

DESCRIPTION

Title of Invention: PROCESS FOR PREPARING SUBSTITUTED
1-O-ACYL-2-DEOXY-2-FLUORO-4-THIO- β -D-ARABINOFURANOSES

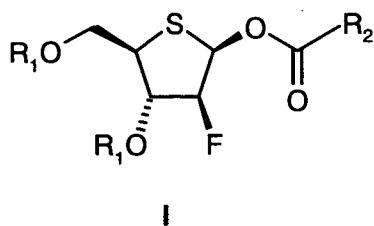
Technical Field

[0001] The present invention relates to a process for preparing 1-O-acyl-2-deoxy-2-fluoro-4-thio- β -D-arabinofuranoses and intermediates thereof.

Background Art

[0002] 4'-Thionucleosides are attractive compounds with respect to antiviral and antineoplastic activity. For example, 1-(2-deoxy-2-fluoro-4-thio- β -D-arabinofuranosyl)cytosine (4'-thio-FAC) was shown to have excellent antitumour activity *in vitro* and *in vivo* [Y. Yoshimura et al; *J. Org. Chem.* 1997, 62, 3140-3152; S. Miura et al, *Cancer Lett.* 1998, 129, 103-110; S. Miura et al, *Cancer Lett.* 1999, 144, 177-182; Y. Yoshimura et al, *Bioorg. Med. Chem.* 2000, 8, 1545-1558; D.A. Zajchowski et al, *Int. J. Cancer* 2005, 114, 1002-1009].

[0003] The invention relates in particular to a novel process for preparing compounds of formula I



in which

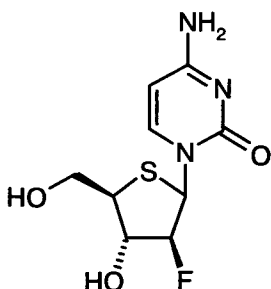
R₁ represents -C(O)-C₁-C₆-alkyl or -C(O)-aryl; and

R₂ represents C₁-C₆-alkyl, C₁-C₄-perfluoroalkyl or aryl.

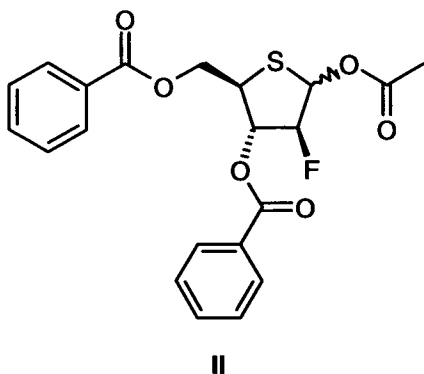
[0004] The compounds of the general formula I are key intermediates in the

preparation of 4'-thionucleosides.

[0005] 1-(2-Deoxy-2-fluoro-4-thio-β-D-arabinofuranosyl)cytosine [4'-thio-FAC]:



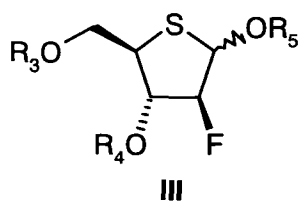
[0006] There is a particular interest in the preparation of 1-(2-deoxy-2-fluoro-4-thio-β-D-arabinofuranosyl)cytosine (4'-thio-FAC) with a view to the compound II:



where in the text below the α-diastereomer of the anomeric acetate is referred to as IIα and IIβ is used for the β-isomer.

[0007] This compound and its preparation was described for the first time in WO 97/73993, WO 97/038001 and in the literature associated therewith [Y. Yoshimura et al, *J. Org. Chem.* 1999, 64, 7912-7920; Y. Yoshimura et al, *Nucleosides Nucleotides* 1999, 18, 815-820; Y. Yoshimura et al, *Nucleic Acids Symposium Series* 1998, 39, 11-12; Y. Yoshimura et al, *Tetrahedron Lett.* 1999, 40, 1937-1940].

[0008] In this context, a preparation route to compounds of the formula III is described



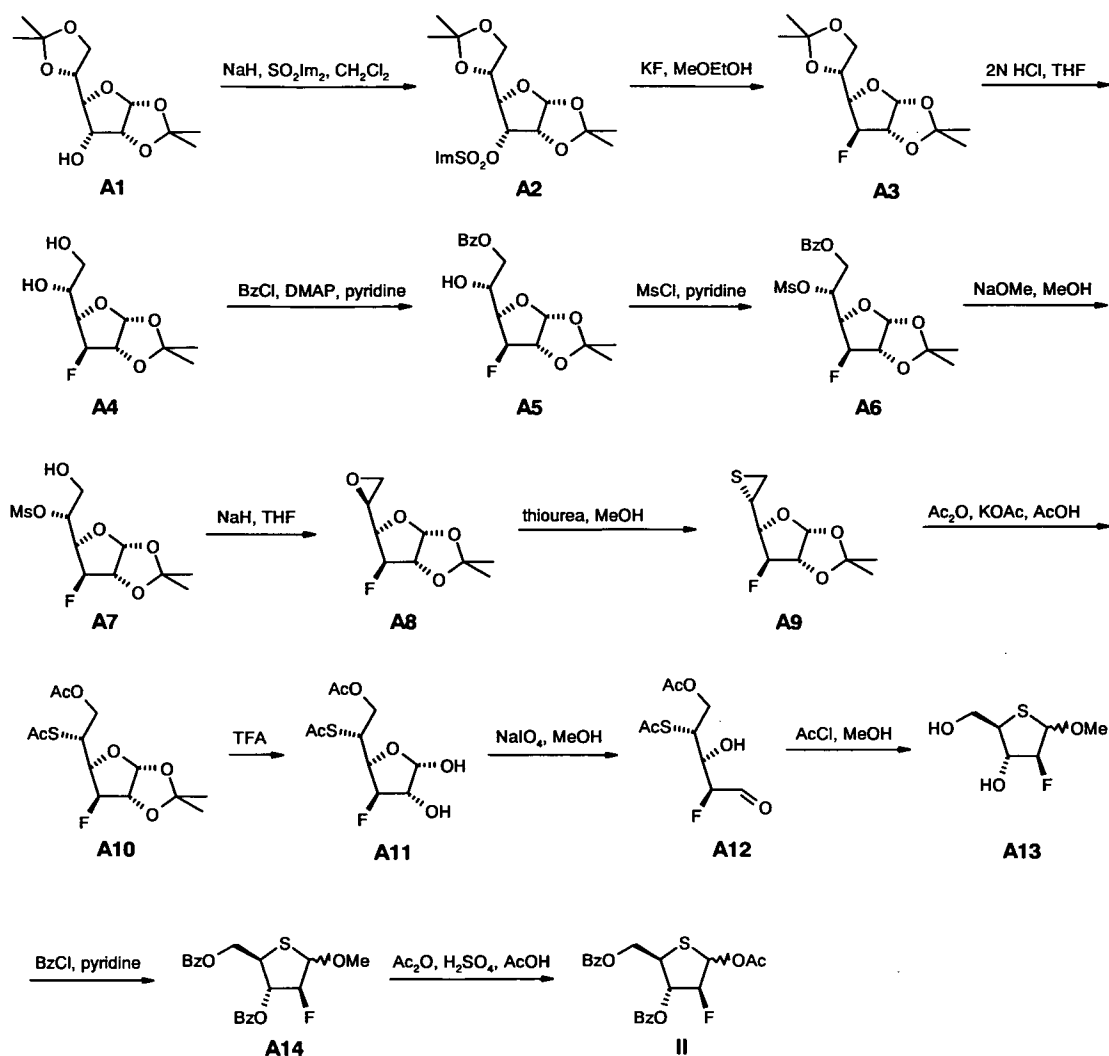
in which

R₃ and R₄ represent alkyl, silyl or acyl, and

R₅ represents acyl.

(Scheme 1).

[0009] [Scheme 1]



[0010] The starting material in Scheme 1 is the commercially available 1,2:5,6-di-O-isopropylidene- α -D-allofuranose (A1) which for its part can be obtained in four steps from D-glucose [D.C. Baker et al, Carbohydr. Res. 1972, 24, 192-197]. Thus, compound II can be obtained in a total of 14 chemical steps starting with 1,2:5,6-di-O-isopropylidene- α -D-allofuranose or 18 chemical steps starting with D-glucose. Here, compound II is obtained as an anomeric mixture consisting of II α and II β . The literature

does not make any statements about the ratio II α / II β [Y. Yoshimura et al, *J. Org. Chem.* 1999, 64, 7912-7920]. Laboratory experiments carried out by the applicant for preparing II analogously to the literature procedure starting with A14 gave II α /II β mixtures of 1:1 to 3:2.

[0011] A disadvantage of the process, known from the prior art, for preparing the compound II is the large number of chemical steps required, which makes the practice of the process on an industrial scale considerably more difficult. Furthermore, in particular when the synthesis is carried out on an industrial scale, there are the following difficulties and problems:

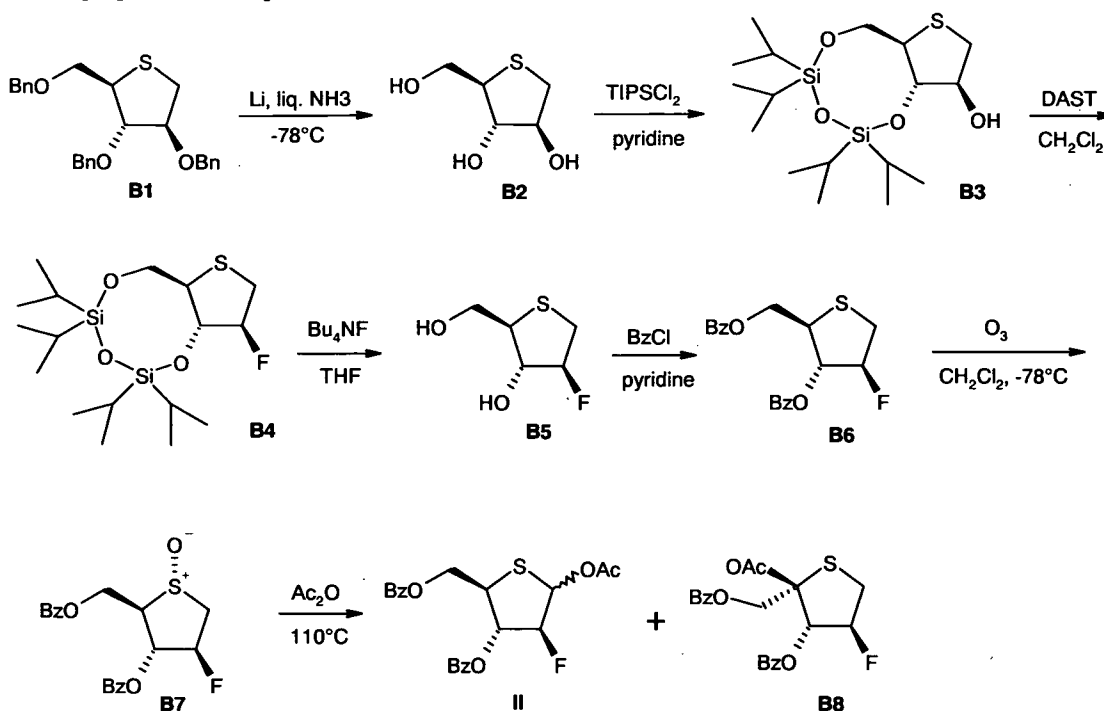
- The process comprises at least five preparative chromatographic separations (prep-HPLC).
- The intermediates A6, A7, A9, A12 are unstable.
- Handling of the viscous liquids in stages A2, A3, A4, A8, A9, A11, A12 is difficult.
- The compound A6 dissolves only very slowly in methanol. In the presence of sodium methoxide (NaOMe), a nucleophilic substitution of the mesylate group by a methoxy group in the compound A7 takes place as a side-reaction. Formation of by-product takes place in particular when the reaction is carried out on a relatively large scale.
- After cleavage of the isopropylidene group, trifluoroacetic acid (TFA) has to be distilled off under reduced pressure since other alternatives for work-up result in a large formation of side-product. On an industrial scale, this is associated with considerable difficulties.

[0012] Owing to the long synthesis sequence and the fact that some of its steps cannot be scaled up, or only with considerable expense, the process shown in Scheme 1 is not suitable for the industrial commercial preparation of the compound II.

[0013] An alternative for preparing the compound II is described in WO 2007/068113

and the literature associated therewith [J.K. Watts et al, *J. Org. Chem.* 2006, 71, 921-925] and is summarized here in Scheme 2.

[0014] [Scheme 2]



[0015] Here, in the last synthesis step, a mixture of the anomeric acetates II in a ratio $\text{II}\alpha/\text{II}\beta$ of from 1:2 to 1:14 is obtained [see also J.K. Watts et al, *J. Org. Chem.* 2006, 71, 921-925]. The by-product B8 is removed by column chromatography.

[0016] Compound B1 can be prepared in 6 steps from L-xylose (which does not occur in nature) [J.K. Watts et al, *J. Org. Chem.* 2006, 71, 921-925]. Thus, compound II can be prepared in a total of 13 chemical steps from L-lyxose.

[0017] A particular disadvantage of this synthesis alternative is due to the fact that the starting material L-lyxose is expensive and very little is commercially available for a synthesis on an industrial scale.

[0018] Furthermore, in particular when the synthesis is carried out on an industrial

scale, there are the following difficulties and problems:

- On each synthesis stage, complicated protective group transformations and in each case a chromatographic purification have to be carried out.
- The use of liquid ammonia and elemental lithium at very low temperatures (step B2).
- Introduction and removal of a particular silyl protective group which has a high molar mass and is difficult to obtain commercially (steps B3 and B5).
- Use of DAST as fluorinating agent. In addition to the fact that DAST is difficult to obtain, safety concerns (handling temperature, decomposition of DAST in an exothermal reaction with formation of gas) play an important role in the scale-up of this reaction (step 4).
- The use of ozone at very low temperatures (B7).
- High temperatures (110°C) during the Pummerer rearrangement and the formation of about 20% of by-product B8 [J.K. Watts et al, *J. Org. Chem.* 2006, 71, 921-925].

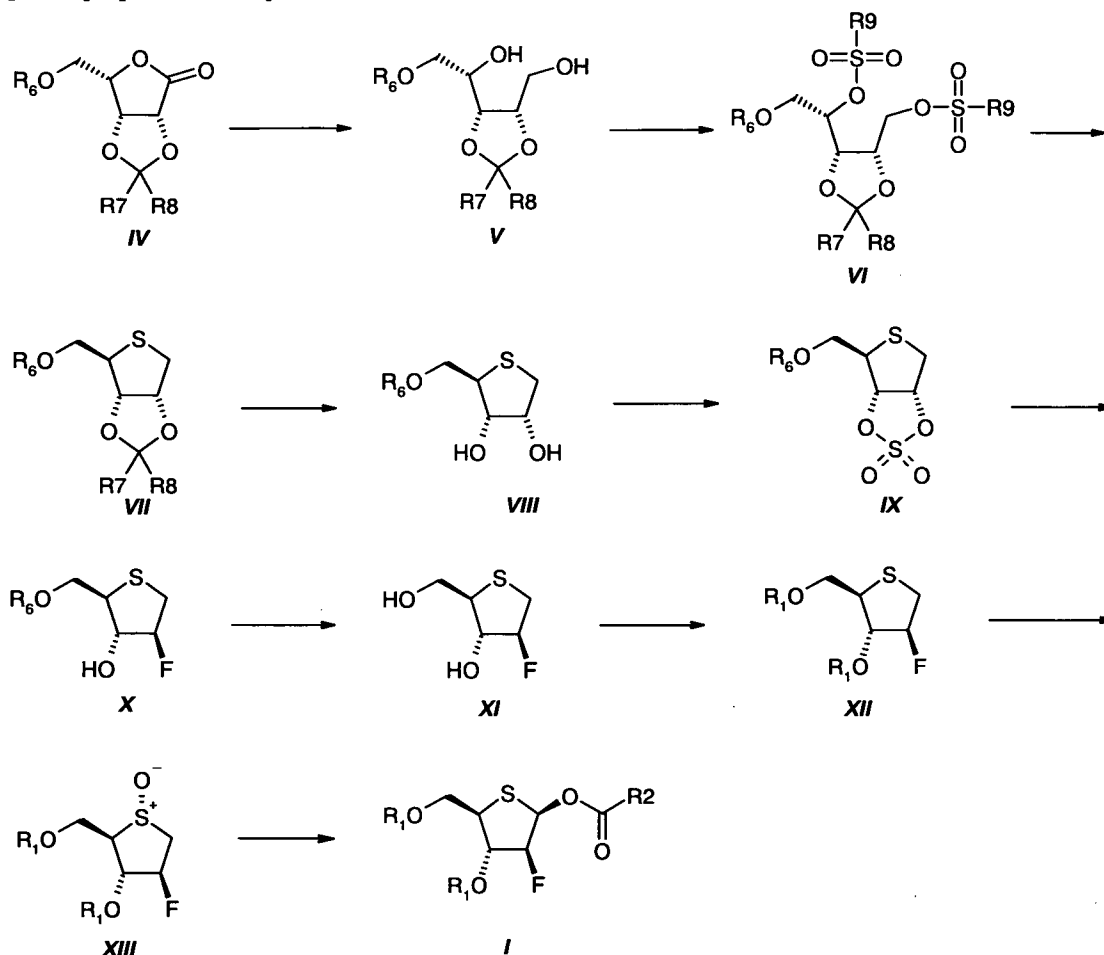
[0019] Owing to the difficulties, described here, in the individual steps of the synthesis, which render scale-up difficult or impossible, and owing to the limited availability of the starting material, the process shown in Scheme 2 is likewise not very suitable for the industrial commercial preparation of the compound II.

Summary of Invention

[0020] Against this background, it was the object of the present invention to provide an alternative process allowing the industrial preparation of compounds of formula I.

[0021] According to the invention, this object was achieved by a process which affords compounds of formula I in high yields in 10 chemical steps starting with commercially readily available compounds of formula IV via the key steps "introduction of the fluorine atom via targeted opening of a cyclic sulphate" and "Pummerer rearrangement of a sulphoxide using a special catalyst" (Scheme 3).

[0022] [Scheme 3]



[0023] Compounds of formula IV, used as starting materials for the process according to the invention, can be synthesized in 4 chemical steps from natural and thus readily available D-ribose. Both D-ribose and compounds of the type IV (for example 5-O-benzyl-2,3-O-isopropylidene-L-lyxono-1,4-lactone) are commercially available (U.S. Patent No. 6,448,415 B1).

[0024] Furthermore, the process according to the invention uses exclusively reagents which are readily available even in kg amounts.

[0025] The intermediates V, VI and VII are isolated only as crude products and in each case employed directly for the next step. Finally, the compound VIII is crystallized in

high purity (> 97%). Thus, time- and resource-intensive purifications (for example preparative chromatography) can be dispensed with.

[0026] Steps IX, XI and XII are likewise not isolated and directly used as crude materials for the subsequent step.

[0027] According to the invention, over the entire synthesis sequence, only 3 intermediates (VIII, X and XIII) have to be isolated, and only a single preparative chromatography is required (X). The intermediates VIII, XII and the product I (II) are isolated in high yields and high purities (> 93%) by crystallization.

[0028] The process according to the invention does not require any complicated protective group transformations.

[0029] The oxidation of the sulphide XII can be carried out in a targeted manner at room temperature using OXONE (potassium monopersulphate triple salt, $2 \text{KHSO}_5 \cdot \text{KHSO}_4 \cdot \text{K}_2\text{SO}_4$), overoxidation can be excluded without any problems by using equimolar amounts (cf. Scheme 2, reaction yielding B7).

[0030] According to the invention, the Pummerer rearrangement ($\text{XIII} \rightarrow \text{I}$) is carried out in the presence of catalytic amounts of potassium bisulphate. By using this catalyst, it is possible to achieve high yields (> 80%) and at the same time very little side-product formation (< 5%) at low reaction temperatures (< 90°C) [cf. Scheme 2, reaction yielding II]. The crude product I obtained comprises so few impurities and also only very small proportions of the α -anomer that a simple crystallization is sufficient for purification.

[0031] The process according to the invention does make use of general chemical transformations, known to the person skilled in the art, for constructing a thiofuranose via formation of a diol, its activation via a bissulphonate and cyclization with sodium sulphide; for protective group techniques and for oxidizing a sulphide with OXONE.

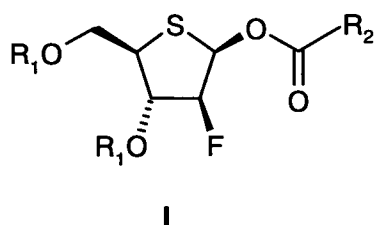
However, a particular aspect of the present invention is the targeted and highly efficient

construction of the individual stereocentres of the thiofuranoses.

[0032] A further aspect of the present invention is the stereospecific introduction of the fluorine atom at the C3 atom of compound X via stereoselective opening of the cyclic sulphate IX.

Description of Embodiments

[0033] In the first step of the process according to the invention for preparing a compound of formula I:

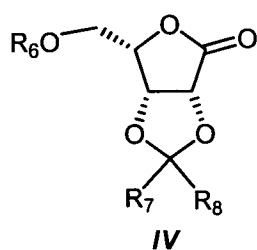


in which

R₁ represents -C(O)-C₁-C₆-alkyl or -C(O)-aryl; and

R₂ represents C₁-C₆-alkyl, C₁-C₄-perfluoroalkyl or aryl,

a lyxonolactone of formula IV

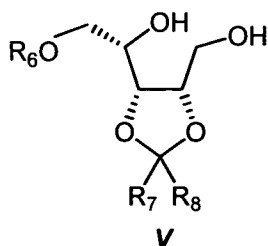


in which

R₆ represents C₁-C₆-alkyl or arylmethylene; and

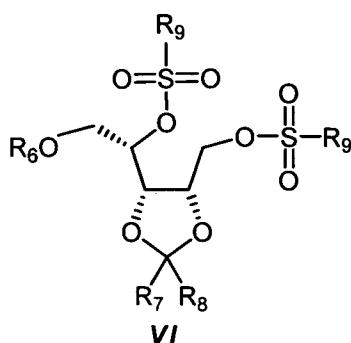
R₇ and R₈ independently of one another represent hydrogen, C₁-C₆-alkyl, C₁-C₄-perfluoroalkyl or aryl;

is reduced in the presence of 0.5-10 molar equivalents of hydride donors of the formula $A(AlH_4)$ or $A(BH_4)$, in which A represents an alkali metal, to give the diol of formula V:



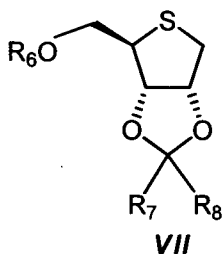
[0034] Here, preference is given to using 0.5-1.5 molar equivalents of lithium aluminium hydride ($LiAlH_4$). The reaction step is preferably carried out at a temperature between 0°C and 30°C.

[0035] In the second step, the diol V is reacted with at least 2 molar equivalents of sulphonyl chloride R_9-SO_2Cl or sulphonic anhydride $R_9-SO_2-O-SO_2-R_9$, in which R_9 represents C_1 - C_6 -alkyl, C_1 - C_4 -perfluoroalkyl or aryl, preferably 2-5 molar equivalents of methanesulphonyl chloride, in the presence of at least 2 molar equivalents of a tertiary amine (for example trimethylamine, triethylamine, diisopropylethylamine) or a pyridine (for example pyridine, 4-N,N-dimethylaminopyridine, collidine, picolines, lutidines), preferably 2-5 molar equivalents of triethylamine, to give a compound of formula VI:

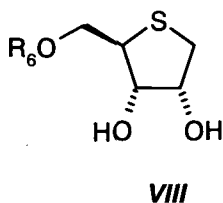


[0036] The reaction step is preferably carried out at a temperature between 0°C and 30°C.

[0037] In the third step, the bissulphonate VI is reacted with at least 1 molar equivalent of sodium sulphide (Na_2S) in a polar aprotic solvent, such as, for example, DMF, NMP, DMA, DMSO, DMEU, preferably NMP (N-methylpyrrolidone), at a temperature of more than 50°C , preferably at temperatures between 50 and 100°C , to give the thiofuranose of formula VII:



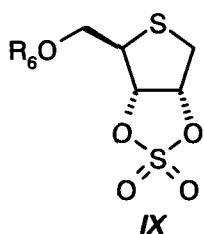
[0038] In step four, the thiofuranose of formula VII is converted in a solvent mixture of water and an organic solvent selected from the group of the ethers (for example diethyl ether, THF, dioxane, MTBE), alcohols (for example methanol, ethanol, isopropanol), carboxylic acids (for example acetic acid), aromatic hydrocarbons (for example benzene, toluene), preferably in a mixture of tetrahydrofuran (THF) and water, with 0.01-5 molar equivalents of an acid selected from the group of the mineral acids (for example HCl, H_2SO_4 , H_3PO_4), alkanesulphonic acids (for example methanesulphonic acid), arylsulphonic acids (for example benzenesulphonic acid, toluenesulphonic acid), perfluorosulphonic acids (for example trifluoromethanesulphonic acid, nonafluorobutanesulphonic acid) or perfluoroalkancarboxylic acids (for example trifluoroacetic acid), preferably 0.01-5 molar equivalents of H_2SO_4 , into the diol of formula VIII:



[0039] The reaction step is preferably carried out at a temperature between 20°C and 100°C.

[0040] The diol VIII is isolated by crystallization from a solvent mixture of an alkane or mixtures thereof – preferably heptane – and a carboxylic ester – preferably isopropyl acetate or ethyl acetate.

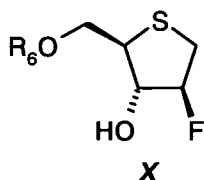
[0041] In step five, the diol of general formula VIII is reacted in the presence of at least 0.2 molar equivalents of a base of the formula AH, A₂CO₃ or A(OtBu), in which A represents an alkali metal; preferably in the presence of 0.2-3 molar equivalents of sodium hydride, with 1-2 molar equivalents of a diol-activating reagent of the formula X₁-SO₂-X₂, in which X₁ and X₂ independently of one another represent Cl or imidazolyl, preferably with 1-2 molar equivalents of sulphonyldiimidazole, to give the cyclic sulphate ester of formula IX:



[0042] The reaction step is preferably carried out at a temperature between -5°C and 20°C.

[0043] In step six, the cyclic sulphate ester of formula IX is initially reacted with 1-3 molar equivalents of an ammonium fluoride of the formula N(R₁₁)₄F, in which R₁₁ represents C₁-C₆-alkyl, preferably with 1-3 molar equivalents of tetrabutylammonium

fluoride, at a temperature between 0°C and 30°C, and the reaction mixture obtained in this manner is reacted with an acid selected from the group of the mineral acids (for example HCl, H₂SO₄), alkylsulphonic acids (for example methanesulphonic acid), arylsulphonic acids (for example benzenesulphonic acid, toluenesulphonic acid), perfluorosulphonic acids (for example trifluoromethanesulphonic acid, nonafluorobutanesulphonic acid) or perfluoroalkancarboxylic acids (for example trifluoroacetic acid), preferably with sulphuric acid (H₂SO₄), to give the ether of formula X:



[0044] The second partial step of the reaction is preferably carried out at a temperature between 20°C and 70°C.

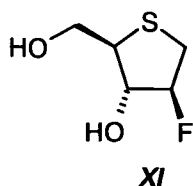
[0045] In step seven, the ether of the formula X is initially, in partial step a), reacted in the presence of at least 1 molar equivalent of a boron halide BY₃, in which Y represents F, Cl or Br, preferably using 1-4 molar equivalents of boron trichloride, at a temperature between 0°C and -80°C.

[0046] In partial step b), the reaction mixture obtained in partial step a) is reacted with a mixture of

an alcohol component selected from the group consisting of a C₁-C₆-alkanol (for example methanol, ethanol, n-propanol, isopropanol, n-butanol, t-butanol, isobutanol), an arylalkanol (for example benzyl alcohol) and phenols (for example phenol); and

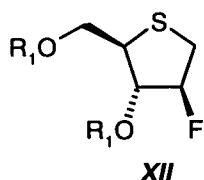
a base selected from the group of aliphatic tertiary amines (for example trimethylamine, triethylamine, diisopropylethylamine) or from the group of pyridines (for

example pyridine, 4-N,N-dimethylaminopyridine, collidine, picolines, lutidines); preferably using a mixture of methanol and pyridine, to give the diol of formula XI:



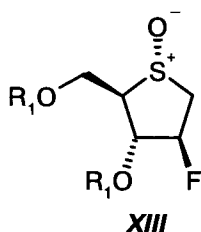
[0047] The process and quenching of the reaction mixture are preferably carried out at temperatures between 0°C and -80°C.

[0048] In step eight, the diol of formula XI is reacted in the presence of at least 2 molar equivalents of a base selected from the group of the aliphatic tertiary amines (for example trimethylamine, triethylamine, diisopropylethylamine) or from the group of the pyridines (for example pyridine, 4-N,N-dimethylaminopyridine, collidine, picolines, lutidines), preferably using 2-10 molar equivalents of pyridine, with at least 2 molar equivalents of an acid chloride R_1-C_1 or an acid anhydride R_1-O-R_1 , in which R_1 represents $-C(O)-C_1-C_6$ -alkyl or $-C(O)$ -aryl; preferably using 2-5 molar equivalents of benzoyl chloride, to give the compound of formula XII:



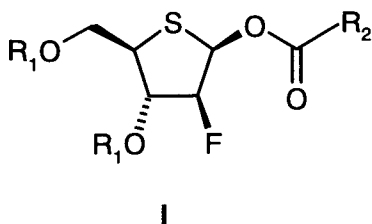
[0049] In step nine, the sulphide of formula XII is oxidized in a solvent mixture of water and a ketone of the formula $R_9-C(O)-R_9'$ in which R_9 and R_9' independently of one another represent C_1-C_6 -alkyl, C_1-C_4 -perfluoroalkyl or aryl, preferably acetone, with 0.5-1 molar equivalent of an alkali metal persulphate of the formula $AHSO_5$, in which A^+ represents an alkali metal, preferably using 0.5-1 molar equivalent of OXONE

(potassium monopersulphate triple salt, $2 \text{KHSO}_5 \cdot \text{KHSO}_4 \cdot \text{K}_2\text{SO}_4$), at a temperature between 0°C and 50°C to give the sulfoxide of formula XIII:



[0050] The product XIII is isolated by crystallization from a suitable solvent, preferably from methyl tert-butyl ether.

[0051] In step ten, the sulfoxide of formula XIII is reacted with at least 1 molar equivalent of an acid anhydride $\text{R}_2\text{—C(O)—O—C(O)—R}_2$, in which R_2 represents $\text{C}_1\text{—C}_6\text{—alkyl}$, $\text{C}_1\text{—C}_4\text{—perfluoroalkyl}$ or aryl; preferably using at least 5 molar equivalents of acetic anhydride, in the presence of 0.01-2 molar equivalents of a protic acid selected from the group of the mineral acids (for example HCl , HBr , H_2SO_4 , H_3PO_4 , alkali metal bisulphates, monobasic alkali metal phosphates), alkanesulphonic acids (for example methanesulphonic acid), arylsulphonic acids (for example benzenesulphonic acid, toluenesulphonic acid), perfluorosulphonic acids (for example trifluoromethanesulphonic acid, nonafluorobutanesulphonic acid) or perfluoroalkancarboxylic acids (for example trifluoroacetic acid), or in the presence of 0.01-2 molar equivalents of a Lewis acid (for example LiCl , MgBr_2 , $\text{Ti(OR}_{13})_4$), in which R_{13} represents $\text{C}_1\text{—C}_6\text{—alkyl}$ or arylmethylene; preferably in the presence of 0.01-2 molar equivalents of potassium bisulphate; at a temperature between 30°C and 100°C to give the compound of formula I:



[0052] The product I is isolated by crystallization from a suitable solvent, preferably ethanol.

[0053] Hitherto, the literature does not provide any examples in which potassium bisulphate catalyses the Pummerer rearrangement of a sulphoxide to the corresponding thioacetal and prevents the formation of side-products.

[0054] The C₁–C₆-alkyl groups of the radicals R₁, R₂, R₆, R₇, R₈, R₉, R₉', R₁₁, and R₁₃ can, for example, be methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, *sec*-butyl, *tert*-butyl, n-pentyl or n-hexyl groups.

[0055] The arylmethylene groups of the radicals R₆, R₉, and R₁₃ can, for example, be benzyl or 4-methoxybenzyl groups.

[0056] The aryl groups of the radicals R₁, R₂, R₇, R₈, R₉, and R₉' can, for example, be phenyl or substituted phenyl groups.

[0057] The C₁–C₄-perfluoroalkyl groups of the radicals R₂, R₇, R₈, R₉, and R₉' can, for example, be trifluoromethyl, pentafluoroethyl or nonafluorobutyl groups.

[0058] The alkali metals A of the hydride donors of the formulae A(AlH₄), A(BH₄), of the bases AH, A₂CO₃, AOTBu, of the alkali metal persulphates AHSO₅ can, for example, be lithium, sodium or potassium.

[0059] The -C(O)-C₁–C₆-alkyl groups of the radical R₁ can, for example, be acetyl, n-propanoyl, isopropanoyl, n-butanoyl, t-butanoyl, isobutanoyl, n-pentanoyl, or n-hexanoyl groups.

[0060] The -C(O)-aryl groups of the radical R₁ can, for example, be benzoyl or

substituted benzoyl groups.

[0061] Preferably, the process according to the invention is used for preparing the compound I (according to Scheme 3) in which

R₁ represents benzoyl, and

R₂ represents methyl,

i.e. for preparing the compound of formula II β .

[0062] According to the present invention, particular preference is given to the process for preparing the compound of formula II β (according to Scheme 3) in which

R₇, R₈ and R₉ represent methyl, and

R₆ represents benzyl.

[0063] Furthermore, the present invention also relates to the intermediates of the preferred embodiment of the process according to the invention (Scheme 4), in particular

1-O-benzyl-3,4-O-isopropylidene-L-arabinitol (C2);

1-O-benzyl-3,4-O-isopropylidene-2,5-di-O-methanesulphonyl-L-arabinitol (C3);

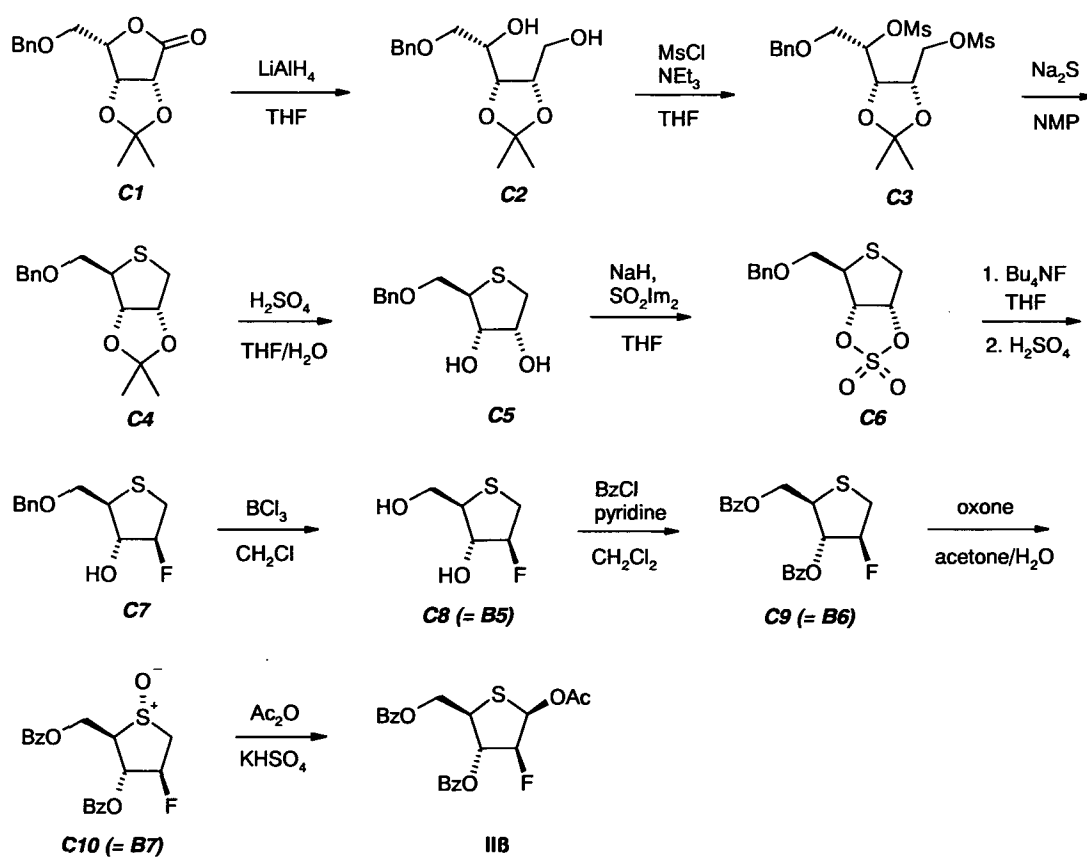
1,4-anhydro-5-O-benzyl-2,3-O-isopropylidene-4-thio-D-ribitol (C4);

1,4-anhydro-5-O-benzyl-2,3-O-sulphonyl-4-thio-D-ribitol (C6);

1,4-anhydro-5-O-benzyl-2-deoxy-2-fluoro-4-thio-D-arabinitol (C7).

[0064] [Scheme 4]

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[0065] The compound C1 (5-O-benzyl-2,3-O-isopropylidene-L-lyxono-1,4-lactone) is commercially available. Hereinbelow, the procedures for the reactions shown in Scheme 4 are described.

[0066] Synthesis Procedures

1-O-Benzyl-3,4-O-isopropylidene-L-arabinitol (C2):

At 0-10°C, 44.68 g (116.78 mmol) of lithium aluminium hydride are metered into a solution of 50 g (179.66 mmol) of C1 in 450 ml of THF, and the mixture is stirred until the reaction has ended. At 20°C, water and aqueous sodium hydroxide solution are then added, and the precipitated solid is filtered off and washed product-free using THF. The solution of the crude product is concentrated and freed completely from the solvent. This gives 53.26 g of C2 (105%) as a crude product which is used in this form for the subsequent step C3.

[0067] ¹H-NMR (400 MHz, DMSO): 7.39-7.24 (m, 5H, H-7 to H-9), 4.81 (t, 1H, 5.46 Hz, 1-OH), 4.65 (d, 1H, 5.84 Hz, 4-OH), 4.5 (s, 2H, 2xH-6), 4.15-4.00 (m, 2H, H-2 and H-3), 3.76 (qd, 1H, 6Hz, 2.5 Hz, H-4), 3.7-3.55 (m, 2H, 2xH-1), 3.49-3.35 (m, 2H, 2x H-5), 1.38 (s, 3H, 10-CH₃), 1.25 (s, 3H, 10-CH₃).

[0068] ¹³C-NMR (75 MHz, CDCl₃): 138.0, 128.8, 128.2, 128.1 (Ar), 108.9 (O-C-O), 77.7 (CH₂), 76.9 (CH₂), 73.8 (CH), 71.9 (CH), 68.9 (CH₂), 61.0 (CH), 28.1 (CH₃), 25.6 (CH₃).

[0069] 1-O-Benzyl-3,4-O-isopropylidene-2,5-di-O-methanesulphonyl-L-arabinitol (C3):

At 20°C, 54.54 g (538.97 mmol) of triethylamine are added to a solution of 53.26 g (179.66 mmol assuming a yield of 100% in step C2) of C2 (crude product) in 450 ml of THF, and 39.39 g (431.17 mmol) of methanesulphonyl chloride are metered in at 0-10°C. The mixture is then stirred until the reaction has ended, water is added and the phases are separated. The aqueous phase is extracted with MTBE, and the combined

organic phases are washed with sat. sodium chloride solution and dilute sodium bicarbonate solution. The solution of the crude product is concentrated and freed completely from the solvents. This gives 86.66 g of C3 (110%) as a crude product which is used in this form for the subsequent step C4.

[0070] ^1H -NMR (400 MHz, CDCl_3): 7.40-7.30 (m, 5H), 4.90 (dt, 1H, 11.5 Hz, 6.6 Hz), 4.56 (dd, 2H, 11.8 Hz), 4.42-4.39 (m, 2H), 4.38-4.35 (m, 2H), 3.83 (dd, 1H, 10.61 Hz, 6.06 Hz), 3.70 (dd, 1H, 10.61 Hz, 5.05 Hz), 3.10 (s, 3H), 3.02 (s, 3H), 1.50 (s, 3H), 1.37 (s, 3H).

[0071] ^{13}C -NMR (75 MHz, CDCl_3): 136.8, 128.6, 128.2, 128.0 (Ar), 109.7 (O-C-O), 77.8, 75.6, 74.5, 73.7 (CH_2), 69.6 (CH_2), 67.7 (CH_2), 39.0, 37.5, 27.2, 25.4.

[0072] 1,4-Anhydro-5-O-benzyl-2,3-O-isopropylidene-4-thio-D-ribitol (C4):

50.99 g (215.59 mmol) of sodium sulphide (33% pure) are added to a solution of 86.66 g (179.66 mmol assuming a yield of 100% in step C3) of C3 (crude product) in 550 ml of N-methyl-2-pyrrolidone, and the mixture is heated to an internal temperature of 80°C and stirred at this temperature until the reaction has ended. At an internal temperature of 20°C, water and MTBE are then added, the phases are separated and the aqueous phase is extracted with MTBE. The combined organic phases are finally washed with water. The solution of the crude product is concentrated and freed completely from the solvents. This gives 56.41 g of C4 (112%) as a crude product which is used in this form for the subsequent step C5.

[0073] ^1H -NMR (400 MHz, DMSO): 7.40-7.25 (m, 5H, H-7 to H-9), 4.89 (t, 1H, 4.7 Hz, H-2), 4.73 (d, 1H, 5.65 Hz, H-3), 4.50 (s, 2H, 2xH-6), 3.55-3.42 (m, 2H, 2xH-5), 3.37 (t, 1H, 6.2 Hz, H-4), 3.10 (dd, 1H, 12.6 Hz, 4.7 Hz, H-1), 2.76 (d, 1H, 12.6 Hz, H-1').

[0074] ^{13}C -NMR (75 MHz, CDCl_3): 137.9, 128.4, 127.9, 127.5 (Ar), 110.9 (O-C-O), 86.3 (CH), 83.8 (CH), 73.2 (CH_2), 72.2 (CH_2), 53.3 (CH), 38.3 (CH_2), 27.2 (CH_3), 25.3

(CH₃).

[0075] 1,4-Anhydro-5-O-benzyl-4-thio-D-ribitol (C5):

A solution of 50 ml of water and 9.22 g (0.094 mmol) of sulphuric acid is added to the solution of 56.41 g (179.66 mmol assuming a yield of 100% in step C4) of C4 (crude product) in 450 ml of THF, and the mixture is heated to 70°C and stirred at this temperature for a plurality of hours. To achieve complete conversion, a few ml are distilled off at 70°C. MTBE is then added at 20°C, the phases are separated and the aqueous phase is extracted with MTBE. The combined organic phases are neutralized with saturated potassium carbonate solution. The solid is filtered off and washed product-free using MTBE. The solution of the crude product is redistilled to isopropyl acetate, and the product is crystallized by addition of heptane. This gives 33.67 g (78% over 4 steps starting with C1) of C5.

[0076] ¹H-NMR (400 MHz, CDCl₃): 7.39-7.29 (m, 5H), 4.56 (s, 2H), 4.37 (dt, 1H, 7.33 Hz, 3.54 Hz), 4.04 (dt, 1H, 7.07 Hz, 6.82 Hz), 3.70 (dd, 1H, 9.09 Hz, 5.31 Hz), 3.62 (t, 1H, 9.09 Hz), 3.56-3.51 (m, 1H), 3.11 (d, 1H, 3.54 Hz), 3.05 (dd, 1H, 11.62 Hz, 4.55 Hz), 2.85 (dd, 1H, 11.62 Hz, 3.03 Hz), 2.65 (d, 1H, 3.54 Hz).

[0077] ¹³C-NMR (75 MHz, CDCl₃): 137.4, 128.6, 128.0, 127.8 (Ar), 80.4, 74.8, 73.6 (CH₂), 73.0 (CH₂), 47.0, 33.6 (CH₂).

Melting point: 78-82°C

[0078] 1,4-Anhydro-5-O-benzyl-2,3-O-sulphonyl-4-thio-D-ribitol (C6):

At 0°C, a solution of 50 g (208.06 mmol) of C5 in 75 ml of THF is added to a suspension of 2.5 g of sodium hydride (in mineral oil) in 100 ml of THF, and the mixture is stirred at 0°C for 1-2 hours. At 0°C, a solution of 45.36 g of sulphonyldiimidazole in 450 ml of THF is then metered in, and the mixture is stirred at 20°C until the reaction is ended. In this form, the crude product is used directly for the subsequent step C7.

[0079] ^1H -NMR (400 MHz, CDCl_3): 7.40-7.26 (m, 5H), 5.41 (dt, 1H, 6.06 Hz, 3.28 Hz), 5.33 (dd, 1H, 6.32 Hz, 2.78 Hz), 4.54 (d, 2H, 2.53 Hz), 3.81 (dd, 1H, 9.85 Hz, 4.29 Hz), 3.72 (m, 1H), 3.64 (dd, 1H, 9.85 Hz, 4.80 Hz), 3.47 (dd, 1H, 13.39 Hz, 5.81 Hz), 3.16 (dd, 1H, 13.39 Hz, 3.28 Hz).

[0080] ^{13}C -NMR (75 MHz, CDCl_3): 137.0, 128.6, 128.2, 127.7 (Ar), 87.9, 86.1, 73.7 (CH_2), 71.2 (CH_2), 51.6, 36.8 (CH_2).

[0081] 1,4-Anhydro-5-O-benzyl-2-deoxy-2-fluoro-4-thio-D-arabinitol (C7):

At 20°C, a solution of 131.3 g of tetrabutylammonium fluoride trihydrate in 150 ml of THF is metered into the solution of the crude product from the preparation of compound C6. The mixture is stirred at 30°C until the reaction is ended.

The reaction mixture is then adjusted to pH 1 using sulphuric acid (33% strength) and stirred at 50°C until the reaction is ended. At 20°C, the pH is then adjusted to 7-10 using aqueous potassium hydroxide solution, and the precipitate formed is filtered off. The phases are separated and the aqueous phase is extracted with dichloromethane. The combined organic phases are concentrated and the crude product is, after complete removal of the solvent, purified by chromatography. This gives 22.68 g of C7 (45%).

[0082] ^1H -NMR (400 MHz, CDCl_3): 7.4-7.27 (m, 5H, H-7 to H-9), 5.04 (qd, 1H, 51.7 Hz, 5.44 Hz, H-2), 4.55 (s, 2H, 2xH-6), 4.37 (td, 1H, 11.7 Hz, 4.9 Hz, H-3), 3.68-3.55 (m, 2H, 2xH-5), 3.45-3.38 (m, 1H, H-4), 3.2-2.99 (m, 2H, 2xH-1).

[0083] ^{13}C -NMR (100 MHz, CDCl_3): 137.65, 128.52, 127.91, 127.77 (Ar), 97.27 (C-2), 79.10 (C-3), 73.46 (C-6), 72.69 (C-5), 48.58 (C-4), 31.72 (C-1).

^{19}F -NMR (376 MHz, CDCl_3): -183.14 (m, 2-F).

Melting point: 83-85°C

[0084] 1,4-Anhydro-2-deoxy-2-fluoro-4-thio-D-arabinitol (C8):

At a temperature of < -65°C, a solution, pre-cooled to -10°C, of 50 g (206.35 mmol) of

C7 in 350 ml of dichloromethane is added to 546.82 g (412.69 mmol) of boron trichloride (1 mol/l in dichloromethane). After 30 minutes at $< -65^{\circ}\text{C}$, the reaction is checked for complete conversion. A mixture of 150 ml of methanol and 116 ml of pyridine is then added at $< -65^{\circ}\text{C}$ to the reaction mixture, and the mixture is heated to 20°C after 15 minutes. The solvents are removed completely by distillation under reduced pressure. Dichloromethane is then added to the residue, and the solvent is removed completely. This gives 133 g of C8 (423%) as a crude product (contains residual amounts of pyridine and pyridinium hydrochloride) which is used in this form for the subsequent step C9.

[0085] $^1\text{H-NMR}$ (400 MHz, DMSO): 5.49 (d, 1H, 4.77 Hz, 3-OH), 4.98 (qd, 1H, 51.55 Hz, 3.76 Hz, H-2), 4.94 (t, 1H, 5.2 Hz, 5-OH), 4.17 (ddd, 1H, 15.18 Hz, 4.14 Hz, 3.76 Hz H-3), 3.61-3.53 (m, 1H, H-5), 3.37-3.30 (m, 1H, H-5'), 3.19-3.02 (m, 2H, H-4 and H-1), 2.93 (ddd, 1H, 18.22 Hz, 12.1 Hz, 3.76 Hz, H-1').

[0086] $^{13}\text{C-NMR}$ (75 MHz, CDCl_3): 97.1 (d, 185 Hz, C-2), 77.5 (d, 24 Hz, C-3), 63.3 (d, 3 Hz, C-5), 50.9 (d, 4 Hz, C-4), 31.1 (d, 22 Hz, C-1).

[0087] 1,4-Anhydro-2-deoxy-2-fluoro-3,5-di-O-benzoyl-4-thio-D-arabinitol (C9):

133 g (206.35 mmol assuming a yield of 100% in step C8) of C8 (crude product) are dissolved in 400 ml of dichloromethane, and 97.92 g (1237.9 mmol) of pyridine are added. 87.01 g (618.97 mmol) of benzoyl chloride are then added dropwise at 10°C , and the mixture is stirred at 20°C until the reaction has ended. Methanol is then added, and the mixture is stirred for 1 hour. Finally, water is added and the phases are separated. The solution of the crude product is concentrated and freed completely from the solvent. This gives 114.53 g of C9 (154%) as a crude product which is used in this form for the subsequent step C10.

[0088] $^1\text{H-NMR}$ (400 MHz, CDCl_3): 8.20-8.00 (m, 4H), 7.65-6.90 (m, 6H), 5.85 (dt, 1H,

9.98 Hz, 2.64 Hz), 5.40 (ddd, 1H, 48.79 Hz, 7.16 Hz, 3.01 Hz), 4.54 (s, 1H), 4.51 (s, 1H), 3.95-3.82 (m, 1H), 3.45-3.35 (m, 1H), 3.35-3.28 (m, 1H).

[0089] ^{13}C -NMR (75 MHz, CDCl_3): 165.0 (C=O), 133.6, 133.1, 129.8, 129.7, 128.5, 128.4, 96.5 (d, 184 Hz, C-2), 79.0 (d, 29 Hz, C-3), 65.2 (d, 4 Hz, C-5), 48.5 (C-4), 34.9 (d, 23 Hz, C-1).

[0090] 1,4-Anhydro-2-deoxy-2-fluoro-3,5-di-O-benzoyl-4-sulphonyl-D-arabinitol (C10): 114.53 g (206.35 mmol assuming a yield of 100% in step C9) of C9 (crude product) are dissolved in 400 ml of acetone, and 60 ml of water are added. At 20°C, 69.77 g (113.49 mmol) of OXONE are then added a little at a time. The reaction is checked for complete conversion, and a dilute solution of sodium sulphite is then added. The reaction mixture is neutralized using saturated sodium bicarbonate solution, and the acetone is then removed completely by distillation under reduced pressure.

Dichloromethane is added to the suspension, the solid is filtered off and the filtercake is washed product-free with dichloromethane. The solution of the crude product is redistilled to MTBE and isolated in this solvent. This gives 56.4 g (72.6% over three steps with C7) of C10.

[0091] ^1H -NMR (400 MHz, CDCl_3): 8.05 (m, 4H), 7.60 (m, 2H), 7.45 (m, 4H), 5.83 (m, 1H), 5.74 (m, 1H), 4.89 (ddd, 1H, 12.1 Hz, 5.1 Hz, 0.9 Hz), 4.75 (ddd, 1H, 12.4 Hz, 7.6 Hz, 0.9 Hz), 3.65 (m, 1H), 3.75 (m, 1H), 3.45 (m, 1H).

[0092] ^{13}C -NMR (75 MHz, CDCl_3): 165.7, 165.2 (C=O), 134.0, 133.5, 130.0, 129.7, 128.6, 128.5 (Ar), 95.4 (d, 185 Hz, C-2), 77.2 (d, 33 Hz, C-3), 71.6 (C-4), 61.1 (d, 2 Hz, C-5), 55.8 (d, 19 Hz, C-1).

[0093] 1-O-Acetyl-2-deoxy-2-fluoro-3,5-di-O-benzoyl-4-thio- β -D-arabinofuranose (II β): 80 ml of acetic anhydride and 361 mg (2.66 mmol) of potassium bisulphate are added to 10 g (26.57 mmol) of C10, and the mixture is stirred at 80°C until the reaction is

ended. The reaction mixture is then codistilled initially repeatedly with toluene and then with ethanol. Finally, the product is crystallized from ethanol. This gives 8.9 g (80%) of the compound II β .

[0094] ^1H -NMR (400 MHz, CDCl_3): 8.10-7.90 (m, 4H, Ar), 7.63-7.29 (m, 6H, Ar), 6.18 (d, 1H, 4.4 Hz), 6.12-6.02 (m, 1H), 5.45 (dd, 1H, 9.04 Hz, 4.52 Hz), 5.28 (dd, 1H, 8.85 Hz, 4.52 Hz), 4.68 (dd, 1H, 11.49 Hz, 6.22 Hz), 4.49 (dd, 1H, 11.49 Hz, 6.41 Hz), 3.74 (dd, 1H, 13.56 Hz, 6.40 Hz), 2.12 (s, 3H).

[0095] ^{13}C -NMR (75 MHz, CDCl_3): 169.6 (COCH₃), 165.8, 165.4 (COPh), 133.6, 133.1 (Ar) 129.8, 129.7, 128.5, 128.2 (Ar), 92.5 (d, 207 Hz, C-2), 75.7 (d, 23 Hz, C-3), 74.0 (d, 17 Hz, C-1), 66.1 (C-5), 42.4 (d, 7 Hz, C-4), 21.0 (CH₃).

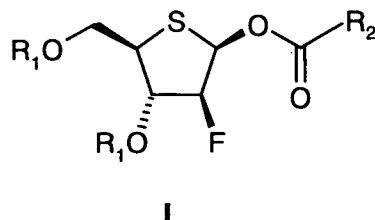
Melting point: 130°C

Industrial Applicability

[0096] The process of the present invention provides an industrially advantageous and excellent preparation of the compounds of the formula I.

Claims

[Claims 1] A process for preparing a compound of formula I



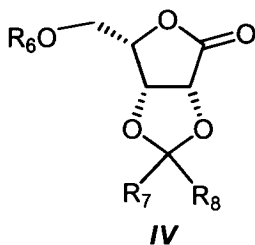
wherein

R₁ represents -C(O)-C₁-C₆-alkyl or -C(O)-aryl; and

R₂ represents C₁-C₆-alkyl, C₁-C₄-perfluoroalkyl or aryl,

which comprises the following steps:

(1) reduction of a lyxonolactone of formula IV



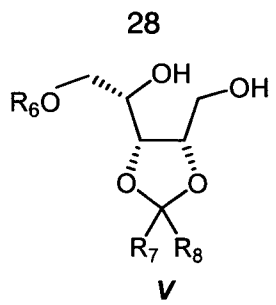
wherein

R₆ represents C₁-C₆-alkyl or arylmethylene; and

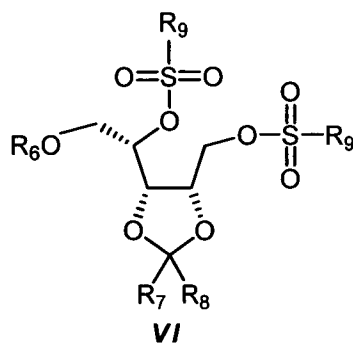
R₇ and R₈ independently represent hydrogen, C₁-C₆-alkyl, C₁-C₄-perfluoroalkyl or aryl;

in the presence of 0.5-10 molar equivalents of hydride donors of the formula

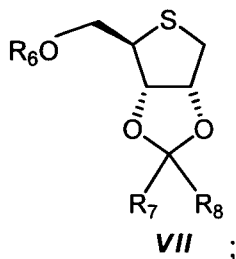
A(AlH₄) or A(BH₄), wherein A is an alkali metal, to give the diol of the formula V:



(2) reaction of the diol of formula V with at least 2 molar equivalents of sulphonyl chloride $R_9\text{-SO}_2\text{Cl}$ or sulphonic anhydride $R_9\text{-SO}_2\text{-O-SO}_2\text{-R}_9$, wherein R_9 represents $C_1\text{-C}_6\text{-alkyl}$, $C_1\text{-C}_4\text{-perfluoroalkyl}$ or aryl, in the presence of at least 2 molar equivalents of a tertiary amine or a pyridine, to give the compound of formula VI:

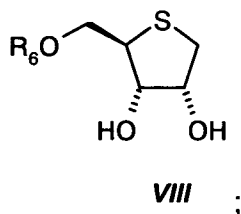


(3) reaction of the bissulphonate of formula VI with at least 1 molar equivalent of sodium sulphide (Na_2S) in a polar aprotic solvent, at a temperature of more than 50°C , to give the thiofuranose of formula VII:

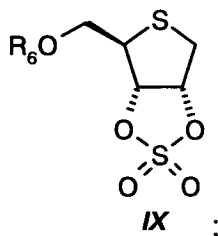


(4) conversion of the thiofuranose of formula VII in a solvent mixture of water and an organic solvent selected from the group of the ethers, alcohols, and aromatic

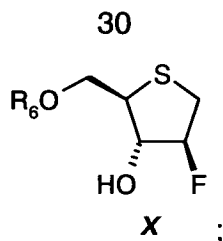
hydrocarbons, with 0.01-5 molar equivalents of an acid selected from the group of the mineral acids, alkanesulphonic acids, arylsulphonic acids, perfluorosulphonic acids and perfluoroalkanecarboxylic acids, into the diol of formula VIII:



(5) reaction of the diol of formula VIII in the presence of at least 0.2 molar equivalents of a base of the formula AH, A₂CO₃ or A(OtBu), wherein A represents an alkali metal; with 1-2 molar equivalents of a diol-activating reagent of the formula X₁-SO₂-X₂, wherein X₁ and X₂ independently represent Cl or imidazolyl, to give the cyclic sulphate ester of formula IX:

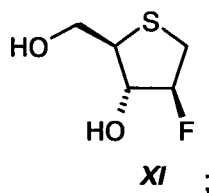


(6) the cyclic sulphate ester of formula IX is initially reacted with 1-3 molar equivalents of an ammonium fluoride of the formula N(R₁₁)₄F, wherein R₁₁ represents C₁-C₆-alkyl, at a temperature between 0°C and 30°C, and the reaction mixture obtained in this manner is reacted with an acid selected from the group of the mineral acids, alkylsulphonic acids, arylsulphonic acids, perfluorosulphonic acids and perfluoroalkanecarboxylic acids to give the ether of formula X:

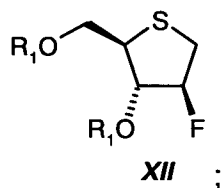


(7) the ether of formula X is

in partial step a) reacted in the presence of at least 1 molar equivalent of a boron halide BY_3 , wherein Y represents F, Cl or Br, at a temperature between 0°C and -80°C ;
in partial step b), the reaction mixture obtained in partial step a) is reacted with a mixture of an alcohol component selected from the group consisting of a C_1 - C_6 -alkanol, an aryl alkanol and phenols; and a base selected from the group of the aliphatic tertiary amines and pyridines; to give the diol of formula XI:

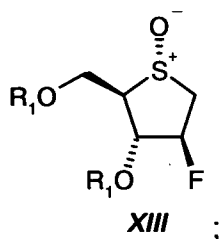


(8) the diol of formula XI is in the presence of at least 2 molar equivalents of a base selected from the group of aliphatic tertiary amines and pyridines, reacted with at least 2 molar equivalents of an acid chloride R_1-C_1 or an acid anhydride R_1-O-R_1 , wherein R_1 represents $-C(O)-C_1-C_6$ -alkyl or $-C(O)$ -aryl; to give the compound of formula XII:



(9) the sulphide of formula XII is oxidized in a solvent mixture of water and a

ketone of the formula $R_9-C(O)-R_9'$, wherein R_9 and R_9' independently represents C_1-C_6 -alkyl, C_1-C_4 -perfluoroalkyl or aryl, with 0.5-1 molar equivalent of an alkali metal persulphate of the formula $AHSO_5$, wherein A^+ represents an alkali metal, at a temperature between 0°C and 50°C to give the sulfoxide of formula XIII:



(10) the sulfoxide of formula XIII is reacted with at least 1 molar equivalent of an acid anhydride $R_2-C(O)-O-C(O)-R_2$, wherein R_2 represents C_1-C_6 -alkyl, C_1-C_4 -perfluoroalkyl or aryl; in the presence of 0.01-2 molar equivalents of a protic acid selected from mineral acids, alkanesulphonic acids, arylsulphonic acids, perfluorosulphonic acids and perfluoroalkancarboxylic acids
or

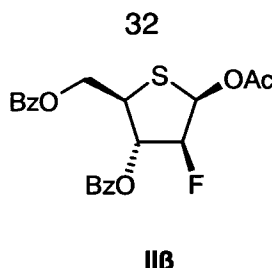
in the presence of 0.01-2 molar equivalents of a Lewis acid or arylmethylene; at a temperature between 30°C and 100°C .

[Claims 2] The process according to Claim 1 for preparing compounds of the formula I wherein

R_1 represents benzoyl, and

R_2 represents methyl.

[Claims 3] The process according to Claim 2 for preparing the compound of the formula II β ,



wherein

R_7 , R_8 and R_9 represent methyl, and

R_6 represents benzyl.

[Claims 4] The process according to any of the preceding claims, wherein in step (1) 0.5-1.5 molar equivalents of lithium aluminium hydride (LiAlH_4) are used.

[Claims 5] The process according to any of the preceding claims, wherein the step (1) and/or the step (2) are carried out at a temperature between 0°C and 30°C .

[Claims 6] The process according to any of the preceding claims, wherein in step (2) 2-5 molar equivalents of methanesulphonyl chloride and 2-5 molar equivalents of triethylamine are used.

[Claims 7] The process according to any of the preceding claims, wherein the reaction in step (3) is carried out at a temperature between 50°C and 100°C in N-methylpyrrolidone.

[Claims 8] The process according to any of the preceding claims, wherein the reaction in step (4) is carried out in a mixture of tetrahydrofuran (THF) and water with 0.01-5 molar equivalents of H_2SO_4 at a temperature between 20°C and 100°C .

[Claims 9] The process according to any of the preceding claims, wherein in step (4) the isolation of the diol VIII is carried out by crystallization from a solvent mixture of heptane and isopropyl acetate or ethyl acetate.

[Claims 10] The process according to any of the preceding claims, wherein in step (5) 0.2-3 molar equivalents of sodium hydride and 1-2 molar equivalents of

sulphonyldiimidazole are used at a temperature between -5°C and 20°C.

[Claims 11] The process according to any of the preceding claims, wherein in step (6) 1-3 molar equivalents of tetrabutylammonium fluoride are used.

[Claims 12] The process according to any of the preceding claims, wherein in step (6) the reaction mixture obtained in the first partial step is reacted at a temperature between 20°C and 70°C with sulphuric acid (H₂SO₄).

[Claims 13] The process according to any of the preceding claims, wherein in partial step a) of step (7) 1-4 molar equivalents of boron trichloride are used.

[Claims 14] The process according to any of the preceding claims, wherein in partial step b) of step (7) the reaction mixture of methanol and pyridine obtained in partial step a) is reacted.

[Claims 15] The process according to any of the preceding claims, wherein the partial steps of step (7) are carried out at temperatures between 0°C and -80°C.

[Claims 16] The process according to any of the preceding claims, wherein step (8) is carried out in the presence of 2-10 molar equivalents of pyridine using 2-5 molar equivalents of benzoyl chloride.

[Claims 17] The process according to any of the preceding claims, wherein step (9) is carried out in a solvent mixture of water and acetone using 0.5-1 molar equivalent of OXONE.

[Claims 18] The process according to any of the preceding claims, wherein in step (9) the sulfoxide XIII is isolated by crystallization from methyl tert-butyl ether.

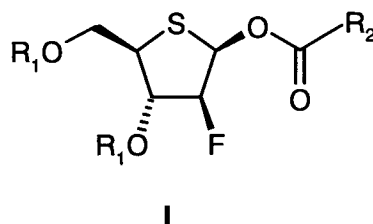
[Claims 19] The process according to any of the preceding claims, wherein step (10) is carried out in the presence of 0.01-2 molar equivalents of potassium bisulphate using at least 5 molar equivalents of acetic anhydride.

[Claims 20] The process according to any of the preceding claims, wherein in step

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(10) the product I is isolated by crystallization from ethanol.

[Claims 21] A process for preparing a compound of the formula I:

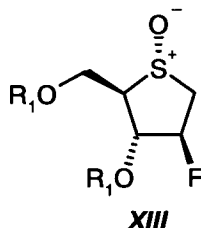


wherein

R₁ represents -C(O)-C₁-C₆-alkyl or -C(O)-aryl; and

R₂ represents C₁-C₆-alkyl, C₁-C₄-perfluoroalkyl or aryl,

which comprises reacting the sulfoxide of formula XIII:



wherein R₁ represents benzoyl, at a temperature between 30°C and 100°C with at least 1 molar equivalent of an acid anhydride R₂-C(O)-O-C(O)-R₂, wherein R₂ represents C₁-C₆-alkyl, C₁-C₄-perfluoroalkyl or aryl; in the presence of 0.01-2 molar equivalents of a protic acid selected from the group of mineral acids, alkanesulphonic acids, arylsulphonic acids, perfluorosulphonic acids and perfluoroalkanecarboxylic acids or

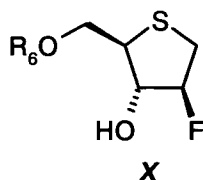
in the presence of 0.01-2 molar equivalents of a Lewis acid, wherein R₁₃ represents C₁-C₆-alkyl or arylmethylene.

[Claims 22] The process according to Claim 21, wherein the reaction is carried out in the presence of 0.01-2 molar equivalents of potassium bisulphate using at least

5 molar equivalents of acetic anhydride.

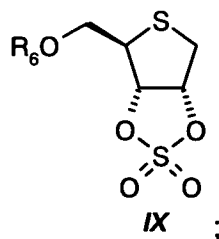
[Claims 23] The process according to Claim 21, wherein the product II β is isolated by crystallization from ethanol.

[Claims 24] The process for preparing a compound of formula X



wherein R₆ represents C₁-C₆-alkyl, arylmethylene, which comprises the following steps:

(a) the cyclic sulphate ester of formula IX



is initially reacted with 1-3 molar equivalents of an ammonium fluoride of the formula N(R₁₁)₄F, wherein R₁₁ represents C₁-C₆-alkyl, at a temperature between 0°C and 30°C, and

(b) the reaction mixture obtained in this manner is reacted with an acid selected from the group of mineral acids, alkylsulphonic acids, arylsulphonic acids, perfluorosulphonic acids and perfluoroalkancarboxylic acids.

[Claims 25] The process according to Claim 24, wherein 1-3 molar equivalents of tetrabutylammonium fluoride are used.

[Claims 26] The process according to Claim 24, wherein the reaction mixture

obtained in the first partial step is reacted at a temperature between 20°C and 70°C with sulphuric acid (H_2SO_4).

[Claims 27] An intermediate produced by the process according to any of the preceding claims, which is selected from

- 1-O-benzyl-3,4-O-isopropylidene-L-arabinitol;
- 1-O-benzyl-3,4-O-isopropylidene-2,5-di-O-methanesulphonyl-L-arabinitol;
- 1,4-anhydro-5-O-benzyl-2,3-O-isopropylidene-4-thio-D-ribitol;
- 1,4-anhydro-5-O-benzyl-2,3-O-sulphonyl-4-thio-D-ribitol; and
- 1,4-anhydro-5-O-benzyl-2-deoxy-2-fluoro-4-thio-D-arabinitol.