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(54) **PROCESS TO PREPARE TREPROSTINIL,
THE ACTIVE INGREDIENT IN REMODULIN**

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patent is extended or adjusted under 35
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(65) **Prior Publication Data**

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Related U.S. Application Data

(60) Provisional application No. 61/014,232, filed on Dec.
17, 2007.

(51) **Int. Cl.**
C07C 62/00 (2006.01)
C07C 65/00 (2006.01)

(52) **U.S. Cl.** **562/466**

(58) **Field of Classification Search** None
See application file for complete search history.

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(57) **ABSTRACT**

This present invention relates to an improved process to pre-
pare prostacyclin derivatives. One embodiment provides for
an improved process to convert benzindene triol to treprosti-
nil via salts of trenprostiniol and to purify trenprostiniol

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1

**PROCESS TO PREPARE TREPROSTINIL,
THE ACTIVE INGREDIENT IN REMODULIN**

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application claims priority from U.S. Provisional Patent Application 61/014,232, filed Dec. 17, 2007, the entire contents of which are incorporated herein by reference.

BACKGROUND

The present invention relates to a process for producing prostacyclin derivatives and novel intermediate compounds useful in the process.

Prostacyclin derivatives are useful pharmaceutical compounds possessing activities such as platelet aggregation inhibition, gastric secretion reduction, lesion inhibition, and bronchodilation.

Treprostinil, the active ingredient in Remodulin®, was first described in U.S. Pat. No. 4,306,075. Treprostinil, and other prostacyclin derivatives have been prepared as described in Moriarty, et al in *J. Org. Chem.* 2004, 69, 1890-1902, *Drug of the Future*, 2001, 26(4), 364-374, U.S. Pat. Nos. 6,441,245, 6,528,688, 6,765,117 and 6,809,223. Their teachings are incorporated by reference to show how to practice the embodiments of the present invention.

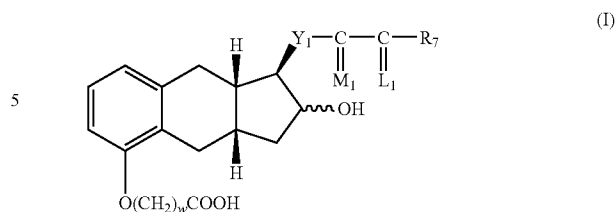
U.S. Pat. No. 5,153,222 describes use of treprostinil for treatment of pulmonary hypertension. Treprostinil is approved for the intravenous as well as subcutaneous route, the latter avoiding septic events associated with continuous intravenous catheters. U.S. Pat. Nos. 6,521,212 and 6,756,033 describe administration of treprostinil by inhalation for treatment of pulmonary hypertension, peripheral vascular disease and other diseases and conditions. U.S. Pat. No. 6,803,386 discloses administration of treprostinil for treating cancer such as lung, liver, brain, pancreatic, kidney, prostate, breast, colon and head-neck cancer. U.S. patent application publication No. 2005/0165111 discloses treprostinil treatment of ischemic lesions. U.S. Pat. No. 7,199,157 discloses that treprostinil treatment improves kidney functions. U.S. patent application publication No. 2005/0282903 discloses treprostinil treatment of neuropathic foot ulcers. U.S. application Ser. No. 12/028,471 filed Feb. 8, 2008, discloses treprostinil treatment of pulmonary fibrosis. U.S. Pat. No. 6,054,486 discloses treatment of peripheral vascular disease with treprostinil. U.S. patent application Ser. No. 11/873,645 filed Oct. 17, 2007 discloses combination therapies comprising treprostinil. U.S. publication No. 2008/0200449 discloses delivery of treprostinil using a metered dose inhaler. U.S. publication No. 2008/0280986 discloses treatment of interstitial lung disease with treprostinil. U.S. application Ser. No. 12/028,471 filed Feb. 8, 2008 discloses treatment of asthma with treprostinil. U.S. Pat. Nos. 7,417,070, 7,384,978 and U.S. publication Nos. 2007/0078095, 2005/0282901, and 2008/0249167 describe oral formulations of treprostinil and other prostacyclin analogs.

Because Treprostinil, and other prostacyclin derivatives are of great importance from a medicinal point of view, a need exists for an efficient process to synthesize these compounds on a large scale suitable for commercial production.

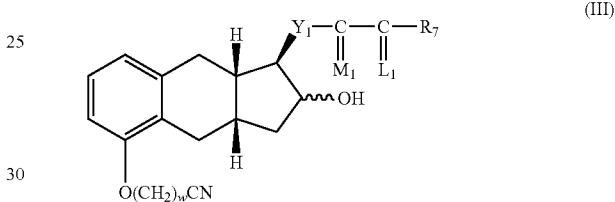
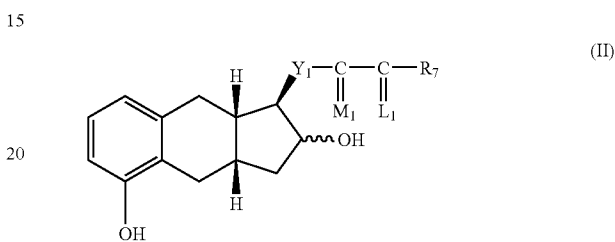
SUMMARY

The present invention provides in one embodiment a pro-

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The process comprises the following steps:
(a) alkylating a compound of structure II with an alkylating agent to produce a compound of formula III,



wherein

w=1, 2, or 3;

Y₁ is trans-CH=CH-, cis-CH=CH-, -CH₂(CH₂)_m-, or -C≡C-; m is 1, 2, or 3;

R₇ is

(1) -C_pH_{2p}-CH₃, wherein p is an integer from 1 to 5, inclusive,

(2) phenoxy optionally substituted by one, two or three chloro, fluoro, trifluoromethyl, (C₁-C₃) alkyl, or (C₁-C₃) alkoxy, with the proviso that not more than two substituents are other than alkyl, with the proviso that R₇ is phenoxy or substituted phenoxy, only when R₃ and R₄ are hydrogen or methyl, being the same or different,

(3) phenyl, benzyl, phenylethyl, or phenylpropyl optionally substituted on the aromatic ring by one, two or three chloro, fluoro, trifluoromethyl, (C₁-C₃) alkyl, or (C₁-C₃) alkoxy, with the proviso that not more than two substituents are other than alkyl,

(4) cis-CH=CH-CH₂-CH₃,

(5) -(CH₂)₂-CH(OH)-CH₃, or

(6) -(CH₂)₃-CH=C(CH₃)₂;

wherein -C(L₁)-R₇ taken together is

(1) (C₄-C₇)cycloalkyl optionally substituted by 1 to 3 (C₁-C₅)alkyl;

(2) 2-(2-furyl)ethyl,

(3) 2-(3-thienyl)ethoxy, or

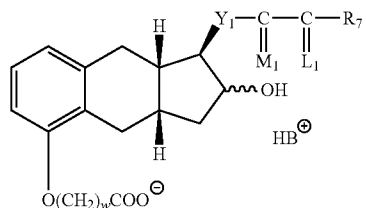
(4) 3-thienyloxymethyl;

M₁ is α-OH:β-R₅ or α-R₅:β-OH or α-OR₁:β-R₅ or α-R₅:β-OR₂, wherein R₅ is hydrogen or methyl, R₂ is an alcohol protecting group, and

L₁ is α-R₃:β-R₄, α-R₄:β-R₃, or a mixture of α-R₃:β-R₄ and α-R₄:β-R₃, wherein R₃ and R₄ are hydrogen, methyl, or fluoro, being the same or different, with the proviso that

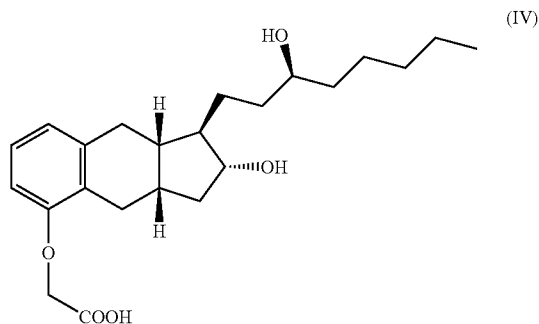
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- (b) hydrolyzing the product of step (a) with a base,
 (c) contacting the product of step (b) with a base B to form a salt of formula I_s,



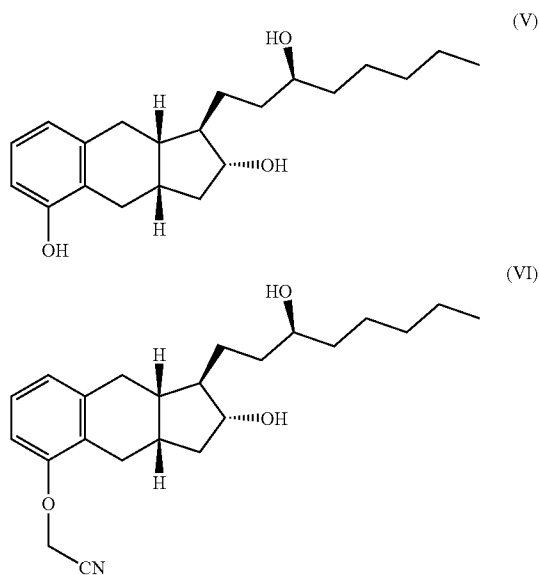
- (d) reacting the salt from step (c) with an acid to form the compound of formula I.

The present invention provides in another embodiment a process for the preparation of a compound of formula IV.



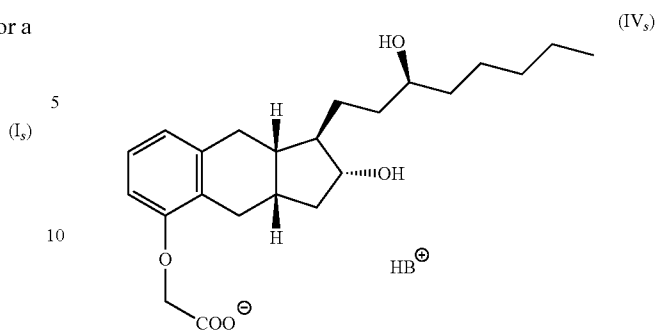
The process comprises the following steps:

- (a) alkylating a compound of structure V with an alkylating agent to produce a compound of formula VI,



- (b) hydrolyzing the product of step (a) with a base,

4



- (d) reacting the salt from step (b) with an acid to form the compound of formula IV.

DETAILED DESCRIPTION

The various terms used, separately and in combinations, in the processes herein described are defined below.

The expression “comprising” means “including but not limited to.” Thus, other non-mentioned substances, additives, carriers, or steps may be present. Unless otherwise specified, “a” or “an” means one or more.

C₁₋₃-alkyl is a straight or branched alkyl group containing 1-3 carbon atoms. Exemplary alkyl groups include methyl, ethyl, n-propyl, and isopropyl.

C₁₋₃-alkoxy is a straight or branched alkoxy group containing 1-3 carbon atoms. Exemplary alkoxy groups include methoxy, ethoxy, propoxy, and isopropoxy.

C₄₋₇-cycloalkyl is an optionally substituted monocyclic, bicyclic or tricyclic alkyl group containing between 4-7 carbon atoms. Exemplary cycloalkyl groups include but not limited to cyclobutyl, cyclopentyl, cyclohexyl, and cycloheptyl.

Combinations of substituents and variables envisioned by this invention are only those that result in the formation of stable compounds. The term “stable”, as used herein, refers to compounds which possess stability sufficient to allow manufacture and which maintains the integrity of the compound for a sufficient period of time to be useful for the purposes detailed herein.

As used herein, the term “prodrug” means a derivative of a compound that can hydrolyze, oxidize, or otherwise react under biological conditions (in vitro or in vivo) to provide an active compound. Examples of prodrugs include, but are not limited to, derivatives of a compound that include biohydrolyzable groups such as biohydrolyzable amides, biohydrolyzable esters, biohydrolyzable carbamates, biohydrolyzable carbonates, biohydrolyzable ureides, and biohydrolyzable phosphate analogues (e.g., monophosphate, diphosphate or triphosphate).

As used herein, “hydrate” is a form of a compound wherein water molecules are combined in a certain ratio as an integral part of the structure complex of the compound.

As used herein, “solvate” is a form of a compound where solvent molecules are combined in a certain ratio as an integral part of the structure complex of the compound.

“Pharmaceutically acceptable” means in the present description being useful in preparing a pharmaceutical composition that is generally safe, non-toxic and neither biologically nor otherwise undesirable and includes being useful for veterinary use as well as human pharmaceutical use.

“Pharmaceutically acceptable salts” mean salts which are

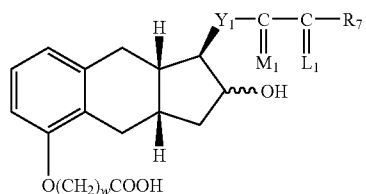
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include acid addition salts formed with organic and inorganic acids, such as hydrogen chloride, hydrogen bromide, hydrogen iodide, sulfuric acid, phosphoric acid, acetic acid, glycolic acid, maleic acid, malonic acid, oxalic acid, methanesulfonic acid, trifluoroacetic acid, fumaric acid, succinic acid, tartaric acid, citric acid, benzoic acid, ascorbic acid and the like. Base addition salts may be formed with organic and inorganic bases, such as sodium, ammonia, potassium, calcium, ethanolamine, diethanolamine, N-methylglucamine, choline and the like. Included in the invention are pharmaceutically acceptable salts or compounds of any of the formulae herein.

Depending on its structure, the phrase "pharmaceutically acceptable salt," as used herein, refers to a pharmaceutically acceptable organic or inorganic acid or base salt of a compound. Representative pharmaceutically acceptable salts include, e.g., alkali metal salts, alkali earth salts, ammonium salts, water-soluble and water-insoluble salts, such as the acetate, amsonate (4,4-diaminostilbene-2,2-disulfonate), benzenesulfonate, benzonate, bicarbonate, bisulfate, bitartrate, borate, bromide, butyrate, calcium, calcium edetate, camsylate, carbonate, chloride, citrate, clavuliate, dihydrochloride, edetate, edisylate, estolate, esylate, fumarate, gluceptate, gluconate, glutamate, glycolylarsanilate, hexafluorophosphate, hexylresorcinolate, hydrabamine, hydrobromide, hydrochloride, hydroxynaphthoate, iodide, isothionate, lactate, lactobionate, laurate, malate, maleate, mandelate, mesylate, methylbromide, methylnitrate, methylsulfate, mucate, napsylate, nitrate, N-methylglucamine ammonium salt, 3-hydroxy-2-naphthoate, oleate, oxalate, palmitate, pamoate (1,1-methene-bis-2-hydroxy-3-naphthoate, einbonate), pantothenate, phosphate/diphosphate, picrate, polygalacturonate, propionate, p-toluenesulfonate, salicylate, stearate, subacetate, succinate, sulfate, sulfosalicylate, suramate, tannate, tartrate, teoate, tosylate, triethiodide, and valerate salts.

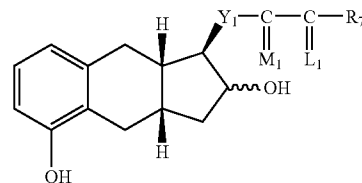
The present invention provides for a process for producing treprostinil and other prostacyclin derivatives and novel intermediate compounds useful in the process. The process according to the present invention provides advantages on large-scale synthesis over the existing method. For example, the purification by column chromatography is eliminated, thus the required amount of flammable solvents and waste generated are greatly reduced. Furthermore, the salt formation is a much easier operation than column chromatography. Moreover, it was found that the product of the process according to the present invention has higher purity. Therefore the present invention provides for a process that is more economical, safer, faster, greener, easier to operate, and provides higher purity.

One embodiment of the present invention is a process for the preparation of a compound of formula I, or a hydrate, solvate, prodrug, or pharmaceutically acceptable salt thereof.

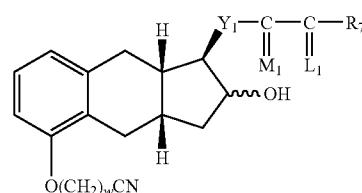


The process comprises the following steps:

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(II)



(III)

wherein

w=1, 2, or 3;

Y₁ is trans-CH=CH-, cis-CH=CH-, -CH₂(CH₂)_m-, or -C≡C-; m is 1, 2, or 3;

R₇ is

(1) -C_pH_{2p}-CH₃, wherein p is an integer from 1 to 5, inclusive,

(2) phenoxy optionally substituted by one, two or three chloro, fluoro, trifluoromethyl, (C₁-C₃) alkyl, or (C₁-C₃) alkoxy, with the proviso that not more than two substituents are other than alkyl, with the proviso that R₇ is phenoxy or substituted phenoxy, only when R₃ and R₄ are hydrogen or methyl, being the same or different,

(3) phenyl, benzyl, phenylethyl, or phenylpropyl optionally substituted on the aromatic ring by one, two or three chloro, fluoro, trifluoromethyl, (C₁-C₃) alkyl, or (C₁-C₃) alkoxy, with the proviso that not more than two substituents are other than alkyl,

(4) cis-CH=CH-CH₂-CH₃,

(5) -(CH₂)₂-CH(OH)-CH₃, or

(6) -(CH₂)₃-CH=C(CH₃)₂;

wherein -C(L₁)-R₇ taken together is

(1) (C₄-C₇)cycloalkyl optionally substituted by 1 to 3 (C₁-C₃)alkyl;

(2) 2-(2-furyl)ethyl,

(3) 2-(3-thienyl)ethoxy, or

(4) 3-thienyloxymethyl;

M₁ is x-OH;β-R₅ or α-R₅;β-OH or α-OR₁;β-R₅ or α-R₅;β-OR₂, wherein R₅ is hydrogen or methyl, R₂ is an alcohol protecting group, and

L₁ is α-R₃;β-R₄, α-R₄;β-R₃, or a mixture of α-R₃;β-R₄ and α-R₄;β-R₃, wherein R₃ and R₄ are hydrogen, methyl, or fluoro, being the same or different, with the proviso that one of R₃ and R₄ is fluoro only when the other is hydrogen or fluoro.

(b) hydrolyzing the product of step (a) with a base,

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