4-diene-17 β -

5 carbothioic acid according to the process of any preceding claim, and converting said compound to the said S-ester.

14. Use of the compounds of formula [II] when made according to the process of any one of claims 1 to 10 for the preparation of therapeutically useful medicaments.

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