

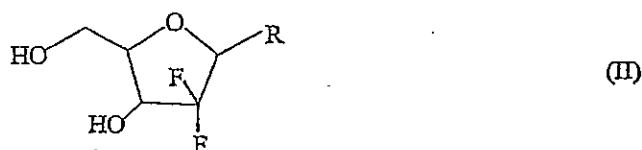
INTERMEDIATE AND PROCESS FOR PREPARING OF β - ANOMER
ENRICHED 2¹-DEOXY,2¹,2¹-DIFLUORO-D-RIBOFURANOSYL
NUCLEOSIDES

FIELD OF THE INVENTION

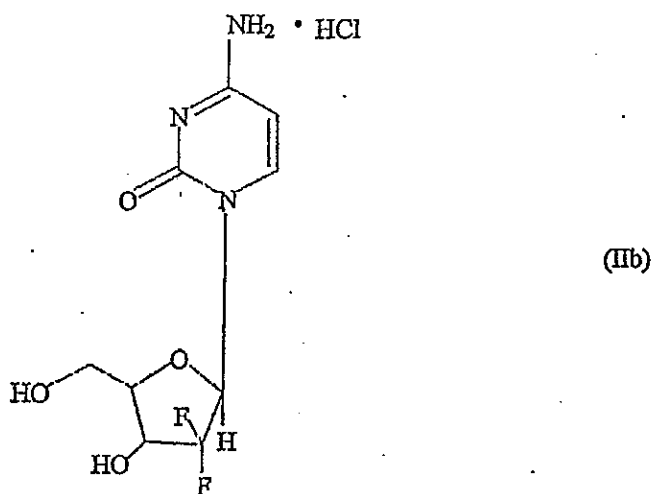
The present invention relates to a novel intermediate of formula (I), a process for preparation thereof and its use in the preparation of β -enriched anomers of therapeutically and commercially valuable 2¹-deoxy-2¹, 2¹-D-ribofuranosyl difluoronucleosides of formula (II), and physiologically acceptable salts thereof. In particular, the present invention relates to a selective process for manufacture of the β -enriched anomer of gemcitabine hydrochloride of formula (IIb) in high purity.

BACKGROUND OF THE INVENTION

2¹-deoxy-2¹, 2¹-D-ribofuranosyl difluoronucleosides of formula (II),



wherein the group R represents a base selected from a pyrimidine or purine derivative and P represents hydrogen or a hydroxy protective group possess useful therapeutic properties and one such 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleoside of therapeutic and commercial importance is gemcitabine hydrochloride of formula (IIb),



first disclosed by Hertel *et al.* in US Patent No. 4,526,988; its continuation-in-part US Patent No. 4,692,434 and divisional, US Patent No. 4 808,614 as an useful antiviral

and later by Grindey *et al.* in US Patent No. 5,464,826 as an useful anti-tumour agent for treatment of susceptible neoplasms in mammals.

US Patents Nos. 4,526,988, 4,692,434 and 4 808,614 disclose a method for synthesis of the 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II) including gemcitabine hydrochloride of formula (IIb) comprising hydrolysis of an alkyl-3-dioxolanyl-2,2-difluoro-3-hydroxypropionate (1) to give a lactone (III), which after suitable protection of the hydroxyl groups is reduced to give the protected 2¹-deoxy-2¹,2¹-difluororibose of formula (IV). The free hydroxy group of compound (IV) thus obtained is converted to a suitable derivative (2), in which the group L acts as a better leaving group for the coupling reaction with the appropriate base to give after removal of the hydroxy protective groups the 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II). The chemistry is summarized hereinbelow:

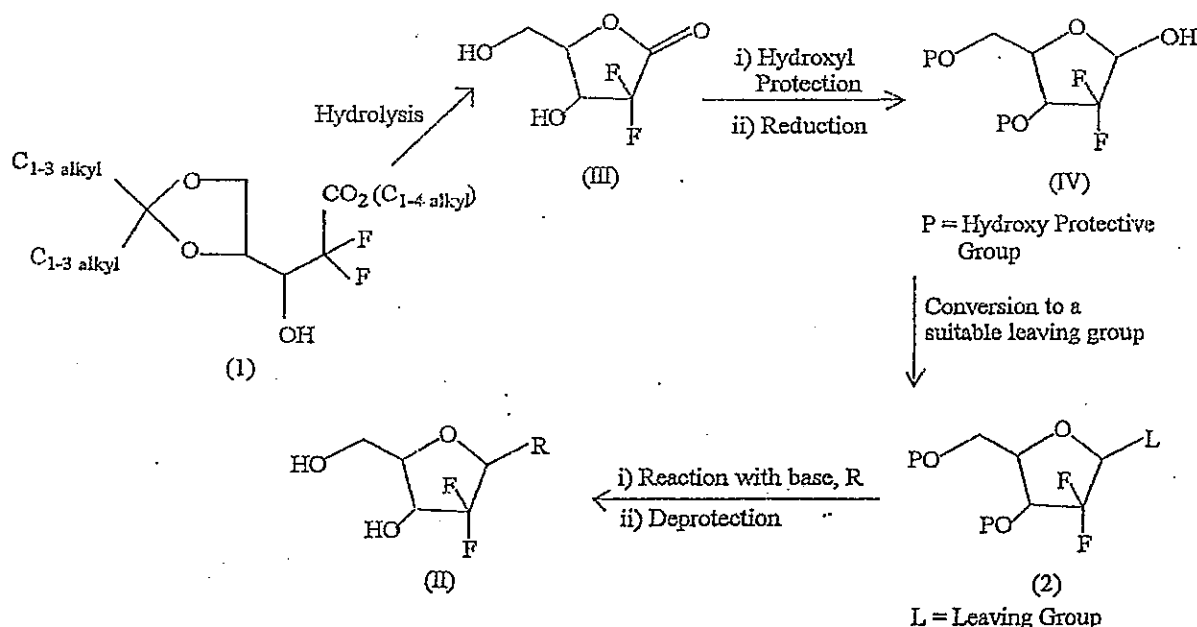
Even though, US Patents Nos. 4,526,988, 4,692,434 and 4 808,614 mention that any protective group to which chemists are accustomed can be employed, however, the use of silyl hydroxy-protecting groups, specially the tert-butyldimethylsilyl group are preferred since these are difficult to cleave under normal conditions and can be removed only by contact with an hydrohalic acid. The reduction of the keto function of lactone (III) to the hydroxy compound (IV) is achieved using reducing agents such as diisobutyl aluminium hydride, lithium aluminium hydride, etc.

The suitable leaving groups of compound (IV) for reaction with the base are those normally employed in organic synthesis such as methanesulfonyl, acetate, halo etc.

However, the method disclosed US Patents Nos. 4,526,988, 4,692,434 and 4 808,614 utilizes expensive hydroxy protective group like tert-butyldimethylsilyl group and reducing agents like diisobutyl aluminium hydride, lithium aluminium hydride, which, moreover, are hazardous, requiring special handling care, thereby increasing the cost and risk of manufacture.

Further, the lactone of formula (III), by virtue of having a chiral center is obtained as a mixture of erythro and threo enantiomers, of which the former one is preferred since it is the biologically more active one and provides a carbohydrate having the stereochemistry of naturally occurring ribose. More often than not, recourse to tedious and expensive chromatography procedures are taken to separate the said enantiomers.

In addition, a second chiral centre is generated when the lactone (III) is reduced to the hydroxy compound (IV), affording a mixture of α - and β -anomers, of which the latter i.e., the β -anomer being more active biologically is preferred. The method disclosed US Patents Nos. 4,526,988, 4,692,434 and 4,808,614 produces protected 2'-deoxy-2',2'-difluororibose of formula (IV) as a mixture of α - and β - anomers in a ratio of 4:1, again more often than not, requiring elaborate purification techniques to remove the undesired α -anomer, further increasing the cost of manufacture of the desired β -anomers of 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of formula (II).



Synthesis of 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides (II) as described in US 4,526,988; US 4,692,434; and US 4,808,614

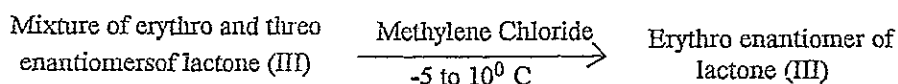
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Many improvements have been reported for manufacture of 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of formula (II) and its intermediates, which are summarized hereinbelow:

- Chou *et al.* in US Patent No. 4,965,374 disclose a method for preparation of the erythro enantiomer of a lactone compound of formula (III), wherein the hydroxy

protective group, P is benzoyl in greater than 95% purity comprising dissolution of a mixture of erythro and threo enantiomers in methylene chloride, cooling the solution to -5°C to $+10^{\circ}\text{C}$ and collecting the precipitated erythro enantiomer through filtration as such or optionally after addition of hexane.

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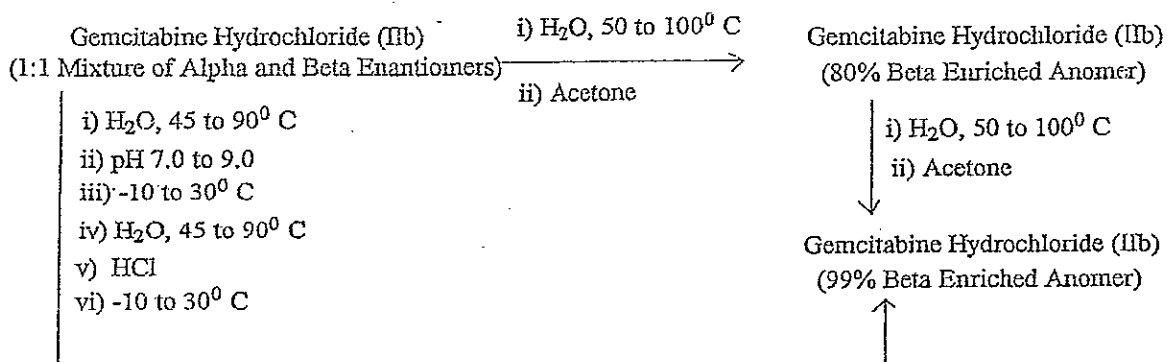


Separation of erythro and threo enantiomers of lactone (III) as disclosed in
US 4,965,374

- 10 ii) Chou *et al.* in US Patent No. 5,223,608 teach a method for obtaining the β -anomer of gemcitabine hydrochloride of formula (IIb) or the corresponding hydrobromide salt in a purity of about 80% comprising the steps of dissolving a 1:1 mixture of α - and β -anomers in water at a temperature of about 50°C to 100°C , followed by addition of acetone to the solution and collecting the said precipitated β -anomer of 80% purity after cooling the mixture to about -10°C to 50°C .

15 US Patent No. 5,223,608 also recites a method for enriching the purity of β -anomer gemcitabine hydrochloride of formula (IIb) or the corresponding hydrobromide salt to 99% comprising subjecting the material of 80% purity as obtained by the abovementioned method to repeated purification utilizing the same purification method.

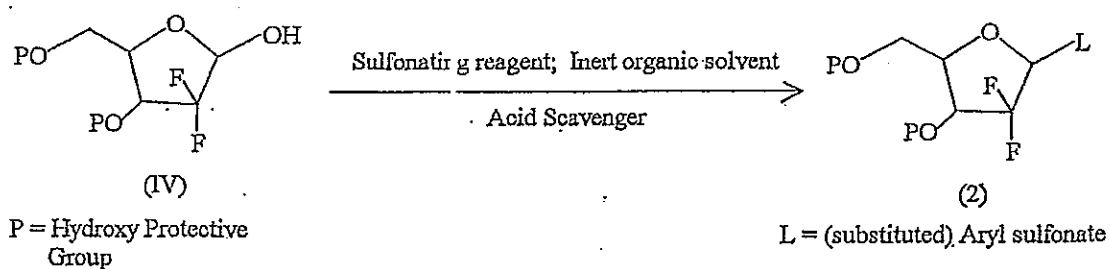
20 US Patent No. 5,223,608 further discloses a method for obtaining β -anomer enriched gemcitabine hydrochloride of formula (IIb) or the corresponding hydrobromide salt in a purity of 99% comprising the steps of dissolving a 1:1 mixture of α - and β -anomers in water at a temperature of about 45°C to 90°C , followed by adjusting the pH of the solution to about 7.0 to 9.0 and collecting the said precipitated β -anomer of the free of 99% purity after cooling the mixture to about -10°C to 30°C . The free base thus obtained is subjected to the same crystallization method in the presence of hydrogen chloride or hydrogen bromide to afford the desired gemcitabine hydrochloride of formula (IIb) or the corresponding hydrobromide salt in an anomeric purity of about 99% of the β -anomer.



Preparation of Beta enriched anomer of gemcitabine hydrochloride (IIb) as described in US 5,223,608

5 The methods disclosed in US Patent No. 5,223,608, however, suffer from a disadvantage in that repeated crystallization steps are required to obtain the product of 99% purity, not only increasing the length but also the cost of manufacture.

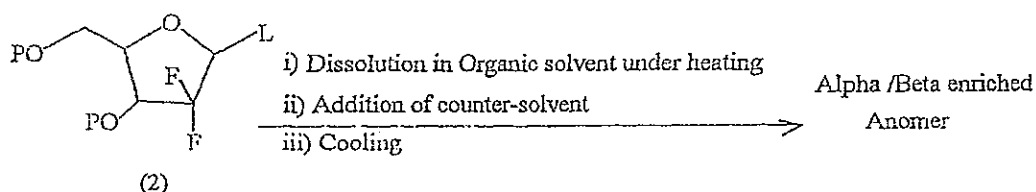
10 iii) Chou *et al.* in US Patent No. 5,252,756 disclose a stereoselective process for preparation of a β -enriched anomer of compound of formula (2), wherein the leaving group L is selected from an arylsulfonate or substituted arylsulfonate comprising contacting the lactol of formula (IV) with a sulfonating reagent in an inert solvent in the presence of an acid scavenger.



Synthesis of Beta- anomer enriched Intermediate Compound (2) as described in US 5,252,756

15 iv) Chou *et al.* in US Patent No. 5,256,797 further describe a method for separation of a mixture of α - and β -anomers of compound of formula (2), wherein the leaving group L is selected from an alkylsulfonate or substituted alkylsulfonate

comprising contacting the anomeric mixture with a solvent, heating the mixture and adding a counter-solvent, followed by lowering the temperature to effect separation of the two enantiomers.



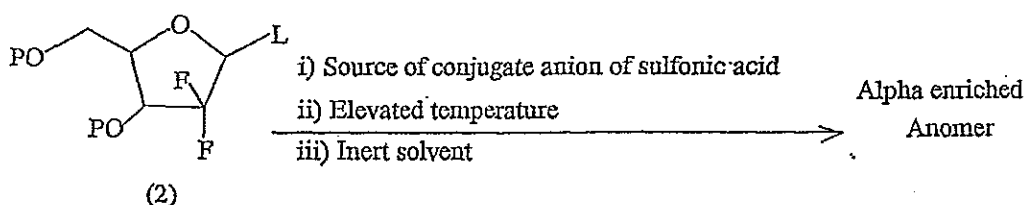
L = (substituted) Alkylsulfonate
Anomeric Mixture of Alpha and Beta
Anomers

Separation of Alpha and Beta anomers of Intermediate Compound (2) as described
in US 5,256,797

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- v) Chou *et al.* in US Patent No. 5,256,798 disclose a method for preparation of a α -anomer enriched anomer of compound (2), wherein the leaving group L is a sulfonate from the corresponding β -anomer of formula comprising treating the latter with a source of conjugate anion of a sulfonic acid at elevated temperatures in an inert solvent.

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L = (substituted) Alkyl/Arylsulfonate
Beta-enriched anomer

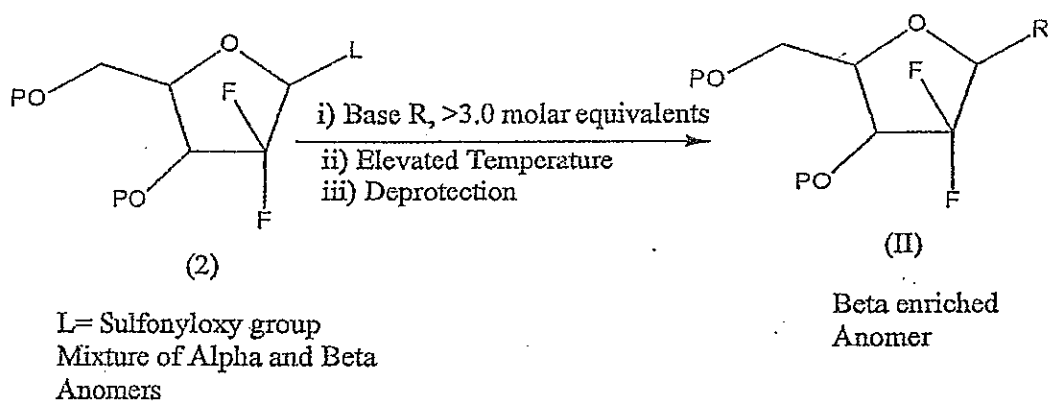
Preparation of Alpha enriched anomers of Intermediate Compound (2) as described
in US 5,256,798

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- vi) Chou *et al.* in US Patent No. 5,371,210 and US 5,401,838 describe a stereoselective fusion glycosylation process for preparation of β -anomer of 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of formula (II), wherein R and P are as defined hereinbefore comprising reacting a difluorocarbohydrate of formula (2), wherein L is an aryl/alkyl sulfonyloxy group as a mixture of α -

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and β -anomers in a ratio equal to greater than 1:1 with an excess of at least 3 molar equivalents of amino/hydroxy protected base, R at elevated temperatures of between 100°C to 160°C , in the absence of a catalyst followed by removal of the amino/hydroxyl protective groups to give the β -anomer of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II).

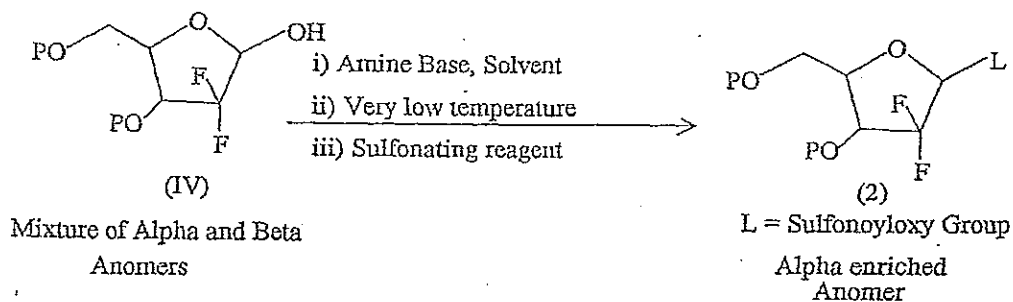


Preparation of Beta enriched anomers of Compound (II) as described in
US 5, 371, 210 and US 5, 401, 838

The method, however, is lengthy since it involves protection and deprotection of functional groups; requires large excess of the base R and, moreover, is not highly suitable for commercial manufacture since it requires elevated temperatures for carrying out the reaction.

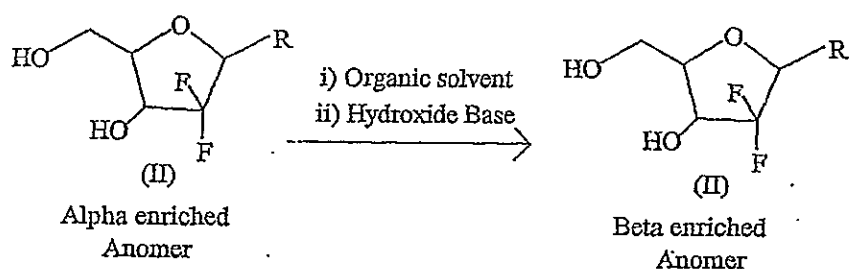
- vii) Chou *et al* in US Patent No. 5,401,861 describes a method for producing an α -enriched anomer of the intermediate compound (2), wherein the leaving group is a sulfonyloxy group comprising treating a solution of a mixture of α - and β -anomers of the lactol compound (IV) with an amine base at very low temperature and adding a sulfonating reagent.

The method, however, suffers from a limitation in that very low temperatures ranging from between -40°C to -120°C is employed for achieving the separation of the α - and β -anomers.



Preparation of Alpha enriched anomer of Intermediate Compound (2)
as described in US 5,401,861

- viii) Britton *et al.* in US Patent No. 5,420,266 disclose a process for anomerizing an α -anomer of formula (II) to the β -anomer by treatment with a hydroxide base in an organic solvent or *vice versa*.

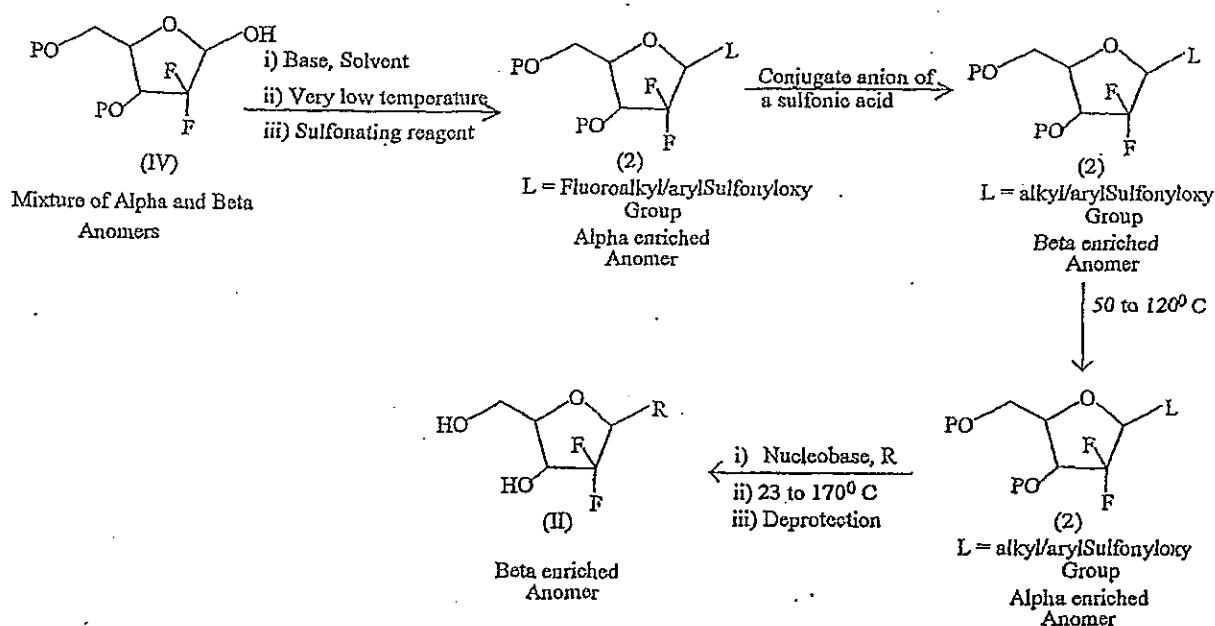


Preparation of Beta enriched anomers of Compound (II) as described
in US 5,420,266

However, the product obtained contains an anomeric ratio of the α - and β -anomers in a ratio ranging between 62:38 to 97:3, which needless to mention, would require further crystallization(s) to obtain the β -anomer of at least 99% purity.

- ix) Jones in US Patent No. 5,424,416 discloses a process for preparation of a β -enriched anomer of compound (II) comprising the steps of contacting a solution of the lactol of formula (IV) with a base at a temperature in the range of -40°C to -120°C , followed by addition of a sulfonating reagent to produce an α -enriched anomer of formula (2), wherein L is a fluoroalkylsulfonoyloxy or fluoroarylsulfonoyloxy group. The compound (2) thus obtained is reacted with a conjugate anion of a sulfonic acid to give the corresponding β -enriched anomer

(2), wherein L is an alkyl/arylsulfonyloxy group. The β -enriched anomer (2) thus obtained is heated to a temperature of between 50°C to 120°C to give the corresponding α -enriched anomer (2), wherein L is an alkyl/arylsulfonyloxy group, which on contact with a nucleobase anion, R in an inert solvent at a temperature of between 23°C to 170°C gives the β -enriched compound of formula (II).

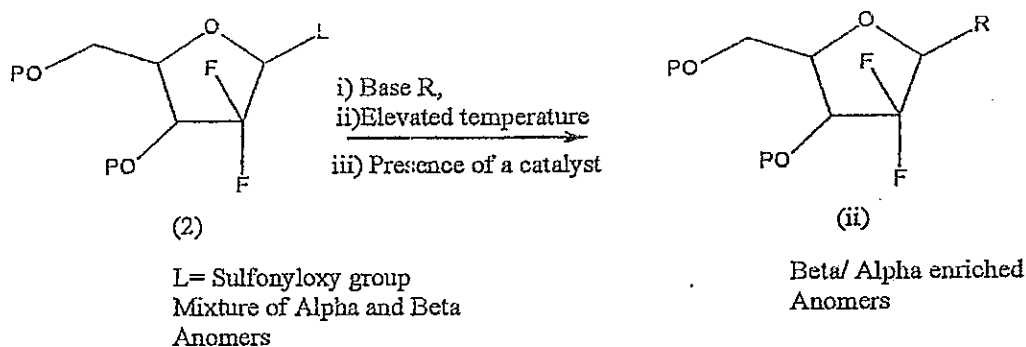


Preparation of β enriched anomer of Compound (II) as described in US 5,424,416

- However, the length of synthesis, the very low and very elevated temperatures are major limitations of the method.
- x) Kjell in US Patent No. 5,426,183 describes a catalytic stereoselective process for preparation of α - and β -enriched anomers of 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of formula (II), wherein R and P are as defined hereinbefore comprising reacting a difluorocarbhydrate of formula (2), wherein L is a sulfonyloxy, cyano, halo, carboalkoxy groups etc. as a mixture of α - and β -anomers in a ratio equal to or greater than 1:1 with the requisite amino/hydroxy protected base, R at elevated temperatures of between 50°C to 100°C , in the presence of a catalyst selected from potassium/barium/cesium trialkyl

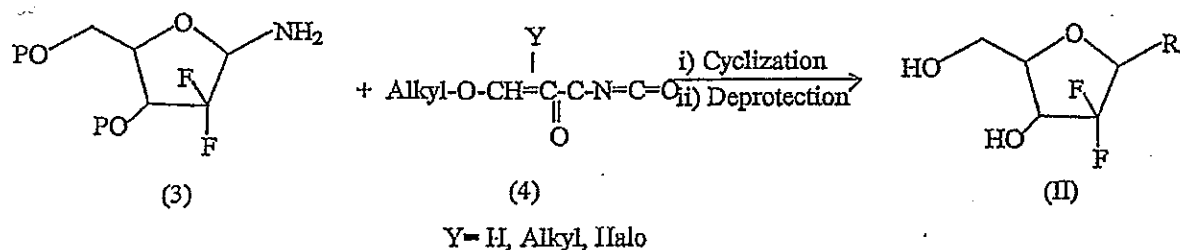
ammonium salts of trifluoromethanesulfonic acid, nanofluorobutanesulfonic acid, sulfuric acid, perchloric acid, nitric acid, trifluoroacetic acid etc. followed by removal of the amino/hydroxyl protective groups to give the β -anomer of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II).

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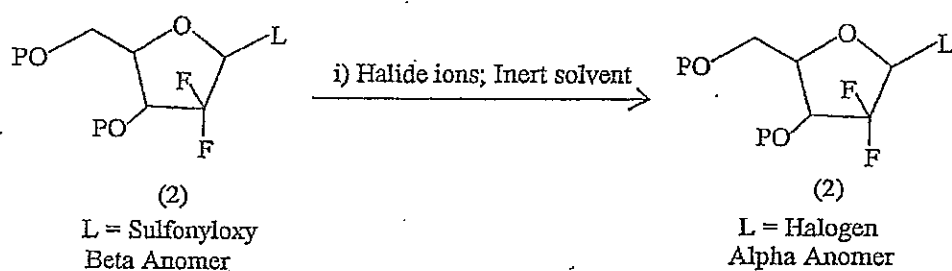
Preparation of Alpha/Beta enriched anomers of Compound (ii) as described in US 5,426,183

- xi) Hertel *et al.* in US Patent No.5,480,992 and its divisional US Patent No.5,541,345 describe another process for preparation of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), wherein R and P are as defined hereinbefore comprising reacting a amine of formula (3) with an acyclic compound of formula (4), wherein the group Y is hydrogen, alkyl or halo followed by cyclization and deprotection to give compound (II).



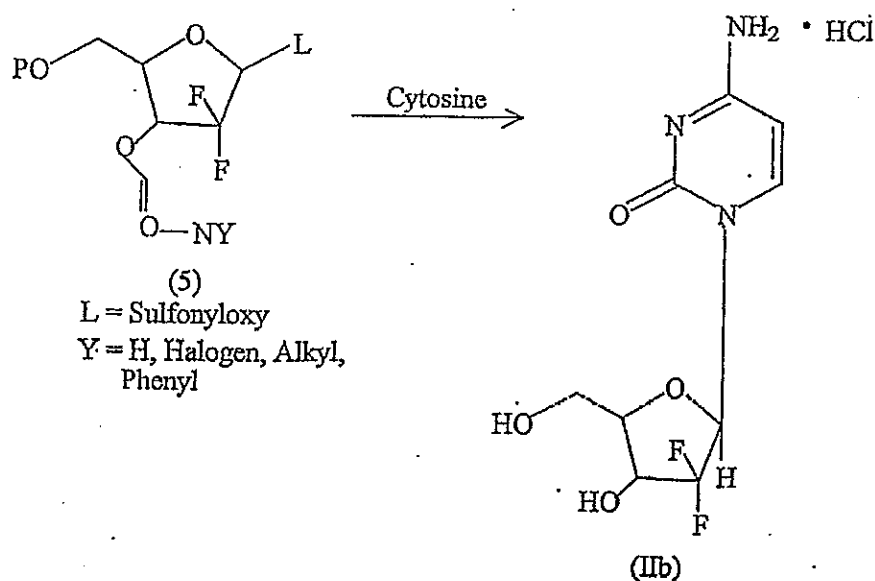
Preparation of Compound (II) as described in US 5,480,992 and US 5,541,345

- xii) Chou *et al.* in US Patent No.5,453,499 describe a stereoselective process for preparation of α - anomer of a halo compound of formula (2), wherein the group L is a halogen from the corresponding β -anomeric compounds wherein the group L is a sulfonyloxy group comprising treating the latter with a source of halide ions in an inert solvent. The halo compounds are intermediates for compound of formula (II).



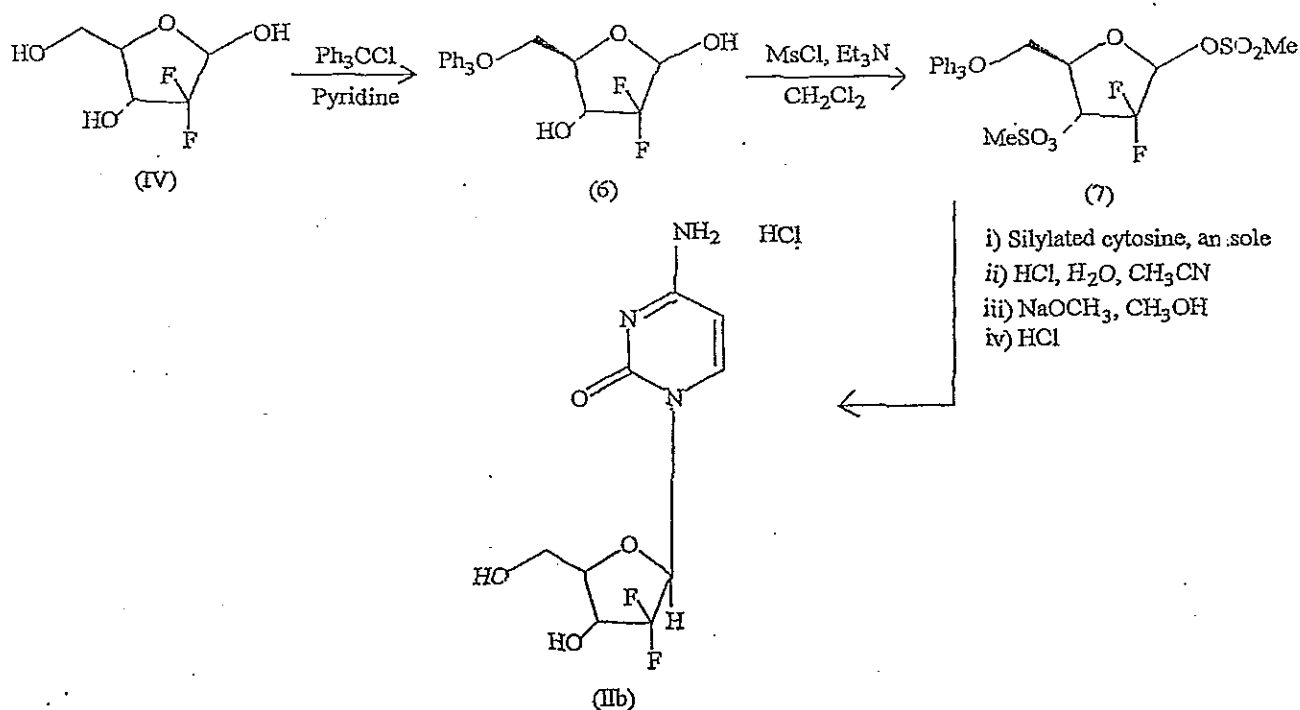
Preparation of Beta enriched Intermediate Compound (2)
as described in US 5,453,499

- xiii) Wildfeuer in US Patent No.5,521,294 describes a method for gemcitabine of formula (IIb) comprising reacting the requisite cytosine with an intermediate of formula (5).



Preparation of gemcitabine hydrochloride (IIb) as
described in US 5,521,294

xiv) Wirth *et al.* in US Patent No. 5,559,222 and its divisional, US Patent No. 5,608,043 disclose a process for preparation of gemcitabine hydrochloride of formula (IIb), which is essentially an improvement of the one described in US 4,526,988; US 4,692,434 and US 4,808,614, the improvement comprising converting the lactol compound of formula (IV) to the 5-O-triphenylmethyl derivative (6), followed by reaction with methanesulfonyl chloride to give the mesyl derivative (7). The mesyl derivative (7) is then reacted with a silylated pyrimidine base, followed by removal of protective groups to give a gemcitabine derivative as a mixture of anomers, which on treatment with a base gives the β -anomer of 98% purity.

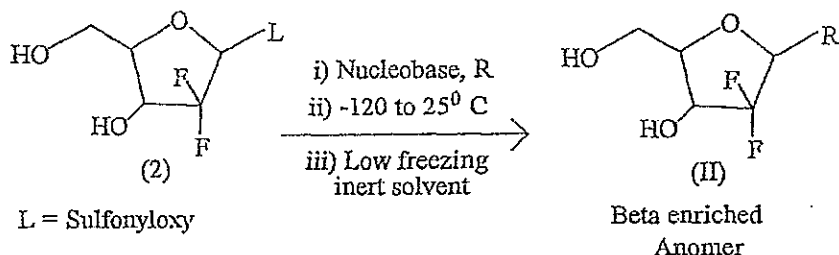


Preparation of gemcitabine hydrochloride (IIb) as described in US 5,559,222 and US 5,608,043

However, the overall yield reported for the process is only 1.3% from compound (IV), which renders it not at all attractive on a commercial scale.

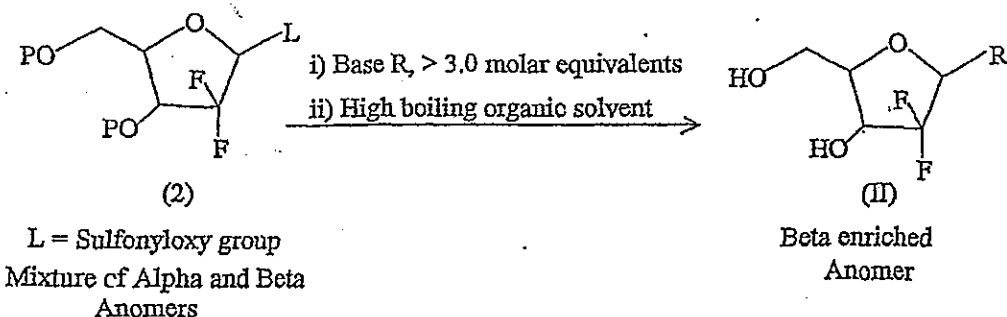
xv) Chou in US Patent No. 5,594,124 discloses a stereoselective process for preparation of a β -enriched anomer of compound (II) comprising glycosylation of compound (2), wherein the group L is sulfonyloxy with the nucleobase, R at a temperature ranging from -120°C to 25°C in a low freezing inert solvent

selected from dichloromethane, 1,2-dichloroethane, dichlorofluoromethane, acetone, toluene, anisole, chlorobenzene or mixture thereof. However, utilization of very low temperatures is a limitation of this process.



Preparation of Beta enriched anomers of Compound (II) as described in US 5,594,124

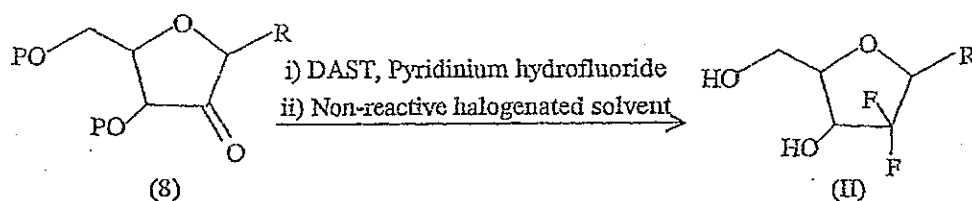
xvi) In a variation, of the above process, Chou *et al.* in US Patent No. 5,606,048 recite a glycosylation process wherein it is carried out in a high boiling inert solvent selected from toluene, xylenes, 1,2-dichloroethane, 1,1,2-trichloroethane, glyme, diglyme, dichlorobromoethane, dibromochloromethane, tribromomethane, dibromomethane, anisole and mixtures thereof. The method, however, is lengthy since it involves protection and deprotection of functional groups; requires large excess of the base R and moreover, is not highly suitable for commercial manufacture since it requires elevated temperatures for carrying out the reaction.



Preparation of Beta enriched anomers of Compound (II) as described in US 5,606,048

- xvii) Kjell in US Patent No. 5,633,367 recites a process for preparation of compound of formula (II) comprising reacting 2-ketonucleoside of formula (8) with diethylammonium sulfur trifluoride (DAST) in the presence of catalytic amount of pyridinium hydrofluoride and a non-reactive halogenated hydrocarbon.

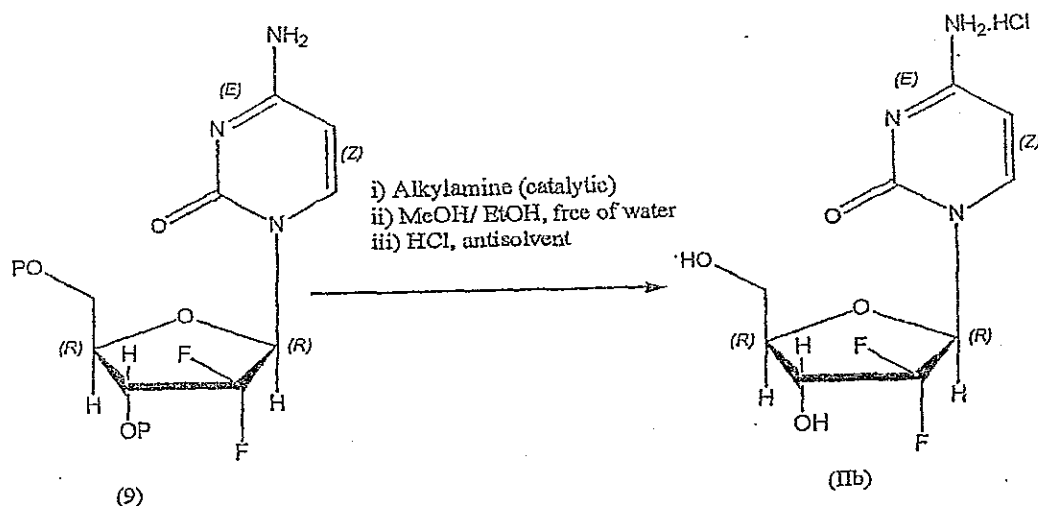
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Preparation of Compound (II) as described in US 5,633,367

- xviii) Berglund in US Patent No. 5,637,688 and its continuation US Patent No. 5,808,048 discloses a method for preparation of gemcitabine hydrochloride of formula (IIb) comprising removal of the benzoyl protective group of the β -anomer of 1-(2'-deoxy-2',2'-difluoro-3',5'-di-O-benzoyl-D-ribofuranosyl)-4-aminopyrimidin-2-one (9) with a catalytic amount of an alkylamine in the presence of methanol or ethanol in an environment free of water, followed by treatment of the deblocked nucleoside with hydrochloric acid and an antisolvent selected from acetone, acetonitrile, tetrahydrofuran, propanol, butanol, isobutanol, sec-butanol and isopropanol and recovering gemcitabine hydrochloride (IIb) from thereof. The method has a severe limitation in that the deblocking reaction requires strictly anhydrous conditions with all reagents and solvents used free of water.

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**Preparation of gemcitabine hydrochloride (Iib) as described
in US 5, 637, 688**

In addition, as per the disclosure of US 4,965,374; US 5223,608; US 434,254; and US 5945,547 and as described in Examples 7, 8, 9, 10, 11, 12, and 13 therein for synthesis of gemcitabine hydrochloride of formula (IIb) it would be further evident that:

a) The removal of the benzoyl protective group of the di-O-benzoyl protected gemcitabine obtained as per the method described in Examples 7 and 11 is achieved through bubbling ammonia gas through a solution of the said di-O-benzoyl protected gemcitabine in methanol, followed by evaporation of methanol and extraction of the oily residue in ethyl acetate to give gemcitabine as a 1:1 mixture of α - and β -anomers.

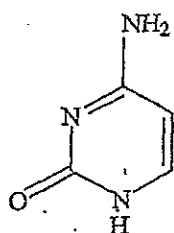
Use of ammonia gas requires special handling and safety precautions, thereby increasing the cost and risk of manufacture.

b) The gemcitabine obtained from step (a) above is invariably obtained as an oil and is converted to the hydrochloride salt by dissolving the oil in hot isopropanol (60°C), followed by addition of Reagent Grade hydrochloric acid and allowing the solution to cool under refrigerated conditions overnight, wherein solid gemcitabine hydrochloride as a 1:1 mixture of α - and β -anomers separates out and is collected

c) The hydrochloride salt obtained in step (b) requires further purification steps as mentioned hereinbefore, viz. repeated crystallization from acetone-water mixture at 50°C to 100°C , repeated crystallization from water at a pH of 7.0 to

9.9 etc. to obtain a material of pharmaceutical grade, all the abovementioned unit operations resulting in the β -anomer of gemcitabine hydrochloride in a yield of about 0.14% to 0.33% only.

Further, it might be noted that a manufacturing process for the β -anomer of gemcitabine or its salts is invariably associated with formation of by-products, specially the corresponding α -anomer and cytosine of formula (V).



(V)

Pharmacopoeial specifications world over are very stringent on the level of the abovementioned impurities present in gemcitabine hydrochloride, which should not be more than 0.1% each.

From the foregoing it would be noticed that the prior art methods for synthesis of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), and gemcitabine hydrochloride of formula (IIb) suffer from anyone or more of the following limitations, viz.,

- i) utilization of expensive hydroxy protective group like-tert-butyldimethylsilyl group and reducing agents like diisobutyl aluminium hydride, lithium aluminium hydride, which, moreover, are hazardous, requiring special handling care, thereby increasing the cost and risk of manufacture;
- ii) utilization of multiple protection and deprotection steps not only increasing the length and cost of manufacture;
- iii) utilization of high boiling solvents and elevated reaction temperatures necessitating high energy consumption;
- iv) utilization of very low temperatures of about -120° C, which is not practical on a commercial scale;
- v) utilization of large excess of the nucleoside base, which while adding to the cost also necessitates elaborate methods for removal of the excess reagent;

- vi) utilization of gaseous ammonia and strictly anhydrous conditions for removal of certain protective groups, necessitating special handling and safety precautions;
- vii) more often than not, resulting in formation of predominant amounts of the undesired α -anomers;
- viii) utilization of expensive and tedious chromatographic procedures and multiple crystallization techniques for obtaining the therapeutically desirable β -enriched anomers, not only increasing the length and cost of manufacture; and
- ix) production of the object 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), and gemcitabine hydrochloride of formula (IIb) in rather poor yields.

A need, therefore, exists for an improved method for manufacture of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), in particular gemcitabine hydrochloride of formula (IIb), which is free of and not associated with the limitations of the prior art and provides the object compounds in higher yields and conforming to pharmacopoeial specifications.

OBJECTS OF THE INVENTION

An object of the present invention is to provide a process for preparation of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), in particular gemcitabine hydrochloride of formula (IIb), which is free of the limitations of the prior art methods.

Another object of the present invention is to provide a novel intermediate for preparation of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), in particular gemcitabine hydrochloride of formula (IIb).

Yet another object of the present invention is to provide a process for preparation of the novel intermediate for 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), in particular gemcitabine hydrochloride of formula (IIb).

A further object of the present invention is to provide a process for preparation of the β -enriched anomer of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), in particular gemcitabine hydrochloride of formula (IIb), which is simple, cost-effective and avoids use of hazardous and expensive reagents and solvents and

moreover, does not require strictly anhydrous conditions and special handling and safety precautions.

Yet further object of the present invention is to provide a process for preparation of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), in particular
5 gemcitabine hydrochloride of formula (IIb) in higher yields.

Another object of the present invention is to provide a process for preparation of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), in particular gemcitabine hydrochloride of formula (IIb), which utilizes a simple and less laborious purification method.

10 Yet, another object of the present invention is to provide a process for preparation of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), in particular gemcitabine hydrochloride of formula (IIb) conforming to pharmacopoeial specifications.

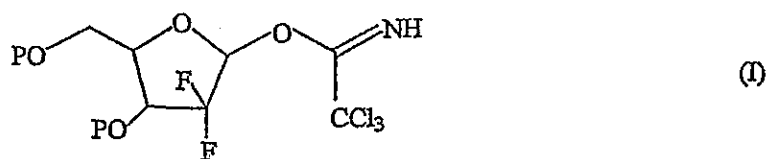
SUMMARY OF THE INVENTION

15 In their endeavour to provide an improved process for manufacture of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II), in particular gemcitabine hydrochloride of formula (IIb), the present inventors found that most, if not all of the limitations of the prior art could be addressed through utilization of :

- a) a novel intermediate for synthesis of the object compounds;
- 20 b) less expensive, less hazardous reagents and solvents; and
- c) a novel and simple crystallization method,

These aspects which form the basis of the present invention and are discussed in detail hereinbelow:

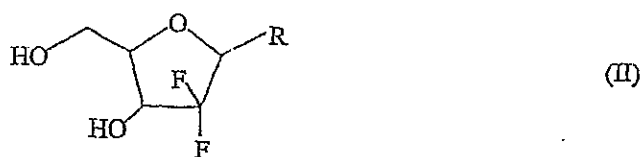
25 In the first place, the present inventors have found the hydroxy function of the lactol compound of formula (IV) could be reacted with trichloroacetonitrile in the presence of a base to give the corresponding trichloroacetimidate of formula (I),



which is novel and not reported hitherto before.

The preparation of the trichloroacetimidate of formula (I) the other reactive derivatives utilized in the prior art and discussed in detail hereinbefore is simple in that it does not require any special or elaborate precautions, economical in that it does away with utilization of expensive reagents and moreover, the product is obtained in near quantitative yield.

Secondly, it was found that the trichloroacetimidate of formula (I) undergoes the glycosylation reaction with the nucleobase, R in a highly stereoselective manner to provide the β -enriched anomer of 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of formula (II),



The glycosylation reaction of the nucleobase, R with the trichloroacetimidate of formula (I) is simply achieved by heating the two together in a suitable solvent, which unlike most of the prior art methods does not require elevated or very low temperatures.

Further the method does away with utilization of very large molar excess of the nucleobase and in fact a quantitative conversion could be achieved using less than or equal to 2 molar equivalents of the said nucleobase, R. This results in formation of a product in higher purity, containing less amounts of the unreacted nucleobase, which makes it more amenable to further purification in giving a product of not only very high chemical and anomeric purity, thereby rendering the method vastly superior over the prior art methods.

Further, it was found the removal of the protective groups of the product obtained after the aforesaid glycosylation reaction, unlike the prior art methods does not require strict anhydrous conditions and could be simply achieved by contacting the protected difluoronucleoside with aqueous ammonia in an alcoholic solvent, from which the deprotected product (II) could be isolated as predominantly the β -anomer. Alternatively, the deprotection can also be achieved by contacting the protected compound with hydroxy ion exchanged anion exchange resins.

Furthermore, it was found the pharmaceutically acceptable salts of the difluoronucleoside (II) could be prepared from the same alcoholic solvent in the which the removal of protective groups is carried by mixing the deprotected

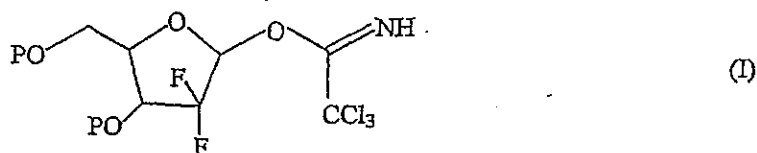
difluoronucleoside with the requisite pharmaceutically acceptable acid and a predominantly β -anomer of the salt could be isolated in high chemical and anomeric purity of $\geq 95\%$ and more often than not $\geq 99\%$, complying with pharmacopoeial specifications in just one crystallization step.

- 5 In addition, it was found that both the chemical and anomeric purity could be further enhanced by optional purification of the difluoronucleoside (II) from a mixture of an aliphatic acid and water, which is again novel and hitherto not reported.

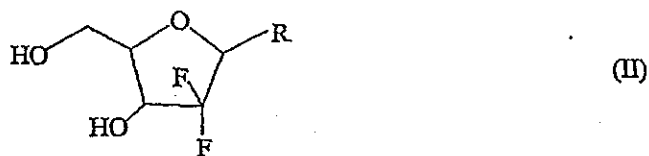
- 10 Last, but not the least it was also found that the lactol compound could be obtained from the corresponding lactone compound (III) by reducing the latter with sodium bis(2-methoxyethoxy)aluminium hydride, commonly known as Vitride, which unlike the other hydride reducing agents utilized in the prior art is less pyrophoric, does not require very low cryogenic temperatures and in fact and can be carried out at temperatures in the range of between -20°C to -30°C .

Thus in accordance with the foregoing,

- 15 In one aspect the present invention provides a novel intermediate of formula (I),

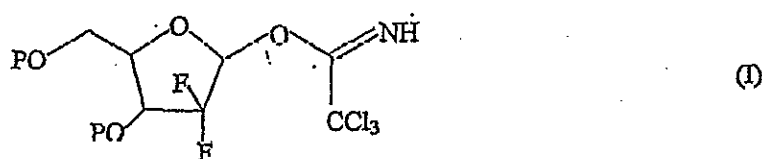


wherein P is hydrogen or a hydroxy protective group, useful for preparation of 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of formula (II), wherein R is a

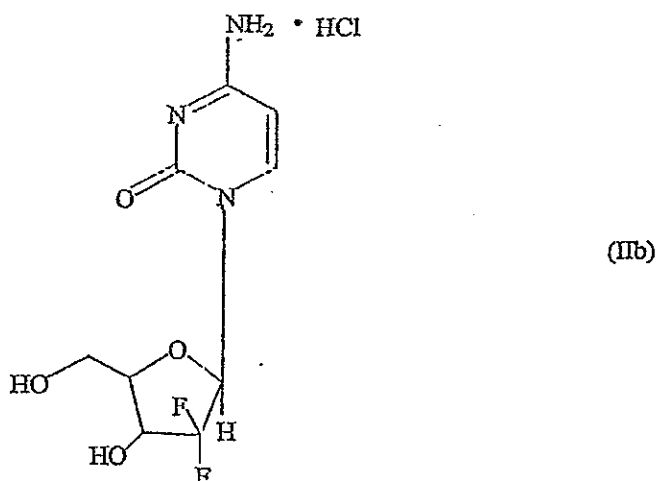


nucleobase selected from a purine or pyrimidine

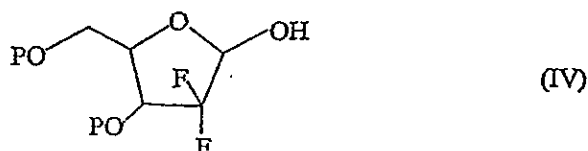
- 20 In another aspect the present invention provides a novel intermediate of formula (I)



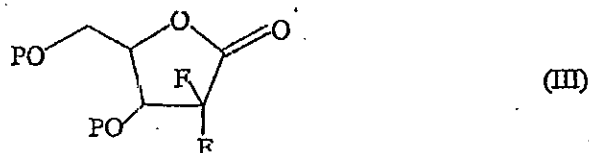
useful for preparation of gemcitabine hydrochloride of formula (IIb).



5 In yet another aspect, the present invention provides a process for preparation of the novel intermediate of formula (I) comprising reaction of the lactol compound of formula (IV), wherein P is as defined hereinbefore with trichloroacetonitrile in an inert organic solvent and in the presence of a base.



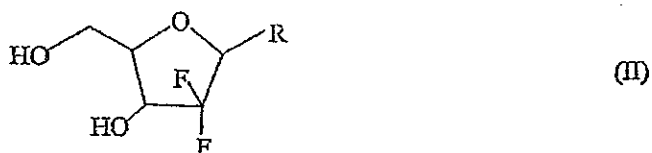
10 In a further aspect the present invention provides a simple, convenient and cost effective process for preparation of the novel intermediate of formula (I) comprising reduction of the lactone compound of formula (III),



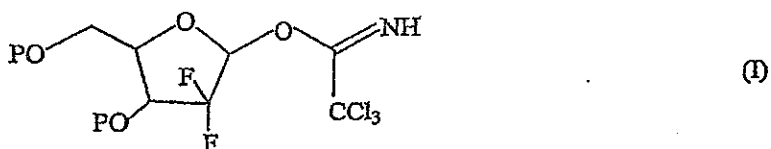
15 wherein P is as defined hereinbefore with sodium bis(2-methoxyethoxy)aluminum hydride, commonly known as vitride in an inert organic solvent at a temperature of

between -20°C to -30°C to give the lactol compound of formula (IV) and reacting the compound of formula (IV) thus obtained with trichloroacetonitrile in an inert organic solvent and in the presence of a base to give the intermediate of formula (I).

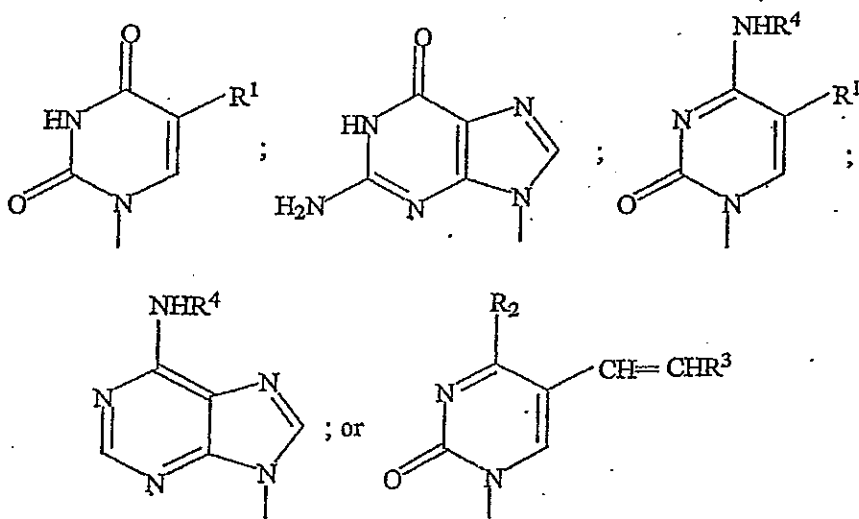
In yet further aspect the present invention provides a process for preparation of
 5 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II),



wherein R is a nucleobase selected from a purine or pyrimidine comprising glycosylation of the novel intermediate of formula (I),



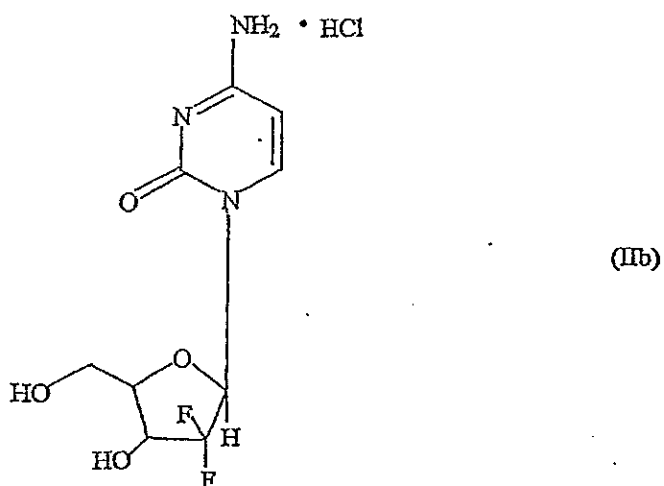
10 wherein P is as defined hereinbefore with a purine or pyrimidine base R, wherein R is selected from



15 and wherein R¹ is hydrogen, alkyl, or halogen; R² is hydroxy; R³ is hydrogen or halogen; and R⁴ is hydrogen or a nitrogen protective group in the presence of an inert

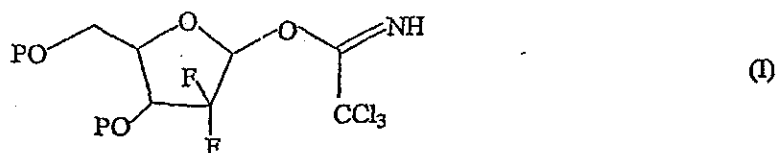
organic solvent and optionally in the presence of a Lewis acid catalyst, followed by removal of the protective groups to give compound of formula (II).

In another aspect the present invention provides a process for preparation of gemcitabine hydrochloride of formula (IIb),



5

comprising glycosylation of the novel intermediate of formula (I)

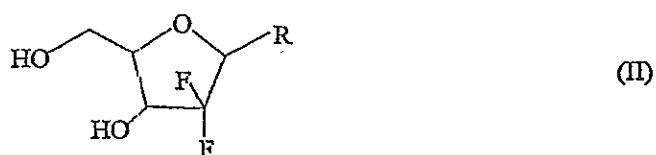


with cytosine of formula (Va) or (Vb),



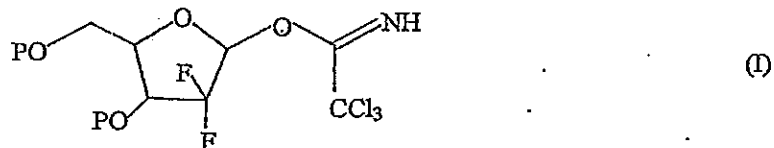
wherein R^4 is a nitrogen protective group and R^5 is a hydroxy protective group in the presence of an inert organic solvent and optionally in the presence of a Lewis acid catalyst, followed by removal of the protective groups and contacting the gemcitabine free base thus obtained with hydrogen chloride to give gemcitabine hydrochloride of formula (IIb).

In yet another aspect the present invention provides a stereoselective glycosylation process for preparation of the β -enriched anomer of 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of formula (II),

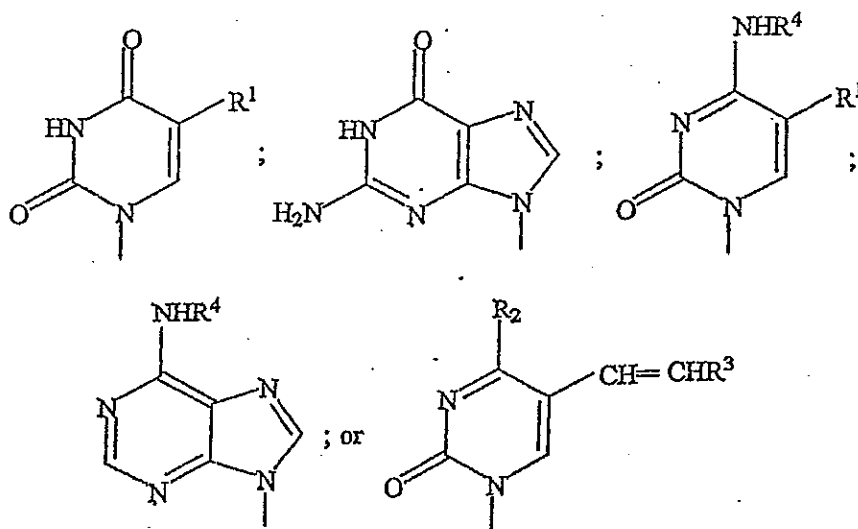


wherein R is a nucleobase selected from a purine or pyrimidine comprising the steps of

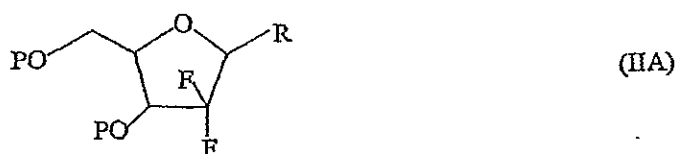
a) glycosylation of the novel intermediate of formula (I),



wherein P is as defined hereinbefore with a purine or pyrimidine base R, wherein R is selected from

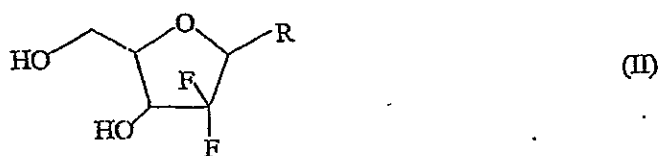


wherein R^1 is hydrogen, alkyl, or halogen; R^2 is hydroxy; R^3 is hydrogen or halogen; and R^4 is hydrogen or a nitrogen protective group in the presence of an inert organic solvent and optionally in the presence of a Lewis acid catalyst to give a protected 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (IIA),



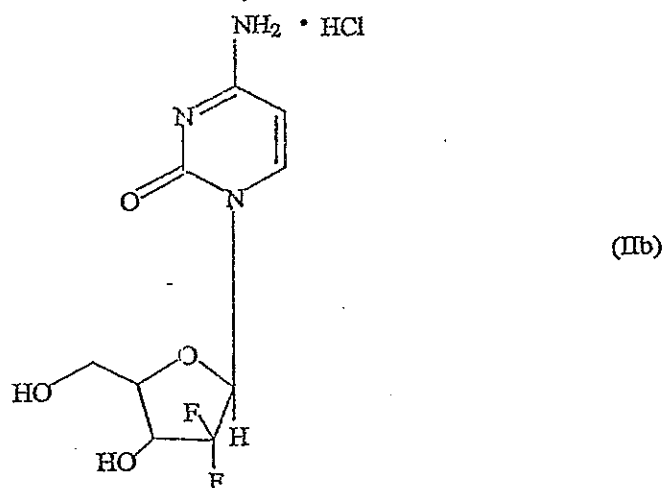
wherein P is as defined as hereinbefore;

- b) removal of the protective groups by treatment of compound of formula (IIA) with aqueous ammonia in the presence of a C₁₋₃ alcohol or with hydroxy ion exchanged anion exchange resins to give the β -enriched anomer of the free base of compound of formula (II);

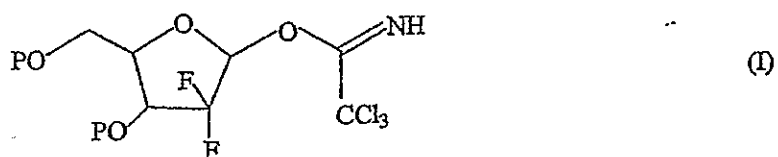


- c) contacting the free base of compound of formula (II) thus obtained with a pharmaceutically acceptable acid in a C₁₋₃ alcohol to give the corresponding the β -enriched anomer of its pharmaceutically acceptable acid addition thereof; and
- d) optionally, enriching the β -anomer content of compound of formula (II) through crystallization from a mixture of a C₂₋₃ aliphatic organic acid and water.

In a further aspect the present invention provides a stereoselective glycosylation process for preparation of greater than 99% β -enriched anomer of gemcitabine hydrochloride formula (IIb)

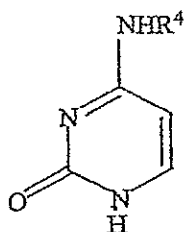


- 5 comprising the steps of
- a) glycosylation of the novel intermediate of formula (I),

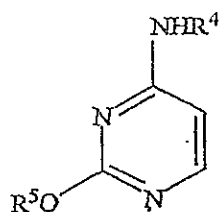


- 10 wherein P is as defined hereinbefore with cytosine of formula (Va) or (Vb),

15



(Va)



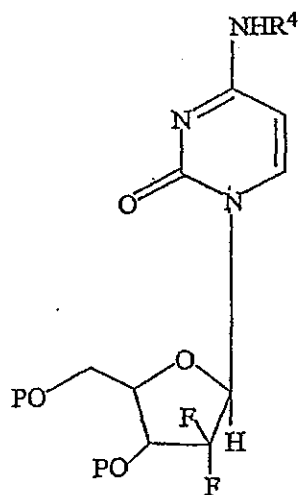
(Vb)

wherein R^4 is a nitrogen protective group and R^5 is a hydroxy protective group in the presence of an inert organic solvent and optionally in the presence of a Lewis acid

5 catalyst to protected gemcitabine free base of formula (IIa),

wherein P and R^4 are as defined hereinbefore;

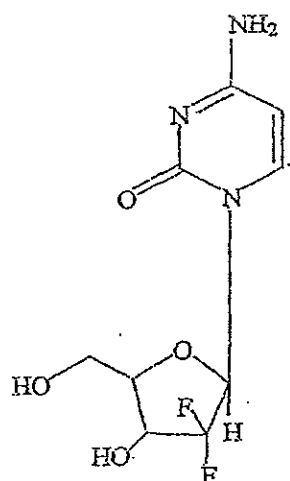
b) removal of the protective groups by treatment of compound of formula (IIa)



(IIa)

10

with aqueous ammonia in the presence of a C_{1-3} alcohol or with hydroxy ion exchanged anion exchange resins to give the β -enriched anomer of gemcitabine free base of formula (IIc);



(IIc)

- c) contacting the gemcitabine free base of formula (IIc) thus obtained with hydrogen chloride in a C₁₋₃ alcohol to give the β-enriched anomer of gemcitabine hydrochloride of formula (IIb) in ≥ 95%, preferably ≥ 99% purity ;
- and
- d) optionally further enriching the β-anomer content of gemcitabine hydrochloride of formula (IIb) to greater than 99% through crystallization from a mixture of a C₂₋₃ aliphatic organic acid and water.

10 DETAILED DESCRIPTION OF THE INVENTION

Preparation of the Novel Intermediate of formula (I)

The trichloroacetimidate compound of formula (I) can be prepared by reacting the lactol compound of formula (IV) with trichloroacetonitrile in an inert organic solvent and in the presence of a base.

- 15 The hydroxy protecting group, P in both compounds of formula (IV) and (I) are ones that are routinely utilized in organic synthesis and may represent, but however, not limited to formyl, 2-chloroacetyl, benzyl, diphenylmethyl, triphenyl methyl, 4-nitrobenzyl, phenoxycarbonyl, tertiary butyl, methoxymethyl, tetrahydropyranyl, allyl, tetrahydrothienyl, 2-methoxethoxy methyl, methoxy acetyl, phenoxy acetyl, isobutyryl,
- 20 ethoxy carbonyl, benzyloxy carbonyl, mesyl, trimethylsilyl, isopropyl dimethylsilyl, methyl diisopropyl silyl, triisopropyl silyl, tertiary butyldimethyl silyl etc.

Suitable inert organic solvents that can be employed are those which are water-immiscible, which apart from their non-participation in the essential reaction are able to

form a two-phase system with water. Such a solvent offers advantage in not only effecting an efficient conversion but also helps in isolation of the product by simple evaporation of the solvent or through work up by addition of water.

Suitable inert water-immiscible organic solvents that can be employed include
5 halogenated e.g. chlorinated hydrocarbons, e.g. dichloromethane and 1,2-dichloroethane; esters e.g. acetic acid (C_{1-4}) alkyl esters e.g. ethyl acetate; ethers e.g. diisopropylether; aromatic hydrocarbons eg. toluene, xylenes etc. Chlorinated hydrocarbons are preferred and amongst these dichloromethane and 1,2-dichloroethane are the most preferred.

10 While both organic and inorganic bases can be utilized, however organic bases are preferred. Suitable organic bases that can be employed include but are not limited to diethylamine, triethylamine, diisopropylethylamine, cyclohexylamine, pyridine, 2,4-dimethylamino pyridine, N-methyl morpholine etc. Triethylamine and diisopropylamine, because of their low cost are preferred.

15 The base can be employed in catalytic or molar proportions to the lactol compound of formula (IV) or in excess thereof. Preferably it is employed in catalytic amounts.

Trichloroacetonitrile can be employed in equimolar proportions to the lactol compound of formula (IV) or in excess thereof. Usually it is employed in molar
20 proportions of 1 to 20 moles per mole of compound of formula (IV). Preferably, the base is employed in molar proportions of 1-1.5 moles per mole of compound of formula (IV).

The trichloroacetimidate formation can be generally carried out by addition of the lactol compound (IV) to a mixture of trichloroacetonitrile and the base in the inert
25 organic solvent at a temperature ranging between -20°C to 20°C and thereafter agitating the reaction mixture at ambient temperature in the range of between 20°C to 30°C for a period of 3 to 10 hours till completion of reaction.

The trichloroacetimidate (I) thus formed can be isolated by simple evaporation of the solvent or it can be isolated by addition of water to the reaction mixture,
30 separation of the organic phase from the aqueous phase, followed by evaporation of the organic solvent and the product thus obtained can be used for the next step of glycosylation reaction with the nucleobase, R as such without any purification.

Alternatively, the reaction mixture after completion of reaction can be washed with water, the separated organic phase can be dried over suitable dehydrating agents

and the solution as such without isolation can be used for next step of glycosylation reaction with the nucleobase, R

The compound of formula (I) normally obtained as an oil can be either the α -anomer or the β -anomer or mixtures thereof.

5 A typical compound of formula (I), wherein the protective group, P is benzoyl and represented by compound of formula (1a) obtained by the abovementioned method was found to possess the following spectral and physical characteristics, viz.

^1H NMR (CDCl_3 , δ): 8.7 (s, NH, 1H), 7.36 - 8.1 (m, Ar, 10H), 6.51 - 6.59 (dd, H-1, 1H), 5.59 - 5.66 (dd, H-3 1H), 4.64 - 4.83 (m, H-5 2H, H-4 1H)

10 ^{13}C NMR (CDCl_3 , δ): 164.7 - 165.9 (C=NH), 127.9 - 130 (Ar), 121.3 (C-2), 97.58 (C-1), 90 (CCl_3), 78.8 (C-4), 71.9 (C-3), 63.8 (C-5).

Mass Spectrum (M^+) : 522.3

Specific rotation +15 to +60°

15 The lactol compound (IV) in turn can be prepared from the lactone compound (III) through reduction with sodium bis(2-methoxyethoxy)aluminium hydride, commonly known as vitride in an inert organic solvent at a temperature of between -20° C to -30° C.

20 Vitride (CAS Reg. No. [22722-98-1]) is available commercially as a 70% solution in toluene, which can be used as such for reducing the lactone (III). Unlike other hydride reducing agents such as lithium aluminium hydride, lithium tertiarybutoxy aluminium hydride, diisobutyl lithium aluminium hydride etc. vitride is comparatively a reducing agent of moderate strength, less pyrophoric, oxygen stable - pumpable liquid, not requiring very low cryogenic temperatures and compatible with most of the ubiquitous aprotic solvents, thereby offering many advantages in its utilization in the process.

25 Typically, the reduction can be carried out by reacting the commercially available 70% solution of vitride in toluene with a solution of the lactone compound (III) in a suitable aprotic solvent under an inert gas atmosphere at a temperature of between -20° C to -30° C for a period of 1 to 2 hrs. The lactol compound (IV) could be isolated by routine work-up procedures.

30 Suitable aprotic solvents that can be employed include tetrahydrofuran, dioxane, N,N-dimethylformamide, N,N-dimethylacetamide etc.

Typically, the product can be isolated by quenching the reaction mixture with 6N hydrochloric acid, followed by extraction with a water-immiscible organic solvent. Evaporation of the organic solvent afford the lactol (IV).

The vitride can be employed in equimolar proportions to the lactone compound of formula (III) or in excess thereof. Usually it is employed in molar proportions of 1 to 3 moles per mole of compound of formula (III). Preferably it is employed in molar proportions of 1-1.5 moles per mole of compound of formula (III).

Preparation of 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II)

The 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (II) can be prepared by glycosylation of the intermediate compound of formula (I), wherein the protective group, P is as defined hereinbefore with the requisite nucleobase, R.

The nucleobase R can be selected from anyone of a pyrimidine or a purine compound represented by the structures shown in Chart-I.

In compounds represented in Chart-I, R¹ can be hydrogen, alkyl, or halogen; while is R² is hydroxy; and whereas R³ is hydrogen or halogen; R⁴ can be hydrogen or a nitrogen protective group. Alkyl is typically a lower alkyl of 1 to 4 carbon atoms, while halogen represents chlorine, bromine, iodine or fluorine; whereas the nitrogen protective group R⁴ are those that are routinely utilized in organic synthesis, in particular acetyl and trialkylsilyl protective groups being preferred.

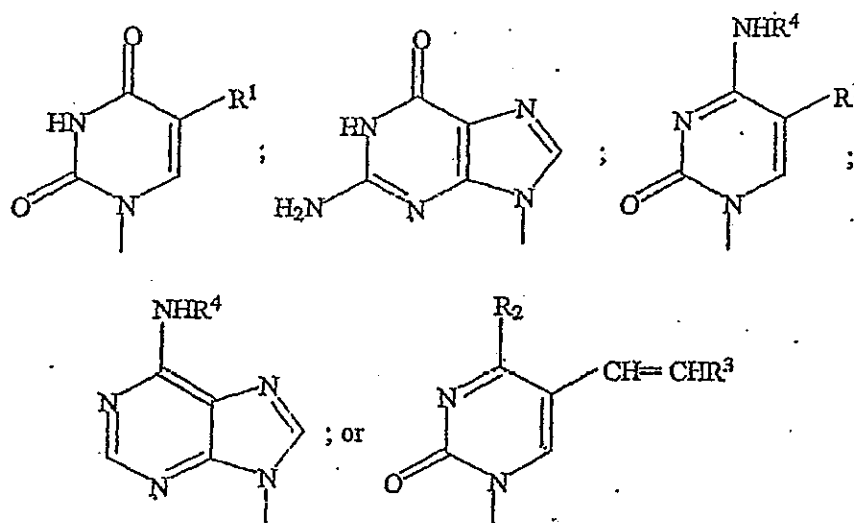


Chart-I: Representative Nucleobase Compounds, R referred to in the Present Invention

The glycosylation reaction is carried out by reaction of compound of formula (I) with anyone of the nucleobase represented in Chart-I in the presence of an inert organic solvent and optionally in the presence of a Lewis acid catalyst to give a protected 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of formula (IIA), wherein P and R are as defined hereinbefore.

Suitable inert organic solvents that can be employed include but are not limited to acetonitrile, toluene, xylene and its isomers, chlorobenzene, ortho-dichlorobenzene, dichloromethane, 1,1-dichloroethane, 1,2-dichloroethane, 1,1,2-trichloroethane, anisol. The preferred inert solvent is 1,2-dichloroethane.

Suitable Lewis acid catalysts that can be employed are selected as tin tetrachloride, trimethylsilyltrifluoromethanesulphonate, trimethylsilyl nonafluorobutylsulphonate, trimethylsilyl perchlorate, borontrifluoride diethyletherate, trimethylsilyl tetrafluoroborate etc., preferably trimethylsilyl trifluoromethane sulphonate.

Typically, the glycosylation reaction is carried out by refluxing together compound (I), the nucleobase, R and optionally the Lewis acid catalyst in anyone of the inert organic solvent mentioned hereinbefore, till completion of reaction to give the protected 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of formula (IIA).

The nucleobase, R can be employed in equimolar proportions to the compound of formula (I) or in excess thereof, but however, below 2 moles per mole of compound of formula (I). Usually it is employed in molar proportions of 1 to 2.0 moles per mole of compound of formula (I). Preferably, the base is employed in molar proportions of 1-1.6 moles per mole of compound of formula (I).

The protected 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of formula (IIA) can be isolated from the reaction mixture by conventional methods eg., addition of water to the reaction mixture and extraction of the product into a organic solvent, If the inert organic solvent utilized in the glycosylation reaction is water-immiscible the product gets extracted automatically into the said solvent. If however, the inert organic solvent utilized in the glycosylation reaction is a water-miscible one, then the product is extracted into any water-immiscible organic solvent such as alkyl esters eg., ethyl acetate; chlorinated hydrocarbons eg., dichloromethane. The protected compound (IIA) can be isolated by evaporation of the organic solvent.

The step of deprotection of the protective groups, P and R⁴, if any is carried out by contacting the protected 2'-deoxy-2',2'-D-ribofuranosyl difluoronucleosides of

formula (IIA) with aqueous ammonia in a solvent selected from a C₁₋₃ alcohol or hydroxy ion exchanged anion exchange resins to give the β-enriched anomer of the free base of compound of formula (II).

5 The deprotection is typically carried out by agitating a solution of the protected 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (IIA) in a C₁₋₃ alcohol with aqueous ammonia at a temperature of between ambient to a temperature of about 60° C for a time sufficient to effect complete removal of the protective groups to give the free base of compound of formula (II).

10 While, a C₁₋₃ alcohol selected from methanol, ethanol, 1-propanol and 2-propanol can be used, however, methanol is most preferred since the protected compounds (IIA) are generally more soluble in it than ethanol, 1-propanol and 2-propanol, by virtue of which the deprotection in methanol can be carried out at ambient temperatures of between 25° C to 30° C, unlike the other two, more often than requiring heating or refluxing. Further, methanol offers advantage in that the salt formation of the
15 free base could be carried out in the same solvent as well as can be crystallized from the same to afford the β-enriched anomer.

Alternatively, the deprotection can be carried out by contacting the protected compound (IIA) with an hydroxy ion exchanged anion exchange resin.

20 Anion exchange resins consisting of chloride as an anion are converted to the corresponding hydroxyl exchanged ones by mixing of the former with aqueous sodium hydroxide for a period of 2 to 3 hrs. The suspension is filtered, the resin bed washed successively with demineralised water till pH of the filtrate was in the range of between 6.0 to 7.0. The washed resin is further washed with a C₁₋₃ alcohol to effect the hydroxyl ion exchange.

25 The hydroxy ion exchanged resin is mixed with compound (IIA) in a C₁₋₃ alcohol at a temperature of from 30° C to 50° C, preferably at a temperature of from 40° C to 45° C for a period of 20 to 40 hours to effect the deprotection. At the end the resin is filtered and the filtrate concentrated to give the free base of compound (II).

30 Suitable anion exchange resins that can be employed are strong base anion exchangers, wherein the ionic form is generally a chloride ion. Typical of such anion exchange resins are the commercially available Amberlite resins like FPA40 Cl, FPA90 Cl, FPA91 Cl, FPA97 Cl, FPA98 Cl, IRA 400, IRA402 Cl, IRA410 Cl etc.

Thus, in a typical embodiment, to a solution of the protected compound (IIA) in methanol is added a 25% aqueous solution of ammonia in water and mixture agitated at room temperature for a period of 4 to 8 hrs till completion of the deprotection. Removal of methanol by evaporation gives the free base of compound (II).

5 In another typical embodiment, an anion exchange resin, for instance, Amberlite IRA 400 is agitated with 5% aqueous sodium hydroxide at room temperature for 2 to 3 hrs and the resin filtered off. The filtered resin is washed successively with demineralised water till pH of the filtrate is in the range of 6.0 to 7.0. The resin is finally washed with a C₁₋₃ alcohol, for instance methanol. The hydroxy ion
10 exchanged resin thus obtained is stirred with the protected compound (IIA) in methanol at a temperature of between 40° C to 45° C for 36 hours. At the end, the resin is filtered off and the filtrate concentrated to give the deprotected free base compound (II).

The deprotected compound (II) obtained by any of the abovementioned two methods is generally obtained as an oil and can be used as such without any purification
15 for formation of its pharmaceutically acceptable salt.

The salt formation can be effected by contacting a solution of the free base (II) in a C₁₋₃ alcohol selected from methanol, ethanol, 1-propanol and 2-propanol with the requisite acid for sufficient time. The salt thus formed can be isolated or crystallized from the same alcoholic solvent or with anyone of methanol, ethanol, 1-propanol or 2-
20 propanol to give the corresponding acid addition salt (II), generally as the β-enriched anomer.

Typical acid addition salts of compound of formula (II) that can be prepared include those salts obtained using acids such as tartaric, citric, acetic, hydrochloric, hydrobromic, sulphuric, phosphoric etc.

25 The anomeric and chemical purity of the acid addition salt can be enriched further, if necessary through one more crystallization of the same from with anyone of methanol, ethanol, 1-propanol or 2-propanol or optionally through crystallization from a mixture of water and a C₂₋₃ aliphatic organic acid, selected from acetic acid and propionic acid.

30 *Preparation of Gemcitabine hydrochloride of formula (IIa)*

Gemcitabine hydrochloride of formula (IIa) can be prepared by glycosylation of the intermediate compound of formula (I), wherein the protective group, P is as defined hereinbefore with the cytosine compounds of formula (Va) or (Vb), wherein R⁴ is a

nitrogen protective group and R^5 is a hydroxy protective group in the presence of an inert organic solvent and optionally in the presence of a Lewis acid catalyst to protected gemcitabine free base of formula (IIa).

5 Suitable inert organic solvents that can be employed include but are not limited to acetonitrile, toluene, xylene and its isomers, chlorobenzene, ortho-dichlorobenzene, dichloromethane, 1,1-dichloroethane, 1,2-dichloroethane, 1,1,2-trichloroethane, anisole. The preferred inert solvent is 1,2-dichloroethane.

10 Suitable Lewis acid catalysts that can be employed are selected as tin tetrachloride, trimethylsilyltrifluoromethanesulphonate, trimethylsilyl nonafluorobutylsulphonate, trimethylsilyl perchlorate, borontrifluoride diethyletherate, trimethylsilyl tetrafluoroborate etc., preferably trimethylsilyl trifluoromethane sulphonate.

15 Typically, the glycosylation reaction is carried out by refluxing together compound (I), the cytosine compounds, (Va) or (Vb) and optionally the Lewis acid catalyst in any one of the inert organic solvents mentioned hereinbefore, till completion of reaction to give the protected gemcitabine compound of formula (IIa).

20 The cytosine compounds (Va) and (Vb) can be employed in equimolar proportions to the compound of formula (I) or in excess thereof, but, however, below 2 moles per mole of compound of formula (I). Usually it is employed in molar proportions of 1 to 2.0 moles per mole of compound of formula (I). Preferably, the base is employed in molar proportions of 1-1.6 moles per mole of compound of formula (I).

25 The protected gemcitabine of formula (IIa) can be isolated from the reaction mixture by conventional methods eg., addition of water to the reaction mixture and extraction of the product into an organic solvent. If the inert organic solvent utilized in the glycosylation reaction is water-immiscible the product gets extracted automatically into the said solvent. If however, the inert organic solvent utilized in the glycosylation reaction is a water-miscible one, then the product is extracted into any water-immiscible organic solvent such as alkyl esters eg., ethyl acetate; chlorinated hydrocarbons eg., dichloromethane. The protected compound (IIa) can be isolated by
30 evaporation of the organic solvent.

The step of deprotection of the protective groups, P and R^4 , is carried out by contacting the protected 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (IIa) with aqueous ammonia in a solvent selected from a C₁₋₃ alcohol or hydroxy ion

exchanged anion exchange resins to give the β -enriched anomer of the gemcitabine free base of compound of formula (IIc).

The deprotection is typically carried out by agitating a solution of the protected 2¹-deoxy-2¹,2¹-D-ribofuranosyl difluoronucleosides of formula (IIa) in a C₁₋₃ alcohol with aqueous ammonia at a temperature of between ambient to a temperature of about 60° C for a time sufficient to effect complete removal of the protective groups to give the free base of compound of formula (II).

While a C₁₋₃ alcohol selected from methanol, ethanol, 1-propanol and 2-propanol can be used, however, methanol is most preferred since the protected compounds (IIa) are generally more soluble in it than ethanol, 1-propanol and 2-propanol, by virtue of which the deprotection in methanol can be carried out at ambient temperatures of between 25° C to 30° C, unlike the other two, more often than requiring heating or refluxing. Further, methanol offers advantage in that the salt formation of the free base could be carried out in the same solvent as well as can be crystallized from the same to afford the β -enriched anomer, having purity >95%.

Alternatively, the deprotection can be carried out by contacting the protected compound (IIa) with an hydroxy ion exchanged anion exchange resin.

Anion exchange resins consisting of chloride as an anion are converted to the corresponding hydroxyl exchanged ones by mixing of the former with aqueous sodium hydroxide for a period of 2 to 3 hrs. The suspension is filtered, the resin bed washed successively with demineralised water till pH of the filtrate was in the range of between 6.0 to 7.0. The washed resin is further washed with a C₁₋₃ alcohol to effect the hydroxyl ion exchange.

The hydroxy ion exchanged resin is mixed with compound (IIa) in a C₁₋₃ alcohol at a temperature of from 30° C to 50° C, preferably at a temperature of from 40° C to 45° C for a period of 20 to 40 hours to effect the deprotection. At the end the resin is filtered and the filtrate concentrated to give the free base of compound (IIc).

Suitable anion exchange resins that can be employed are strong base anion exchangers, wherein the ionic form is generally a chloride ion. Typical of such anion exchange resins are the commercially available Amberlite resins like FPA40 Cl, FPA90 Cl, FPA91 Cl, FPA97 Cl, FPA98 Cl, IRA 400, IRA402 Cl, IRA410 Cl etc.

Thus, in a typical embodiment, to a solution of the protected compound (IIa) in methanol is added a 25% aqueous solution of ammonia in water and mixture agitated at

room temperature for a period of 4 to 8 hrs till completion of the deprotection. Removal of methanol by evaporation gives the free base of compound (IIc).

In another typical embodiment, an anion exchange resin, for instance, Amberlite IRA 400 is agitated with 5% aqueous sodium hydroxide at room temperature for 2 to 3 hrs and the resin filtered off. The filtered resin is washed successively with demineralised water till pH of the filtrate is in the range of 6.0 to 7.0. The resin is finally washed with a C₁₋₃ alcohol, for instance methanol. The hydroxy ion exchanged resin thus obtained is stirred with the protected compound (IIa) in methanol at a temperature of between 40° C to 45° C for 36 hours. At the end, the resin is filtered off and the filtrate concentrated to give the deprotected free base compound (IIc).

The gemcitabine free base (IIc) obtained by any of the abovementioned two methods is generally obtained as an oil and can be used as such without any purification for formation of its hydrochloride salt.

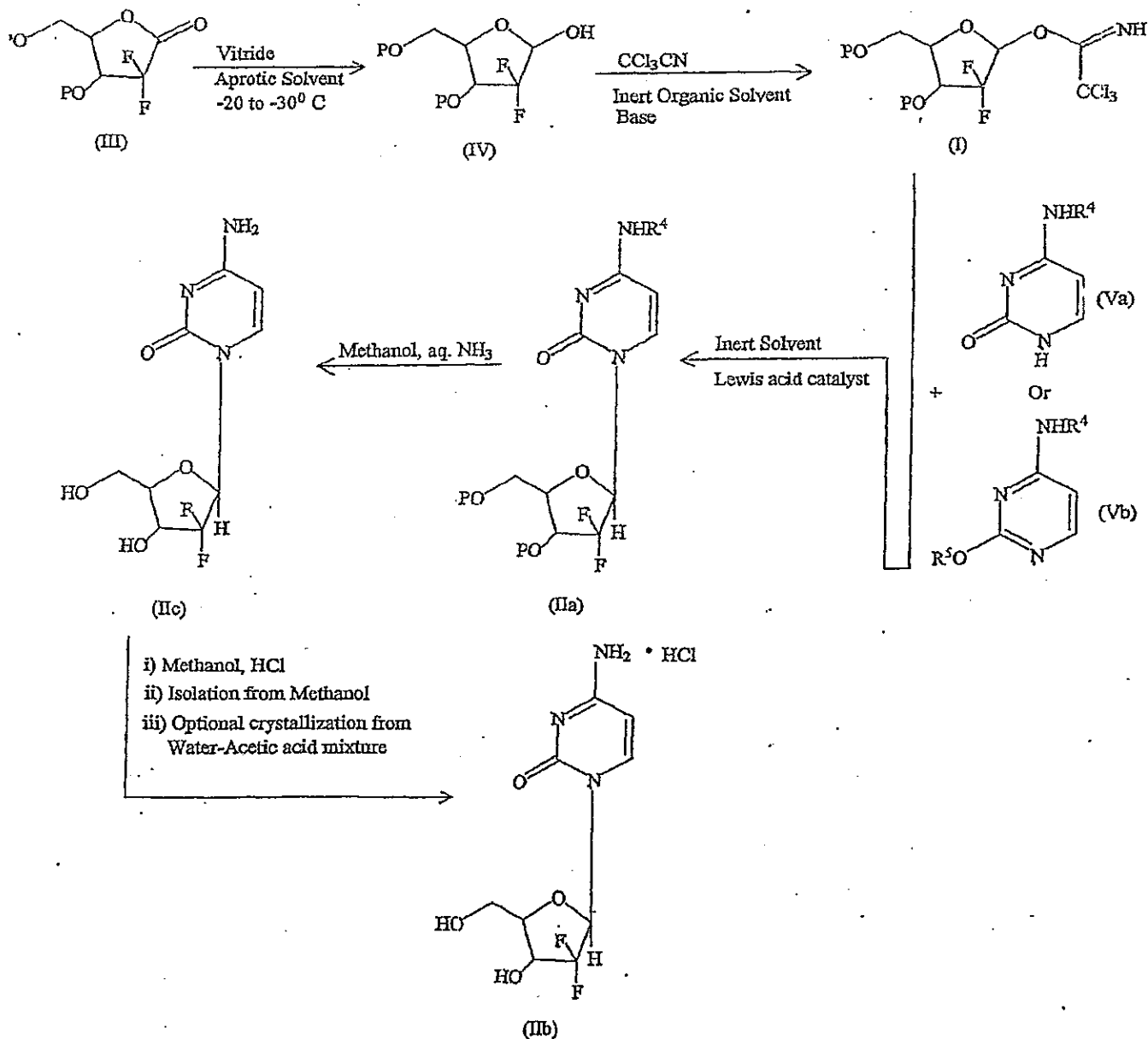
The salt formation can be effected by contacting a solution of the free base (IIc) in a C₁₋₃ alcohol selected from methanol, ethanol, 1-propanol and 2-propanol with hydrogen chloride for sufficient time. Both aqueous and gaseous hydrogen chloride can be employed. The hydrochloride salt thus formed can be isolated or crystallized from the same alcoholic solvent or with anyone of methanol, ethanol, 1-propanol or 2-propanol to give gemcitabine hydrochloride (IIb), generally as the β-enriched anomer having an anomeric purity >95%, most often having an anomeric purity >99%.

The anomeric and chemical purity of gemcitabine hydrochloride (IIb) thus obtained can be enriched to >99%, if necessary through one more crystallization of the same from with anyone of methanol, ethanol, 1-propanol or 2-propanol or optionally through crystallization from a mixture of water and a C₂₋₃ aliphatic organic acid, selected from acetic acid and propionic acid.

While all the abovementioned C₂₋₃ aliphatic organic acids do normally provide gemcitabine hydrochloride of formula (IIb) in high anomeric purity, acetic acid is the most preferred since it provides a compound of high chemical purity as well.

Typically, to a solution of the hydrochloride salt (IIb) in water is added acetic acid and the mixture agitated at room temperature for 10 to 12 hrs to effect crystallization. The crystallized salt (IIb) can be isolated by filtration, centrifugation or decantation and dried to give pure (IIb).

The preparation of gemcitabine hydrochloride (IIb) in high chemical and anomeric purity as per the method of the present invention is summarized in Scheme-1.



Scheme-I : Preparation of Gemcitabine Hydrochloride (IIb) As Per The Preferred Embodiment Of The Present Invention

The invention can be further understood by the following examples, which in no way should be construed as to limiting the scope of the invention.

Example-1

Preparation of 2¹-Deoxy-2¹,2¹-difluoro-3,5-bisbenzoyloxy-D-ribose trichloroacetimidate (Compound of formula Ia)

Step-1: Preparation of lactol, viz. 2¹-Deoxy-2¹,2¹-difluoro-D-ribofuranose-3,5-dibenzoate (Compound of formula IV)

Sodium bis(2-methoxyethoxy)aluminium hydride (Vitrade; 70% in toluene; 80 ml; 0.287 mol) was added slowly to a solution of 2¹-deoxy-2¹,2¹-difluoro-3,5-dibenzoate-1-oxoribose (III; 100 gm; 0.265 mol) in dry tetrahydrofuran cooled to -30° C under an atmosphere of nitrogen. After the addition, the reaction mixture was agitated at the same temperature for 1hr and quenched by the addition of 6N hydrochloric acid. The reaction mixture was extracted with ethyl acetate. The organic layer was separated and washed with 5% sodium bicarbonate solution followed by water. Concentration of the organic layer under reduced pressure gave 100gm (99.5%) of the title compound as an oil.

¹H NMR (CDCl₃, δ): 5.6 (m, H-1, 1H), 5.45 - 5.32 (br, H-3, 1H), 4.7 (m, H-4, 1H), 4.65 (br, H-5, 2H), 3.6 (s, 1H, OH).

Step-2: Preparation of 2¹-Deoxy-2¹,2¹-difluoro-3,5-bisbenzoyloxy-D-ribose trichloroacetimidate (Ia)

To a mixture of trichloroacetonitrile (179.5 gm; 1.246 mol), diisopropyl ethylamine (3.73 gm; 0.028 mol), cooled to at -10 to 0° C under an atmosphere of nitrogen was added slowly a solution of 2¹-Deoxy-2¹,2¹-difluoro-D-ribofuranose-3,5-dibenzoate (Compound of formula IV obtained in Step-1; 25 gm; 0.066 mol) in 1,2-dichloroethane (50 ml). The reaction mixture was allowed to come to room temperature and stirred for further 5 hr till completion of reaction. The organic solvent was evaporated under reduced pressure to give 35 gm (100%) of the title compound as an oil.

A purified sample had the following spectroscopic characteristics.

¹H NMR (CDCl₃, δ): 8.7 (s, NH, 1H), 7.36 - 8.1 (m, Ar, 10H), 6.51 - 6.59 (dd, H-1, 1H), 5.59 - 5.66 (dd, H-3 1H), 4.64 - 4.83 (m, H-5 2H, H-4 1H)

¹³C NMR (CDCl₃, δ): 164.7 - 165.9 (C=NH), 127.9 - 130 (Ar), 121.3 (C-2), 97.58 (C-1), 90 (CCl₃), 78.8 (C-4), 71.9 (C-3), 63.8 (C-5).

Mass Spectrum (M^+) : 522.3

Specific rotation +15 to +60°

Example-2

- 5 Preparation of 2¹-Deoxy-2¹,2¹-difluoro-3,5-dibenzoate-N⁴-acetyl cytidine (Protected Gemcitabine, IIa)

A mixture 2¹-Deoxy-2¹,2¹-difluoro-3,5-bisbenzoyloxy-D-ribose trichloroacetimidate (Ia; 5.22g; 0.01 mol), Silylated N-acetyl cytosine (Vb; 2.45 gm; 0.016 mol w.r.t. N-Acetylcytosine) and trimethylsilyl trifluoromethane sulphonate (6.41 gm; 0.01 mol) in 1,2-dichloroethane (50 ml) was refluxed overnight. The reaction mixture was cooled to room temperature and washed with two 50 ml portions each of water followed by washing with 5% sodium bicarbonate solution and with a saturated solution of sodium chloride. Removal of dichloroethane under reduced pressure gave 5.12 gm (37%) of the title compound, a portion of it was chromatographed on silica gel.

Mass Spectrum (M^+) : 512.35

Example-3

Preparation of 2¹-Deoxy-2¹,2¹-difluoro-3,5-dibenzoate-N⁴-acetyl cytidine (Protected Gemcitabine, IIa)

20 To a mixture of trichloroacetonitrile (47.6 gm; 0.33 mol), diisopropyl ethylamine (3.73 gm; 0.028 mol), cooled to -10 to 0° C under an atmosphere of nitrogen was added slowly a solution of 2¹-Deoxy-2¹,2¹-difluoro-D-ribofuranose-3,5-dibenzoate (IV; 25 gm; 0.066 mol) in 1,2-dichloroethane (50 ml). The reaction mixture was allowed to come to room temperature and stirred for further 5 hr till completion of reaction.

25 To the above reaction mixture containing 2¹-Deoxy-2¹,2¹-difluoro-3,5-bisbenzoyloxy-D-ribose trichloroacetimidate (Ia; 34.5g; 0.066 mol) *in situ*, was added Silylated N-acetyl cytosine (15.2 gm; 0.1 mol w.r.t. N-Acetylcytosine) and trimethylsilyl trifluoromethane sulphonate (22 gm; 0.1 mol) in 1,2-dichloromethane (300 ml) and the mixture refluxed overnight. The reaction mixture was cooled to room temperature and washed with two 100 ml portions each of water followed by washing with 5% sodium bicarbonate solution and with a saturated solution of sodium chloride. Removal of dichloroethane under reduced pressure gave 30gm (88.7%) of the title compound.

Example-4

Preparation of 2'-Deoxy-2',2'-difluorocytidine (Gemcitabine free base IIc)

To a solution of the protected Gemcitabine (IIa: 7 gm; obtained in Example-2 and 3) in methanol (35 ml) was added a solution of ammonium hydroxide (20%, 14 ml) and the mixture stirred at room temperature for 24 hr. Methanol was removed under reduced pressure to give the title compound as an oil.

Example-5

Preparation of Gemcitabine Hydrochloride (IIb)

The residue obtained from Example-4 (Gemcitabine free base, IIc) was dissolved in methanol (28 ml) and decolourised with activated carbon (0.7 gm). The carbon was filtered off and to the filtrate was added Conc. hydrochloric acid (1.12 ml) and the mixture cooled to 0° C and agitated at a temperature of 0° C to 5° C for 1 hr and the precipitated solid filtered and dried to give 0.56 gm (12.7%) of the title compound as a white crystalline solid. HPLC analysis showed the product to be comprising of 95% of the β -anomer.

Example-6

Purification of Gemcitabine Hydrochloride (IIb)

The Gemcitabine hydrochloride (0.56 gm; obtained from Example-5) was dissolved in D.M water (4.5 ml) at 55 – 60° C. The solution was decolourised with activated carbon (56 mg) and the carbon filtered off. The filtrate was mixed with acetic acid (45 ml) and the mixture was stirred at room temperature for 2h. The precipitated solid was filtered and dried at 60-70° C under vacuum for 5-6 hr to give 0.45 gm (80%) of Gemcitabine hydrochloride (IIb) having an anomeric purity of 99.94 % of the β -anomer.

Example-7

Preparation of 2'-Deoxy-2',2'-difluorocytidine (Gemcitabine free base IIc)

Amberlite IRA 400 (100 gm; 20-25 mesh; chloride as the ionic form) was stirred with aqueous sodium hydroxide (5%; 500 ml) at room temperature for 2 to 3 hrs. The resin was filtered off and the bed washed successively with demineralised water till pH of the filtrate was in the range of 6.0 to 7.0. The resin bed was then washed with methanol and dried at room temperature.

To a solution of the protected Gemcitabine (IIa: 5.5 gm; obtained in Example-2 and 3) in methanol (50 ml) was added the hydroxy ion exchanged resin as obtained

above (2.25 gm) and the mixture stirred at a temperature of 40° C to 45° C for 36 hrs. The resin was filtered off, washed with methanol. The filtrate was concentrated under reduced pressure to 2.0 gm (71%) of the title compound as an oil.

Example-8

5 *Preparation of Gemcitabine Hydrochloride (IIb)*

The residue obtained from Example-7 (Gemcitabine free base, IIc) was dissolved in methanol (20 ml) and decolourised with activated carbon (0.35 gm). The carbon was filtered off and to the filtrate was added Conc. hydrochloric acid (1.0 ml) and the mixture cooled to 0° C and agitated at a temperature of 0° C to 5° C for 1 hr and
10 the precipitated solid filtered and dried to give 0.43 gm (18.9%) of the title compound as a white crystalline solid. HPLC analysis showed the product to be comprising of 95% of the β -anomer.

Example-9

Purification of Gemcitabine Hydrochloride (IIb)

15 The Gemcitabine hydrochloride (0.43 gm; obtained from Example-8 was dissolved in D.M water (3.5 ml) at 55 – 60° C. The solution was decolourised with activated carbon (50 mg) and the carbon filtered off. The filtrate was mixed with acetic acid (34 ml) and the mixture was stirred at room temperature for 2hrs. The precipitated solid was filtered and dried at 60-70° C under vacuum for 5-6 hr to give 0.35gm (81%)
20 of Gemcitabine hydrochloride (IIb) having an anomeric purity of 99.94 % of the β -anomer.

Example-10

Preparation of 2-Deoxy-2,2-difluoro-3,5-dibenzoate-5-fluoro uridine hydrochloride salt.

25 5-Fluorouracil (5 gm; 0.038 mol) was heated with hexamethyldisilazane (13.77gm; 0.085mol) and catalytic amount (0.50 ml) of methanesulfonic acid in acetonitrile (15ml) at 110-120° C for 5-6 hrs to get a clear solution. The reaction mixture was concentrated under reduced pressure to give a gummy mass which was heated to 60° C and mixed with a solution of 2¹-Deoxy-2¹,2^{1'}-difluoro-3,5-bisbenzoyloxy-D-ribose trichloroacetimidate (Ia; 6.70 gm; 0.013mol) in acetonitrile.
30 (5 ml), followed by addition of trimethylsilyl trifluoromethane sulphonate (7.12 gm; 0.03 mol). The reaction mixture was heated under agitation at 90° C for 10hrs.

The reaction mixture was poured in to a mixture dichloromethane and water (100 ml; 1:1). The organic phase was separated and washed with 5% sodium bicarbonate solution, water and then evaporated to give 6.28 g (100%) of a white solid. Chromatography of the solid over silica gel using a mixture of ethyl acetate and hexane (1:1) gave 3.25 gm (51.7%) of the free base (IIa)

^1H NMR (CDCl_3 , δ) : 4.59 (q, 1H, H-4'), 4.68, 4.91 (dd, dd, 2H, H-5'), 5.79 (dd, 1H, H-3'), 6.52 (q, 1H, H-1'), 8.06 (d, 1H, H-6)

Mass Spectrum (M^+): 489

The removal of the benzoyl protective group and conversion of the unprotected free base thus obtained to its hydrochloride salt was effected as per the methods described in Examples 4-9 gave 2-Deoxy-2,2-difluoro-3,5-dibenzoate-5-fluoro uridine hydrochloride salt in an anomeric purity of 70% of the β -anomer.

Example-11

Preparation of 2-Deoxy-2,2-difluoro-3,5-dibenzoate-5-fluoro cytidine hydrochloride salt

5-Fluorocytosine (5 gm; 0.038 mol) was heated with hexamethyldisilazane (6.308 gm; 0.039mol) and catalytic amount (0.50) of methanesulfonic at 110-120 $^\circ$ C for 5 to 6hrs to get a clear solution. The temperature was brought down to 50 $^\circ$ C and the silylated mass mixed with a solution of 2 1 -Deoxy-2 1 ,2 1 -difluoro-3,5-bisbenzoyloxy-D-ribose trichloroacetimidate (Ia; 6.70 gm; 0.013mol) in acetonitrile (7 ml), followed by addition of trimethylsilyl trifluoromethane sulphonate (7.12 gm; 0.03 mol). The reaction mixture was heated under agitation at 90 $^\circ$ C for 10hrs.

The reaction mixture was poured in to a mixture dichloromethane and water (100 ml; 1:1). The organic phase was separated and washed with 5% sodium bicarbonate solution, water and then evaporated to give 6.0 g of a white solid. Chromatography of the solid over silica gel using a mixture of ethyl acetate and hexane (1:1) gave 2.0 gm (31.8%) of the free base.

^1H NMR (CDCl_3 , δ) : 4.56 (q, 1H, H-4'), 4.73, 4.78 (dd, dd, 2H, H-5'), 5.79 (dd, 1H, H-3'), 6.63 (q, 1H, H-1'), 8.09 (d, 1H, H-6)

Mass: Spectrum : 488

The removal of the benzoyl protective group and conversion of the unprotected free base thus obtained to its hydrochloride salt was effected as per the methods

described in Examples 4-9 gave 2-Deoxy-2,2-difluoro-3,5-dibenzoate-5-fluoro uridine hydrochloride salt in an anomeric purity of 68% of the β -anomer.

Example-12

Preparation of 2-Deoxy-2,2-difluoro-3,5-dibenzoate-5-thymidine hydrochloride salt

5 Thymine (5 gm; 0.04 mol) was heated with hexamethyldisilazane (15.2 gm; 0.094 mol) and catalytic amount (0.5 ml) of trimethylsilyl chloride in acetonitrile (20 ml) at 110-120° C for 5-6 hrs to get a clear solution. The reaction mixture was concentrated under reduced pressure to give a gummy mass which was redissolved in fresh acetonitrile (10 ml). To the solution was then added a solution of 2¹-Deoxy-2¹,2¹-difluoro-3,5-bisbenzoyloxy-D-ribose trichloroacetimidate (Ia; 7.0 gm; 0.0134mol) in acetonitrile (10 ml), followed by trimethylsilyl trifluoromethane sulphonate (7.37 gm; 0.033 mol). The reaction mixture was heated under agitation at 90 C for 5hrs. The reaction mixture was poured in to a mixture dichloromethane and water (100 ml; 1:1). The organic phase was separated and washed with 5% sodium bicarbonate solution, water and then evaporated to give 6.0 gm of a white solid, which was chromatographed over silica gel using a mixture of ethyl acetate and hexane.

Mass Spectrum : 485

The removal of the benzoyl protective group and conversion of the unprotected free base thus obtained to its hydrochloride salt was effected as per the methods described in Examples 4-9 gave 2-Deoxy-2,2-difluoro-3,5-dibenzoate-5-fluoro uridine hydrochloride salt in an anomeric purity of 70% of the β -anomer.

Example-13

Preparation of 2-Deoxy-2,2-difluoro-3,5-dibenzoate-uridine hydrochloride salt

25 Uracil (5 gm; 0.044 mol) was heated with hexamethyldisilazane (76.8. gm; 0.47 mol) and of trimethylsilyl chloride (40 ml) at 135-140° C for 5-6 hrs to get a clear solution. The reaction mixture was concentrated under reduced pressure to give a gummy mass, which was redissolved in fresh acetonitrile (20 ml). To the solution was then added a solution of 2¹-Deoxy-2¹,2¹-difluoro-3,5-bisbenzoyloxy-D-ribose trichloroacetimidate (Ia; 7.5 gm; 0.0143 mol) in acetonitrile (50 ml), followed by trimethylsilyl trifluoromethane sulphonate (10.43 gm; 0.047 mol). The reaction mixture was heated under agitation at 90°C for 10hrs.

The reaction mixture was poured in to a mixture dichloromethane and water (100 ml; 1:1). The organic phase was separated and washed with 5% sodium

bicarbonate solution, water and then evaporated to give 6.5 gm of a white solid, which was chromatographed over silica gel using a mixture of ethyl acetate and hexane .

Mass Spectrum: M^+ : 472.5

5 The removal of the benzoyl protective group and conversion of the unprotected free base thus obtained to its hydrochloride salt was effected as per the methods described in Examples 4-9 gave 2-Deoxy-2,2-difluoro-3,5-dibenzoate-5-fluoro uridine hydrochloride salt in an anomeric purity of 65% of the β -anomer.

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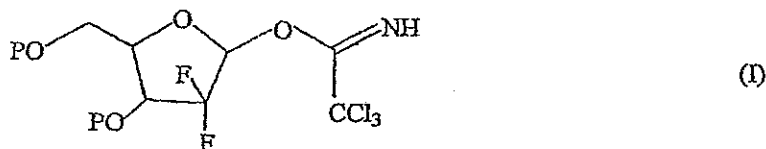
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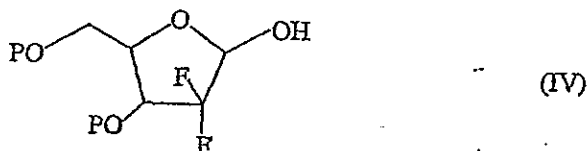
We Claim

1. A compound of formula (I),



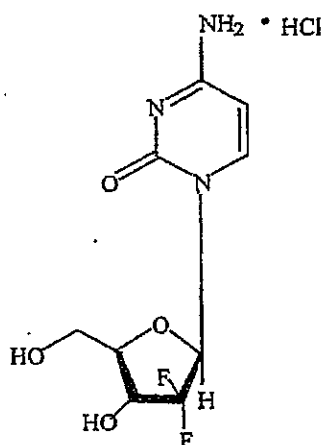
wherein P is hydrogen or a hydroxy protective group

2. A compound of formula (I) according to claim 1, wherein the protective group, P is selected from anyone of formyl, 2-chloroacetyl, benzyl, diphenylmethyl, triphenyl methyl, 4-nitrobenzyl, phenoxycarbonyl, tertiary butyl, methoxymethyl, tetrahydropyranyl, allyl, tetrahydrothienyl, 2-methoxethoxy methyl, methoxy acetyl, phenoxy acetyl, isobutyryl, ethoxy carbonyl, benzyloxy carbonyl, mesyl, trimethylsilyl, isopropyl dimethylsilyl, methyl diisopropyl silyl, triisopropyl silyl, or tertiary butyldimethyl silyl.
3. A process for preparation of compound of formula (I) which comprises reacting a lactol compound of formula (IV),



- wherein P is as defined hereinbefore with trichloroacetonitrile in an inert organic solvent and in the presence of a base,
4. A process as claimed in claim 3, wherein the organic solvent is selected from halogenated hydrocarbons, acetic acid (C₁₋₄) alkyl esters, ethers and aromatic hydrocarbons.
5. A process as claimed in claim 3 or 4, wherein the inert organic organic solvent is selected from dichloromethane 1,2-dichloroethane, ethyl acetate, diisopropylether or toluene.
6. A process as claimed in any one of claims 3 to 5, wherein the base is selected from diethylamine, triethylamine, diisopropylethylamine, cyclohexylamine, pyridine, 2,4-dimethylamino pyridine, and N-methyl morpholine

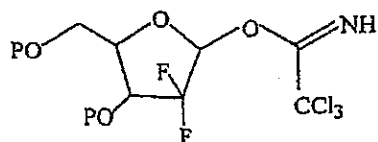
7. A process as claimed in any one of claims 3 to 6, wherein the base is employed in catalytic, equimolar or in molar proportions of 1 to 3 moles per mole of compound of formula (IV), preferably, in catalytic amounts.
8. A process as claimed in any one of claims 3 and 7, wherein trichloroacetonitrile is employed in equimolar proportions to the lactol compound of formula (IV) or in molar proportions of 1 to 20 moles per mole of compound of formula (IV), preferably in molar proportions of 1.0 to 15 moles per mole of compound of formula (IV).
9. A process as claimed in any one of claims 3 and 9, wherein the reaction is carried out at a temperature in the range of between -20°C to 20°C .
10. A stereoselective glycosylation process for preparation of greater than 99% β -enriched anomer of gemcitabine hydrochloride formula (IIb),



(IIb)

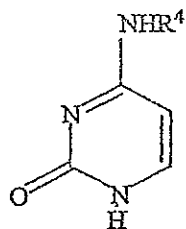
comprising the steps of

- a) glycosylating a compound of formula (I),

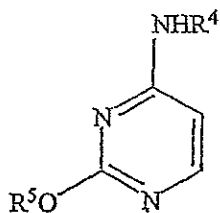


(I)

wherein P is as defined hereinbefore with cytosine of formula (Va) or (Vb),



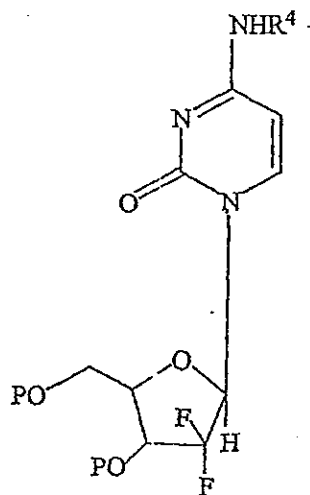
(Va)



(Vb)

wherein R^4 is a nitrogen protective group and R^5 is a hydroxy protective group
in the presence of an inert organic solvent and optionally in the presence of a
Lewis acid catalyst to protected gemcitabine free base of formula (IIa),

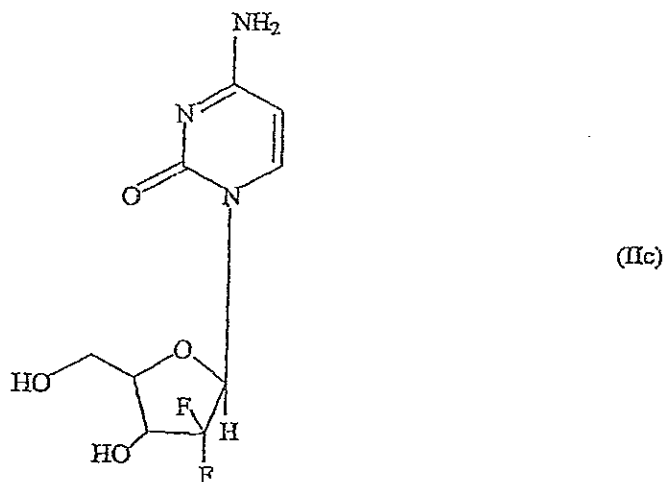
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(IIa)

wherein P and R^4 are as defined hereinbefore;

- b) removing said protective groups by treating said compound of formula (IIa) with aqueous ammonia in the presence of a C₁₋₃ alcohol or with hydroxy ion exchanged anion exchange resins to give the β -enriched anomer of gemcitabine free base of formula (IIc);



- 5 c) contacting the gemcitabine free base of formula (IIc) thus obtained with hydrogen chloride in a C₁₋₃ alcohol to give the β -enriched anomer of gemcitabine hydrochloride of formula (IIb) in $\geq 95\%$, preferably $\geq 95\%$ purity ; and
- 10 d) optionally further enriching the β -anomer content of gemcitabine hydrochloride of formula (IIb) to greater than 99% through crystallization from a mixture of a C₂₋₃ aliphatic organic acid and water.
11. A process as claimed in claim 10, wherein the nitrogen protective group R⁴ and the hydroxyl group R⁵ in compounds of formula (Va) and (Vb) are acetyl or trialkylsilyl.
- 15 12. A process as claimed in claim 10 or 11, wherein the inert organic solvent is selected from acetonitrile, toluene, xylene and its isomers, chlorobenzene, ortho-dichlorobenzene, dichloromethane, 1,1-dichloroethane, 1,2-dichloroethane, 1,1,2-trichloroethane, and anisole.
- 20 13. A process as claimed in any one of claims 10 to 12, wherein the Lewis acid catalyst is selected from tin tetrachloride, trimethylsilyl(trifluoromethanesulphonate, trimethylsilyl nonafluorobutylsulphonate, trimethylsilyl perchlorate, borontrifluoride diethyletherate, and trimethylsilyl tetrafluoroborate.

14. A process as claimed in any one of claims 10 to 13, wherein the cytosine compounds (Va) and (Vb) are employed in molar proportions of 1 to 2.0 moles per mole of compound of formula (I).
15. A process as claimed in any one of claims 10 to 14, wherein the C₁₋₃ alcohol is selected from methanol, ethanol, 1-propanol or 2-propanol.
16. A process as claimed in any one of claims 10 to 15, wherein the deprotection of protective groups, P, R⁴, and R⁵ comprises treatment of compound of formula (IIa) with aqueous ammonia in the presence of a C₁₋₃ alcohol is carried out at a temperature of between ambient to a temperature of about 60° C.
17. A process as claimed in any one of claims 10 to 16, wherein anion exchange resin is a strong base anion exchange resin.
18. A process as claimed in any one of claims 10 to 17, wherein the strong base anion exchange resin is selected from Amberlite resins such as FPA40 Cl, FPA90 Cl, FPA91 Cl, FPA97 Cl, FPA98 Cl, IRA 400, IRA402 Cl, and IRA410 Cl.
19. A process as claimed in any one of claims 10 to 13, wherein C₂₋₃ aliphatic organic acid is acetic acid or propionic acid.