

Process for the Production of 3-Oxo-pregn-4-ene-21,17-carbolactones by the Metal-Free Oxidation of 17-(3-Hydroxypropyl)-3,17-dihydroxyandrostanes

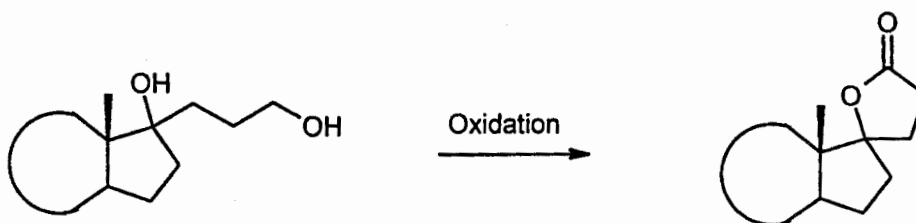
This invention relates to processes for the production of 3-oxo-pregnane-21,17-carbolactones as well as 3-oxo-pregn-4-ene-21,17-carbolactones, in particular processes for the production of 3-oxo-17 α -pregnane-21,17-carbolactones as well as 3-oxo-17 α -pregn-4-ene-21,17-carbolactones. In addition, the invention relates to the dichloromethane hemisolvate of 6 β ,7 β ;15 β ,16 β -dimethylene-3-oxo-17 α -pregnan-5 β -ol-21,17-carbolactone.

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Examples of pharmacologically active steroid-21,17-carbolactones are eplerenone (9 α ,11 α -epoxy-7 α -methoxycarbonyl-3-oxo-17 α -pregn-4-ene-21,17-carbolactone), drospirenone (6 β ,7 β ;15 β ,16 β -dimethylene-3-oxo-17 α -pregn-4-ene-21,17-carbolactone), spironolactone (7 α -acylthio-3-oxo-17 α -pregn-4-ene-21,17-carbolactone), canrenone (3-oxo-17 α -pregna-4,6-diene-21,17-carbolactone), and prorenone (6 β ,7 β -methylene-3-oxo-17 α -pregna-4,6-diene-21,17-carbolactone).

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The build-up of the steroid-21,17-spirolactone can be carried out by oxidation of the corresponding 17-hydroxy-17-(3-hydroxypropyl) steroid



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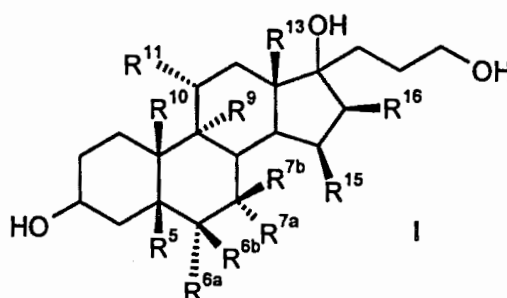
with suitable oxidizing agents such as chromic acid (Sam et al. J. Med. Chem. 1995, 38, 4518-4528), pyridinium chlorochromate (EP 075189), pyridinium dichromate (Bittler et al; Angew. Chem. [Applied Chem.] 1982, 94, 718-719; Nickisch et al. Liebigs Ann. Chem. 1988, 579-584), or potassium bromate in the presence of a ruthenium catalyst (EP 918791). The clearly pronounced formation of by-products by a number of secondary reactions is disadvantageous in the oxidation process of the prior art with chromium(VI) derivatives, by which the isolation of the pure product is hampered and the yield is reduced. The by-product profile is improved namely by the ruthenium-catalyzed oxidation (EP 918791), and thus also the yield increases. The use of transition metals in the production of pharmaceutical active ingredients, however, is generally associated with the drawback that the removal of heavy metal traces is already connected with an elevated expense. Moreover, large amounts of heavy metal-containing wastes accumu-

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late in the production, and said wastes can be removed only in an intensive and costly way.

The object of this invention therefore consists in making available an alternate process
 5 for the production of 3-oxo-pregnane-21,17-carbolactones as well as 3-oxo-pregn-4-ene-21,17-carbolactones from the corresponding 17-(3-hydroxypropyl)-3,17-dihydroxy-androstanes that makes it possible to produce the target compounds with a higher yield and purity.

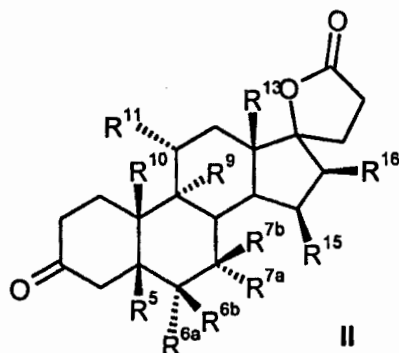
This object was achieved according to the invention in that the 17-(3-hydroxypropyl)-
 10 3,17-dihydroxyandrostanes of general formula I



in which

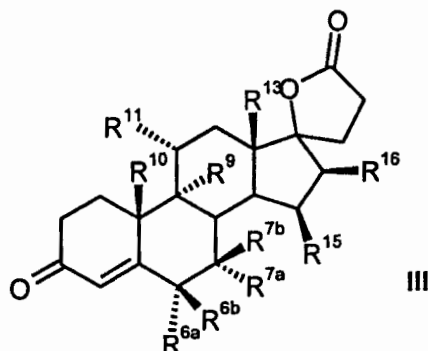
- R^5 is hydrogen, hydroxy;
- R^{6a} is hydrogen, together with R^5 a double bond, or together with R^{7a} a $-CH_2$ group;
- R^{6b} is hydrogen, together with R^{7b} a $-CH_2$ group or a double bond;
- R^{7a} is hydrogen, C_1 - C_4 -alkyl, C_1 - C_4 -alkoxycarbonyl, C_1 - C_4 -thioacyl or together with R^{6a} a $-CH_2$ group;
- R^{7b} is hydrogen, or together with R^{6b} a $-CH_2$ group;
- 20 R^9 is hydrogen, together with R^{11} a double bond, or together with R^{11} an epoxy group $-O-$;
- R^{10} is hydrogen, methyl, or ethyl;
- R^{11} is hydrogen, together with R^9 a double bond or together with R^9 an epoxy group $-O-$;
- 25 R^{13} is hydrogen, methyl or ethyl;
- R^{15} is hydrogen, C_1 - C_4 -alkyl, together with R^{16} a $-CH_2$ group or a double bond,
- R^{16} is hydrogen, together with R^{15} a $-CH_2$ group or a double bond,

are reacted with an organic or inorganic hypochlorite as an oxidizing agent in the presence of catalytic amounts of a 2,2,6,6-tetramethylpiperidine-N-oxide derivative to form the 3-oxo-pregnane-21,17-carbolactones of Formula II



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If R^5 is a hydroxy group, the compounds of formula II can be converted in the presence of an acid at $\text{pH} < 5$ with water being eliminated into compounds of formula III



- 10 Metal-free oxidations of alcohols to the corresponding aldehydes, ketones, carboxylic acids, lactols, and lactones are collectively referred to in the survey article of W. Adam et al., Chem. Rev. 2001, 101, 3499-3548. Metal-free oxidations in the presence of 2,2,6,6-tetramethylpiperidine-N-oxide (TEMPO) are described by van Bekkum et al. in Synthesis 1996, 1153-1174.

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Primary alcohols can be oxidized to aldehydes with sodium bromite (NaBrO_2) or calcium hypochlorite [$\text{Ca}(\text{OCl}_2)$] in the presence of TEMPO derivatives [S. Torii et al. J. Org. Chem. 1990, 55, 462-466]. Sodium hypochlorite (NaOCl) can also be used as an oxidizing agent (Org. Synth. 69, 212).

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The oxidation of secondary alcohols to ketones and in particular the oxidation of primary alcohols to carboxylic acids (or with suitable diols to lactones) requires a co-catalyst (P. L. Anelli et al., J. Org. Chem. 1987, 52, 2559-2562). As a co-catalyst, a bromide (generally KBr or NaBr) is used. The addition of bromide ions can be useful even in the oxi-

1 dation of primary alcohols to aldehydes (P. L. Anelli et al., J. Org. Chem. 1987, 52,
2 2559-2562).

3 The danger of the formation of bromine-containing by-products under oxidative condi-
4 tions is disadvantageous in the use of bromides as co-catalysts. This oxidation method
5 is especially suitable for the oxidation of primary alcohols to the corresponding alde-
6 hydes.

7 Without the addition of bromide, the TEMPO-catalyzed oxidation of secondary alcohols
8 to the corresponding ketones requires higher excesses of hypochlorite [3-4 molar
9 equivalents of $\text{Ca}(\text{OCl})_2$, thus 6-8 molar equivalents of OCl^- ; (S. Tori et al. J. Org.
10 Chem. 1990, 55, 462-466)].

11 The oxidative lactonization of 1,4-diols proceeds in many stages via the aldehyde,
12 which first forms lactol in an intermediate stage; the quasi-secondary hydroxy group of
13 said lactol must then be further oxidized. The oxidative lactonization of 1,4-diols there-
14 fore requires still harder conditions (at least equimolar amounts of the TEMPO deriva-
15 tive (J. M. Bobbitt et al., J. Org. Chem. 1991, 56, 6110-6114) or other oxidizing agents
16 in connection with increased amounts of the TEMPO catalyst (J. Einhorn, J. Org. Chem.
17 1996, 61, 7452-7454; in the presence of a bromide addition: S. D. Rychnovsky, J. Org.
18 Chem. 1999, 64, 310-312; in the presence of bromide ions produced in situ from the
19 oxidizing agent sodium bromite: S. Torii, J. Org. Chem. 1990, 55, 462-466). In view of
20 the prior art, it was therefore surprising that oxidative lactonization on the D-ring and the
21 oxidation of the secondary 3-hydroxy group of the 17-(3-hydroxypropyl)-3,17-
22 dihydroxyandrostanes of general formula I (altogether three oxidation stages) can be
23 performed successfully at the same time under mild conditions in the presence of cata-
24 lytic amounts of TEMPO derivatives. In addition, it was surprising that the process ac-
25 cording to the invention can be performed with only 1.0 to 2.0 equivalents of hypochlo-
26 rite per oxidation stage, thus altogether 3.0 to 6.0 molar equivalents of hypochlorite
27 quite without the co-catalytic bromide additions.

28 The process according to the invention is performed with a total of at least 3 molar
29 equivalents of alkali hypochlorite, organic hypochlorite or at least 1.5 molar equivalents
30 of alkaline-earth hypochlorite as oxidizing agent; preferably with 3-6 molar equivalents
31 of alkali hypochlorite, or 1.5-3 molar equivalents of alkaline-earth hypochlorite, espe-
32 cially preferably 3-4 molar equivalents of alkali hypochlorite or 1.5-2 molar equivalents
33 of alkaline-earth hypochlorite.

The concentration of the aqueous hypochlorite solution during the oxidation is preferably adjusted such that it is 0.8 to 1.1 mol of hypochlorite/kg.

Sodium hypochlorite, potassium hypochlorite, calcium hypochlorite or tert-butyl hypochlorite are preferably used as oxidizing agents.

The 2,2,6,6-tetramethylpiperidine-N-oxide derivatives (TEMPO derivatives) are used in catalytic amounts, whereby the amount is preferably 1-5 mol%, especially preferably 1-1.5 mol%.

Suitable TEMPO derivatives are, i.a., the 2,2,6,6-tetramethylpiperidine-N-oxide (TEMPO), the 4-methoxy-2,2,6,6-tetramethylpiperidine-N-oxide (4-MeO-TEMPO) as well as the 4-benzyloxy-2,2,6,6-tetramethylpiperidine-N-oxide (4-BnO-TEMPO).

TEMPO is preferably used according to this invention, especially preferably in an amount of 1-5 mol%, quite especially preferably 1-1.5 mol%.

The oxidation is carried out in an organic solvent or in a two-phase solvent-water mixture, whereby the solvent is selected such that both the TEMPO derivative and the compounds of formula I can be well dissolved therein.

The reaction is preferably performed in a two-phase system. The process according to the invention is quite preferably performed in a dichloromethane-water mixture.

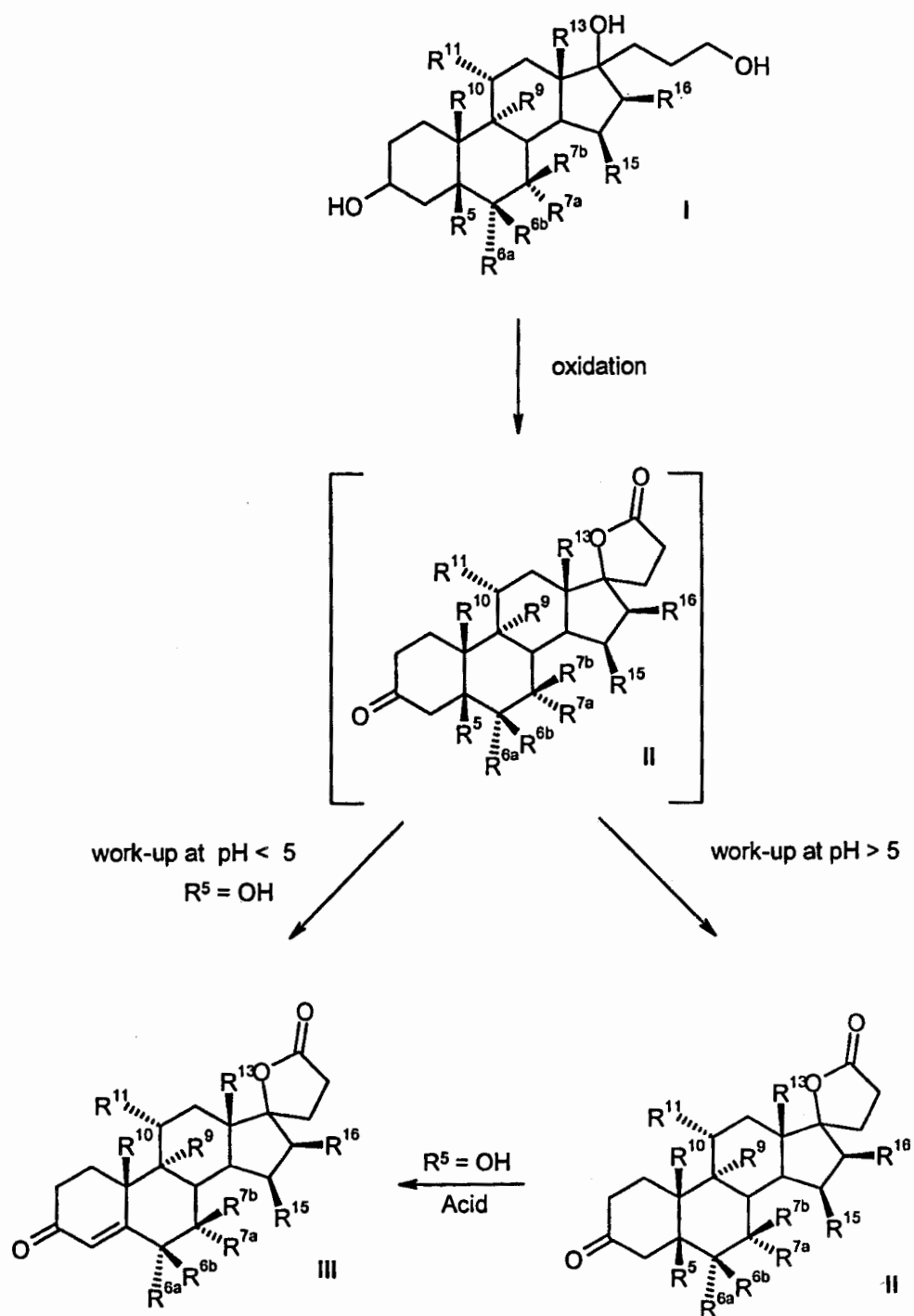
The oxidation is performed according to the invention at a temperature of 0 to 20°C, preferably at 10-20°C.

During the oxidation, the pH of the reaction solution is to be at least 8.0; preferably 8.5 to 10.0; especially preferably 9.0 to 9.5.

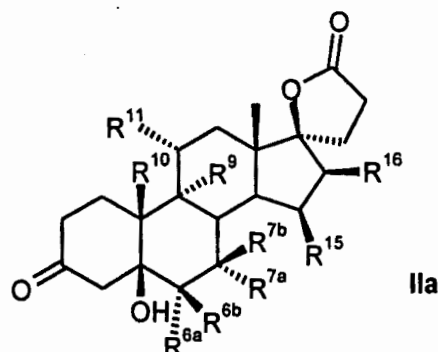
The pH can suitably be adjusted with a suitable Brönsted acid, such as organic acids (e.g., acetic acid) or inorganic acids (HCl, H₂SO₄, H₃PO₄) or acid salts of multivalent acids (bicarbonates, hydrogen sulfates, hydrogen phosphates, etc.). Alkali bicarbonates, especially preferably potassium bicarbonate, are preferably used.

The oxidation reaction is brought to a halt by adding a reducing agent to quench excess hypochlorite reagent. For this purpose, any reducing agent with corresponding redox potential that is known to one skilled in the art is suitable. An aqueous alkali hydrogen sulfite solution is preferably used according to this invention. Sodium or potassium hydrogen sulfite (NaHSO₃ or KHSO₃), the aqueous solution of sodium or potassium disulfite (Na₂SO₂O₅ or K₂S₂O₅) is especially preferably used.

- If, in the reaction mixture, the excess hypochlorite reagent at $\text{pH} < 5$ is quenched thus without the addition of a base or a basic buffer, or in the presence of a further acid addition, the 3-oxo-pregnane-21,17-carbolactones of formula II (if $\text{R}^5 = \text{OH}$) thus eliminate
5 water, and equally the 3-oxo-pregn-4-ene-21,17-carbolactones of formula III are formed in the reaction mixture. The completion of the oxidation reaction at a pH of less than 5 makes possible the production of compounds of formula III in a one-pot process.
- If, in the reaction mixture, the excess hypochlorite reagent is quenched with the addition of a base or a basic buffer at $\text{pH} > 5$, the 3-oxo-pregnane-21,17-carbolactones of for-
10 mula II can be isolated. The completion of the oxidation reaction at a pH of more than 5 makes possible the specific production of compounds of formula II.
- Since in the case $\text{R}^5 = \text{OH}$ the solubility of the compounds of formula II in comparison to the compounds of formula III in organic solvents is lower, the specific isolation of the compounds of formula II as an intermediate on the path to compounds of formula III
15 offers the special advantage of the possibility of a more effective purification (e.g., by crystallization). The purified intermediates can be reacted according to the methods that are known in the literature with a suitable acid (such as, e.g., sulfuric acid, hydrochloric acid, para-toluenesulfonic acid, etc.) to form compounds of formula III (EP 0918791).
- 20 To adjust the pH, any suitable inorganic or organic base or any suitable buffer or any suitable buffer system can be used. The base or buffer is preferably added mixed or in parallel to the reaction mixture with the reducing agent.
- According to this invention, sodium phosphate (Na_3PO_4) is preferably used as a basic buffer.
- 25 17-(3-Hydroxypropyl)-3,17-dihydroxyandrostanes of general formula I can be obtained, e.g., starting from the correspondingly substituted 3-hydroxy-17-ketoandrostanes by the addition of propargyl alcohol at C-17 and subsequent hydrogenation of the triple bond (EP 918791, EP 51143, DE 3026783) or as described by N. W. Atwater in J. Org. Chem. 1961, 26, 3077 and in US 4,069,219 or in the documents cited therein.
- 30 The corresponding 3-hydroxy-17-ketoandrostanes can be produced in turn from the correspondingly substituted 3-hydroxyandrost-5-en-17-one (EP 51143, DE 3026783).

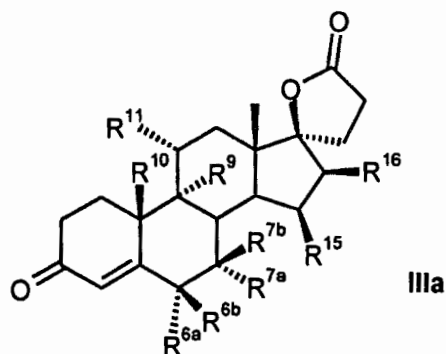


The process according to the invention is suitable especially for the production of 3-oxo-17 α -pregnane-21,17-carbolactones of formula IIa



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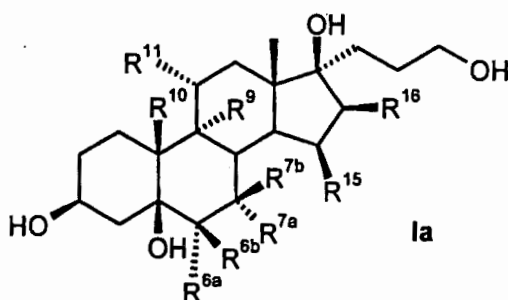
as well as 3-oxo-17 α -pregn-4-ene-21,17-carbolactones of formula IIIa,



in which the substituents R have the following meaning:

- | | |
|----|--|
| 10 | R^{6a} is hydrogen or together with R^{7a} a $-\text{CH}_2$ group;
R^{6b} is hydrogen, together with R^{7b} a $-\text{CH}_2$ group, or a double bond;
R^{7a} is hydrogen, $\text{C}_1\text{-C}_4$ -alkoxycarbonyl, or $\text{C}_1\text{-C}_4$ -thioacyl;
R^{7b} is hydrogen, or together with R^{6b} a $-\text{CH}_2$ group,
R^9 is hydrogen, together with R^{11} a double bond or together with R^{11} |
| 15 | an epoxy group $-\text{O}-$;
R^{10} is hydrogen, or methyl;
R^{11} is hydrogen, together with R^9 a double bond or together with R^9 an epoxy group $-\text{O}-$;
R^{15} is hydrogen, together with R^{16} a $-\text{CH}_2$ group or a double bond; |
| 20 | R^{16} is hydrogen, together with R^{15} a $-\text{CH}_2$ group or a double bond; |

whereby as starting materials, the 17-(3-hydroxypropyl)-3,17-dihydroxyandrostanes of general formula Ia



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are used.

The process according to the invention for the production of compounds of formulas IIa and IIIa,

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in which

R^{6a} , R^{7a} , R^9 , R^{11}

are hydrogen;

R^{6b} and R^{7b}

together are a $-CH_2$ group;

R^{10}

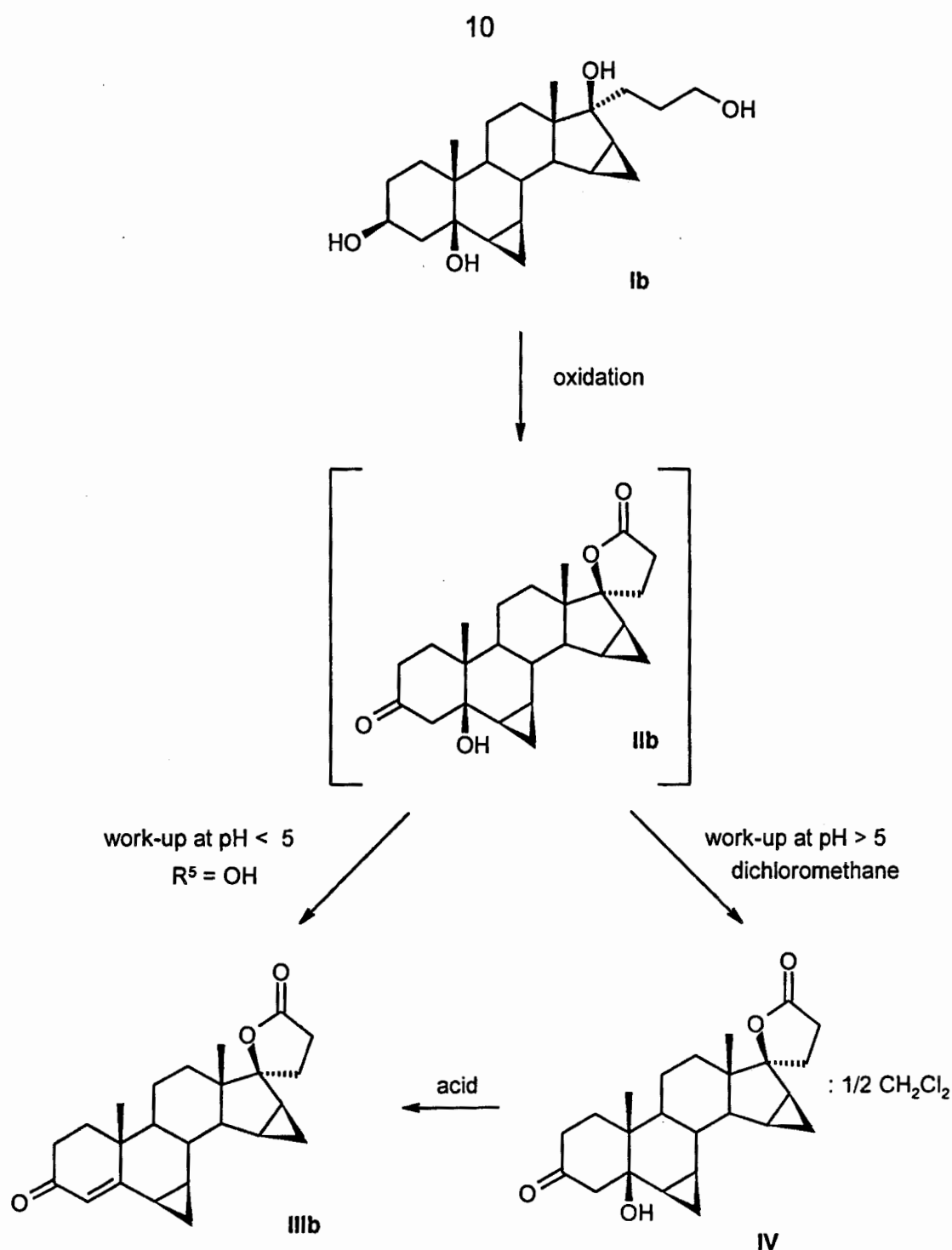
is methyl;

R^{15} and R^{16}

together are a $-CH_2$ group;

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thus compounds IIb as well as IIIb, whereby the compound of formula Ib is used as a starting material is quite especially suitable.



Another aspect of this invention is the poorly soluble dichloromethane-hemisolvate IV that is formed, surprisingly enough, from compound IIb when the process according to the invention is performed in dichloromethane and is worked up, basic, at pH > 5. During the oxidation, this poorly soluble product precipitates, and thus the influence of the oxidizing agent and thus possible further reactions, which can result in the formation of by-products, are evaded.

The dichloromethane-hemisolvate IV is distinguished by a strict and constant melting point, which is 121°C, while compound IIb melts at 188°C. DSC (Differential Scanning Calorimetry) measurements have shown that compound IV is stable up to the melting point.

- After the reaction is completed, the precipitation of compound IV from the reaction solution by adding a non-polar solvent, preferably an ether, especially preferably diisopropyl ether, is completed. The non-polar oxidation and elimination products that are produced with the oxidation remain largely dissolved in the ether-dichloromethane mixture, which makes possible an extremely slight isolation of the compound IV at a high purity. In this way, compound IV with a yield of 82% is obtained. The thus obtained product contains no more than 6% steroidal contaminants and can easily be reacted without further purification according to known methods with a suitable acid to form drospirenone IIIb (EP 918791). The synthesis variant that runs through the isolated compound IV offers the additional advantage of a considerably higher total yield at IIIb by a simpler and more effective purification in the final stage. The total yield at IIIb is 77%, around 7% higher than according to the Ru-catalyzed oxidation process and subsequent water elimination and even around 21% higher than according to the one-pot process according to EP 075189 (Tab. 1).
- As an alternative, Ib can be oxidized to IIb and converted directly to IIIb in the same pot by the reaction mixture being worked up under acidic conditions at pH < 5.

Tab. 1: Comparison of the Yields of the Process According to the Invention Compared to the Process of the Prior Art

Process	Yield (% of Theory)		
	Ib → IIb	IIb → IIIb	Total (Ia→IIIb)
Process According to the Invention	82 (in the form of IV)	94	77
Ru-Catalyzed Oxidation According to EP 918791	75	94	70
CrO ₃ Oxidation According to EP 075189*	not isolated	not isolated	56

* See Table on page 7 EP 918791

This invention is explained in more detail based on the examples below, without being limited thereto.

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Production Process

General Operating Procedure 1 (GOP1): Synthesis of Compounds of Formula II

76.9 mmol of a compound of formula I is dissolved or suspended in 135 ml of dichloromethane. First, 0.15 g (1 mmol) of TEMPO is added to the mixture at 15°C. The addition of a solution that consists of 134 g of a 15.25% aqueous sodium hypochlorite solution (230.7 mmol) and 8.20 g (82 mmol) of potassium bicarbonate in 114 ml of water is carried out, whereby a pH-value of 9.1 is set. After the reaction is completed, the excess oxidizing agent is quenched at 15°C by adding an aqueous solution that consists of 12.5 g (76.5 mmol) of sodium phosphate and 10.6 g (55.8 mmol) of sodium disulfite ($\text{Na}_2\text{S}_2\text{O}_5$) and 121 ml of water.

The product of formula II is isolated from the organic phase by being precipitated from the reaction solution by adding 240 ml of diisopropyl ether, continuing to be stirred for 3 hours at 25°C, being filtered off and dried. As an alternative, the product that is already partially precipitated during the reaction depending on solubility in dichloromethane can be dissolved again by adding dichloromethane, and the organic phase is separated and redistilled in diisopropyl ether. The product that is precipitated in this case is filtered off with 300 ml of water, washed and dried.

25 General Operating Procedure 2 (GOP2): Synthesis of Compounds of Formula III in a One-pot Process

76.9 mmol of a compound of formula I is dissolved or suspended in 135 ml of dichloromethane. First, 0.15 g (1 mmol) of TEMPO is added at 15°C to the mixture. The addition of a solution that consists of 134 g of a 15.25% aqueous sodium hypochlorite solution (230.7 mmol) and 8.20 g (82 mmol) of potassium bicarbonate in 114 ml of water is carried out, whereby a pH-value of 9.1 is set. After the reaction is completed, the excess oxidizing agent is quenched at 15°C by adding an aqueous solution of 10.6 g (55.8 mmol) of sodium disulfite ($\text{Na}_2\text{S}_2\text{O}_5$) in 121 ml of water.

The pH of the reaction solution is set at pH < 5 by adding dilute, aqueous sulfuric acid, and stirring is continued at room temperature until the reaction is complete.

The isolation of the product of formula III is carried out analogously to the isolation of the compounds of formula II according to GOP1, whereby the neutral washed organic phase is redistilled on diisopropyl ether. The product that is precipitated in this case is
 5 filtered off, washed with 300 ml of water and dried.

General Operating Procedure 3 (GOP3): Synthesis of Compounds of Formula III Starting from Compounds of Formula II, in which $R^5 = OH$:

0.1 mol of a compound of formula II, in which $R^5 = OH$, obtained according to GOP1, is
 10 suspended in 65 ml of tetrahydrofuran or dioxane and acidified to a pH of 1 by adding 5 ml of 20% sulfuric acid. At room temperature, stirring of the reaction mixture is continued until dehydration is completed.

The isolation of the product of formula III is carried out by precipitation by means of the addition of 90 ml of water. The precipitated product is filtered off with water, washed
 15 neutral and dried.

Example 1 6 β ,7 β ;15 β ,16 β -Dimethylene-3-oxo-17 α -pregnan-5 β -ol-21,17-carbolactone-dichloromethane hemisolvate (IV):

20 According to GOP1, 30 g (0.0769 mol) of 17 α -(3-hydroxypropyl)-6 β ,7 β ;15 β ,16 β -dimethylene-androstane-3 β ,5 β ,17 β -triol is reacted.

During the reaction, the product 6 β ,7 β ;15 β ,16 β -dimethylene-3-oxo-17 α -pregnan-5 β -ol-21,17-carbolactone accumulates in the form of its dichloromethane hemisolvate. After excess oxidizing agent is destroyed and after working-up according to GOP1, 27 g of
 25 6 β ,7 β ;15 β ,16 β -dimethylene-3-oxo-17 α -pregnan-5 β -ol-21,17-carbolactone-dichloromethane hemisolvate (0.0630 mol) = 82% of theory is isolated.

$[\alpha]_D^{20} = -61^\circ$ (c = 1.0; $CHCl_3$); melting point = 121°C;

1H -NMR (400 MHz, $CDCl_3$): δ = 0.52 (q J = 5.5 Hz, 1H, 21 α -H [of the 15,16-methylene bridge]), 0.68-0.78 (m, 2H, 20-H [of the 6,7-methylene bridge]), 0.89-0.97 (m, 1H, 6-H),
 30 0.93 (s, 3H, 19-H), 0.99 (s, 3H, 18-H), 1.19-1.52 (m, 7H), 1.54-1.85 (m, 6H), 1.92 (dd J = 3.8 and 11.8 Hz, 1H, 14-H), 2.06-2.16 (m, 1H, 22-H), 2.17-2.27 (m, 1H, 2 α -H), 2.32-2.69 (m, 5H), 2.96 (d J = 15.6 Hz, 1H, 4 α -H), 5.30 (s, 1H, CH_2Cl_2).

- ^{13}C -NMR (400 MHz, CDCl_3): δ = 9.97 (CH_2 , C-21), 11.63 (CH_2 , C-20), 16.74 (CH , C-15), 16.79 (CH , C-7), 17.29 (CH_3 , C-19), 19.83 (CH_3 , C-18), 21.75 (CH_2 , C-11), 24.31 (CH , C-16), 24.76 (CH , C-6), 29.35 (CH_2 , C-23), 30.70 (CH_2 , C-22), 33.96 (CH , C-8), 34.47 (CH_2 , C-1), 36.26 (CH_2 , C-2), 37.31 (CH_2 , C-12), 40.25 (C, C-10), 41.81 (C, C-13), 47.59 (CH , C-9), 52.18 (CH , C-14), 53.44 (CH_2Cl_2), 53.48 (CH_2 , C-4), 75.57 (C, C-5), 96.24 (C, C-17), 176.63 (C, C-24), 210.56 (C, C-3).
- MS (EI, 70eV) m/e = 384 (M^+); m/e = 366 ($\text{M}^+ - \text{H}_2\text{O}$); m/e = 314 ($\text{M}^+ - \text{C}_4\text{H}_6\text{O}$); m/e = 111 ($\text{C}_7\text{C}_{11}\text{O}^+$); m/e = 91 ($\text{C}_6\text{H}_{11}\text{O}^+$); m/e = 55 ($\text{C}_3\text{H}_3\text{O}^+$); m/e = 43 ($\text{C}_2\text{H}_3\text{O}^+$).
- IR: ν = 3483 cm^{-1} (OH); ν = 1757 cm^{-1} (C=O, lactone); ν = 1708 cm^{-1} (C=O); ν = 1200 cm^{-1} (O-C=O); ν = 1011 cm^{-1} (C-O)

Example 2 6 β ,7 β ;15 β ,16 β -Dimethylene-3-oxo-17 α -preg-4-ene-21,17-carbolactone (IIIb):

- According to GOP2, 30 g (0.0769 mol) of 17 α -(3-hydroxypropyl)-6 β ,7 β ;15 β ,16 β -dimethylene-androstane-3 β ,5 β ,17 β -triol is reacted. After excess oxidizing agent is destroyed according to GOP2, the reaction mixture is acidified with 10% sulfuric acid solution to a pH of 1 and stirred for 30 minutes at 25°C. After working-up according to GOP2, 21.5 g of 6 β ,7 β ;15 β ,16 β -dimethylene-3-oxo-17 α -preg-4-ene-21,17-carbolactone (0.059 mol) = 76.7% of theory is isolated.

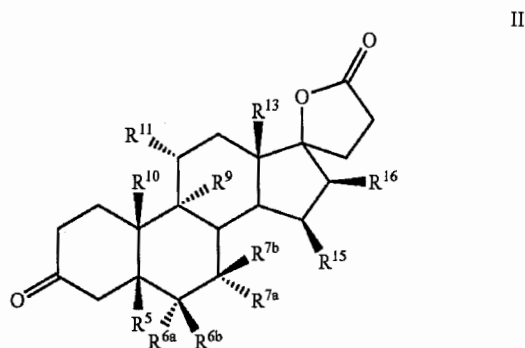
- $[\alpha]_D^{22} \approx -182^\circ$ (c = 0.5 CHCl_3); melting point = 201.3°C; UV (MeOH): $\epsilon_{265} = 19,000$; most important ^1H -NMR data (CDCl_3): δ = 0.40-0.67 (m, 1H, cyclopropyl H), 1.01 (s, 3H, 18-H), 1.11 (s, 3H, 19-H), 6.04 (s, 1H, 4-H) (D. Bittler, H. Hofmeister, H. Laurent, K. Nickisch, R. Nickolson, K. Petzoldt, R. Wiechert; Angew. Chem. Int. Ed. Engl. 1982, 21, 696-697);
- MS (EI, 70eV) m/e = 366 (M^+); m/e = 338 ($\text{M}^+ - \text{CO}$); m/e = 351 ($\text{M}^+ - \text{CH}_3$); significant fragments: m/e = 111; m/e = 136; m/e = 199; m/e = 217; m/e = 242; m/e = 255; m/e = 268; m/e = 293 [Interpretation: See W. Krause, G. Kuehne; Steroids 1982, 40, 81-90].

Example 3 6 β ,7 β :15 β ,16 β -dimethylene-3-oxo-17 α -preg-4-ene-21,17-carbolactone (IIIb):

- 5 According to GOP3, 30 g (70,25 mmol) of 6 β ,7 β :15 β ,16 β -dimethylene-3-oxo-17 α -pregnane-5 β -ol-21,17-carbolactone dichlormethane hemisolvat (from Example 1) is reacted to yield 24.30 g of drospirenone (yield: 94.5%).

Claims

1. A process for the production of a 3-oxo-pregnane-21,17-carbolactones of formula II



in which

R⁵ is hydrogen, or hydroxy;

R^{6a} is hydrogen, together with R⁵ a double bond, or together with R^{7a} a --CH₂-group;

R^{6b} is hydrogen, together with R^{7b} a --CH₂-group or a double bond;

R^{7a} is hydrogen, C₁-C₄-alkyl, C₁-C₄-alkoxycarbonyl, C₁-C₄-thioacyl or together with R^{6a} a --CH₂-group, R^{7b} is hydrogen, or together with R^{6b} a --CH₂-group;

R⁹ is hydrogen, together with R¹¹ a double bond, or together with R¹¹ an epoxy group --O--;

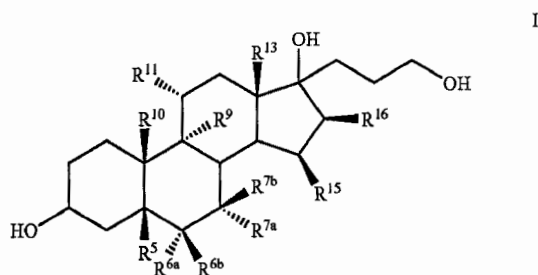
R¹⁰ is hydrogen, methyl, or ethyl;

R¹¹ is hydrogen, together with R⁹ a double bond or together with R⁹ an epoxy group --O--;

R¹³ is hydrogen, methyl or ethyl;

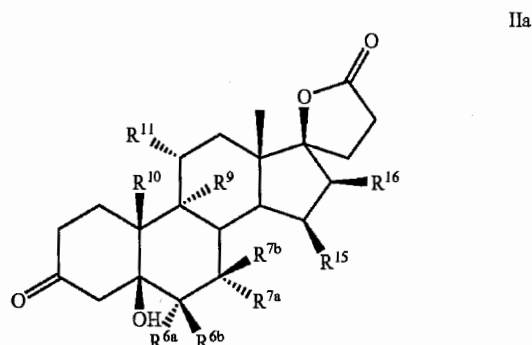
R¹⁵ is hydrogen, C₁-C₄-alkyl, together with R¹⁶ a --CH₂-group or a double bond,

R¹⁶ is hydrogen, together with R¹⁵ a --CH₂-group or a double bond, comprising reacting a compound of formula I



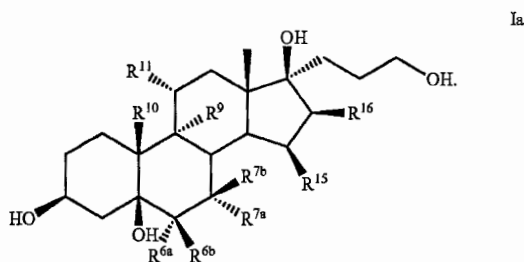
with at least 3 molar equivalents of an organic or inorganic hypochlorite as oxidizing agent in the presence of a catalytic amount of a 2,2,6,6-tetramethylpiperidine-N-oxide derivative at a pH of at least 8.0.

2. A process according to claim 1 for the production of a 3-oxo-17 α -pregnane-21,17-carbolactones of formula IIa



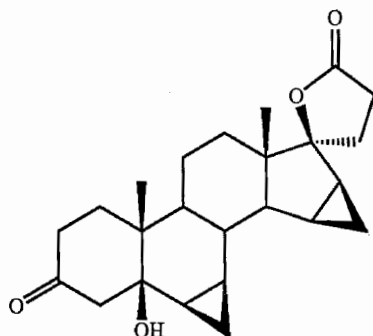
in which

- R^{6a} can be hydrogen or together with R^{7a} a --CH₂--group;
 - R^{6b} can be hydrogen, together with R^{7b} a --CH₂--group, or a double bond;
 - R^{7a} can be hydrogen, C₁-C₄-alkoxycarbonyl, or C₁-C₄-thioacyl;
 - R^{7b} can be hydrogen, or together with R^{6b} a --CH₂--group,
 - R⁹ can be hydrogen, together with R^{11a} double bond or together with R¹¹ an epoxy group --O--;
 - R¹⁰ can be hydrogen, or methyl;
 - R¹¹ can be hydrogen, together with R⁹ a double bond or together with R⁹ an epoxy group --O--;
 - R¹⁵ can be hydrogen, together with R¹⁶ a --CH₂--group or a double bond;
 - R¹⁶ can be hydrogen, together with R¹⁵ a --CH₂--group or a double bond,
- comprising reacting a compound of formula Ia



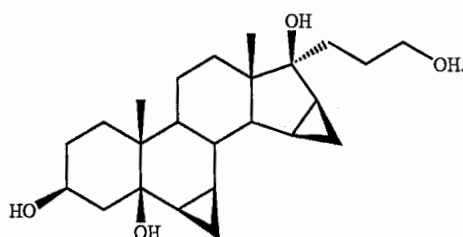
3. A process according to claim 1 for the production of the compound of formula IIb,

IIb



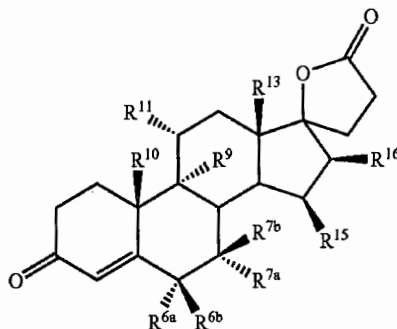
comprising reacting the compound of formula Ib

Ib



4. A process for the production of a 3-oxo-pregn-4-ene-21,17-carbolactones of formula III

III



in which

R^{6a} is hydrogen, together with R^5 a double bond, or together with R^{7a} a $--CH_2$ group;

R^{6b} is hydrogen, together with R^{7b} a $--CH_2$ -group or a double bond;

R^{7a} is hydrogen, C_1 - C_4 -alkyl, C_1 - C_4 -alkoxycarbonyl, C_1 - C_4 -thioacyl or together with R^{6a} a $--CH_2$ -group,

R^{7b} is hydrogen, or together with R^{6b} a $--CH_2$ -group;

R^9 is hydrogen, together with R^{11} a double bond, or together with R^{11} an epoxy group $--O--$;

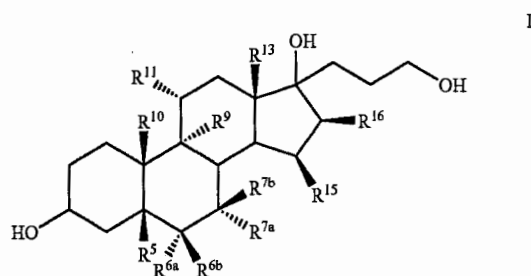
R^{10} is hydrogen, methyl, or ethyl;

R^{11} is hydrogen, together with R^9 a double bond or together with R^9 an epoxy group $--O--$;

R^{13} is hydrogen, methyl or ethyl;

R^{15} is hydrogen, C_1 - C_4 -alkyl, together with R^{16} a $--CH_2--$ group or a double bond,

R^{16} is hydrogen, together with R^{15} a $--CH_2--$ group or a double bond,
comprising reacting a compound of general formula I

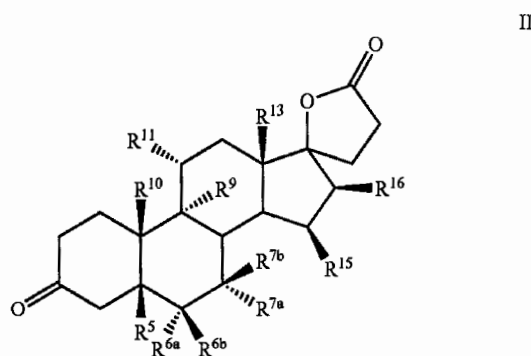


in which

R^5 is hydroxy; and

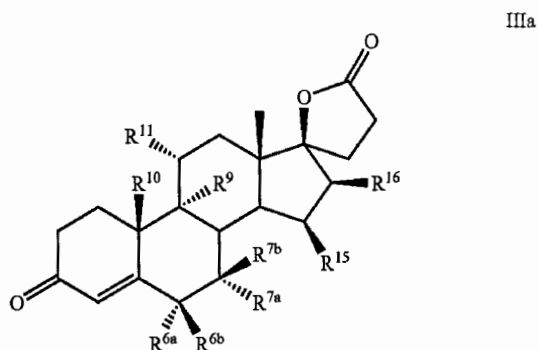
R^{6a} , R^{6b} , R^{7a} , R^{7b} , R^{10} , R^{11} , R^{13} , R^{15} , R^{16} have the same meaning as in formula III, with at least 3 molar equivalents of an organic or inorganic hypochlorite as an oxidizing agent in the presence of a catalytic amount of a 2,2,6,6-tetramethyl-piperidine-N-oxide derivative at a pH of at least 8.0

to form the corresponding compound of formula II



and subsequently eliminating water at $pH < 5$, optionally in the presence of an acid.

5. A process according to claim 4 for the production of a 3-oxo-17 α -pregn-4-ene-21,17-carbolactones of formula IIIa



in which

R^{6a} can be hydrogen or together with R^{7a} a $--CH_2-$ group;

R^{6b} can be hydrogen, together with R^{7b} a $--CH_2-$ group, or a double bond;

R^{7a} can be hydrogen, C_1-C_4 -alkoxycarbonyl, or C_1-C_4 -thioacyl;

R^{7b} can be hydrogen, or together with R^{6b} a $--CH_2-$ group,

R^9 can be hydrogen, together with R^{11} a double bond or together with R^{11} an epoxy group $--O--$;

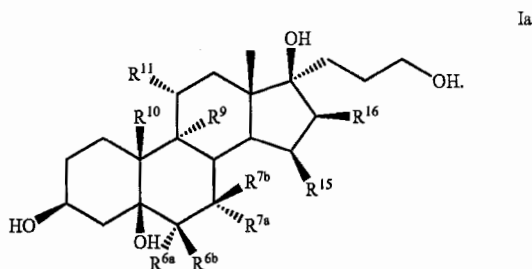
R^{10} can be hydrogen, or methyl;

R^{11} can be hydrogen, together with R^9 a double bond or together with R^9 an epoxy group $--O--$;

R^{15} can be hydrogen, together with R^{16} a $--CH_2-$ group or a double bond;

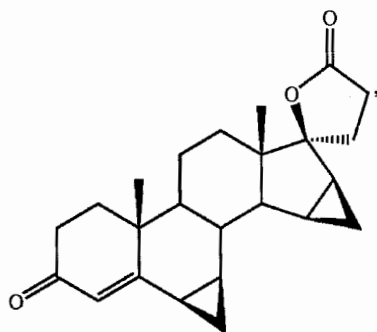
R^{16} can be hydrogen, together with R^{15} a $--CH_2-$ group or a double bond,

comprising reacting a compound of formula Ia



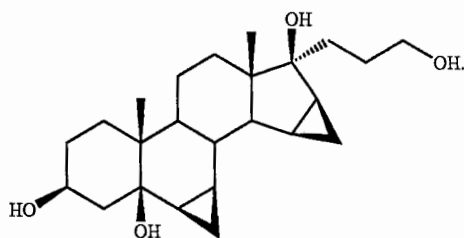
6. A process according to claim 4 for the production of a compound of formula IIIb

IIIb



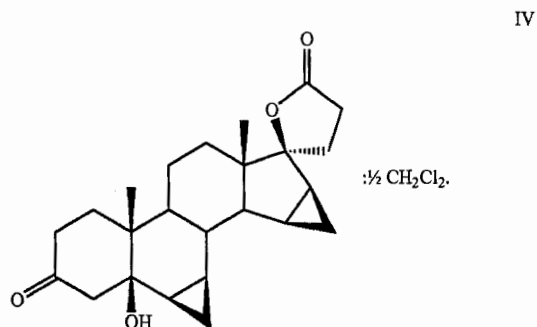
comprising reacting the compound of formula Ib

Ib



7. A process according to claim 4, wherein the compound of formula II is isolated before step b).
8. A process of claim 5 wherein the compound of Formula II corresponding to the compound of formula Ia is isolated before step b).
9. A process of claim 5 wherein the compound of Formula II corresponding to the compound of formula Ib is isolated before step b).
10. A process according to claim 1, wherein the reaction is performed in a two-phase solvent-water mixture.
11. A process according to claim 4, wherein the reaction is performed in a two phase solvent-water mixture.
12. A process according to claim 10, wherein the solvent is dichloromethane.
13. A process according to claim 11, wherein the solvent is dichloromethane.

14. A process according to claim 12 for the production of dichloromethane hemisolvate IV:



15. A process according to claim 1, wherein 1-5 mol % of the 2,2,6,6-tetramethylpiperidine-N-oxide derivative is used.
16. A process according to claim 4, wherein 1-5 mol % of the 2,2,6,6-tetramethylpiperidine-N-oxide derivative is used.
17. A process according to claim 1, wherein 1-1.5 mol % of 2,2,6,6-tetramethylpiperidine-N-oxide is used.
18. A process according to claim 4, wherein 1-1.5 mol % of 2,2,6,6-tetramethylpiperidine-N-oxide is used.
19. A process according to claim 1, wherein 3-6 molar equivalents of alkali hypochlorite are used.
20. A process according to claim 4, wherein 3-6 molar equivalents of alkali hypochlorite are used.
21. A process according to claim 1, wherein 3-4 molar equivalents of sodium hypochlorite are used.
22. A process according to claim 4, wherein 3-4 molar equivalents of sodium hypochlorite are used.
23. A process according to claim 1, wherein the pH of the reaction solution is

between 8.5 and 10.0.

24. A process according to claim 4, wherein the pH of the reaction solution is between 8.5 and 10.0.

25. A process according to claim 1, wherein the pH of the reaction solution is set with potassium bicarbonate.

26. A process according to claim 1, wherein the reaction temperature is 0 to 20° C.

27. A process according to claim 4, wherein the reaction temperature is 0 to 20° C.

28. A process according to claim 1, wherein after the oxidation reaction is completed, a reducing agent for annihilating excess hypochlorite reagent is added to the reaction mixture.

29. A process according to claim 4, wherein after the oxidation reaction is completed, a reducing agent for annihilating excess hypochlorite reagent is added to the reaction mixture.

30. A process according to claim 28, wherein the reducing agent is added with the addition of a base or a basic buffer at a pH of more than 5.

31. A process according to claim 29, wherein the reducing agent is added with the addition of a base or a basic buffer at a pH of more than 5.

32. A process according to claim 28, wherein an aqueous alkali hydrogen sulfite solution is used as a reducing agent.

33. A process according to claim 29, wherein an aqueous alkali hydrogen sulfite solution is used as a reducing agent.

34. A process according to claim 28, wherein as a reducing agent, sodium

hydrogen sulfite or potassium hydrogen sulfite is used in the form of the aqueous solution of sodium disulfite or potassium disulfite.

35. A process according to claim 29, wherein as a reducing agent, sodium hydrogen sulfite or potassium hydrogen sulfite is used in the form of the aqueous solution of sodium disulfite or potassium disulfite.

36. A process according to claim 30, wherein sodium phosphate (Na_3PO_4) is used as a base or a basic buffer.

37. A process according to claim 31, wherein sodium phosphate (Na_3PO_4) is used as a base or a basic buffer.

38. 6β , 7β , 15β , 16β -Dimethylene-3-oxo- 17α -pregnan- 5β -ol-21, 17-carbolactone-dichloromethane hemisolvate.

39. A process of claim 1 wherein said derivative is 2,2,6,6-tetramethylpiperidene-N-oxide, 4-methoxy-2,2,6,6-tetramethylpiperidene-N-oxide or 4-benzyloxy-2,2,6,6-tetramethylpiperidene-N-oxide.

40. A process for the production of drospirenone comprising reacting 6β , 7β ; 15β , 16β -dimethylene-3-oxo- 17α -pregnan- 5β -ol-21, 17-carbolactone-dichloromethane hemisolvate with an acid.

41. A process of claim 40 wherein the acid is sulfuric acid, hydrochloric acid or para-toluene sulfonic acid.