

MODIFIED NUCLEOSIDE PHOSPHORAMIDITES**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] The present application is a U.S. application claiming the benefit of priority to U.S. Provisional Application No. 62/558,763, filed September 14, 2017, the entirety of which is hereby incorporated by reference.

BACKGROUND

[0002] Oligonucleotide synthesis is extremely important for providing access to custom-made oligonucleotides of the desired sequence. To obtain the desired oligonucleotide, the building blocks (monomers) are sequentially coupled to the growing oligonucleotide chain in the order required by the sequence of the product.

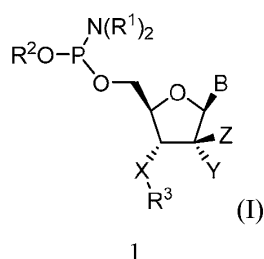
[0003] Modified oligonucleotides, having modifications at, e.g., the 2' and/or 3' position have received increased interest over the past years as useful in, e.g., therapeutic applications. While synthetic methods for constructing modified oligonucleotides exist, there is a need for additional synthetic options to synthesize a diverse array of modified oligonucleotides. New monomeric nucleosides of high purity, and which are capable of being synthesized at higher yield and at high volume, are needed to meet the demand for new modified oligonucleotides.

[0004] Monomers described herein meet this need by providing novel monomers useful for the synthesis of modified oligonucleotides.

SUMMARY

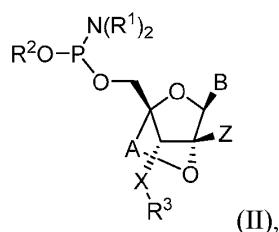
[0005] The present disclosure relates to compounds and compositions containing 5'-phosphoramidite nucleoside monomers, and methods of making and use.

[0006] The present disclosure is directed to compounds having a structure represented by Formula (I):



X is O or NH; Y is selected from the group consisting of O-PG , $-\text{O}(\text{CR}^4)_a\text{CR}^4_3$, $-\text{O}(\text{CR}^4)_b\text{OCR}^4_3$ and $-\text{O}(\text{CR}^4)_b\text{-CR}^4=\text{CR}^4_2$; Z is H; PG is a protecting group; B is a natural or an unmodified nucleobase or a modified nucleobase or a protected version thereof; each R^1 is independently C_{1-6} alkyl or cycloalkyl; R^2 is $\text{CH}_2\text{CH}_2\text{CN}$ or C_{1-6} alkyl; or one R^1 and R^2 together form an optionally substituted C_{1-6} cycloalkyl; R^3 is H or PG; R^4 is independently in each instance H or F; a is an integer of 0-2; and b is an integer of 1-3. In some embodiments, when X is O, then Y is $-\text{O}(\text{CR}^4)_a\text{CR}^4_3$, $-\text{O}(\text{CR}^4)_b\text{OCR}^4_3$ or $-\text{O}(\text{CR}^4)_b\text{-CR}^4=\text{CR}^4_2$.

[0007] The present disclosure is also directed to compounds having a structure represented by Formula (II):



X is O or NH; Z is H; B is a natural or an unmodified nucleobase or a modified nucleobase or a protected version thereof; R^1 is independently a C_{1-6} alkyl or cycloalkyl; R^2 is $\text{CH}_2\text{CH}_2\text{CN}$ or a C_{1-6} alkyl; or one R^1 and R^2 together form an optionally substituted C_{1-6} cycloalkyl; R^3 is H or a protecting group; A is $-(\text{CR}'\text{R}')_{1-2}$; and R' is independently in each instance H or Me.

[0008] In some embodiments, X is NH, Y is O-PG , OEt or O-methoxyethoxy and Z is H.

[0009] In some embodiments, R^1 is C_{2-3} alkyl. In some embodiments, R^1 is isopropyl.

[0010] In embodiments, R^3 is PG. In some embodiments, PG is trityl. In some embodiments, PG is monomethoxytrityl (MMTr) or trityl when X is NH. In some embodiments, PG is 4,4'-dimethoxytrityl (DMTr) or trityl when X is O.

[0011] In some embodiments, B is selected from adenine (A), guanine (G), thymine (T), cytosine (C), uracil (U) and 5-methylcytosine (5-me-C), or a protected version thereof. In some embodiments, B is selected from 6-N-benzoyladenosine (A^{Bz}), 4-N-benzoylcytidine (C^{Bz}), and 2-N-isobutyrylguanosine (G^{iBu}).

[0012] The present disclosure is also directed to a composition comprising at least one compound of Formula (I) or Formula (II). In embodiments, the composition further comprises one or more other agents selected from the group consisting of reactants, solvents and impurities. In embodiments, the composition comprises less than 5%, less than 4%, less than 3%, less than 2% or less than 1% impurities. In some embodiments, the composition has a purity of >95%, e.g., 96, 97, 98, 99%, or more.

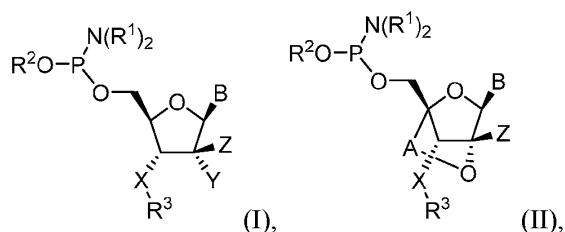
[0013] The present disclosure is further directed to methods of making an oligonucleotide comprising at least one modified nucleoside. The method comprises reacting a compound of Formula (I) with another monomer to form the oligonucleotide.

DETAILED DESCRIPTION

[0014] The present disclosure is described herein in greater detail.

Compounds of the Present Disclosure

[0015] Compounds of the present disclosure include one or more compounds of the following Formula (I) and/or (II):



wherein

X is O or NH; Y is selected from the group consisting of O-PG , $-\text{O}(\text{CR}^4)_a\text{CR}^4_3$, $-\text{O}(\text{CR}^4)_b\text{OCR}^4_3$ (e.g., OEt, O-methoxyethoxy, and OCF_3); Z is H; PG is a protecting group; B is a natural or an unmodified nucleobase or a modified nucleobase or a protected version thereof; each R^1 is independently C_{1-6} alkyl or cycloalkyl; R^2 is $\text{CH}_2\text{CH}_2\text{CN}$ or C_{1-6} alkyl; or one R^1 and R^2 together form an optionally substituted C_{1-6} cycloalkyl; R^3 is H or PG; R^4 is independently in each instance H or F; a is an integer of 0-2 (e.g., 0, 1 or 2); and b is an integer of 1-3 (e.g., 1, 2 or 3), A is $-(\text{CR}'\text{R}')_{1-2}-$; and R' is independently in each instance H or Me.

[0016] In some embodiments, when X is O, then Y is $-\text{O}(\text{CR}^4)_a\text{CR}^4_3$, $-\text{O}(\text{CR}^4)_b\text{OCR}^4_3$ or $-\text{O}(\text{CR}^4)_b\text{-CR}^4=\text{CR}^4_2$. In some embodiments, X is O, Y is OEt or O-methoxyethoxy and Z is H. In other embodiments, X is NH, Y is OP, OEt or O-methoxyethoxy and Z is H.

[0017] In nucleotides of Formula (I), Y is $-\text{O}(\text{CR}^4)_2\text{OCR}^4_3$. In some embodiments, R^4 is H in each instance. In other embodiments, at least one R^4 is F, for example, 1, 2, 3, 4, 5, 6, or 7 R^4 s are F. In some embodiments, CR^4_3 contains 1, 2 or 3 F atoms. For example, in embodiments, Y is selected from the group consisting of $-\text{OCH}_2\text{CH}_2\text{OCH}_3$ (or MOE), $-\text{OCF}_2\text{CH}_2\text{OCH}_3$, $-\text{OCH}_2\text{CF}_2\text{OCH}_3$, $-\text{OCH}_2\text{CH}_2\text{OCF}_3$, $-\text{OCF}_2\text{CF}_2\text{OCH}_3$, $-\text{OCH}_2\text{CF}_2\text{OCF}_3$, $-\text{OCF}_2\text{CH}_2\text{OCF}_3$, $-\text{OCF}_2\text{CF}_2\text{OCF}_3$, $-\text{OCHFCH}_2\text{OCH}_3$, $-\text{OCHFCHFOCH}_3$, $-\text{OCHFCH}_2\text{OCFH}_2$, $-\text{OCHFCH}_2\text{OCHF}_2$ and $-\text{OCH}_2\text{CHFOCH}_3$.

[0018] In the nucleotide of Formula (I), Y is $-\text{OCR}^4_3$, $-\text{O}(\text{CR}^4)_1\text{-OCR}^4_3$, or $-\text{O}(\text{CR}^4)_2\text{-CR}^4_3$. In some embodiments, Y is $-\text{OCR}^4_3$ or $-\text{OCR}^4_2\text{CR}^4_3$. In some embodiments, R^4 is H in each instance. In other embodiments, at least one R^4 is F, for example, 1, 2, 3, 4, or 5 R^4 s are F. In some embodiments, OCR^4_3 contains 1, 2 or 3 F atoms. For example, in embodiments, Y is selected from the group consisting of $-\text{OCH}_3$ (or Me), $-\text{OCFH}_2$, $-\text{OCHF}_2$, OCF_3 , $-\text{OCH}_2\text{OCH}_3$, $-\text{OCFH}_2\text{OCH}_3$, $-\text{OCHF}_2\text{OCH}_3$, $-\text{OCF}_3\text{OCH}_3$, $-\text{OCH}_2\text{OCFH}_2$, $-\text{OCH}_2\text{OCHF}_2$, $-\text{OCH}_2\text{OCF}_3$, $-\text{OCFH}_2\text{OCH}_3$, $-\text{OCFH}_2\text{OCFH}_2$, $-\text{OCFH}_2\text{OCHF}_2$, $-\text{OCFH}_2\text{OCF}_3$, $-\text{OCHF}_2\text{OCH}_3$, $-\text{OCHF}_2\text{OCFH}_2$, $-\text{OCHF}_2\text{OCHF}_2$, $-\text{OCHF}_2\text{OCF}_3$, $-\text{O}(\text{CR}^4)_3\text{OCR}^4_3$, $-\text{OCH}_2\text{CH}_3$ (or Et), $-\text{OCFH}_2\text{CH}_3$, $-\text{OCHF}_2\text{CH}_3$, $-\text{OCF}_3\text{CH}_3$, $-\text{OCH}_2\text{CFH}_2$, $-\text{OCH}_2\text{CHF}_2$, $-\text{OCH}_2\text{CF}_3$, $-\text{OCFH}_2\text{CH}_3$, $-\text{OCFH}_2\text{CFH}_2$, $-\text{OCFH}_2\text{CHF}_2$, $-\text{OCFH}_2\text{CF}_3$, $-\text{OCHF}_2\text{CH}_3$, $-\text{OCHF}_2\text{CFH}_2$, $-\text{OCHF}_2\text{CHF}_2$, $-\text{OCHF}_2\text{CF}_3$, $-\text{OCH}_2\text{CH}_2\text{CH}_3$, $\text{OCF}_2\text{CH}_2\text{CH}_3$, $\text{OCH}_2\text{CF}_2\text{CH}_3$, $\text{OCH}_2\text{CH}_2\text{CF}_3$, $\text{OCF}_2\text{CF}_2\text{CH}_3$, $\text{OCH}_2\text{CF}_2\text{CF}_3$, $\text{OCF}_2\text{CH}_2\text{CF}_3$, $\text{OCF}_2\text{CF}_2\text{CF}_3$, $\text{OCHFCH}_2\text{CH}_3$, OCHFCHFOCH_3 , $\text{OCHFCH}_2\text{CFH}_2$, $\text{OCHFCH}_2\text{CHF}_2$ and $\text{OCH}_2\text{CHFCH}_3$. In embodiments, Y is $-\text{OCH}_3$ (or Me) or $-\text{OCH}_2\text{CH}_3$ (or Et).

[0019] In some embodiments of Formula (I), Y is $-\text{O}(\text{CR}^4)_b\text{-CR}^4=\text{CR}^4_2$. In some embodiments, b is 1, 2 or 3. In some embodiments, R^4 is H in each instance. In other embodiments, at least one R^4 is F, for example, 1, 2, 3, 4, 5, 6, or 7 R^4 s are F. In some embodiments, a CR^4_2 contains 1 or 2 F atoms, e.g. an internal R^4_2 contains 1 or 2 F atoms, or the terminal R^4_2 contains 1 or 2 F atoms.

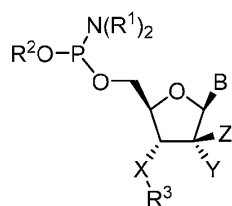
[0020] In some embodiments, R^1 is a C_{2-3} alkyl (e.g., an ethyl or isopropyl).

[0021] In some embodiments, R^3 is a protecting group, PG. Protecting groups may include an amine or alcohol protecting group, such as a silyl protecting group (e.g., tert-Butyldimethylsilyl ether (TBMDS), tert-Butyldiphenylsilyl (TBDPS), Triisopropylsilyl ether (TIPS)) or monomethoxytrityl (MMTr) or 4,4'-dimethoxytrityl (DMTr) or tritoyl or any other suitable protecting groups such as those in Wuts, Peter GM, and Theodora W. Greene. *Greene's protective groups in organic synthesis*. John Wiley & Sons, 2006. In some embodiments, when more than one alcohol and/or amine is protected, the alcohols and/or amines may be orthogonally protected.

[0022] In compounds of Formula (II), A is $-(CR'R')_{1-2}-$. In some embodiments, A is $-(CR'R')-$ in other embodiments, A is $-(CR'R')_2-$. R' is independently in each instance H or Me. In some embodiments, one R' is Me and the remaining R' are H. In other embodiments all R' are H. In some embodiments, X is NH in Formula (II). In some embodiments, A is not $-(CR'R')_1-$ when $R'=H$ and $X=NH$.

[0023] The natural or unmodified nucleobase or a modified nucleobase or a protected version thereof is not particularly limited. In some embodiments, B is selected from purine bases, such as, adenine (A) and guanine (G), diaminopurine (DAP) and pyrimidine bases, such as, thymine (T), cytosine (C) and uracil (U) and/or other synthetic and natural nucleobases such as 5-methylcytosine (5-me-C), 5-hydroxymethyl cytosine. In some embodiments, B is a protected nucleobase, such as a protected U, T, C, 5meC, A or G. Protection moieties are known in the art, and are not particularly limited, but include, for example, amino protecting groups (e.g., acetamide protecting groups, such as benzamide and isobutyramide). In some embodiments, B is 6-N-benzoyl adenosine (A^{Bz}), 4-N-Benzoylcytidine (C^{Bz}), 2-N-isobutyrylguanosine (G^{iBu}).

[0024] In some embodiments, the compound is selected from the following table.

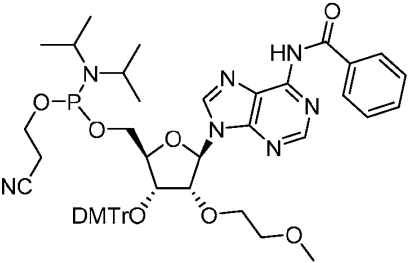
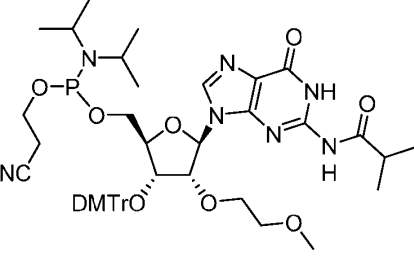
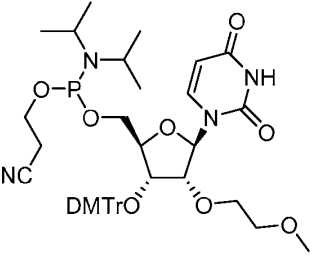
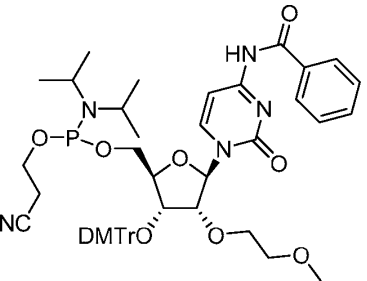
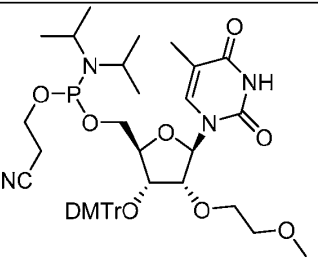
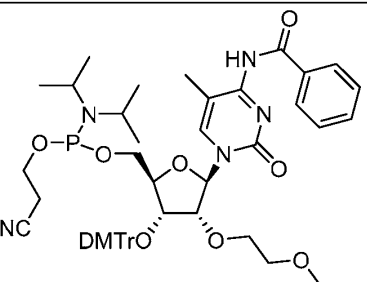


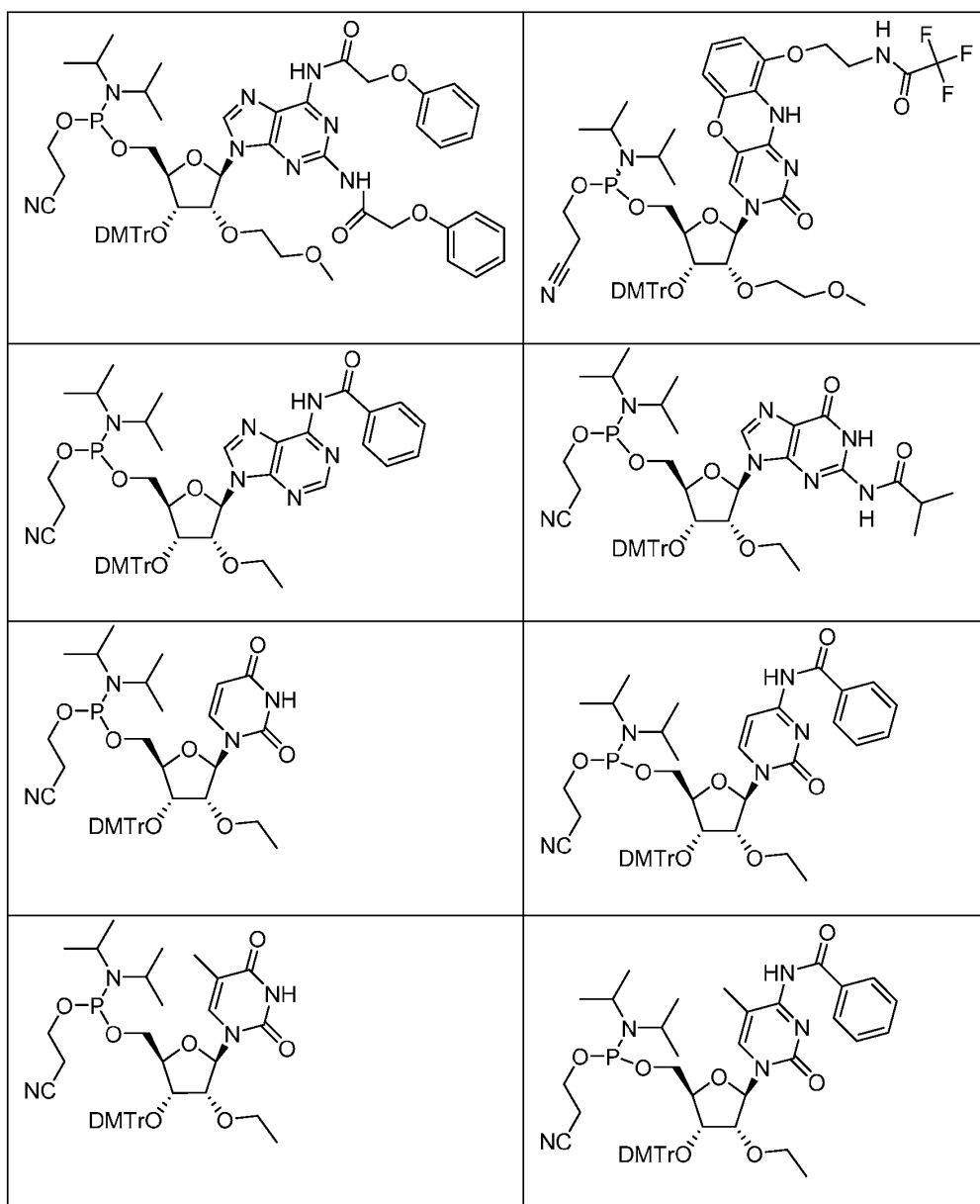
X	Y	Z	B	R^1	R^2	R^3
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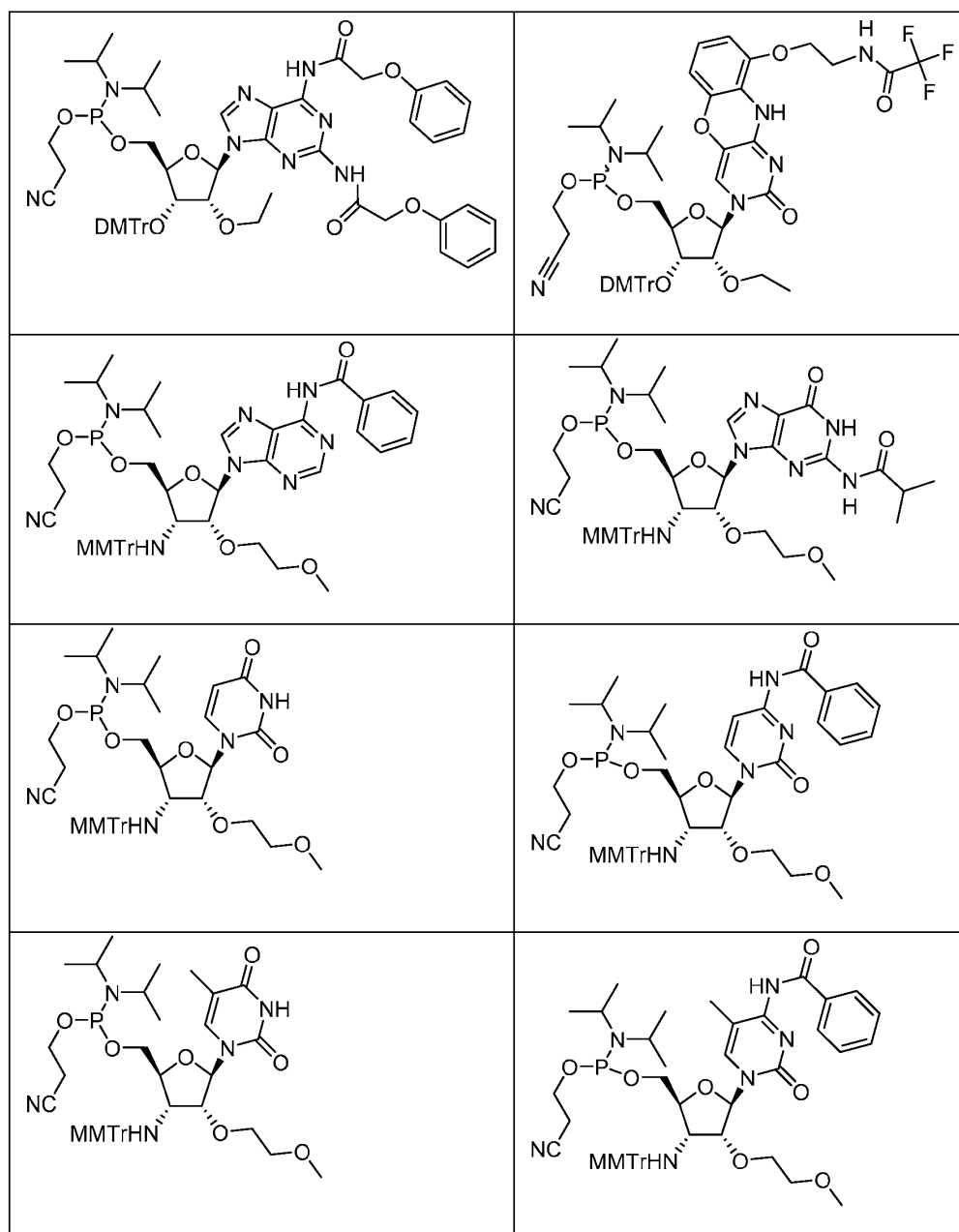
NH	OP	H	U/T/C/5meC/A/G/DAP	iPr	CH ₂ CH ₂ CN	MMTr
NH	OE _t	H	U/T/C/5meC/A/G/DAP	iPr	CH ₂ CH ₂ CN	MMTr
NH	<i>O</i> -methoxyethyl	H	U/T/C/5meC/A/G/DAP	iPr	CH ₂ CH ₂ CN	MMTr
NH	OCF ₃	H	U/T/C/5meC/A/G/DAP	iPr	CH ₂ CH ₂ CN	MMTr
O	OE _t	H	U/T/C/5meC/A/G/DAP	iPr	CH ₂ CH ₂ CN	DMTr
O	<i>O</i> -methoxyethyl	H	U/T/C/5meC/A/G/DAP	iPr	CH ₂ CH ₂ CN	DMTr

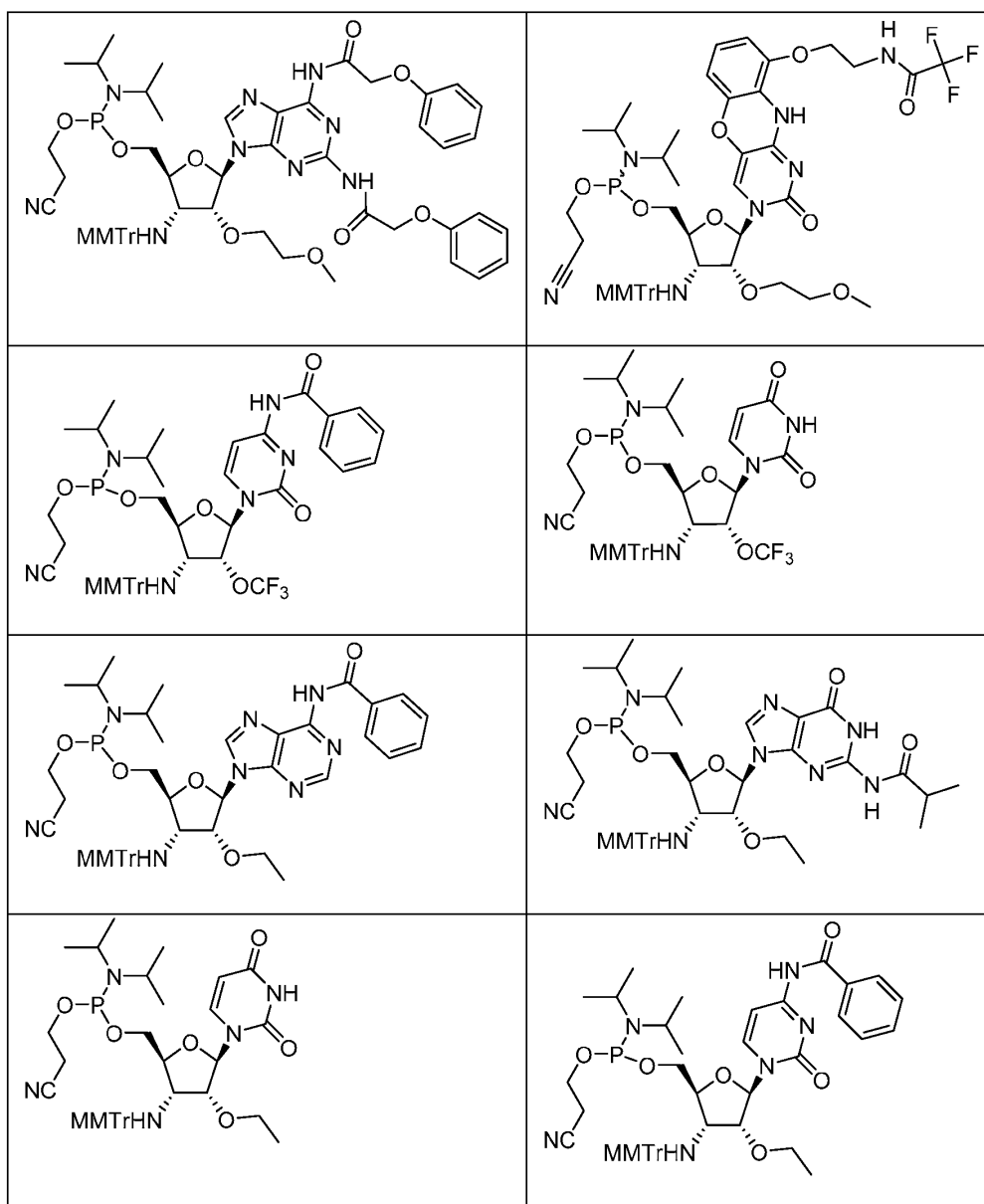
*B may be a protected nucleobase (e.g., A^{Bz}, C^{Bz}, G^{iBu}).

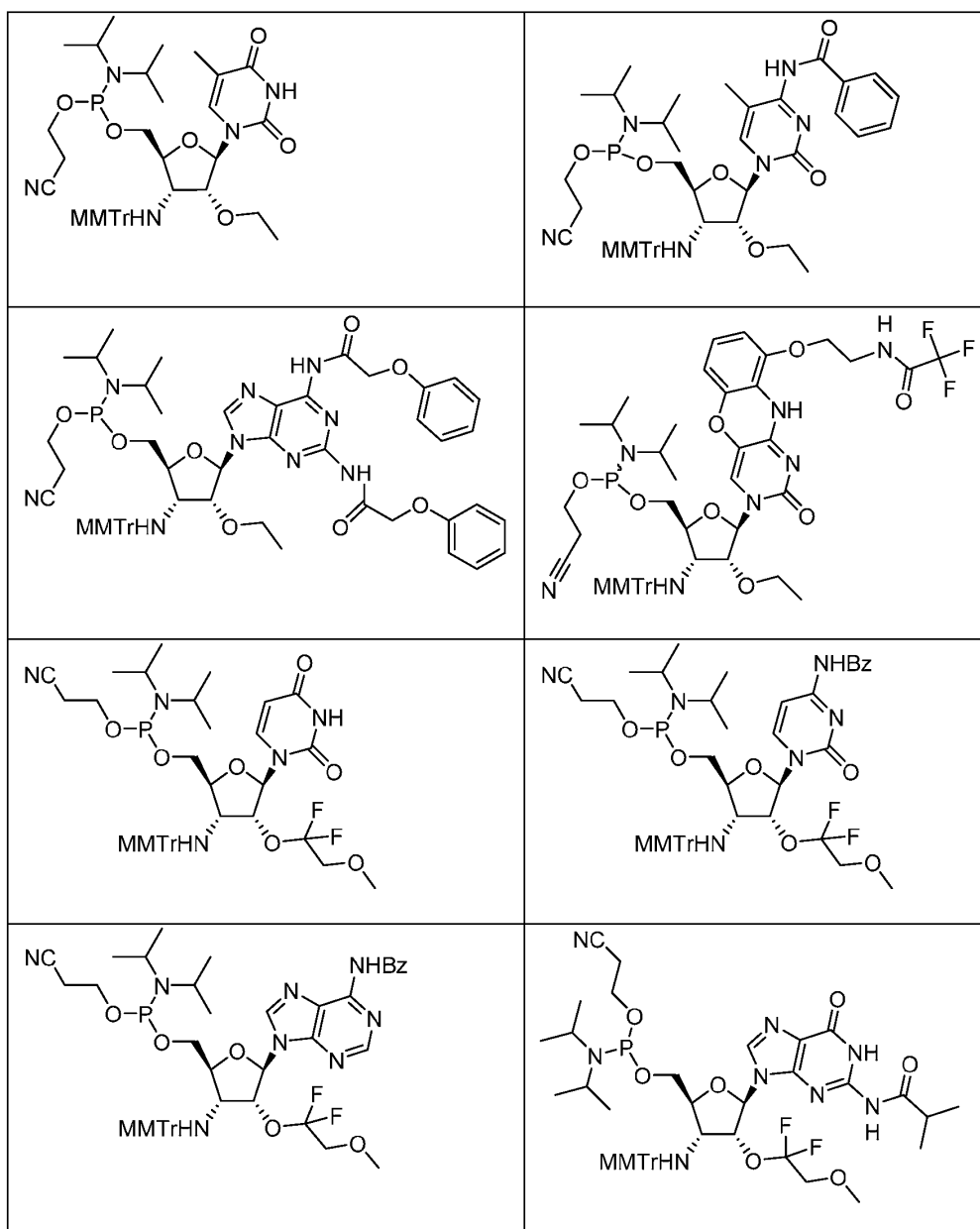
[0025] In some embodiments, the compound is selected from the following table.

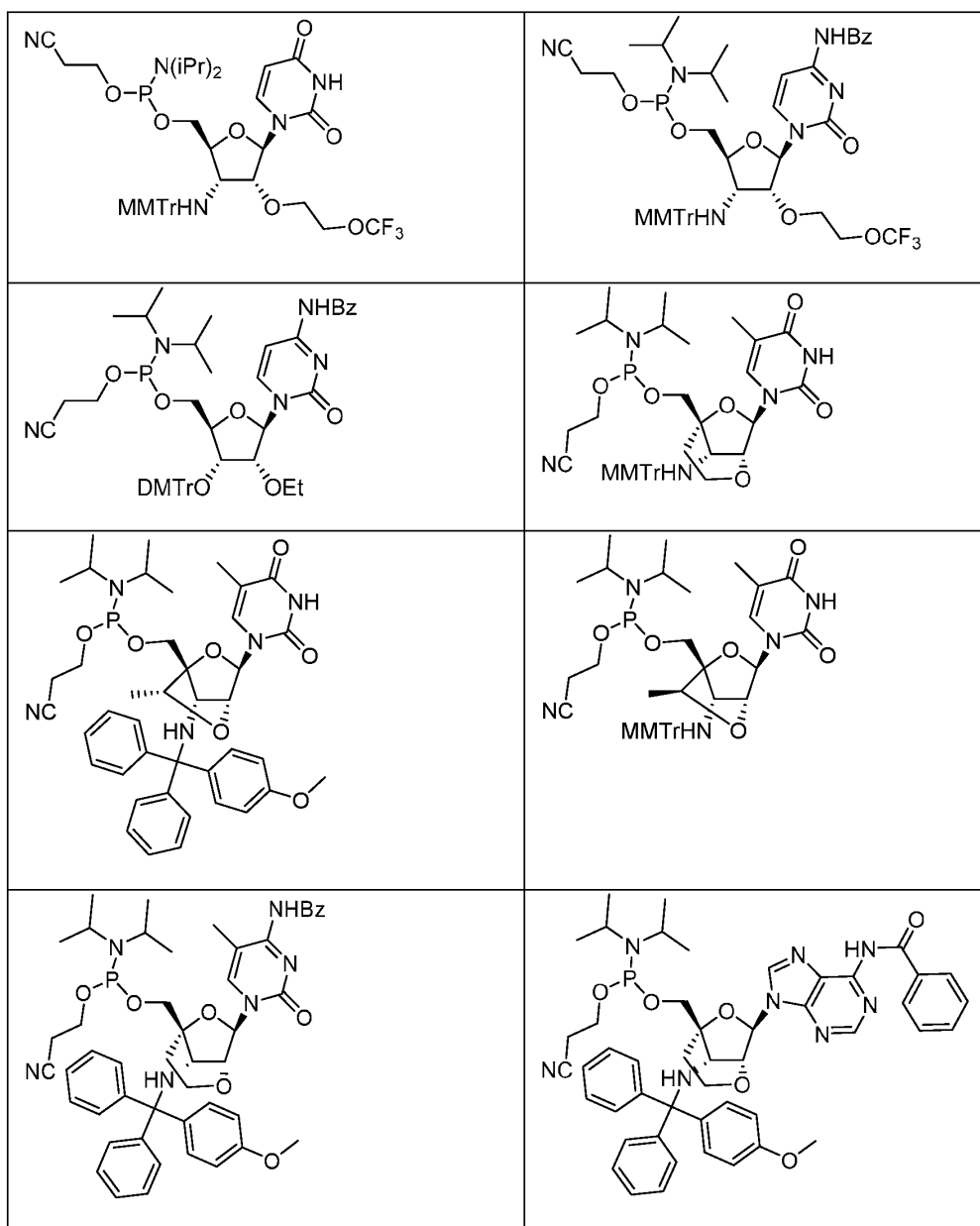
	
	
	

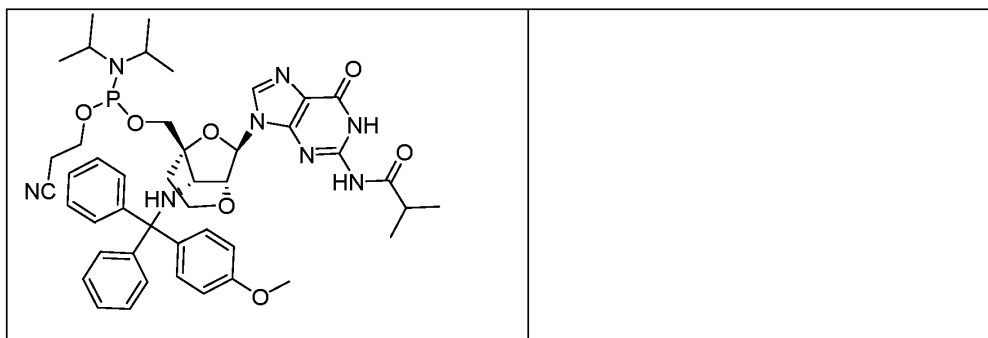












Compositions

[0026] The present disclosure also encompasses compositions comprising a compound of the present disclosure and one or more reactants or solvents or impurities.

[0027] In some embodiments, the compositions comprising a compound of the present disclosure have a purity of 95%, 96%, 97%, 98%, 99%, 99.5%, 99.6%, 99.7%, 99.8%, 99.9%, 99.95% or more.

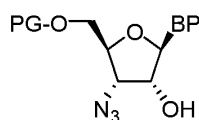
Methods of Use

[0028] The compositions of the present disclosure may be used as synthetic precursors for oligonucleotides comprising modified nucleosides, e.g., those in U.S. Provisional Applications 62/420801, 62/394737, 62/394738 and 62/394739, each of which is incorporated by reference. The modified oligonucleotides may be synthesized by methods in the art, e.g., on an ABI-394 synthesizer using the 93-step cycle written with modifications to deblock, coupling and wait steps. The solid support can be 3'-NHTr-5'-LCAA-CPG. Each oligonucleotide is individually synthesized using methods described herein.

Methods of Making

[0029] The compositions of the present disclosure may be synthesized by synthetic procedures such as those set forth in the below Examples.

[0030] Some embodiments include 2'-O-alkylation of a starting material, such as the following:



where PG is a protecting group, such as trityl and BP is a protected nucleobase, protected with, e.g., PMB. The compound is alkylated, followed by deprotection of the PGO and reprotection with, e.g., a Bz moiety, followed by deprotection of the nucleobase and subsequent conversion of the N₃ to N-R₃.

[0031] Some embodiments include protection of a compound, such as that in the previous paragraph where the nucleobase is a purine, with C-6-OBn. In some embodiments, this reduces de-purination during deprotection of, e.g., 5'-O-DMTr and C-2-NH-MMTr group under acidic conditions. Other embodiments include protection of the exocyclic amine group in a compound, such as that in the previous paragraph where the nucleobase is a purine, with a bulky protecting group such as 4-monomethoxy trityl group to achieve 2'-O-alkylation in high yield.

[0032] Some embodiments include protection of a compound, such as that in the previous paragraph where the nucleobase is a pyrimidine to achieve 2'-O-alkylation by protecting the pyrimidine with a PMB moiety.

Definitions

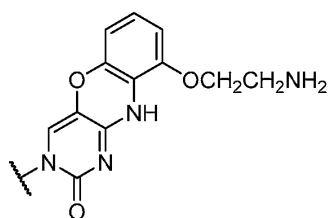
[0033] It is to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to limit the scope of the present invention. The following definitions shall apply unless otherwise indicated.

[0034] "Pharmaceutically acceptable" refers to a material that is not biologically or otherwise undesirable, i.e., the material may be incorporated into a pharmaceutical composition administered to a patient without causing any undesirable biological effects or interacting in a deleterious manner with any of the other components of the composition in which it is contained. When the term "pharmaceutically acceptable" is used to refer to a pharmaceutical carrier or excipient, it is implied that the carrier or excipient has met the required standards of toxicological and manufacturing testing or that it is included on the Inactive Ingredient Guide prepared by the U.S. and Drug administration.

[0035] “Modified nucleoside” refers to a nucleoside having, independently, a modified sugar moiety and/or modified nucleobase.

[0036] “Unmodified” or “natural” nucleobases include the purine bases adenine (A) and guanine (G), and the pyrimidine bases thymine (T), cytosine (C) and uracil (U). “Modified nucleobases” include other synthetic and natural nucleobases such as 5-methylcytosine (5-me-C), 5-hydroxymethyl cytosine, xanthine, hypoxanthine, 2-aminoadenine, 6-methyl and other alkyl derivatives of adenine and guanine, 2-propyl and other alkyl derivatives of adenine and guanine, 2-thiouracil, 2-thiothymine and 2-thiocytosine, 5-halouracil and cytosine, 5-propynyl ($\text{C}\equiv\text{C}-\text{CH}_3$) uracil and cytosine and other alkynyl derivatives of pyrimidine bases, 6-azo uracil, cytosine and thymine, 5-uracil (pseudouracil), 4-thiouracil, 8-halo, 8-amino, 8-thiol, 8-thioalkyl, 8-hydroxyl and other 8-substituted adenines and guanines, 5-halo particularly 5-bromo, 5-trifluoromethyl and other 5-substituted uracils and cytosines, 7-methylguanine and 7-methyladenine, 2-F-adenine, 2-amino-adenine, 8-azaguanine and 8-azaadenine, 7-deazaguanine and 7-deazaadenine and 3-deazaguanine and 3-deazaadenine. Further modified nucleobases include tricyclic pyrimidines such as phenoxazine cytidine (1H-pyrimido[5,4-b][1,4]benzoxazin-2(3H)-one), phenothiazine cytidine (1H-pyrimido[5,4-b][1,4]benzothiazin-2(3H)-one), G-clamps such as a substituted phenoxazine cytidine (e.g. 9-(2-aminoethoxy)-H-pyrimido[5,4-b][1,4]benzoxazin-2(3H)-one), carbazole cytidine (2H-pyrimido[4,5-b]indol-2-one), pyridoindole cytidine (H-pyrido[3,2,5]pyrrolo[2,3-d]pyrimidin-2-one). Modified nucleobases may also include those in which the purine or pyrimidine base is replaced with other heterocycles, for example 7-deaza-adenine, 7-deazaguanosine, 2-aminopyridine and 2-pyridone.

[0037] In some embodiments, the modified nucleobase is selected from the group consisting of 5-methylcytosine, 2,6-diaminopurine, 5-methyluracil, and a g-clamp. In some embodiments, the g-clamp is



[0038] It is noted that, as used herein and in the appended claims, the singular forms "a", "an", and "the" include plural referents unless the context clearly dictates otherwise. It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis for use of such exclusive terminology as "solely", "only" and the like in connection with the recitation of claim elements, or use of a "negative" limitation.

[0039] The term "about" will be understood by persons of ordinary skill in the art and will vary to some extent depending upon the context in which it is used. If there are uses of the term which are not clear to persons of ordinary skill in the art given the context in which it is used, "about" will mean up to plus or minus 10% of the particular term. Certain ranges are presented herein with numerical values being preceded by the term "about". The term "about" is used herein to provide literal support for the exact number that it precedes, as well as a number that is near to or approximately the number that the term precedes. In determining whether a number is near to or approximately a specifically recited number, the near or approximating unrecited number may be a number, which, in the context in which it is presented, provides the substantial equivalent of the specifically recited number.

[0040] Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limit of that range and any other stated or intervening value in that stated range, is encompassed within the invention. The upper and lower limits of these smaller ranges may independently be included in the smaller ranges and are also encompassed within the invention, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the invention.

[0041] This disclosure is not limited to particular embodiments described, as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present invention will be limited only by the appended claims.

[0042] As will be apparent to those of skill in the art upon reading this disclosure, each of the individual embodiments described and illustrated herein has discrete components and features which may be readily separated from or combined with the features of any of the other several

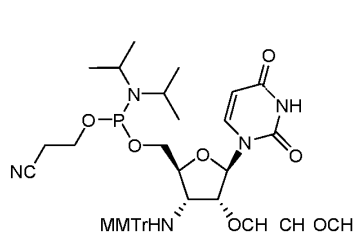
embodiments without departing from the scope or spirit of the present invention. Any recited method can be carried out in the order of events recited or in any other order that is logically possible.

[0043] All publications and patents cited in this specification are herein incorporated by reference as if each individual publication or patent were specifically and individually indicated to be incorporated by reference and are incorporated herein by reference to disclose and describe the methods and/or materials in connection with which the publications are cited. The citation of any publication is for its disclosure prior to the filing date and should not be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided may be different from the actual publication dates that may need to be independently confirmed.

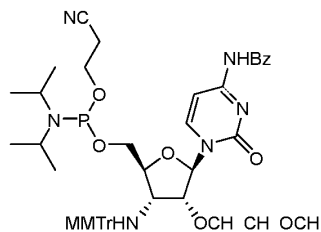
Examples

[0044] The following examples illustrate certain embodiments of the present disclosure to aid the skilled person in practicing the disclosure. Accordingly, the examples are in no way considered to limit the scope of the disclosure.

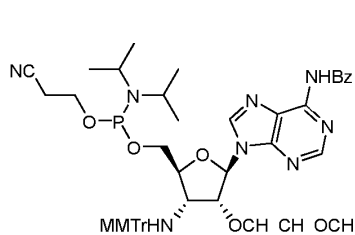
Examples 1-4



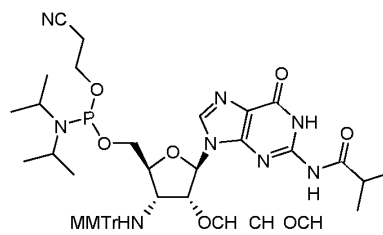
Example 1



Example 2



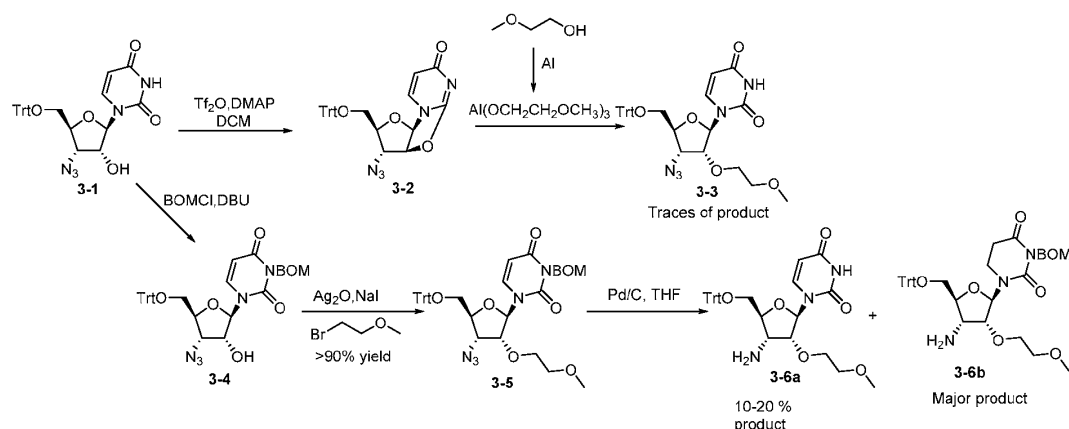
Example 3



Example 4

[0045] The appropriately protected 2'-O-methoxy ethyl-3'-aminonucleoside-5'-phosphoramidite building blocks (examples 1, 2, 3, and 4 were prepared after chemical transformations shown in Schemes 1, 2, 3, 4, and 5.

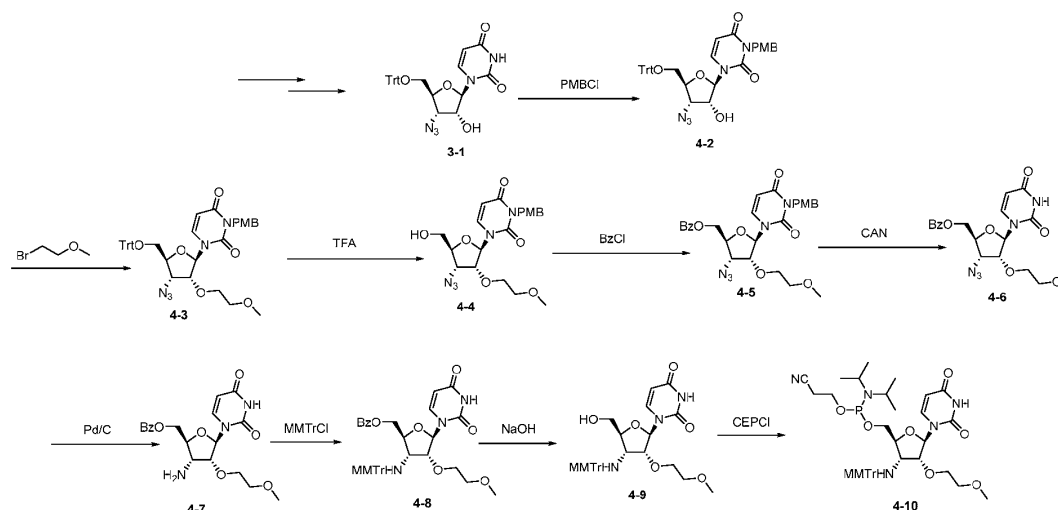
Scheme 1



[0046] Scheme 1 discloses synthesis of uracil-based 3'-NH-MMTr-2'-O-methoxyethyl phosphoramidites (such as example 1). The key 3'-azido-2'-methoxyethyl Intermediate **3-3** was obtained in low yields via anhydrous Intermediate **3-2**.

[0047] Due to low yielding alkylation, **3-1** was reacted with BOMCl/DBU to give N-3 protected Intermediate **3-4**, which was alkylated by using 2-bromoethyl methyl ether/ Ag_2O / NaI/DMF to give 2'-O-methoxyethyl derivative **3-5**. Deprotection of N-3-BOM group using hydrogenation condition (Pd/C/ H_2) resulted in 10-20% desired 3'-amino Intermediate **3-6a** along with significant over reduced side product **3-6b**.

Scheme 2



[0048] Scheme 2 discloses an alternative approach to achieve 2'-O-alkylation in high yield. Intermediate **3-1** was treated with PMBCl/ DBU/ DMF to give N-3 protected Intermediate **4-2**, which was subjected to 2'-O alkylation using 2-bromoethyl methyl ether/ Ag₂O/ NaI/DMF to provide a 2'-O-methoxyethyl derivative (Intermediate **4-3**). 5'-de-tritylation of Intermediate **4-3** and re-protection of its 5'-hydroxyl group using benzoyl chloride provided Intermediate **4-5**.

[0049] De-protection of PMB group of Intermediate **4-5** in mild conditions to give Intermediate **4-6**. 3'-azido group of intermediate **4-6** was reduced to an amine, which was then immediately protected, such as reaction with 4-monomethoxytritylchloride, to give **4-8**. The 5'-benzyl ester was then cleaved using an alkaline solution, followed by phosphitylation using known methods to give the desired 2'-O-methoxyethoxy uridine phosphoramidite monomer **4-10**.

[0050] Preparation of Intermediate (4-2): To a solution of **3-1** (45.30 g, 88.56 mmol) in DMF (120.00 mL) was added PMBCl (20.80 g, 132.84 mmol) and DBU (44.61 g, 177.12 mmol), the mixture was stirred at r.t. for 2 h. Water was added, extracted with EA. The organic layer was concentrated and purified by column to give **4-2** (52.00 g, 82.32 mmol) as a white solid. ESI-LCMS: m/z 632.3 [M+H]⁺.

[0051] Preparation of Intermediate (4-3): To a solution of **4-2** (50.00 g, 79.15 mmol) in DMF (120.00 mL) was added 2-Bromoethyl methyl ether (16.50 g, 118.73 mmol) and Ag₂O (18.34 g, 79.15 mmol, 2.57 mL), then NaI (5.93 g, 39.58 mmol) was added. The reaction mixture was

stirred at r.t. for 12 h. LC-MS showed work well. Filtered and added water and EA, the organic layer was concentrated and purified by column to give **4-3** (52.00 g, 75.39 mmol) as a colorless oil. ESI-LCMS: m/z 690.4 $[M+H]^+$.

[0052] Preparation of Intermediate (4-4): To a solution of **4-3** (52.00 g, 75.39 mmol) in DCM (200.00 mL) was added TFA (150.00 mL). The mixture was stirred at r.t. for 1 h. The reaction mixture was slowly added to cold NH_4OH , extracted with DCM. The organic layer was concentrated and purified to give **4-4** (31.00 g, 69.28 mmol) as a colorless oil. ESI-LCMS: m/z 448.2 $[M+H]^+$. 1H -NMR ($DMSO-d_6$, 400MHz): δ ppm 8.02 (d, $J = 8.12$ Hz, 1H), 7.26-7.23 (m, 2H), 6.87-6.84 (m, 2H), 5.87-5.81 (m, 2H), 5.38 (t, $J = 5.0$ Hz, 1H), 4.96-4.85 (m, 2H), 4.36-4.34 (m, 1H), 4.17-4.14 (m, 1H), 4.00-3.97 (m, 1H), 3.83-3.77 (m, 1H), 3.75-3.72 (m, 1H), 3.71 (s, 3H), 3.70-3.68 (m, 1H), 3.61-3.56 (m, 1H), 3.45-3.43 (m, 2H), 3.18 (s, 3H).

[0053] Preparation of Intermediate (4-5): To a solution of **4-4** (31.00 g, 69.28 mmol) in Pyridine (200.00 mL) was added $BzCl$ (13.14 g, 93.87 mmol), the reaction mixture was stirred at r.t. for 15 min and concentrated and purified by column to give **4-5** (35.10 g, 63.8 mmol) as a white solid. ESI-LCMS: m/z 552.2 $[M+H]^+$.

[0054] Preparation of Intermediate (4-6): To a solution of **4-5** (35.10 g, 63.8 mmol) in acetonitrile (300.00 mL) and water (100.00 mL) was added Ceric ammonium nitrate (105 g, 191.40 mmol), the reaction mixture was stirred at r.t. for 12 h and concentrated and extracted with EA. The organic layer was concentrated and purified by column to give **4-6** (27.5 g, 63.75 mmol) as a yellow solid. ESI-LCMS: m/z 432.2 $[M+H]^+$.

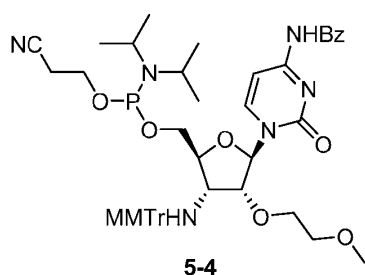
[0055] Preparation of Intermediate (4-7): To a solution of **4-6** (27.50 g, 63.75 mmol) in THF (500.00 mL) was added Pd/C (3.00 g), the reaction mixture was stirred at r.t. for 12 h and filtered and concentrated to give **4-7** (25.00 g, 61.67 mmol) as a yellow solid. ESI-LCMS: m/z 406.2 $[M+H]^+$.

[0056] Preparation of Intermediate (4-8): To a solution of **4-7** (25.00 g, 61.67 mmol) in DCM (300.00 mL) was added $MMTrCl$ (28.49 g, 92.51 mmol) and Collidine (14.95 g, 123.34 mmol), then $AgNO_3$ (15.7 g, 92.5 mmol) was added. The reaction mixture was stirred at r.t. for 1 h., and filtered and the organic layer was washed water, dried over Na_2SO_4 and purified by silica gel column to give **4-8** (33.00 g, 48.69 mmol) as a yellow solid.

[0057] Preparation of Intermediate (4-9): To a solution of **4-8** (14.50 g, 21.39 mmol) was added 1 N NaOH in methanol (200 mL) in water (20 mL), the reaction mixture was stirred at r.t. for 1 h. and concentrated and extracted with DCM, the organic layer was concentrated and purified by silica gel column to give **4-9** (11.50 g, 20.05 mmol) as a white solid. $^1\text{H-NMR}$ ($\text{DMSO-}d_6$, 400MHz): δ ppm 11.26 (s, 1H), 7.95 (d, $J = 8.4\text{Hz}$, 1H), 7.47-7.44 (m, 4H), 7.34-7.17 (m, 8H), 6.82 (d, $J = 8.8\text{Hz}$, 2H), 5.50-5.48 (m, 2H), 5.13 (t, $J = 3.6\text{Hz}$, 1H), 4.05-3.98 (m, 3H), 3.78 (s, 3H), 3.52-3.49 (m, 1H), 3.34-3.32 (m, 2H), 3.14 (s, 3H), 3.08-3.04 (m, 1H), 2.89-2.86 (m, 1H), 2.70 (d, $J = 10.0\text{ Hz}$, 1H), 1.51 (d, $J = 4.4\text{Hz}$, 1H).

[0058] Preparation of (4-10): To a solution of **4-9** (11.50 g, 20.05 mmol) in DCM (100.00 mL) was added DMAP (489.85 mg, 4.01 mmol) and DIPEA (10.36 g, 80.19 mmol, 14.01 mL). Then CEPCl (5.70 g, 24.06 mmol) was added to the solution. The mixture was stirred at r.t. for 30 min. The reaction was quenched with saturated NaHCO_3 . The organic layer was washed with brine, dried over Na_2SO_4 , concentrated to give the crude product. The crude product was purified by Flash-Prep-HPLC. The product was dissolved in anhydrous toluene and concentrated for three times. Then the product was dissolved anhydrous acetonitrile and concentrated for three times. This resulted in 13 g to give **4-10** as a white solid. MS m/z $[\text{M-H}]^-$ (ESI): 772.3; $^1\text{H-NMR}$ (CDCl_3 , 400MHz): 9.01(s, 1H), 8.07-7.61(m, 1H), 7.53-7.41(m, 6H), 7.29-7.15 (m, 5H), 6.79-6.76 (m, 2H), 5.63-5.57 (m, 2H), 4.27-4.15 (m, 2H), 4.06-3.95 (m, 1H), 3.85-3.77(m, 1H), 3.75(s, 3H), 3.69-3.35(m, 7H), 3.23(d, $J=4\text{Hz}$, 1H), 2.26-2.91(m, 3H), 2.59(t, $J = 6.4\text{Hz}$, 1H), 1.75-1.39(m, 1H), 1.21-1.11(m, 12H). $^{31}\text{PNMR}$ (162 MHz, CDCl_3): 149.10, 148.26.

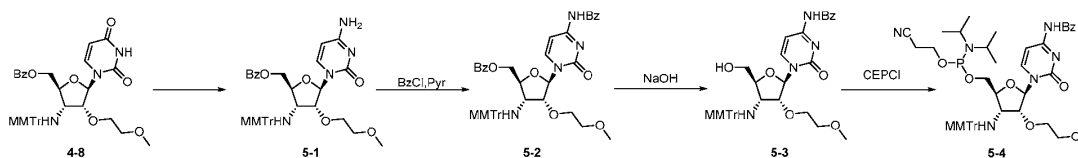
Example 2



[0059] The 2'-O-methoxyethoxy-NH-benzoyl- cytosine phosphoramidite compound **5-4** was obtained by conversion of uridine intermediate 4-8 into 3'-amino cytidine analogue 5-1 followed

by phosphitylation using known protocols to give the desired 2'-O-methoxyethoxy cytidine phosphoramidite monomer **5-4** as shown below in scheme 3.

Scheme 3



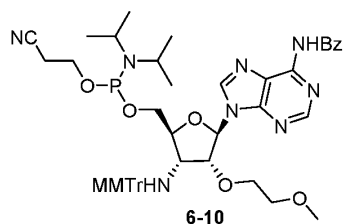
[0060] Preparation of Intermediate (5-1): To a solution of **4-8** (18.50 g, 27.30 mmol) in acetonitrile (250.00 mL) was added TPSCl (16.49 g, 54.60 mmol) and DMAP (6.67 g, 54.60 mmol), then TEA (5.52 g, 54.60 mmol, 7.56 mL) was added to the solution. The reaction mixture was stirred at r.t. for 5 h under N₂. NH₄OH (50.00 mL) was added to the reaction mixture. The mixture was stirred at r.t. for 12 h. The solution was concentrated and extracted with EA. The organic layer was washed by brine and dried over Na₂SO₄. The organic layer was concentrated and purified by silica gel column to give **5-1** (16.00 g, 23.64 mmol) as a yellow solid.

[0061] Preparation of Intermediate (5-2): To a solution of **5-1** (16.00 g, 23.64 mmol) in Pyridine (100.00 mL) was added BzCl (4.96 g, 35.46 mmol) at 0 °C. The mixture was stirred at r.t. for 1 h. The solution was concentrated and purified by silica gel column to give **5-2** (17.40 g, 22.28 mmol) as a white solid.

[0062] Preparation of Intermediate (5-3): Compound **5-2** (17.40 g, 22.28 mmol) was added to 180 mL of 1 N NaOH solution in Pyridine/MeOH/H₂O (65/30/5) at 0 °C. The suspension was stirred at 0 °C for 15 min. The reaction mixture was quenched by addition of sat. NH₄Cl solution. The solution was extracted with EA and the combined organic layers were washed with sat. NaHCO₃ solution, brine, dried over Na₂SO₄, filtered and concentrated. The residue was purified by column to give **5-3** (12.50 g, 18.47 mmol) as white solid. ¹H-NMR (DMSO-*d*₆, 400MHz): δ ppm 12.25 (s, 1H), 8.53 (d, *J* = 7.6Hz, 1H), 8.01 (d, *J* = 5.2Hz, 2H), 7.64-7.60 (m, 1H), 7.52-7.42 (m, 6H), 7.31 (d, *J* = 8.8Hz, 2H), 7.26-7.14 (m, 7H), 6.79 (d, *J* = 8.8Hz, 2H), 5.55 (s, 1H), 5.23 (t, *J* = 3.6Hz, 1H), 4.09-3.97 (m, 3H), 3.73 (s, 3H), 3.70-3.66 (m, 1H), 3.38-3.34 (m, 2H), 3.17 (s, 3H), 3.11-3.05 (m, 1H), 2.96-2.91 (m, 1H), 2.68 (d, *J* = 10.8Hz, 1H), 1.49 (d, *J* = 4Hz, 1H).

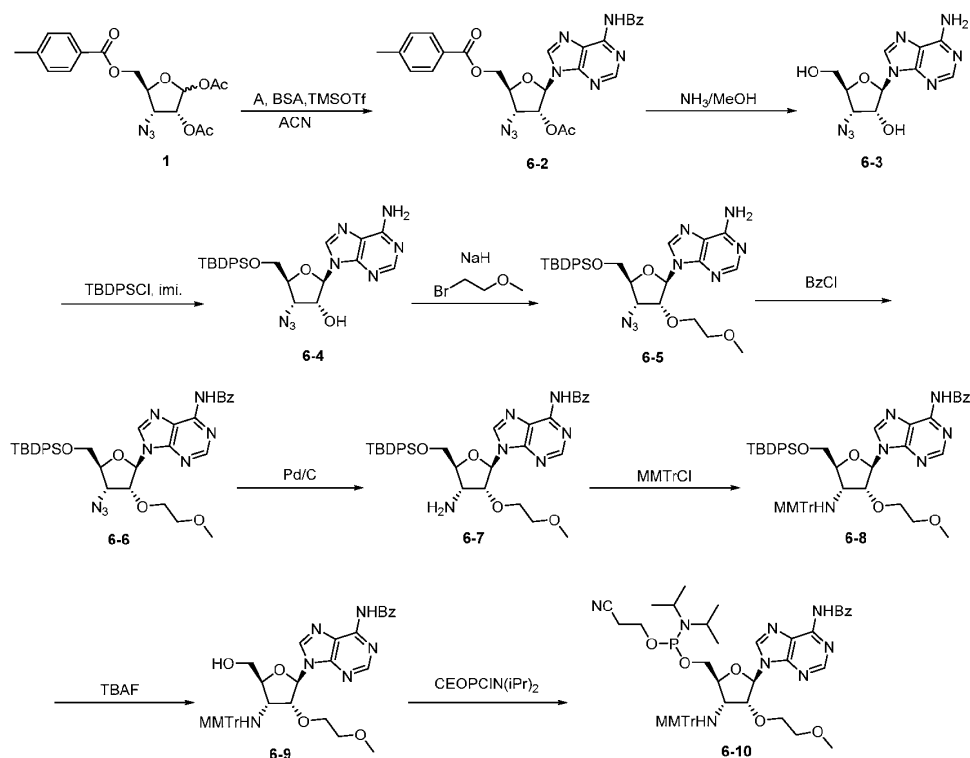
[0063] Preparation of (5-4): To a solution of **5-3** (12.50 g, 18.47 mmol) in DCM (100.00 mL) was added DMAP (451.30 mg, 3.69 mmol) and DIPEA (9.55 g, 73.88 mmol, 12.90 mL), then CEPCl (5.25 g, 22.16 mmol) was added. The mixture was stirred at r.t. for 30 min. The reaction was quenched with saturated NaHCO₃. The organic layer was washed with brine, dried over Na₂SO₄, concentrated to give the crude product. The crude was by Flash-Prep-HPLC. The product was dissolved in anhydrous toluene and concentrated for three times. Then the product was dissolved anhydrous acetonitrile and concentrated for three times. This resulted in 13 g to give **5-4** as a white solid. MS m/z [M-H]⁻ (ESI): 875.4. ¹H-NMR (400 MHz, CDCl₃): δ ppm 8.64-8.20 (m, 2H), 7.90-7.88 (m, 2H), 7.62-7.58 (m, 1H), 7.53-7.39 (m, 8H), 7.25-7.15 (m, 6H), 6.78-6.74 (m, 2H), 5.69 (d, *J*=1.72Hz, 1H), 4.37-4.21 (m, 2H), 4.10-4.03 (m, 1H), 3.90-3.79 (m, 2H), 3.75 (d, *J*=1.64Hz, 3H), 3.68-3.52 (m, 3H), 3.46-3.42 (m, 2H), 3.26 (d, *J*=1.2Hz, 3H), 3.17-2.97 (m, 2H), 2.94-2.87 (m, 1H), 2.67-2.48 (m, 2H), 1.79-1.51(m, 1H), 1.26-1.18 (m, 12H). ³¹PNMR (162 MHz, CDCl₃): 148.93, 148.03

Example 3



[0064] The synthesis of the 2'-O-methoxyethyl adenosine analogue **6-10** was achieved as shown below in scheme 4. The intermediate 6-2 under basic condition (NH₃/MeOH) resulted in diol 6-3, which then upon protection of 5'-hydroxy group using TBDPSCl to give 6-4. Intermediate 6-4. Then, 2'-O alkylation of 6-4 using 2-bromoethyl methyl ether/NaH/DMF to give 2'-O-methoxyethyl derivative 6-5 without the protection of C-6-exocyclic amine of 6-4. In an inventive way selective alkylation of 2'-OH group of intermediate 6-4 was achieved.

Scheme 4



[0065] 3'-Azido group of intermediate 6-5 was reduced to the amine 6-7, which was then immediately protected, such as reaction with 4-monomethoxytritylchloride, to give the precursor 6-8 after de-protection of 5'-OTBDPS group using TBAF/THF. The phosphitylation of 6-9 using known protocols to give the desired 2'-O-methoxyethoxy adenine-NH-benzoyl phosphoramidite monomer 6-10.

[0066] **Preparation of Intermediate (6-2):** To a solution of compound **1** (79.50 g, 210.68 mmol) in dry ACN (1.20 L) was added N-(5H-Purin-6-yl)benzamide (100.80 g, 421.36 mmol) and BSA (180.07 g, 884.86 mmol). The resulting suspension was stirred at 50°C until clear. Then the mixture was cooled at -20°C and TMSOTf (93.54 g, 421.36 mmol) was added by syringe. Then the mixture was stirred at 70°C for 72 h under N₂, and quenched with sat NaHCO₃ and extracted with DCM. The organic layer was dried over Na₂SO₄, then solvent was evaporated, and the residue was purified on silica gel to afford compound **6-2** (107.50 g, 192.26 mmol, 91.26% yield) as a yellow solid. ¹H-NMR (400 MHz, DMSO): δ = 11.28 (s, 1H), 8.64 (d, *J* = 6.4 Hz,

2H), 8.05 (d, $J = 8.0$ Hz, 2H), 7.84 (d, $J = 8.0$ Hz, 2H), 7.66 (t, $J = 7.6$ Hz, 1H), 7.56 (t, $J = 8.0$ Hz, 2H), 7.33 (d, $J = 8.0$ Hz, 2H), 6.37 (d, $J = 3.6$ Hz, 1H), 6.17 (dd, $J = 6.0$ Hz, 1H), 5.09 (t, $J = 6.8$ Hz, 1H), 4.69-4.56 (m, 2H), 4.40-4.38 (m, 1H), 2.39 (s, 3H), 2.17 (s, 3H). ESI-LCMS: m/z 557.2 $[M+H]^+$.

[0067] Preparation of Intermediate (6-3): To a solution of compound **6-2** (107.50 g, 192.26 mmol) dissolved in 33 wt.% methylamine in ethanol (600.00 mL), then the mixture were stirred at 20°C for 16 h, then solvent was evaporated, washed with 50% EtOAc in petroleum ether (1.5 L), filtered to afford compound **6-3** (52.50 g, 179.64 mmol, 93.44% yield) as a slightly yellow solid. ESI-LCMS: m/z 293.1 $[M+H]^+$.

[0068] Preparation of Intermediate (6-4): A solution of compound **6-3** (52.50 g, 179.64 mmol), imidazole (18.32 g, 269.46 mmol) and TBDPS-Cl (54.34 g, 197.60 mmol) in pyridine (500.00 mL) was stirred at 20°C for 2 h, LC-MS showed **6-3** was consumed. Then quenched with MeOH (30 mL), concentrated to give the crude product which was purified on silica gel with to afford compound **6-4** (72.60 g, 136.81 mmol, 76.16% yield) as a white solid. $^1\text{H-NMR}$ (400 MHz, DMSO): $\delta = 8.29$ (s, 1H), 8.10 (s, 1H), 7.63-7.59 (m, 4H), 7.48-7.33 (m, 8H), 6.36 (d, $J = 5.6$ Hz, 1H), 5.97 (d, $J = 4.4$ Hz, 1H), 5.10-5.06 (m, 1H), 4.47 (t, $J = 5.6$ Hz, 1H), 4.14-4.11 (m, 1H), 3.94 (dd, $J = 11.2$ Hz, 1H), 3.83 (dd, $J = 11.6$ Hz, 1H), 0.99 (s, 9H). ESI-LCMS: m/z 531.3 $[M+H]^+$.

[0069] Preparation of Intermediate (6-5): A solution of **6-4** (35.00 g, 65.96 mmol) and 1-Bromo-2-methoxyethane (18.33 g, 131.91 mmol) in dry DMF (400.00 mL), was added NaI (19.77 g, 131.91 mmol) and Ag₂O (15.29 g, 65.96 mmol), the mixture was stirred at room temperature for 5 h. Then the reaction was poured into ice water, extracted with EA, washed with brine and dried over anhydrous Na₂SO₄. The solvent was evaporated, and the residue was purified on silica gel to give **6-5** (23.70 g, 40.26 mmol, 61.04% yield) as a white solid and by-product of TBDPS lost 5.20 g, 9.81 mmol, 14.87% yield) as a white solid. $^1\text{H-NMR}$ (400 MHz, DMSO): $\delta = 8.31$ (s, 1H), 8.11 (s, 1H), 7.63-7.60 (m, 4H), 7.47-7.44 (m, 2H), 7.40-7.36 (m, 6H), 6.10 (d, $J = 4.4$ Hz, 1H), 5.02 (t, $J = 4.8$ Hz, 1H), 4.69 (t, $J = 5.6$ Hz, 1H), 4.18-4.14 (m, 1H), 3.95 (dd, $J = 11.6$ Hz, 1H), 3.84 (dd, $J = 11.6$ Hz, 1H), 3.78-3.75 (m, 2H), 3.45 (t, $J = 4.8$ Hz, 1H), 3.16 (s, 3H), 0.99 (s, 9H). ESI-LCMS: m/z 589.5 $[M+H]^+$.

[0070] Preparation of Intermediate (6-6): To a solution of **6-5** (31.23 g, 53.04 mmol) in pyridine (300.00 mL) at 0°C, was added BzCl (11.22 g, 79.56 mmol) dropwise. The mixture was stirred at r.t. for 2 h. Then the solution was cooled to 0 °C, and ammonium hydroxide (20 mL, 30%) was added and the mixture was allowed to warm to r.t., then the solvent was evaporated, 300 mL H₂O and 600 mL EA were added into separate the solution, the aqueous was extracted by EA, combined the organic and washed with brine, dried over anhydrous Na₂SO₄, the solvent was removed and the residue was purified on silica gel to give **6-6** (28.70 g, 41.42 mmol, 78.09% yield) as a white solid. ESI-LCMS: m/z 693.4 [M+H]⁺.

[0071] Preparation of Intermediate (6-7): A solution of **6-6** (28.70 g, 41.42 mmol) in EA (150.00 mL) was added Pd/C (3.00 g) and MeOH (150.00 mL) under H₂. The mixture was stirred at r.t. for 5 h. Then the reaction was filtered and the filtrate concentrated to give **6-7** (25.49 g, 38.22 mmol, 92.27% yield) as a gray solid. ESI-LCMS: m/z 667.3 [M+H]⁺.

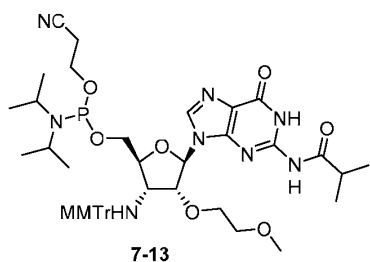
[0072] Preparation of Intermediate (6-8): To a solution of **6-7** (25.49 g, 38.22 mmol) and AgNO₃ (12.98 g, 76.44 mmol) in DCM (300.00 mL) was added collidine (13.89 g, 114.66 mmol) and MMTrCl (19.43 g, 57.33 mmol), the mixture was stirred at r.t. for 2 h. Then the reaction was poured into ice water, the organic layer extracted with DCM, washed with brine and dried over anhydrous Na₂SO₄, the solvent was removed and the residue was purified on silica gel to give **6-8** (32.79 g, 34.92 mmol, 91.36% yield) as a gray solid.

[0073] Preparation of Intermediate (6-9): A solution of **6-8** (32.79 g, 34.92 mmol) in THF (300.00 mL) was added TBAF (1M, 35.00 mL), the mixture was stirred at room temperature for 15 h. Then the solvent was removed and the residue was purified on silica gel with EA to give **6-9** (22.22 g, 31.71 mmol, 90.82% yield) as a white solid. ¹H-NMR (400 MHz, CDCl₃): δ = 8.68 (s, 1H), 8.32 (s, 1H), 8.04 (d, J = 7.2 Hz, 2H), 7.61-7.57 (m, 1H), 7.53-7.48 (m, 6H), 7.40 (d, J = 8.8 Hz, 2H), 7.21-7.12 (m, 6H), 6.73 (d, J = 8.8 Hz, 2H), 6.09 (d, J = 2.4 Hz, 2H), 4.08-4.02 (m, 2H), 3.93-3.87 (m, 1H), 3.72 (s, 3H), 3.58-3.53 (m, 1H), 3.43-3.39 (m, 3H), 3.24-3.19 (m, 4H), 2.19 (br, 1H).

[0074] Preparation of (6-10): To a solution of **6-9** (14.00 g, 19.98 mmol), DMAP (488.19 mg, 4.00 mmol) and DIPEA (6.46 g, 49.95 mmol, 8.73 mL) in dry DCM (100.00 mL) was added CEPCl (5.68 g, 23.98 mmol) dropwise under Ar. The mixture was stirred at room temperature for 1 h. Then the reaction was washed with 10% NaHCO₃ (aq) and brine, dried over Na₂SO₄, the

solvent was removed and the residue was purified by column chromatography, then concentrated to give the crude product. The crude product (10 g, dissolved in 10 mL of ACN) was purified by Flash-Prep-HPLC to obtain **6-10** (12.60 g, 13.98 mmol, 69.99% yield) as a white solid. Then the product was dissolved in dry toluene (15 mL) and concentrated three times, and with dry ACN three times. $^1\text{H-NMR}$ (400 MHz, CDCl_3): δ = 9.12 (d, J = 46.8 Hz, 1H), δ = 8.71 (d, J = 11.6 Hz, 1H), 8.50 (s, 0.6H), 8.22 (s, 0.4H), 8.04 (t, J = 7.2 Hz, 2H), 7.63-7.59 (m, 1H), 7.55-7.46 (m, 6H), 7.40-7.37 (m, 2H), 7.19-7.06 (m, 6H), 6.69 (dd, J = 8.8 Hz, 2H), 6.03 (d, J = 3.2 Hz, 1H), 4.36-4.24 (m, 2H), 3.92-3.78 (m, 2H), 3.71 (d, J = 11.6 Hz, 3H), 3.67-3.33 (m, 7H), 3.29 (d, J = 11.2 Hz, 3H), 3.17-3.10 (m, 1H), 2.88 (dd, J = 27.2 Hz, 1H), 2.65-2.50 (m, 2H), 2.38 (d, J = 4.4 Hz, 0.4H), 1.80 (d, J = 4.0 Hz, 0.6H), 1.23-1.15 (m, 12H). $^{31}\text{PNMR}$ (400 MHz, CDCl_3): 148.86, 148.22. ESI-LCMS: m/z 901.3 $[\text{M}+\text{H}]^+$.

Example 4

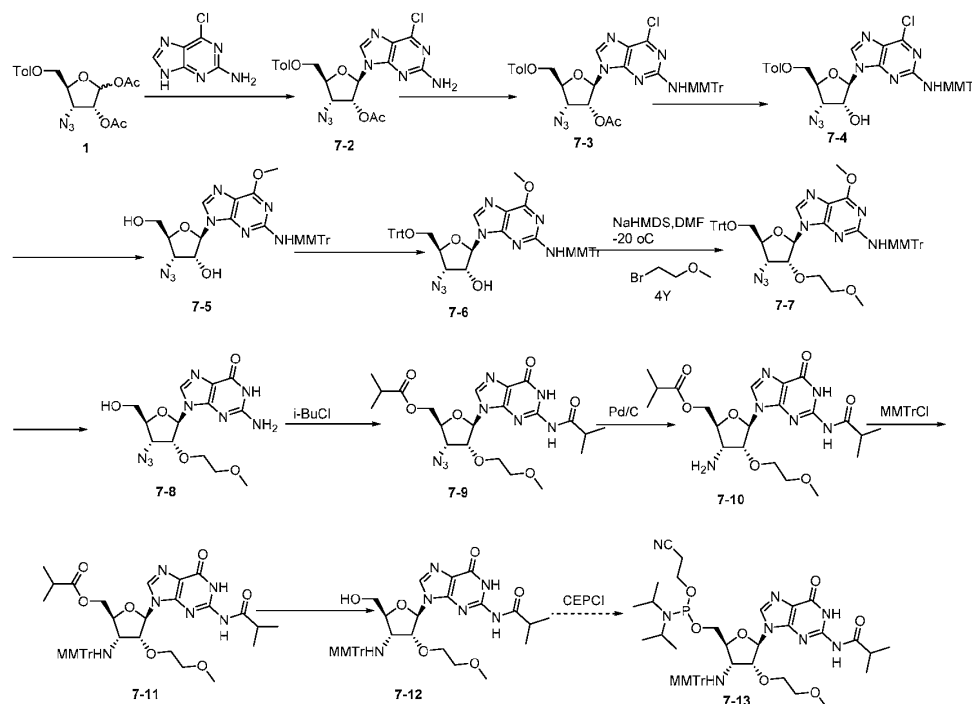


[0075] The synthesis of guanosine-based 2'-methoxyethoxy phosphoramidite **7-13** shown in scheme 5. It was envisioned that stereo selective coupling of C-3-azidoribose **1** with nucleobase 2-amino-6-chloropurine was key steps to get various guanosine-based 3'-NH-MMTr-2'-O-alkylated phosphoramidites. This was absolutely required to get efficient 2'-O-alkylations and to eliminate any base alkylations. For this purpose, C-3'-azido-chloro-amine purine nucleoside **7-2 b** was synthesized from nucleobase coupling of **1** and 2-amino-6-chloro purine in ~70% isolated yield. Then, the protection of 2-amino group of **7-2** by using MMTrCl to give **7-3**, which after deprotection of 2'-O-acetyl and 5'-O-toluoyl group by using $\text{NH}_4\text{OH}/0^\circ\text{C}$ to give 2'-hydroxy intermediate **7-4**.

[0076] De-protection of 5'-O-toluyl group of intermediate **7-4** by treatment with a base followed by re-protection of 5'-OH group with trityl group afforded key 2'-OH intermediate **9-6** for

alkylation. This inventive de-protection and re-protection strategy was necessary for efficient synthesis of 2'-O-alkylated intermediate **7-7** under basic conditions (NaHMDS/DMF).

Scheme 5



[0077] Next hydrolysis of 6-methoxy group and de-tritylation simultaneously under carefully controlled acidic conditions afforded 3'-azido-2'-methoxy guanosine intermediate **7-8**, which was subjected with *i*BuCl to give bisisobutyrate **7-9** followed by reduction and MMTTr protection of 3'-amino group of intermediate resulted in 3'-NH-MMTTr -2'-methoxy ethoxy guanosine nucleoside **7-11**. Further selective de-protection of 5'-O-isobutyrate using basic conditions at low temperature resulted in 2'-methoxy ethoxy guanosine amidite precursor **7-12**. The phosphitylation of **7-12** using standard protocols to give the desired 2'-O-methoxyethoxy guanosine phosphoramidite monomer **7-13**.

[0078] Preparation of Intermediate (7-2): To a solution of **1** (60.00 g, 152.00 mmol) in dry ACN (1300.00 mL) was added 2-amino-6-chloropurine (54.0 g, 318.5 mmol) and BSA (136.0g, 667.82 mmol). The resulting suspension was stirred at 50°C until clear. Then the mixture was cooled at -20°C and TMSOTf (60.0g, 271.00 mmol) was added dropwise. Then the mixture was

stirred at 70°C for 18 h, and quenched with sat NaHCO₃ and extracted with DCM. The organic layer was dried over Na₂SO₄ and purified on silica gel and recrystallized to give **7-2** (55.20g, 113.38 mmol) as a white solid. ¹H-NMR (400 MHz, CDCl₃): δ ppm 7.87 (d, *J* = 8.4 Hz, 2H), 7.82 (s, 1H), 7.25 (d, *J* = 8.0 Hz, 2H), 6.09 (dd, *J* = 5.6 Hz, 1H), 5.97 (d, *J* = 4.0 Hz, 1H), 5.17 (s, 2H), 4.84-4.80 (m, 2H), 4.60-4.56 (m, 1H), 4.44-4.41 (m, 1H), 2.43 (s, 3H), 2.22 (s, 3H). ESI-LCMS: *m/z* 487.1 [M+H]⁺.

[0079] Preparation of Intermediate (7-3): To a solution of **7-2** (33.2 g, 68.20 mmol) dissolved in DCM (300.00 mL), DMAP (1.67g, 13.60 mmol) and DIEA (22.04g, 136.4 mmol), MMTrCl (42.0 g, 136.4 mmol) were added. And the mixture were stirred at r.t. for 16 h under N₂. The mixture was then quenched with sat. NaHCO₃ and extracted with DCM. The organic layer was dried over Na₂SO₄ and the residue was purified by silica gel to afford compound **7-3** (51.00 g, 67.20 mmol, 98.51% yield) as a white solid. ESI-LCMS: *m/z* 759.4 [M+H]⁺.

[0080] Preparation of Intermediate (7-4): To a solution of **7-3** (54.00 g, 212.06 mmol) in THF (400 L) was added NH₄OH (100.00 mL) at 0°C. The reaction mixture was stirred at r.t. for 48 h, and concentrated and purified by silica gel with 1-2% MeOH in DCM to give **7-4** (51.00 g, 178.48 mmol, 99.98% yield) as a yellow solid. ¹H-NMR (400 MHz, DMSO): δ ppm 8.26 (d, *J* = 4.4 Hz, 1H), 8.17 (s, 1H), 7.78-7.76 (m, 2H), 7.35-7.25 (m, 12H), 7.16 (t, *J* = 7.2 Hz, 2H), 6.82 (dd, *J* = 8.8 Hz, 2H), 6.14 (s, 1H), 5.62 (s, 1H), 4.40-4.35 (m, 4H), 3.69 (s, 3H), 3.36 (s, 1H), 2.39 (s, 3H). ESI-LCMS: *m/z* 717.4 [M+H]⁺.

[0081] Preparation of Intermediate (7-5): To a solution of sodium methoxide in methanol (300.00 mL, 2N) was added **7-4** (47.00 g, 65.54 mmol), the mixture was stirred at r.t. for 1 h. The mixture was concentrated in vacuo to give the crude product which was purified by CC (DCM: methyl alcohol=50:1) to give **7-5** (36.50 g, 61.38 mmol, 93.66% yield) as white solid. ¹H-NMR (400 MHz, DMSO): δ ppm 8.15 (s, 1H), 7.47 (s, 1H), 7.41-7.32 (m, 4H), 7.32-7.23 (m, 6H), 7.18 (t, *J* = 7.16 Hz, 2H), 6.85 (d, *J* = 8.68 Hz, 2H), 6.19 (s, 1H), 5.77 (s, 1H), 5.28 (s, 1H), 4.81 (s, 1H), 4.20-4.06 (m, 1H), 3.90 (s, 1H), 3.72 (s, 3H), 3.65-3.50 (m, 2H). ESI-LCMS: *m/z* 595.4 [M+H]⁺.

[0082] Preparation of Intermediate (7-6): To a solution of **7-5** (36.50 g, 61.38 mmol) in dry DCM (5.00 mL) was added DIPEA (15.87 g, 122.77 mmol, 21.44 mL), DMAP (1.50 g, 12.28 mmol) and TrtCl (20.48 g, 73.66 mmol). The resulting suspension was stirred at r.t. for 20 h

under Nitrogen and concentrated in vacuo. The product was purified by cc (PE: EA =10:1~3:1) to give **7-6** (46.00 g, 54.96 mmol, 89.55% yield) as white solid. ¹H-NMR (400 MHz, DMSO): δ ppm 8.08 (s, 1H), 7.47-7.35 (m, 7H), 7.34-7.10 (m, 20H), 6.80 (d, *J* = 7.76 Hz, 2H), 6.25 (s, 1H), 5.81 (s, 1H), 4.86 (s, 1H) 4.10-3.87 (m, 2H), 3.69 (s, 3H), 3.56-3.30 (m, 2H), 3.29-3.02 (m, 3H), 2.00 (s, 1H). ESI-LCMS: *m/z* 837.4 [M+H]⁺.

[0083] Preparation of Intermediate (7-7): To a solution of **7-6** (32.00 g, 38.23 mmol) in dry DMF (300.00 mL) was added tetrabutylammonium iodide (3.82 g, 11.47 mmol), 1-bromo-2-methoxyethane (15.94 g, 114.69 mmol) and NaHMDS (21.03 g, 114.69 mmol) added dropwise at -10°C. The resulting suspension was stirred at -10°C for 30 h and stirred at r.t. for 2 h. The product was quenched with sat. NH₄Cl and extracted with DCM. The organic layer was concentrated in vacuo to give the crude product which was purified by silica gel column to give **7-7** (31.46 g, 35.15 mmol, 91.94% yield) as white solid. ¹H-NMR (400 MHz, DMSO): δ ppm 8.04 (s, 1H), 7.40-7.34 (m, 6H), 7.33-7.08 (m, 20H), 6.78 (d, *J* = 8.9 Hz, 2H), 5.83 (s, 1H), 4.04-3.98 (m, 1H), 3.68 (s, 3H), 3.67-3.46 (m, 3H), 3.44-3.36 (m, 2H), 3.27-3.15 (m, 2H), 3.12 (s, 3H), 2.88 (s, 1H). ESI-LCMS: *m/z* 895.4 [M+H]⁺.

[0084] Preparation of Intermediate (7-8): To a solution of **7-7** (42.00 g, 46.93 mmol) in 1,4-dioxane (150.00 mL) was added 6 N hydrochloric acid (46.93 mmol, 150.00 mL) at r.t. The resulting suspension was stirred at r.t. for 30 min. The mixture was extracted with petroleum ether. The water layer was stirred at r.t. for 24 h. The mixture was concentrated in vacuo to give **7-8** (20.00 g, 37.12 mmol,) as white solid. ¹H-NMR (400 MHz, DMSO): δ ppm 11.08-10.82 (m, 1H), 8.41-8.13 (m, 1H), 7.35-6.99 (m, 1H), 6.85-6.62 (m, 2H), 5.90-5.78 (m, 1H), 4.71 (t, *J* = 5.16 Hz, 1H), 4.46 (t, *J* = 4.64 Hz, 1H), 4.02-3.97 (m, 1H), 3.78-3.70 (m, 2H), 3.70-3.62 (m, 1H), 3.57 (dd, *J* = 12.12 Hz, 1H), 3.43 (t, *J* = 4.60 Hz, 2H), 3.18 (s, 3H). ESI-LCMS: *m/z* 367.2 [M+H]⁺.

[0085] Preparation of Intermediate (7-9): To a solution of **7-8** (20.00 g, 54.60 mmol) in pyridine (100.00 mL) was added isobutyl chloride (17.45 g, 163.80 mmol) drop-wise at r.t. The resulting suspension was stirred at r.t. for 1 h. The mixture was extracted with DCM and washed with water. The organic layer was concentrated in vacuo. Dissolved in pyridine and added drop-wise isobutyl chloride (17.45 g, 163.80 mmol) at r.t. The resulting suspension was stirred at r.t. for 1

h., concentrated and purified by silica gel column to give **7-9** (13.00 g, 25.67 mmol) as a white solid. ESI-LCMS: m/z 507.3 $[M+H]^+$.

[0086] Preparation of Intermediate (7-10): To a solution of **7-9** (13.00 g, 25.67 mmol) in THF (100.00 mL) was added palladium 10% on carbon (1.30 g), the mixture was stirred at r.t. for 20 h at H₂. Filtered and the filtrate was concentrated in vacuo to give **7-10** (11.70 g, 24.35 mmol) as brown solid. ESI-LCMS: m/z 481.3 $[M+H]^+$.

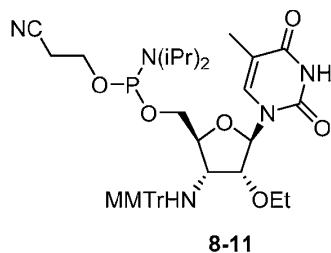
[0087] Preparation of Intermediate (7-11): To a solution of **7-10** (11.70 g, 24.35 mmol) in DCM (150.00 mL) was added MMTrCl (11.25 g, 36.53 mmol) and 2,4,6-collidine (5.90 g, 48.70 mmol) at 0°C, the mixture was stirred at r.t. for 30 min and added AgNO₃ (6.20 g, 36.53 mmol) at 0°C. The mixture was stirred at r.t. for 2 h under N₂, filtered and the organic layer was washed by water and dried over Na₂SO₄, concentrated to give the crude product which was purified by silica gel column to give **7-11** (8.5 g, 11.22 mmol) as a white solid. ESI-LCMS: m/z 753.5 $[M+H]^+$.

[0088] Preparation of Intermediate (7-12): To a solution of **7-11** (8.5 g, 11.29 mmol) in pyridine (50.00 mL) was added 2 N NaOH (50.00 mL) dropwise at 0°C, the mixture was stirred at 0°C for 20 min. Then the reaction was neutralized with saturated NH₄Cl (aq.) to pH=7-8, and 300 mL H₂O and 800 mL DCM were added in to separate the solution, the aqueous was extracted by DCM, the combined organic layer was washed with brine, dried over anhydrous Na₂SO₄, the solvent was removed and the residue was purified on silica gel to give **7-12** (6.3 g, 9.23 mmol, 81.73% yield) as a white solid. ¹H-NMR (400 MHz, DMSO): δ ppm 11.78 (br s, 1H), 11.41 (s, 1H), 8.11 (s, 1H), 7.46 (t, J = 7.28 Hz, 4H), 7.31-7.21 (m, 6H), 7.15 (t, J = 7.32 Hz, 2H), 6.76 (d, J = 8.92 Hz, 2H), 5.82 (s, 1H), 5.08 (t, J = 4.08 Hz, 1H), 3.99-3.85 (m, 3H), 3.65 (s, 3H), 3.62-3.55 (m, 1H), 3.42-3.38 (m, 2H), 3.29-3.19 (m, 1H), 3.10 (s, 3H), 3.06-2.99 (m, 1H), 2.89-2.74 (m, 2H), 1.96 (d, J = 4.08 Hz, 1H), 1.20-1.12 (m, 6H). ESI-LCMS: m/z 883.4 $[M+H]^+$.

[0089] Preparation of (7-13): To a solution of **7-12** (6.3 g, 9.10 mmol) in DCM (60 mL) was added DMAP (222.00 mg) and DIPEA (5.9 mL). Then CEPCl (2.60 g) was added. The reaction mixture was stirred at r.t. for 1 h., the mixture was washed with saturated NaHCO₃ and brine, dried over Na₂SO₄, purified by Flash-Prep-HPLC. This resulted in 5.04 g **7-13** as a white solid. ¹H-NMR (400 MHz, CDCl₃): δ ppm 11.96 (br s, 1H), 8.57 (s, 1H), 7.98-7.67 (m, 1H), 7.55-7.46 (m, 4H), 7.42-7.34 (m, 2H), 7.25-7.18 (m, 4H), 7.18-7.08 (m, 2H), 6.78-6.68 (m, 2H), 5.79-5.69

(m, 1H), 4.27-4.11 (m, 2H), 4.10-3.73 (m, 2H), 3.73-3.67(m,3H), 3.66-3.31 (m, 7H), 3.30-3.21 (m, 3H), 2.07-2.97 (m, 1H), 2.94-2.78 (m, 1H), 2.70-2.50 (m, 3H), 2.30-1.68 (m, 1H), 1.30-1.07 (m, 18H). ^{31}P NMR (162 MHz, CDCl_3): 149.09, 148.09. ESI-LCMS: m/z 883.4 $[\text{M}+\text{H}]^+$.

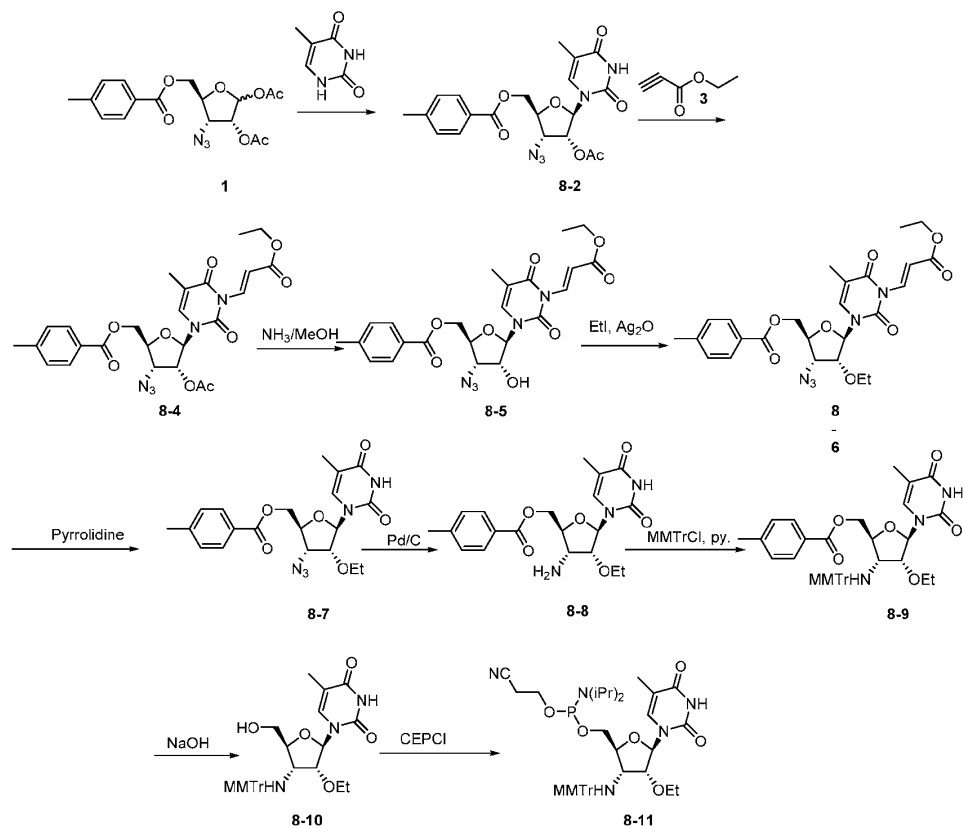
Example 5



[0090] The appropriately protected 2'-O-ethyl-3'-amino-5'-phosphoramidite (example 8, 9, 10, 11), were prepared after chemical transformations shown in Schemes 6-10.

[0091] First for the synthesis of thymine based 3'-NH-MMtr-2'-O-ethyl phosphoramidites example 9, intermediate 2 was protected such as methyl propylate in the presence of dimethylaminopyridine (Scheme 6) to give base N-3 protected intermediate **8-4** to facilitate the 2'-O-alkylation in higher yield. Further deacetylation of **8-4** to give C-2'-hydroxy intermediate 8-5.

Scheme 6



[0092] Further alkylation using iodoethane afforded 2'-O-ethyl nucleoside **8-6**. Intermediate **8-6** was converted to thymine base 2'-O-ethyl-3'-amino-5'-phosphoramidite **8-11** by following the similar chemistry for compound **4-10** shown in previous Scheme 1.

[0093] Preparation of Intermediate (8-4): To a solution of **8-2** (22.0 g, 49.62 mmol) in MeCN (400 mL) was added DMAP (1.2 g, 9.92 mmol). Then **3** (5.8 g, 419.5 mmol) was added, the mixture was stirred at r.t. for 2 h under N_2 . Concentrated and purified by a silica gel column by (PE:EA = 6:1) to afford **8-4** (22.0 g, 40.63 mmol, 81.9% yield) as a yellow oil. ESI-LCMS: m/z 564 $[\text{M}+\text{Na}]^+$.

[0094] Preparation of Intermediate (8-5): To a solution of **8-4** (28.0 g, 51.71 mmol) in MeOH (400 mL) was added con. NH_4OH aqueous solution (28 mL) at 0°C . The reaction mixture was

stirred at 0°C for 1.5 h. Concentrated and purified by a silica gel column by (PE:EA = 10:1~2:1) to afford **8-5** (21.0 g, 42.04 mmol, 81.3% yield) as a yellow oil. ESI-LCMS: m/z 522 [M+Na]⁺.

[0095] Preparation of Intermediate (8-6): To a solution of **8-5** (20.0 g, 40.04 mmol) in iodoethane (100 mL) was added Ag₂O (18.6 g, 80.08 mmol). The reaction mixture was stirred at 50 °C for 5 h, filtered with diatomite and concentrated to afford **8-6** (16.0, 30.33 mmol, 75.7% yield) as a yellow oil which was used directly in next step. ESI-LCMS: m/z 528 [M+H]⁺.

[0096] Preparation of Intermediate (8-7): To a solution of **8-6** (16.0 g, 30.33 mmol) in MeCN (400 mL) was added pyrrolidine (8.63 g, 121.32 mol, 12 mL), the reaction mixture was stirred at r.t. overnight. Concentrated and purified by a silica gel column by (DCM:MeOH = 100:1~50:1) to afford **7** (12.0 g, 27.94 mmol, 92.1% yield) as a yellow oil. ESI-LCMS: m/z 430 [M+H]⁺.

Preparation of Intermediate (8-8): To a solution of **8-7** (12.0 g, 27.94 mmol) in THF (200 mL) was added Pd/C (1.2 g), the mixture was stirred at r.t. under H₂ overnight. LC-MS showed **7** was totally consumed. Filtered and washed with DCM (100 mL * 3), then concentrated to afford **8-8** (11.0 g, 27.27 mmol, 97.6% yield) as a gray solid which was used directly in next step. ESI-LCMS: m/z 404 [M+H]⁺.

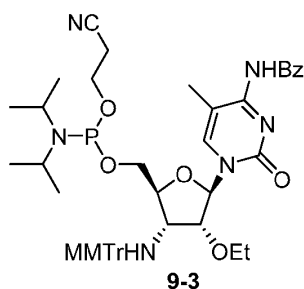
[0097] Preparation of Intermediate (8-9): To a solution of **8-8** (10.0 g, 24.79 mmol) in DCM (80 mL) was added MMTrCl (11.4 g, 37.18 mmol), 2,4,6-collidine (2.0 g, 16.61 mmol, 6.5 mL) and AgNO₃ (6.3 g, 37.18 mmol), the mixture was stirred at r.t. for 1.5 h. Filtered and the organic layer was washed with water and dried over Na₂SO₄, then concentrated and purified by a silica gel column by (PE:EA=5:1~1:1) to afford **8-9** (16.0 g, 23.68 mmol, 95.5% yield) as a light-yellow solid.

[0098] Preparation of Intermediate (8-10): **8-9** (4.0 g, 5.92 mmol) was added to the solution of 1.0 N NaOH solution (20 mL, MeOH/H₂O = 9:1). The reaction mixture was stirred at 40 °C for 2 h, concentrated and extracted with DCM (20 mL * 2), the organic layer was dried over Na₂SO₄ and concentrated, the residue was purified by a silica gel column by (DCM:MeOH=200:1~50:1) to afford **8-10** (3.0 g, 53.8 mmol, 90.9 yield) as a white solid.

[0099] Preparation of (8-11): To a solution of **8-10** (2.36 g, 4.23 mmol) in DCM (2.0 mL) was added DMAP (103 mg, 0.8 mmol) and DIPEA (2.2 g, 16.92 mmol, 2.96 mL). Then CEPCl (1.0 g, 4.23 mmol) was added. The reaction mixture was stirred at r.t. for 1 h., washed with saturated

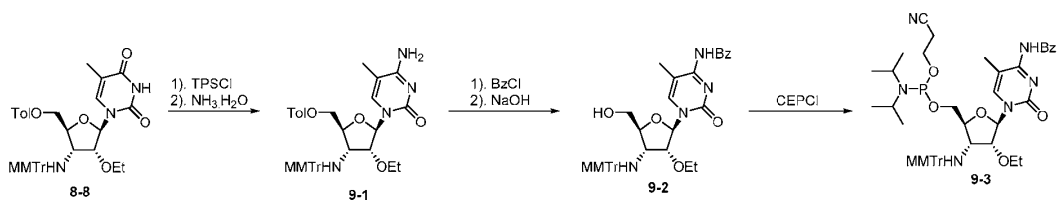
NaHCO₃ (5 mL), separated the organic layer and washed the water layer with DCM (10 mL * 2). The combined organic layer was washed with brine, dried over Na₂SO₄, concentrated and purified by Flash-Prep-HPLC to afford **8-11** (2.45 g, 3.23 mmol, 76.36% yield) as a white solid. ¹H NMR (400 MHz, CDCl₃) δ 8.62 (s, 1H), 7.74 (dd, *J* = 1.4 Hz, 0.5H), 7.60-7.50 (m, 4H), 7.51-7.41 (m, 2H), 7.34-7.16 (m, 7H), 7.12 (d, *J* = 1.4 Hz, 0.5H), 6.88-6.76 (m, 2H), 5.66 (s, 1H), 4.37-4.23 (m, 1H), 4.16-4.05 (m, 1H), 4.05-3.94 (m, 0.5H), 3.88-3.74 (m, 4.5H), 3.72-3.35 (m, 3H), 3.22 (td, *J* = 10.3, 4.7 Hz, 0.5H), 3.03-2.89 (m, 1.5H), 2.80-2.69 (m, 1H), 2.61 (t, *J* = 6.5 Hz, 1H), 2.37 (td, *J* = 6.6, 1.3 Hz, 1H), 1.97 (d, *J* = 3.5 Hz, 0.5H), 1.91 (dd, *J* = 11.4, 1.2 Hz, 3H), 1.52 (d, *J* = 4.7 Hz, 0.5H), 1.29-1.17 (m, 12H), 1.08 (td, *J* = 7.0, 4.9 Hz, 3H). ³¹P NMR (162 MHz, CDCl₃) δ 149.31, 147.14. ESI-LCMS: *m/z* 576 [M+H]⁺.

Example 6



[0100] The 2'-O-ethyl-NH-benzoyl 5-methyl cytosine phosphoramidite **9-3** was obtained by conversion of thymidine intermediate **8-8** into 3'-amino cytidine analogue **9-1** followed by phosphitylation using known protocols to give the desired 2'-O-ethyl cytidine phosphoramidite monomer **9-3** as shown below in scheme 7.

Scheme 7

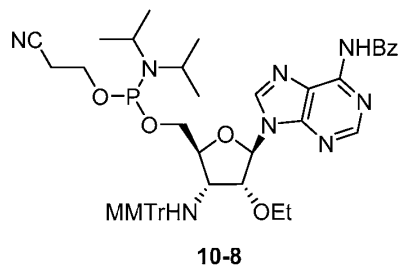


[0101] Preparation of Intermediate (9-1): To a solution of **8-8** (8.2 g, 12.09 mmol) in dry MeCN (40 mL) was added TPSCl (2.5 g, 24.18 mmol) and DMAP (2.95 g, 24.18 mmol), then TEA (2.5

g, 24.18 mmol, 3.4 mL) was added, the reaction mixture was stirred at r.t. for 12 h under N₂. Then con.NH₄OH aqueous solution (20 mL) was added, the result mixture was allowed to stirred at r.t. for another 3 h, then concentrated and purified by silica gel column to afford **9-1** (7.7 g, 11.35 mmol, 93.9% yield) as a light-yellow oil.

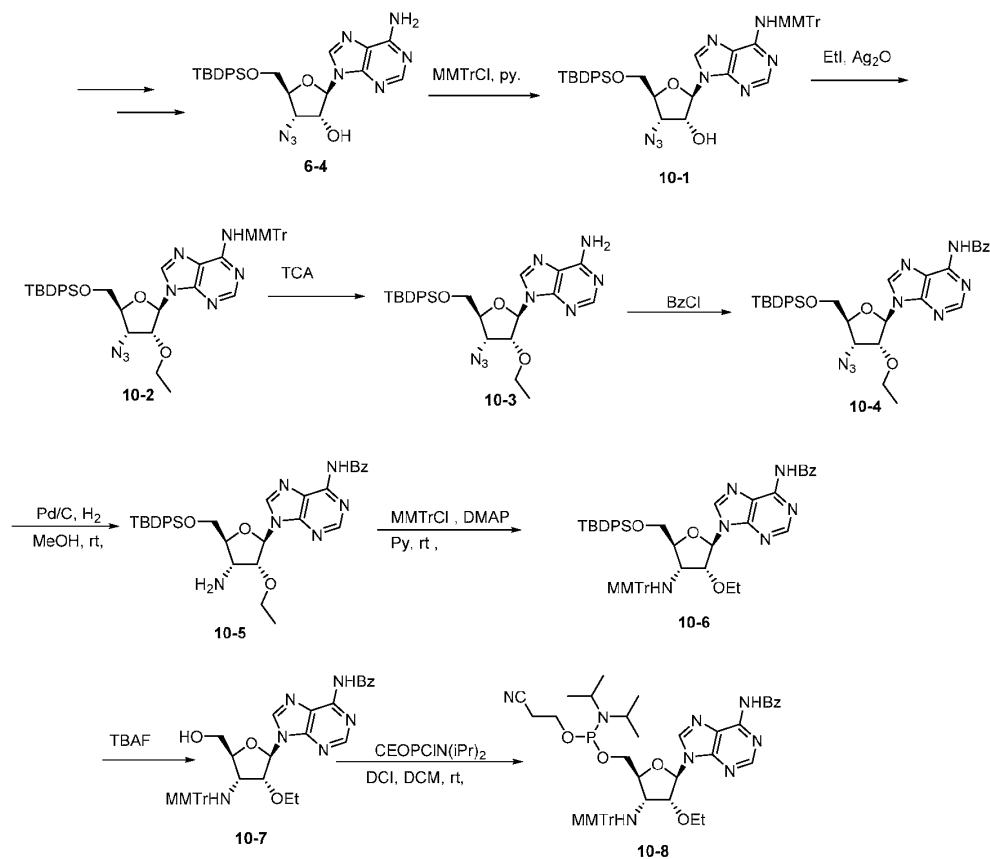
[0102] Preparation of Intermediate (9-2): To a solution of **9-1** (8.0 g, 11.86 mmol) in pyridine (80 mL) was added benzoyl chloride (2.0 g, 14.23 mmol, 1.6 mL) at 0°C, the reaction mixture was allowed warm to r.t. and stirred for another 1 h, 2.0 N NaOH (80 mL, MeOH/H₂O = 9:1) was added at 0°C, and then the mixture was allowed to stirred at 0°C for another 2 h, quenched with sat. NH₄Cl solution (20 mL) extracted with DCM (30 mL * 2) dried over Na₂SO₄, filtered and concentrated. The residue was purified by a silica gel chromatography (DCM:MeOH = 200:1~50:1) to afford **9-2** (5.4 g, 8.2 mmol, 66.3% yield) as yellow solid. ¹H NMR (400 MHz, CDCl₃) δ 13.35 (s, 1H), 8.40-8.28 (m, 2H), 7.93 (d, *J* = 1.3 Hz, 1H), 7.61-7.51 (m, 5H), 7.51-7.43 (m, 4H), 7.33-7.22 (m, 6H), 6.89-6.72 (m, 2H), 5.66 (s, 1H), 4.26-4.19 (m, 2H), 4.08 (dt, *J* = 10.4, 2.0 Hz, 1H), 3.80 (s, 3H), 3.74-3.63 (m, 1H), 3.12 (td, *J* = 10.3, 4.5 Hz, 1H), 2.95-2.84 (m, 2H), 2.05 (d, *J* = 1.1 Hz, 3H), 1.91 (d, *J* = 4.5 Hz, 1H), 1.29 (t, *J* = 7.1 Hz, 1H) 1.13 (t, *J* = 7.0 Hz, 3H).

[0103] Preparation of (9-3): To a solution of **9-2** (4.2 g, 6.36 mmol) in DCM (4 mL) was added DMAP (776 mg, 6.36 mmol), DIPEA (821 mg, 6.36 mmol, 1.1 mL) and then CEPCl (1.5 g, 6.36 mmol). The reaction mixture was stirred at r.t. for 1 h., quenched with sat. NaHCO₃ solution, extracted with DCM (30 mL * 2), the organic layer was dried over Na₂SO₄ and the solvent was evaporated, the residue was purified by a Flash-Prep-HPLC to afford **9-3** (4.9 g, 5.69 mmol, 89.47% yield) as light yellow solid. ¹H NMR (400 MHz, CDCl₃) δ 13.31 (s, 1H), 8.40-8.31 (m, 2H), 8.03 (s, 0.5H), 7.60-7.52 (m, 5H), 7.52-7.43 (m, 4H), 7.40 (s, 0.5H), 7.31-7.18 (m, 7H), 6.86-6.78 (m, 2H), 5.67 (d, *J* = 2.3 Hz, 1H), 4.42-4.26 (m, 1H), 4.24-4.11 (m, 1H), 4.06-3.98 (m, 0.5H), 3.90-3.81 (m, 1.5H), 3.79 (d, *J* = 3.0 Hz, 3H), 3.75-3.56 (m, 2H), 3.55-3.37 (m, 1H), 3.22 (td, *J* = 10.4, 4.5 Hz, 0.5H), 3.04-2.87 (m, 1.5H), 2.86-2.73 (m, 1H), 2.63 (t, *J* = 6.4 Hz, 1H), 2.40 (t, *J* = 6.5 Hz, 1H), 2.13 (dd, *J* = 19.9, 1.1 Hz, 3H), 1.99 (d, *J* = 3.8 Hz, 0.5H), 1.54 (d, *J* = 4.5 Hz, 0.5H), 1.31-1.21 (m, 12H), 1.10 (td, *J* = 7.0, 4.8 Hz, 3H). ³¹P NMR (162 MHz, CDCl₃) δ 149.48, 147.08. ESI-LCMS: *m/z* 861 [M+H]⁺.

Example 7

[0104] The synthesis of the 2'-O-ethyl adenosine phosphoramidite **10-8** was achieved as shown below in scheme 8. Protection of exocyclic amine group of **6-4** with bulky protecting group such as 4-monomethoxy trityl group was necessary to achieve 2'-O-alkylation in high yield. Then, intermediate **6-4** by reaction with $\text{Ag}_2\text{O}/\text{EtI}$ afforded 2'-O-ethyl intermediate **10-2** in 94% isolated yield after deprotection of MMTr group. This protection strategy resulted in efficient synthesis of key 3'-azido-2'-OEt intermediate **10-3** in high yields. This intermediate **10-3** was converted to 2'-O-ethyl adenosine phosphoramidite **10-8** by following the similar chemistry described for compound **6-10** (scheme 4).

Scheme 8



[0105] Preparation of Intermediate (10-1): To a solution of compound **6-4** (23.6 g, 44 mmol) in DCM (400.00 mL), DMAP (543 mg, 4 mmol) and TEA (9.2 g, 9 mmol), MMTr-Cl (20.6 g, 67 mmol) was added, the mixture was stirred at 20°C for 16 h under N₂. LC-MS showed **6-4** was consumed, quenched with sat. NaHCO₃ and extracted with DCM. The organic layer was dried over Na₂SO₄ and concentrated to give the crude product which was purified on silica gel with 20-50% EtOAc in petroleum ether to afford compound **10-1** (26.1 g, 32 mmol, 73.09% yield) as a slightly yellow solid. ¹H-NMR (400 MHz, DMSO): δ = 8.38 (s, 1H), 7.84 (s, 1H), 7.60-7.55 (m, 4H), 7.46-7.20 (m, 19H), 6.84 (d, *J* = 8.8 Hz, 2H), 6.35 (d, *J* = 5.6 Hz, 1H), 5.95 (d, *J* = 4.4 Hz, 1H), 5.14-5.12 (m, 1H), 4.46 (t, *J* = 5.6 Hz, 2H), 4.11-4.05 (m, 1H), 3.90-3.82 (m, 2H), 3.72 (s, 3H), 0.94 (s, 8H). ESI-LCMS: *m/z* 803.4 [M+H]⁺.

[0106] Preparation of Intermediate (10-2): To a solution of compound **10-1** (26.1 g, 32 mmol) in $\text{CH}_3\text{CH}_2\text{I}$ (200 mL), Ag_2O (9.7 g, 42 mmol) was added. The mixture was refluxed at 80 °C for 1 h. Then filtered to get the compound **10-2** (25.4 g, 30mmol, 94.04% yield) as a yellow solid. ESI-LCMS: m/z 831.3 $[\text{M}+\text{H}]^+$.

[0107] Preparation of Intermediate (10-3): A solution of compound **10-2** (25.4 g, 30 mmol) was dissolved in DCM (200 mL) was added TCA (12 mL), the mixture was stirred at 20°C for 6 h, LC-MS showed **10-2** was consumed, then washed with saturated NaHCO_3 , concentrated to give the crude product which was purified on silica gel with 1-3% MeOH in DCM to afford compound **10-3** (15.7 g, 28 mmol, 91.95% yield) as a white solid. $^1\text{H-NMR}$ (400 MHz, DMSO): δ = 8.33 (s, 1H), 8.10 (s, 1H), 7.63-7.60 (m, 4H), 7.47-7.37 (m, 8H), 6.09 (d, J = 4.0 Hz, 1H), 4.95(t, J = 4.8 Hz, 1H), 4.67(t, J = 5.6 Hz, 1H), 4.17-4.13 (m, 1H), 3.97-3.93 (m, 1H), 3.86-3.82 (m, 1H), 3.68-3.63 (m, 2H), 1.15-1.11 (m, 3H), 0.97 (s, 9H). ESI-LCMS: m/z 589.2 $[\text{M}+\text{H}]^+$.

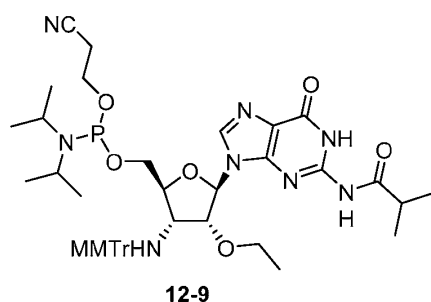
[0108] Preparation of Intermediate (10-4): To a solution of compound **10-3** (15.7 g, 28 mmol) in pyridine (150 mL) at 0°C, BzCl (4.7 g, 34 mmol) was added by syringe over 5 minutes, then the mixture was allowed to warm up to 20°C. Then stirred at r.t. under N_2 for 1 h. The solution was cooled to 0 °C, and ammonium hydroxide (20 mL, 30%) was added and the mixture was allowed to warm to r.t. and stirred at r.t. for 2 h. The mixture was diluted with EA and Water, extracted with EA, the combined organic layer was washed with brine, dried over anhydrous Na_2SO_4 , concentrated to give the crude product which was purified on silica gel to afford compound **10-4** (10.9 g, 16 mmol, 58.52% yield) as a white solid. ESI-LCMS: m/z 663.8 $[\text{M}+\text{H}]^+$.

[0109] Preparation of Intermediate (10-5): To a solution of compound **10-4** (10.9 g, 16 mmol) in THF (100 mL), Pd/C (1.9 g) were added, the mixture was stirred at 20 °C for 6 h under H_2 , then filtered and the filtrate concentrated to afford compound **10-5** (9.8 g, 15 mmol, 93.95% yield) as a white solid. ESI-LCMS: m/z 637.4 $[\text{M}+\text{H}]^+$.

[0110] Preparation of Intermediate (10-6): To a solution of compound **10-5** (9.8 g, 15 mmol) in anhydrous DCM (100 mL), collidine (3.7 g, 31 mmol) and AgNO_3 (3.9 g, 31 mmol), MMTr-Cl (5.7 g, 18 mmol) were added, the mixture was stirred at 20°C for 1 h under N_2 , then filtered, washed with H_2O and dried over Na_2SO_4 , concentrated to give the residue which was purified on

[0111] Preparation of Intermediate (10-7): To a solution of compound **10-6** (10.5 g, 11 mmol) in THF (100 mL), TBAF (1M) (11 mmol, 12 mL) was added, the mixture was stirred at 20°C overnight, then washed with saturated NaHCO₃, concentrated to give the residue which was purified on silica gel with 1-2% MeOH in DCM to afford compound **10-7** (5.6 g, 8 mmol, 72.28% yield) as a white solid.

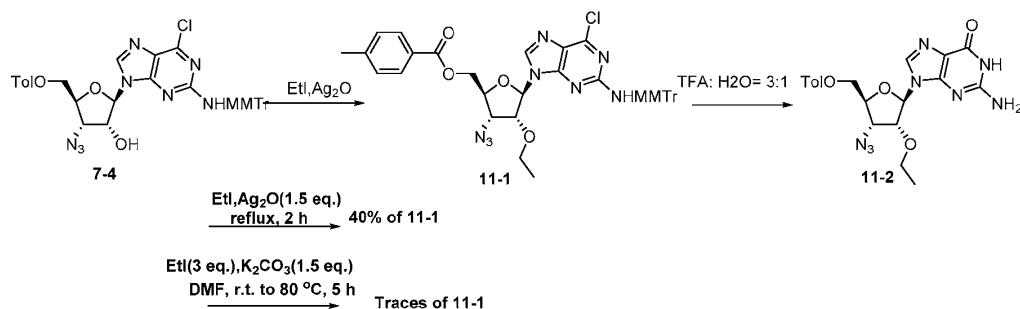
Example 8



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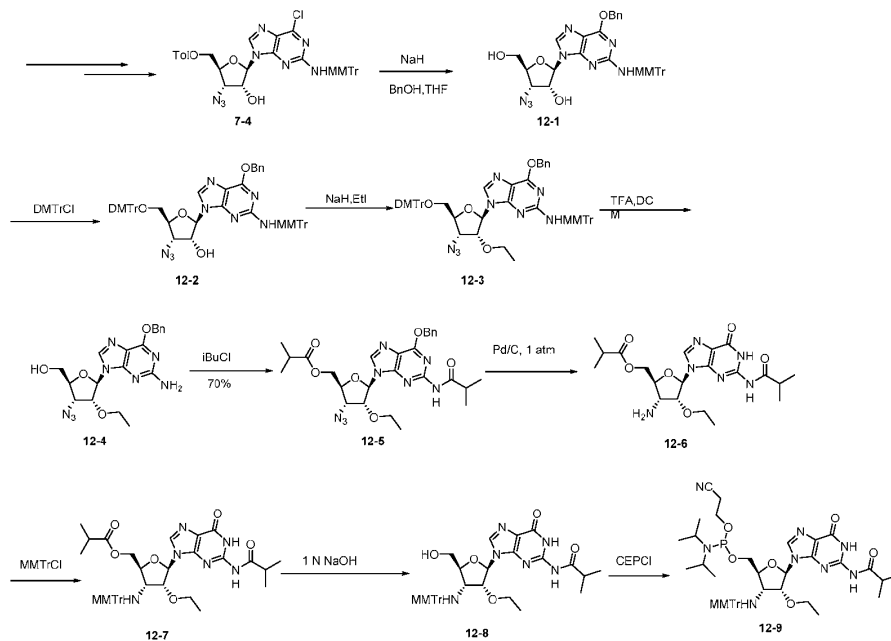
alkylation using EtI/Ag₂O or EtI/ K₂CO₃ desired 2'-OEt intermediate **7-5** could not be obtained in high yield as shown below in scheme 9.

Scheme 9



[0114] Therefore, an innovative way to improve on 2'-O alkylation and to make more stable guanosine intermediate under acidic conditions was designed as shown below in scheme 10. The reaction of 6-chloro intermediate **7-4** with NaH/BnOH/THF resulted in simultaneous substitution of C-6-Cl with BnOH and hydrolysis of 5'-O-toluylester in one step to give C-6-OBn intermediate **12-1**.

Scheme 10



[0115] The 5'-hydroxy group was selectively protected with DMTr to give 2'-OH nucleoside **12-2**. Resulting intermediate **12-2** was reacted with NaH/EtI to give 2'-O-ethyl intermediate **12-3**, which was subjected under acidic conditions (TFA/DCM) to afford 5'-hydroxy intermediate **12-4** without any de-purination. Then, the reaction of **12-4** with iBuCl resulted in bis-isobutyrate intermediate **12-5**, which on hydrogenation by using Pd/C gave 2'-O-ethyl guanosine intermediate **12-6**. This de-protection and re-protection strategy were applied successfully for efficient 2'-O-alkylations under basic conditions (NaH/EtI/THF). The resulted 2'-O-ethyl intermediate **12-6** was converted to desired 2'-O-ethylguanosine phosphoramidite monomer **12-9** by following the similar procedure described for compound 7-13 in example 12.

[0116] Preparation of Intermediate (12-1): To a solution of compound **7-4** (48.0 g, 66 mmol) in 50mL of THF was added 90 mL of a sodium benzyloxide solution in benzyl alcohol (freshly prepared by addition of NaH(13g) in 90mL of benzyl alcohol). The reaction mixture was stirred at room temperature for 1 h and treated with 50 mL of a saturated solution of NH₄Cl. The mixture was extracted with CH₂Cl₂ and the combined organic layers dried over Na₂SO₄. The crude product was purified by column chromatography to give **12-1** (17.5g, 26 mmol, 45.63%). ¹H-NMR (400 MHz, DMSO): δ ppm 8.13 (s, 1H), 7.59 (s, 1H), 7.34-7.16 (m, 15H), 6.82 (d, *J* = 8.8 Hz, 2H), 6.13 (s, 1H), 5.76 (s, 1H), 5.20-5.12 (m, 1H), 5.10-4.78 (m, 2H), 3.88-3.70 (m, 2H), 3.60 (s, 3H), 3.58-3.51 (m, 1H), 3.34 (s, 1H). ESI-LCMS: *m/z* 671.2 [M+H]⁺.

[0117] Preparation of Intermediate (12-2): To a solution of compound **12-1** (17.5 g, 26 mmol) in pyridine (200 mL) was added DMTrCl (10.5 g, 31 mmol) at 0°C. Then the mixture was stirred at 35°C for 4 h. Solvent was evaporated. The crude product was purified by column chromatography to give product **12-2** (21.8 g, 22 mmol, 85.87% yield) as a white solid. ESI-LCMS: *m/z* 974.6 [M+H]⁺.

[0118] Preparation of Intermediate (12-3): To a solution of **12-2** (21.8 g, 22 mmol) in THF (300 mL) was added NaH (1.1 g, 44 mmol) at 0 °C. Then EtI (10.4g, 67mmol) was added in reaction mixture and the mixture was stirred at 35 °C for 4 h, then treated with 50 mL of a saturated solution of NH₄Cl. The mixture was extracted with CH₂Cl₂ and the combined organic layers dried over Na₂SO₄. Solvent was evaporated to give **12-3** (21.2 g, 21 mmol, 94.55% yield) as a yellow solid.

[0119] Preparation of Intermediate (12-4): To a solution of **12-3** (21.2 g, 21 mmol) in DCM (200 mL) was added TFA (10 mL) at 0 °C. Then the mixture was stirred at 35 °C for 4 h. Quenched with saturated NaHCO₃ and washed with brine, dried over Na₂SO₄, purified by purified by column chromatography to give **12-4** (8.7 g, 20 mmol, 96.32% yield) as a white solid. ¹H-NMR (400 MHz, DMSO): δ ppm 8.17 (s, 1H), 7.53-7.50 (m, 2H), 7.42-7.36 (m, 3H), 6.61 (d, *J* = 8.8 Hz, 2H), 5.91-5.90 (m, 1H), 5.76 (s, 1H), 5.51-5.50 (m, 2H), 4.76-4.75 (m, 1H), 4.55-4.54 (m, 1H), 4.06-3.97 (m, 3H), 3.64-3.58 (m, 4H), 2.51 (s, 1H). ESI-LCMS: *m/z* 427.2 [M+H]⁺.

[0120] Preparation of Intermediate (12-5): To a solution of **12-4** (8.7 g, 20 mmol) in pyridine (100 mL) was added *i*BuCl (5.4 g, 51 mmol), the mixture was stirred at r.t. for 1.5 h. The organic layer was washed by water and dried over Na₂SO₄ and purified by column chromatography to give **12-5** (8.5 g, 15 mmol, 73.54% yield) as a white solid. ESI-LCMS: *m/z* 567.4 [M+H]⁺.

[0121] Preparation of Intermediate (12-6): To a solution of **12-5** (8.5 g, 15 mmol) in THF (100 mL) was added Pd/C (801 mg, 6 mmol) at 25 °C. Then the mixture was stirred under H₂ for 16 h. Filtered and washed by EA, concentrated to give crude product **12-6** (6.7 g, 14 mmol, 99.15% yield) as a yellow solid. ESI-LCMS: *m/z* 451.3 [M+H]⁺.

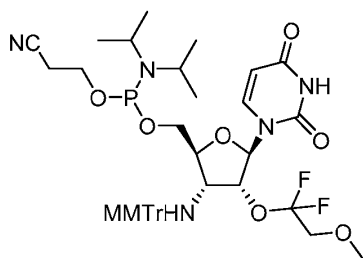
[0122] Preparation of Intermediate (12-7): To a solution of compound **12-6** (6.7 g, 14 mmol) in anhydrous DCM (70 mL), collidine (3.7 g, 31 mmol) and AgNO₃ (3.0 g, 17 mmol), MMTr-Cl (5.5 g, 17 mmol) were added, the mixture was stirred at 20 °C for 1 h under N₂, then filtered, washed with H₂O and dried over Na₂SO₄, concentrated to give the residue which was purified by column chromatography to afford compound **12-7** (8.4g, 11 mmol, 75.19% yield) as a white solid.

[0123] Preparation of Intermediate (12-8): Compound **12-7** (8.4 g, 11 mmol) was added to 80 mL of 1 N NaOH solution in MeOH/THF/H₂O (65/30/5) at 0 °C. The suspension was stirred at 0 °C for 2 h. The reaction was quenched by addition of sat. NH₄Cl solution. The solution was extracted with DCM and the combined organic layers were washed with sat. NaHCO₃ solution, brine, dried over Na₂SO₄, filtered, and concentrated. The residue was purified by column chromatography to give **12-8** (5.60 g, 8.35 mmol, 72.28% yield) as white solid. ¹H-NMR (400 MHz, DMSO): δ ppm 12.13 (br s, 1H), 11.38 (s, 1H), 8.10 (s, 1H), 7.47-7.44 (m, 4H), 7.30-7.13 (m, 8H), 6.75 (d, *J* = 8.96 Hz, 2H), 5.79 (s, 1H), 5.10 (t, *J* = 4.28 Hz, 1H), 3.95-3.89 (m, 3H),

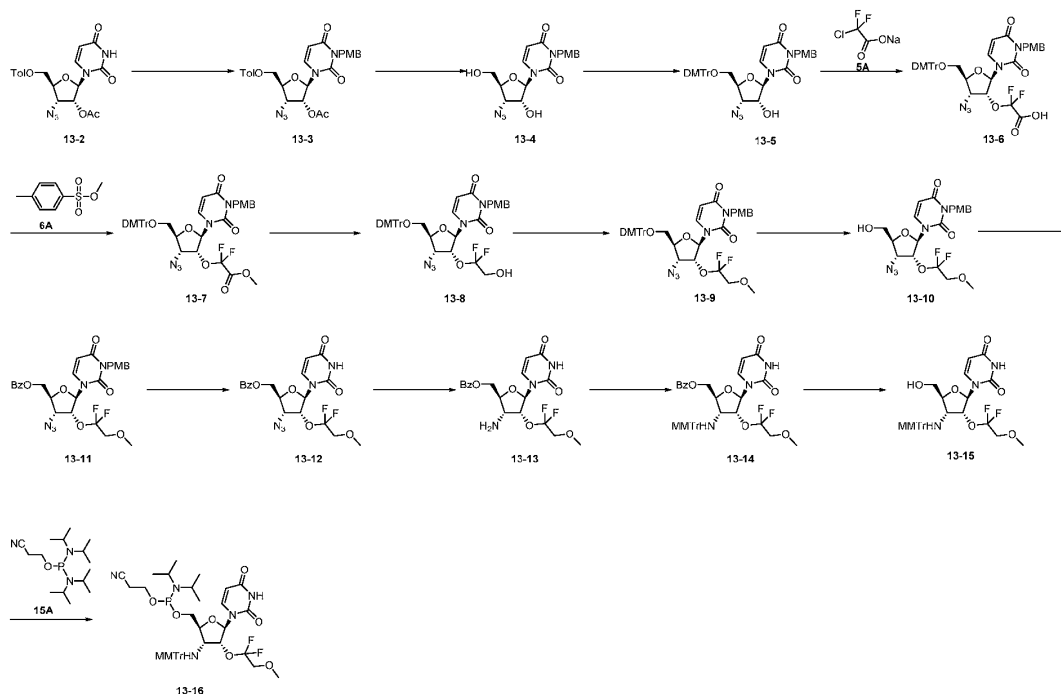
3.65 (s, 3H), 3.46-3.26 (m, 2H), 2.84-2.80 (m, 2H), 2.79-2.72 (m, 1H), 1.85 (s, 1H), 1.18-1.13 (m, 6H), 1.08-0.98 (m, 3H).

[0124] Preparation of (12-9): To a solution of **12-8** (5.60 g, 8.35 mmol) in DCM (50mL) was added DMAP (220 mg) and DIPEA (3 mL). Then CEPCl (2.6 g) was added. The reaction mixture was stirred at r.t. for 1 h, washed with saturated NaHCO₃ and brine, dried over Na₂SO₄, purified by column chromatography and Flash-Prep-HPLC. This resulted in 5.4 g (70.04%) of **12-9** as a white solid. ¹H-NMR (400 MHz, CDCl₃): δ ppm 12.11 (br s, 1H), 8.88 (s, 1H), 7.97-7.64 (m, 1H), 7.51-7.49 (m, 4H), 7.39-7.34 (m, 2H), 7.23-7.09 (m, 6H), 6.75-6.69 (m, 2H), 5.67-5.65 (m, 1H), 4.22-4.08 (m, 2H), 3.84-3.29 (m, 10H), 2.87-2.51 (m, 5H), 2.08-1.61 (m, 1H), 1.24-1.07 (m, 18H), 1.01-0.98 (m, 3H). ³¹P-NMR (162 MHz, CDCl₃): 149.03, 147.96. ESI-LCMS: m/z 853.4 [M+H]⁺.

Example 9



Scheme 11



[0125] **Preparation of Intermediate (13-3):** A solution of **13-2** (260.0 g, 605.5 mmol) and DBU (305.0 g, 1.21 mol) in DMF (1.5 L) was added PMBCl (113.7 g, 908.2 mmol). The mixture was stirred at r.t. for 2 h, poured into cold water, extracted with EA, washed with brine and dried over anhydrous Na₂SO₄, concentrated to give the crude product **13-3** (460.0 g, crude) as a yellow oil. ESI-LCMS: m/z 550 [M+H]⁺.

[0126] **Preparation of Intermediate (13-4):** A solution of **13-3** (460.0 g, crude) in the mixture of THF (1.5 L) and H₂O (500 mL) was added NaOH (167.4 g, 4.1 mol). The reaction was stirred at r.t. for 15 h, and then poured into cold water, extracted with EA. The combined organic layer was washed with brine and dried over anhydrous Na₂SO₄, concentrated to obtain the crude product which was washed with PE:EA = 5:1 to give the product **13-4** (212.0 g, 544.4 mmol, 89.92% yield over two steps) as a white solid. ESI-LCMS: m/z 390 [M+H]⁺.

[0127] **Preparation of Intermediate (13-5):** A solution of **13-4** (207.0 g, 531.6 mmol) and pyridine (210.2 g, 2.6 mol, 214 mL) in DCM (2 L) was added DMTrCl (197.6 g, 584.8 mmol) under N₂. The mixture was stirred at room temperature for 1 h, quenched with MeOH,

concentrated to obtain a residue which was purified by column chromatography to give **13-5** (330.0 g, 477.0 mmol, 89.7% yield) as a yellow solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 7.81 (d, *J* = 8.0 Hz, 1H), 7.39 (d, *J* = 7.6 Hz, 2H), 7.33 (t, *J* = 7.6 Hz, 2H), 7.28-7.25 (m, 7H), 6.91 (d, *J* = 7.6 Hz, 4H), 6.86 (d, *J* = 8.4 Hz, 2H), 6.33 (d, *J* = 5.2 Hz, 1H, exchanged with D₂O), 5.49 (d, *J* = 8.0 Hz, 1H), 4.91 (s, 2H), 4.51 (dd, *J* = 5.2, 8.8 Hz, 1H), 4.21 (t, *J* = 6.8 Hz, 1H), 4.08-4.05 (m, 1H), 3.75 (s, 6H), 3.72 (s, 3H). ESI-LCMS: *m/z* 692 [M+H]⁺.

[0128] Preparation of Intermediate (13-6): A solution of **13-5** (150.0 g, 216.8 mmol) in dry THF (750 mL) were added NaH (10.4 g, 433.7 mmol) and Methyl p-toluenesulfonate (66.1 g, 433.7 mmol) at 0°C, the mixture was allowed to stir at r.t., and TBAI (16.0 g, 43.3 mmol) was added. The reaction was stirred at 80°C for 2 days, and then quenched with sat NH₄Cl(aq.), extracted with EA, washed with brine, dried over Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to give **13-6** (55.0 g, 70.0 mmol, 32.28% yield) as a yellow solid. ESI-LCMS: *m/z* 786 [M+H]⁺.

[0129] Preparation of Intermediate (13-7): A solution of **13-6** (52.0 g, 66.1 mmol) and K₂CO₃ (18.2 g, 132.3 mmol) in dry DMF (500 mL) was added Methyl p-toluenesulfonate (18.4 g, 99.2 mmol) under Ar. The mixture was stirred at r.t. for 15 h, poured into cold water, extracted with EA, washed with brine and dried over anhydrous Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to give **7** (38.5 g, 48.1 mmol, 72.74% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 7.81 (d, *J* = 8.4 Hz, 1H), 7.41-7.38 (m, 2H), 7.34-7.31 (m, 2H), 7.28-7.23 (m, 7H), 6.92-6.90 (m, 4H), 6.84-6.81 (m, 2H), 5.98 (d, *J* = 3.6 Hz, 1H), 5.59 (d, *J* = 8.4 Hz, 1H), 5.40 (dd, *J* = 3.6, 6.4 Hz, 1H), 4.90 (dd, *J* = 14.0, 32.0 Hz, 2H), 4.67 (dd, *J* = 6.4, 7.6 Hz, 1H), 4.09-4.05 (m, 1H), 3.74 (d, *J* = 0.8 Hz, 6H), 3.70 (s, 3H). ¹⁹F-NMR (376 MHz, DMSO-*d*₆): -75.31, -75.69, -76.69, -77.35. ESI-LCMS: *m/z* 800 [M+H]⁺.

[0130] Preparation of Intermediate (13-8): To a solution of **13-7** (33.0 g, 41.2 mmol) in THF (600 mL) were added NaBH₄ (2.3 g, 61.8 mmol) and EtOH (20 mL) at 0°C. The mixture was allowed to stir at r.t. for 4 h, and quenched with sat NH₄Cl(aq.), extracted with EA, washed with brine, dried over Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to give **13-8** (25.0 g, 32.3 mmol, 78.51% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 7.78 (d, *J* = 8.4 Hz, 1H), 7.41-7.38 (m, 2H), 7.34-7.30 (m, 2H), 7.28-7.21 (m, 7H), 6.92-6.89 (m, 4H), 6.84-6.82 (m, 2H), 5.98 (d, *J* = 4.4 Hz, 1H), 5.83 (t, *J* = 6.8 Hz, 1H),

5.60 (d, $J = 8.0$ Hz, 1H), 5.30 (t, $J = 5.3$ Hz, 1H), 4.90 (dd, $J = 14.0, 33.2$ Hz, 2H), 4.61 (t, $J = 6.0$ Hz, 1H), 4.08-4.05 (m, 1H), 3.74 (d, $J = 0.8$ Hz, 6H), 3.70 (s, 3H), 3.39 (dd, $J = 4.0, 14.8$ Hz, 1H), 3.30 (dd, $J = 2.8, 11.2$ Hz, 1H). ^{19}F -NMR (376 MHz, DMSO- d_6): -79.67, -80.04, -80.87, -81.25. ESI-LCMS: m/z 772 $[\text{M}+\text{H}]^+$.

[0131] Preparation of Intermediate (13-9): To a solution of **13-8** (26.0 g, 33.6 mmol) in THF (250 mL) were added NaH (808 mg, 33.6 mmol) and MeI (23.9 g, 168.4 mmol, 10.4 mL) at 0°C. The mixture was allowed to stir at r.t. for 15 h, and poured into cold water, extracted with EA, washed with brine, dried over Na_2SO_4 , concentrated to obtain the crude product **13-9** (29.0 g) as a yellow oil. ESI-LCMS: m/z 786 $[\text{M}+\text{H}]^+$.

[0132] Preparation of Intermediate (13-10): A solution of **13-9** (29.0 g, 36.9 mmol) in DCM (200 mL) was added a solution of p-TsOH (10.0 g) in MeOH (20 mL). The mixture was stirred at r.t. for 0.5 h, and washed with saturated NaHCO_3 to pH = 7, dried over Na_2SO_4 , concentrated to obtain a residue which was purified by column chromatography to give **13-10** (13.5 g, 27.9 mmol, 82.90% yield over two steps). ^1H -NMR (400 MHz, DMSO- d_6): $\delta = 7.99$ (d, $J = 4.4$ Hz, 1H), 7.22 (d, $J = 8.4$ Hz, 2H), 6.85 (d, $J = 8.8$ Hz, 2H), 6.01 (d, $J = 5.2$ Hz, 1H), 5.89 (d, $J = 8.0$ Hz, 1H), 5.46 (t, $J = 4.8$ Hz, 1H), 5.17 (t, $J = 6.4$ Hz, 1H), 4.90 (dd, $J = 14.0, 32.4$ Hz, 2H), 4.43 (t, $J = 5.2$ Hz, 1H), 4.00-3.97 (m, 1H), 3.74-3.67 (m, 6H), 3.64-3.60 (m, 1H), 3.33 (s, 3H). ESI-LCMS: m/z 484 $[\text{M}+\text{H}]^+$.

[0133] Preparation of Intermediate (13-11): To a solution of **13-10** (28.0 g, 57.9 mmol) and TEA (11.7 g, 115.8 mmol, 16 mL) in DCM (300 mL) was added BzCl (12.2 g, 86.8 mmol) under Ar. The mixture was stirred at r.t. for 2 h, and poured into cold water, extracted with EA, washed with brine, dried over Na_2SO_4 , concentrated to obtain a residue which was purified by column chromatography to give **13-11** (31.0 g, 52.7 mmol, 91.10% yield) as a clear oil. ^1H -NMR (400 MHz, DMSO- d_6): $\delta = 8.00$ (d, $J = 3.2$ Hz, 1H), 7.77 (d, $J = 8.0$ Hz, 1H), 7.68 (t, $J = 7.6$ Hz, 1H), 7.54 (t, $J = 7.6$ Hz, 1H), 7.20 (d, $J = 8.8$ Hz, 2H), 6.82 (d, $J = 8.4$ Hz, 2H), 5.97 (d, $J = 4.4$ Hz, 1H), 5.78 (d, $J = 8.4$ Hz, 1H), 5.38 (t, $J = 6.4$ Hz, 1H), 4.87 (dd, $J = 14.0, 27.2$ Hz, 2H), 4.65-4.60 (m, 2H), 4.56-4.51 (m, 1H), 4.28-4.24 (m, 1H), 3.76 (t, $J = 10.4$ Hz, 2H), 3.69 (s, 3H), 3.35 (s, 3H). ESI-LCMS: m/z 588 $[\text{M}+\text{H}]^+$.

[0134] Preparation of Intermediate (13-12): A solution of **13-11** (30.0 g, 51.0 mmol) in the mixture of ACN (300 mL) and H_2O (100 mL) was added CAN (83.9 g, 153.1 mmol). After the

mixture was stirred at 45°C for 24 h, poured into water, extracted with EA, washed with brine and dried over anhydrous Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to give **13-12** (20.0 g, 42.7 mmol, 83.80% yield) as a white solid. ESI-LCMS: m/z 468 [M+H]⁺.

[0135] Preparation of Intermediate (13-13): A solution of **13-12** (13.0 g, 27.8 mmol) in THF (150 mL) were added TPP (10.9 g, 41.7 mmol) and H₂O (5.0 g, 278.1 mmol). The mixture was stirred at 60°C for 5 h, concentrated to obtain a residue which was purified by column chromatography to give **13-13** (11.5 g, 26.0 mmol, 93.67% yield) as a white solid. ESI-LCMS: m/z 442 [M+H]⁺.

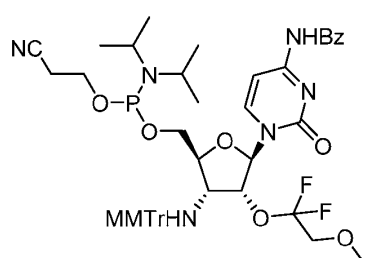
[0136] Preparation of Intermediate (13-14): A solution of **13-13** (10.5 g, 23.7 mmol) and DMAP (581 mg, 4.7 mmol) in DCM (100 mL) were added MMTrCl (11.0 g, 35.6 mmol) and TEA (4.8 g, 47.5 mmol, 6.6 mL) under N₂. The mixture was stirred at r.t. for 1 h, quenched with MeOH and concentrated to obtain a residue which was purified by column chromatography to give **13-14** (15.7 g, 22.0 mmol, 92.47% yield) as a white solid. ESI-LCMS: m/z 714 [M+H]⁺.

[0137] Preparation of Intermediate (13-15): A solution of **13-14** (4.0 g, 5.6 mmol) in 1 N NaOH (MeOH:H₂O = 4:1) (80 mL), the mixture was stirred at room temperature for 1 h, and the reaction was neutralized with saturated NH₄Cl (aq) to pH = 7~8, extracted by EA, washed with brine, dried over anhydrous Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to give **13-15** (3.2 g, 5.2 mmol, 93.66% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 11.37 (d, *J* = 2.4 Hz, 1H, exchanged with D₂O), 7.91 (d, *J* = 8.0 Hz, 1H), 7.50-7.48 (m, 4H), 7.39-7.36 (m, 2H), 7.29 (t, *J* = 7.6 Hz, 4H), 7.22-7.18 (m, 2H), 6.86 (d, *J* = 8.8 Hz, 2H), 6.19 (d, *J* = 6.0 Hz, 1H), 5.67 (dd, *J* = 2.0, 8.0 Hz, 1H), 5.16 (t, *J* = 4.8 Hz, 1H), 4.28 (t, *J* = 5.6 Hz, 1H), 3.78 (dd, *J* = 7.6, 12.8 Hz, 2H), 3.73 (s, 3H), 3.38 (s, 3H), 3.31-3.26 (m, 4H), 3.06-3.01 (m, 1 H). ¹⁹F-NMR (376 MHz, DMSO-*d*₆): -73.96, -74.34, -78.81, -79.20. ESI-LCMS: m/z 610 [M+H]⁺.

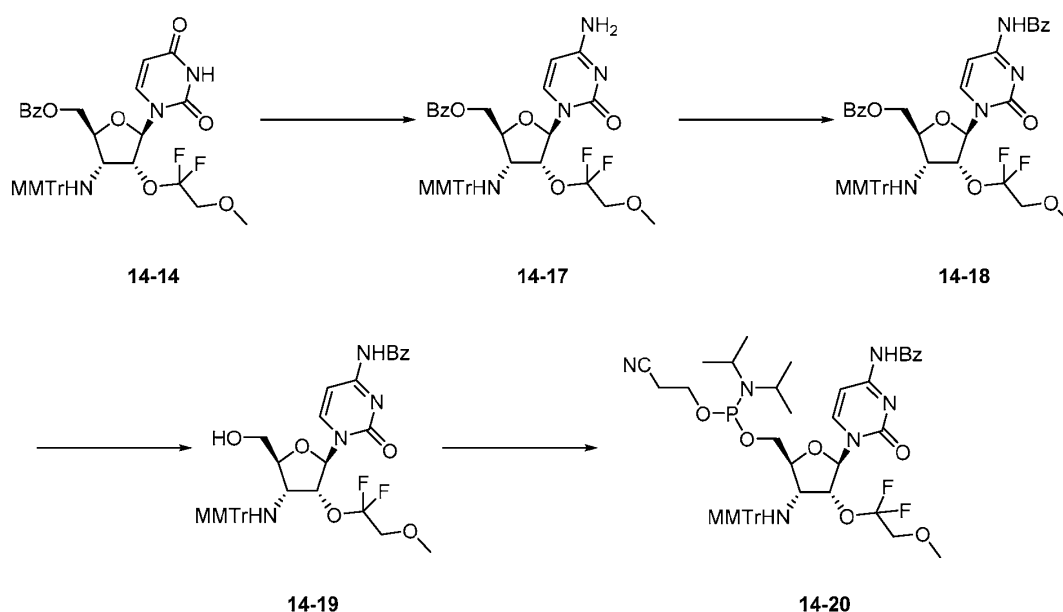
[0138] Preparation of (13-16): A solution of **13-15** (1.5 g, 2.4 mmol) and DCI (145 mg, 1.2 mmol) in dry DCM (30 mL) was added CEP[N(iPr)₂]₂ (816 mg, 2.7 mmol) under Ar. The mixture was stirred at r.t. for 1 h. The reaction was washed with 10% NaHCO₃ (aq.) and brine, dried over Na₂SO₄ and concentrated to obtain the crude product which was purified by column chromatography. This resulted in to give **13-16** (1.5 g, 1.8 mmol, 75.28% yield) as a white solid.

$^1\text{H-NMR}$ (400 MHz, $\text{DMSO-}d_6$): δ = 11.41 (s, 1 H), 7.64 (dd, J = 8.0, 41.6 Hz, 1H), 7.51-7.47 (m, 4H), 7.38-7.36 (m, 2H), 7.29 (t, J = 7.6 Hz, 4H), 7.20 (t, J = 7.2 Hz, 2H), 6.86 (dd, J = 3.6, 8.8 Hz, 2H), 6.14 (dd, J = 6.8, 106.8 Hz, 1H), 5.69 (dd, J = 8.0, 66.4 Hz, 1H), 3.82-3.63 (m, 7H), 3.61-3.42 (m, 5H), 3.39-3.28 (m, 7H), 3.20-2.93 (m, 1H), 2.75-2.72 (m, 1H), 2.68-2.64 (m, 1H), 1.10 (dd, J = 4.8, 6.8 Hz, 6H), 1.00 (dd, J = 6.4, 36.4 Hz, 6H). $^{31}\text{P-NMR}$ (162 MHz, $\text{DMSO-}d_6$): 148.37, 147.75. $^{19}\text{F-NMR}$ (376 MHz, $\text{DMSO-}d_6$): -73.87, -74.25, -74.62, -78.45, -78.83, -78.99, -79.37. ESI-LCMS: m/z 808 $[\text{M-H}]^-$.

Example 10



Scheme 12



[0139] Preparation of Intermediate (14-17): A solution of **14-14** (7.1 g, 9.9 mmol), DMAP (2.4 g, 19.9 mmol) and TEA (2.0 g, 19.9 mmol, 2.77 mL) in dry ACN (100 mL) was added TIPSCl

(4.5 g, 14.9 mmol). After the mixture was stirred at r.t. for 3 h, con.NH₄OH (30 mL) was added, and the reaction was stirred at r.t. for 6 h. Upon of completion, the solvent was removed, and the residue was dissolved in EA, washed with sat NH₄Cl (aq.) and brine, dried over anhydrous Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to give **14-17** (6.1 g, 8.5 mmol, 86.03% yield) as a white solid. ESI-LCMS: m/z 713 [M+H]⁺.

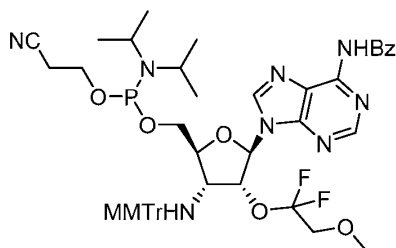
[0140] Preparation of Intermediate (14-18): To a solution of **14-17** (5.1 g, 7.1 mmol) in pyridine (50 mL) at 0°C, was added BzCl (1.5 g, 10.7 mmol) dropwise. After the mixture was stirred for 1 h at r.t., 200 mL H₂O and 300 mL EA were added to separate the solution, the aqueous was extracted by EA, the combined organic layer was washed with brine, dried over Na₂SO₄, concentrated to obtain the crude product **14-18** (6.2 g) as a yellow oil. ESI-LCMS: m/z 817 [M+H]⁺.

[0141] Preparation of Intermediate (14-19): A solution of the crude product **14-18** (6.2 g) in pyridine (60 mL) was added 2N NaOH (in MeOH:H₂O=4:1) (30 mL) dropwise at 0°C, the mixture was stirred at 0°C for 15 min. Neutralized with saturated NH₄Cl (aq.) to give the pH = 7~8, and 300 mL H₂O and 400 mL EA were added in to separate the solution, the aqueous was extracted by EA, the combined organic layer was washed with brine, dried over Na₂SO₄, concentrated to obtain the crude product which was purified by MPLC to give **14-19** (4.1 g, 5.7 mmol, 80.3% yield over two steps) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 11.30 (s, 1H, exchanged with D₂O), 8.47 (d, *J* = 7.6 Hz, 1H), 8.02 (d, *J* = 7.6 Hz, 2H), 7.63 (t, *J* = 7.2 Hz, 1H), 7.54-7.45 (m, 6H), 7.35-7.25 (m, 7H), 7.19 (t, *J* = 7.2 Hz, 2H), 6.83 (d, *J* = 8.8 Hz, 2H), 6.10 (d, *J* = 3.6 Hz, 1H), 5.19 (t, *J* = 4.0 Hz, 1H), 3.77-3.70 (m, 6H), 3.64-3.61 (m, 2H), 3.46-3.43 (m, 1H), 3.35 (s, 3H), 3.31-3.26 (m, 1H), 3.03 (d, *J* = 8.8 Hz, 1H, exchanged with D₂O). ¹⁹F-NMR (376 MHz, DMSO-*d*₆): -73.47, -73.85, -78.26, -79.64. ESI-LCMS: m/z 713 [M+H]⁺.

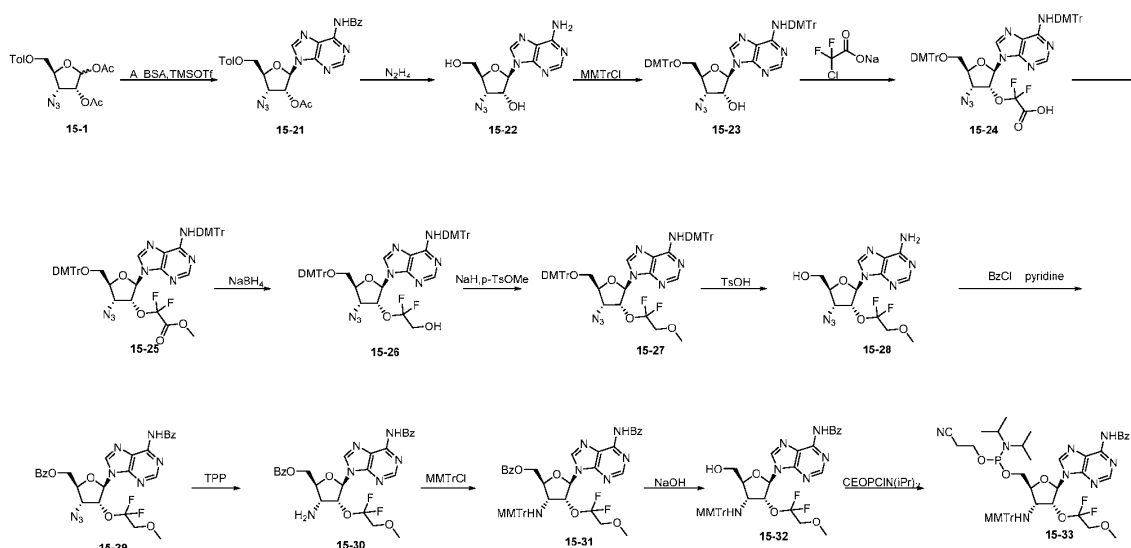
[0142] Preparation of (14-20): A solution of **14-19** (1.7 g, 2.3 mmol) and DCI (170 mg, 1.1 mmol) in dry DCM (20 mL) was added CEP[N(iPr)₂]₂ (790 mg, 2.6 mmol) under Ar. The mixture was stirred at r.t. for 1 h. The reaction was washed with 10% NaHCO₃ (aq.) and brine, dried over Na₂SO₄ and concentrated to obtain the crude product which was purified by column chromatography. This resulted in to give **14-20** (1.8 g, 1.9 mmol, 82.7% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 11.35 (s, 1 H), 8.20 (dd, *J* = 8.0, 81.6 Hz, 1H), 8.03-8.00 (m, 2H), 7.64 (t, *J* = 7.6 Hz, 1H), 7.54-7.44 (m, 6H), 7.37-7.16 (m, 9H), 6.82 (dd, *J* = 9.2, 16.4

Hz, 2H), 6.14 (dd, $J = 4.8, 90.4$ Hz, 1H), 4.15-4.02 (m, 1H), 3.90-3.40 (m, 11H), 3.36-3.24 (m, 6H), 3.12-2.98 (m, 1H), 2.77-2.73 (m, 2H), 1.13 (d, $J = 6.8$ Hz, 6H), 1.05 (dd, $J = 6.8, 28.0$ Hz, 6H). ^{31}P -NMR (162 MHz, DMSO- d_6): 148.20, 147.96. ^{19}F -NMR (376 MHz, DMSO- d_6): -73.36, -73.74, -73.98, -74.36, -77-89, -78.28, -78.55, -78.94. ESI-LCMS: m/z 913 $[\text{M}+\text{H}]^+$.

Example 11



Scheme 13



[0143] **Preparation of Intermediate (15-21):** To a solution of compound **15-1** (90 g, 238.5 mmol) in dry Acetonitrile (900 mL) was added N-(5H-Purin-6-yl)benzamide (85.6 g, 357.7 mmol) and BSA (155.3 g, 763.2 mmol). The resulting suspension was stirred at 50°C for 30 min. Then the mixture was at -5°C and TMSOTf (79.5 g, 357.8 mmol) was added by syringe. Then the mixture was stirred at 80°C for 72 h under N_2 . The mixture was cooled and concentrated. And then added water and extracted with EA. The extract was washed with brine, dried over Na_2SO_4 , and

concentrated to give the residue which was purified by column chromatography to afford **15-21** (120 g, 215.62 mmol, 90.4% yield) as a yellow solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 8.56 (s, 1H), 8.53 (s, 1H), 8.00 (t, *J* = 8.0 Hz, 2H), 7.76-7.74 (d, *J* = 8.0 Hz, 2H), 7.64~7.60 (t, *J* = 7.5 Hz, 1H), 7.54~7.50 (t, *J* = 7.68 Hz, 2H), 7.27~7.25 (d, *J* = 7.8 Hz, 2H), 6.31 (d, *J* = 3.3 Hz, 1H), 6.14~6.11 (m, 1H), 5.05~5.01 (t, *J* = 8.0 Hz, 1H), 4.67~4.63 (m, 1H), 4.53-4.49 (m, 1H), 4.37-4.34 (m, 1H), 2.31 (s, 3H), 2.12 (s, 3H). ESI-LCMS: *m/z* 556 [M+H]⁺.

[0144] Preparation of Intermediate (15-22): To a solution of **15-21** (120 g, 215.6 mmol) and Methylamine (267.9 g, 8.6 mol) in Methanol (1300 mL) was stirred at r.t for 18 h under N₂. The mixture was concentrated and stirred at 25% EA in PET for 1 h to afford **15-22** (52 g, 1778.0 mmol, 82.5% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 8.36 (s, 1H), 8.15 (s, 1H), 7.40 (s, 2H), 6.24-6.22 (d, *J* = 8.0 Hz, 1H), 5.91~5.90 (d, *J* = 4 Hz, 1H), 5.63~5.60 (m, 1H), 5.04~5.00 (m, 1H), 4.34~4.32 (m, 1H), 3.99~3.98 (d, *J* = 4 Hz, 1H), 3.72~3.55 (m, 2H). ESI-LCMS: *m/z* 292 [M+H]⁺.

[0145] Preparation of Intermediate (15-23): To a solution of **15-22** (50 g, 171.1 mmol) and DMTrCl (121.7 g, 359.3 mmol) in pyridine (250 mL) was stirred for 2 h at r.t.. The mixture was quenched with water, extracted with EA, dried over Na₂SO₄, concentrated to give the residue which was purified by column chromatography to afford **15-23** (117 g, 130.4mmol, 76.2% yield) as a yellow solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 8.29 (s, 1H), 7.76 (s, 1H), 7.20-7.12 (m, 19H), 6.74 (m, 8H), 5.87 (s, 1H), 5.08 (s, 1H), 4.39 (s, 1H), 3.62 (s, 12H), 3.32~3.10 (m, 2H). ESI-LCMS: *m/z* 896 [M+H]⁺.

[0146] Preparation of Intermediate (15-24): To a solution of **15-23** (115 g, 128.2 mmol) and THF (800 mL) was stirred at 5°C under N₂. NaH (4.0 g, 167.4 mmol) was slowly added below 10°C, and Sodium chlorodifluoroacetate (25.5 g, 167.4 mmol) and TBAI (5.6 g, 16.7mmol) were added at 5°C. The reaction was refluxed for 18 h. Cooled to r.t., the reaction was quenched with saturated NH₄Cl (aq.) and extracted with EA, washed with brine, dried over Na₂SO₄, concentrated to give the residue which was purified by column chromatography to give **15-24** (56 g, 56.6 mmol, 48.3% yield) as a yellow crude solid. ESI-LCMS: *m/z* 990 [M+H]⁺.

[0147] Preparation of Intermediate (15-25): To a solution of **15-24** (56 g, 57.3 mmol), methyl p-toluenesulfonate (15.8 g, 84.8 mmol) and K₂CO₃ (15.6 g, 113.0 mmol) in dry DMF (560 mL) was stirred at r.t. for 18 h under N₂. The mixture was quenched with water, extracted with EA,

wash with brine and concentrated to obtain a residue which was purified by column chromatography to afford **15-25** (33 g, 32.8 mmol, 58.1% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-d₆): δ = 8.40 (s, 1H), δ = 7.82 (s, 1H), 7.40 (s, 1H), 7.31-7.16 (m, 18H), 6.82-6.79 (m, 8H), 6.24-6.23 (d, *J* = 4.0 Hz, 1H), 6.00-5.99 (t, 1H), 4.88-4.85 (t, 1H), 4.17-4.14 (m, 1H), 3.79 (s, 3H), 3.68 (s, 12H), 3.31-3.30 (m, 2H). ¹⁹F-NMR (376 MHz, DMSO-d₆): -75.75, -76.14, -76.89, -77.28. ESI-LCMS: *m/z* 1004 [M+H]⁺.

[0148] Preparation of Intermediate (15-26): To a solution of **15-25** (30 g, 29.9 mmol) in THF (300 mL) was added NaBH₄ (1.7 g, 44.8 mmol) and EtOH (100 mL) at 5°C. The mixture was allowed to stir at r.t. for 1.5 h, and quenched with sat NH₄Cl (aq.), extracted with EA, washed with brine, dried over Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to afford **15-26** (22 g, 22.5 mmol, 75.4% yield) as a yellow solid. ¹H-NMR (400 MHz, DMSO-d₆): δ = 8.35 (s, 1H), 7.79 (s, 1H), 7.26-7.13 (m, 21H), 6.77-6.75 (m, 9H), 6.14-6.13 (d, *J* = 4.0 Hz, 1H), 5.90 (t, 1H), 4.74-4.72 (t, 1H), 4.11 (s, 1H), 3.63 (s, 12H), 3.28-3.25 (m, 2H). ¹⁹F-NMR (376 MHz, DMSO-d₆): -79.94, -80.31, -80.77, -81.15. ESI-LCMS: *m/z* 976 [M+H]⁺.

[0149] Preparation of Intermediate (15-27): To a solution of **15-26** (20 g, 20.5 mmol) in THF (100 mL) were added NaH (491.7 mg, 20.5 mmol) and Methyl p-toluenesulfonate (11.4 g, 61.5 mmol) at 5°C. The mixture was allowed to stir at r.t. for 3 h, and was poured into cold water, extracted with EA, washed with brine, dried over Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to afford **15-27** (16.5 g, 16.7 mmol, 81.3% yield) as a yellow solid. ¹H-NMR (400 MHz, DMSO-d₆): δ = 8.40 (s, 1H), 7.86 (s, 1H), 7.37-7.30 (m, 4H), 7.28-7.26 (m, 5H), 7.24-7.18 (m, 12H), 6.84-6.81 (m, 8H), 6.17-6.16 (d, *J* = 4.0 Hz, 1H), 5.92-5.89 (t, 1H), 4.79-4.76 (t, 1H), 4.15-4.11 (m, 1H), 3.70 (s, 12H), 3.31 (s, 5H). ¹⁹F-NMR (376 MHz, DMSO-d₆): -76.83, -77.22, -78.05, -78.43. ESI-LCMS: *m/z* 990 [M+H]⁺.

[0150] Preparation of Intermediate (15-28): To a solution of **15-27** (15.5 g, 15.6 mmol) in DCM (155 mL) was added a solution of TsOH (6.2 g, 36.0 mmol) in MeOH (30 mL). The mixture was stirred at r.t. for 0.5 h, and washed with saturated NaHCO₃ to pH = 7-8, extracted with EA, dried over Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to give **15-28** (4.6 g, 11.4 mmol, 72.8% yield) as a white solid. ESI-LCMS: *m/z* 386 [M+H]⁺.

[0151] Preparation of Intermediate (15-29): To a solution of **15-28** (4.4 g, 11.3 mmol) in pyridine (40 mL) was slowly added BzCl (8.0 g, 56.7 mmol) at 5°C. The mixture was allowed to stir at r.t. for 2 h, and quenched with little water, ammonium hydroxide was slowly added at 4°C until intermediate product was disappeared. The mixture was extracted with EA, washed with brine, dried over Na₂SO₄, concentrated to obtain a crude product which was purified by column chromatography. This resulted in to give **15-29** (6.0 g, 10.1 mmol, 89.1% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 8.67-8.66 (t, 1H), 8.47-8.44 (t, 1H), 8.02-7.97 (m, 4H), 7.69-7.62 (m, 2H), 7.56-7.52 (m, 4H), 6.32-6.31 (d, *J* = 4.0Hz, 1H), 6.09~6.06 (m, 1H), 5.00~4.98 (m, 1H), 4.71~4.67 (m, 1H), 4.58~4.54 (m, 1H), 4.43~4.41 (m, 1H), 3.77~3.72 (m, 2H), 3.31 (m, 3H). ¹⁹F-NMR (376 MHz, DMSO-*d*₆): -76.97, -77.35, -78.19, -78.57. ESI-LCMS: *m/z* 594 [M+H]⁺.

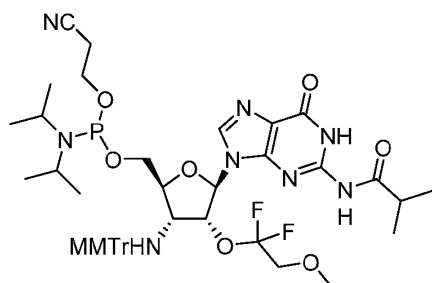
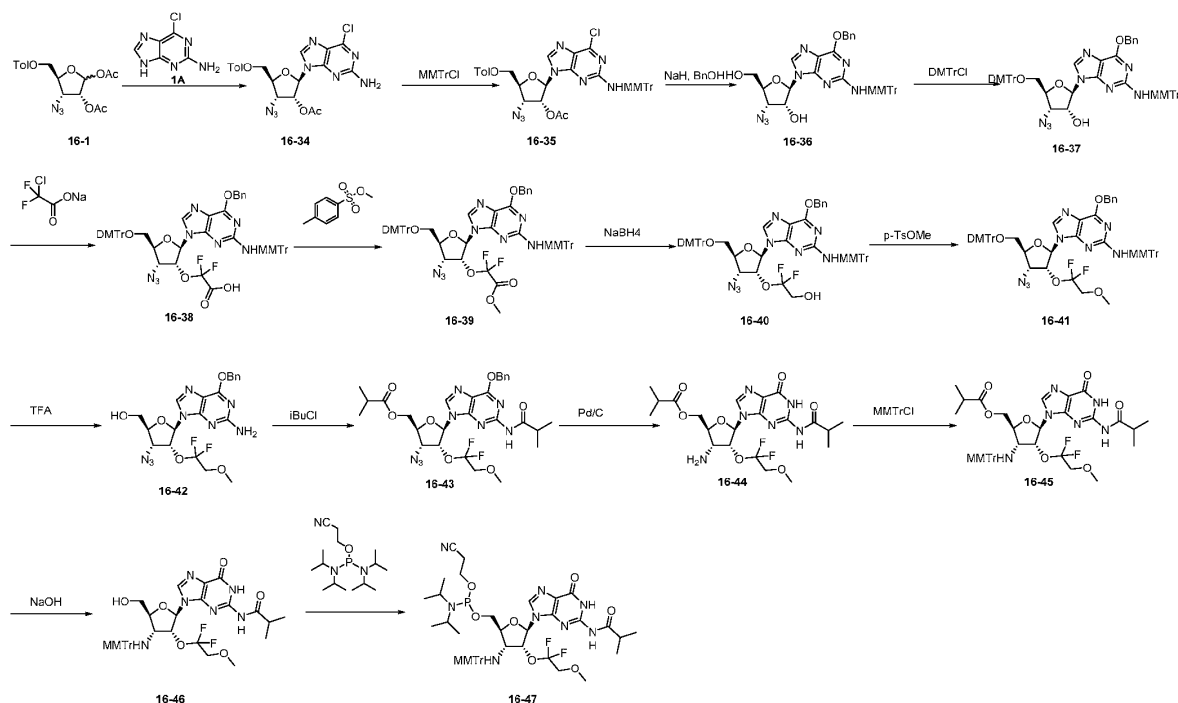
[0152] Preparation of Intermediate (15-30): To a solution of **15-29** (6.0 g, 10.1 mmol) in THF (70 mL) was added PPh₃ (4.0 g, 15.1 mmol) and water (1.8 g, 100.9 mmol) under N₂. The mixture was stirred at 45°C for 15 h, poured into cold water, adjusted to pH = 1~2 by 2N HCl (aq.), extracted with EA. Then the aqueous phase was adjusted to pH = 7~8 with saturated NaHCO₃ (aq.), extracted with EA, washed with brine, dried over Na₂SO₄, concentrated to afford **15-30** (5.5 g, 9.7 mmol, 95.9% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 8.67 (s, 2H), 8.03-8.01 (m, 2H), 7.88-7.86 (m, 2H), 7.65-7.61 (m, 2H), 7.56-6.46 (m, 5H), 6.30~6.29 (d, *J* = 4.0Hz, 1H), 5.42~5.40 (m, 1H), 4.69~4.66 (m, 1H), 4.51~4.47 (m, 1H), 4.08~4.09 (m, 2H), 3.87-3.80 (m, 2H), 3.46 (s, 5H). ¹⁹F-NMR (376 MHz, DMSO-*d*₆): -75.65, -76.03, -77.47, -77.86. ESI-LCMS: *m/z* 568 [M+H]⁺.

[0153] Preparation of Intermediate (15-31): To a solution of **15-30** (5.5 g, 9.6 mmol) in dry DCM (55 mL) was added MMTTrCl (4.5 g, 14.5 mmol) and TEA (2.0 g, 19.3 mmol) under N₂. The mixture was allowed to stir at r.t. for 1.0 h, and quenched with water, extracted with DCM, washed with brine, dried over Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to afford **15-31** (7.3 g, 8.7 mmol, 89.8% yield) as a yellow solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 8.46 (s, 1H), 8.41 (s, 1H), 8.00-7.98 (d, *J* = 8.0Hz, 2H), 7.62-7.44 (m, 12H), 7.38-7.34 (m, 4H), 7.17-7.12 (m, 4H), 7.06~7.01 (m, 2H), 6.67~6.65 (d, *J* = 8.0Hz, 2H), 6.17 (s, 1H), 4.57~4.54 (d, *J* = 12Hz, 1H), 4.35~4.18 (m, 4H), 3.70~3.65 (m, 2H),

3.50 (s, 3H), 3.31 (s, 3H). ^{19}F -NMR (376 MHz, DMSO- d_6): -73.61, -74.00, -77.94, -78.32. ESI-LCMS: m/z 840 $[\text{M}+\text{H}]^+$.

[0154] Preparation of Intermediate (15-32): To a solution of **15-31** (7.2 g, 8.5 mmol) in pyridine (70 mL) was slowly added 2N NaOH (aq.) (510.0 mg, 10.3 mmol) at 5~10°C. The mixture was allowed to stir at r.t. for 10 min, neutralized with sat NH_4Cl (aq.) to pH 7~8, extracted with EA, washed with brine, dried over Na_2SO_4 , concentrated to obtain a crude product which was purified by column chromatography. This resulted in to give **15-32** (5.8 g, 7.9 mmol, 92.2% yield) as a white solid. ^1H -NMR (400 MHz, DMSO- d_6): δ = 8.63 (s, 2H), 7.99-7.97 (d, J =8.0Hz, 2H), 7.64-7.60 (m, 1H), 7.54-7.50 (m, 2H), 7.42-7.38 (m, 4H), 7.27-7.25 (d, J = 8.0 Hz, 2H), 7.21- 7.16 (m, 4H), 7.12- 7.09 (m, 2H), 6.72- 6.70 (d, J = 8.0 Hz, 2H), 6.28-6.27 (d, J = 8.0 Hz, 1H), 5.59 (m, 1H), 3.96 (s, 4H), 3.76-3.74 (m, 1H), 3.68-3.63 (m, 2H), 3.60 (s, 3H), 3.47-3.41 (m, 2H), 3.27 (s, 3H). ^{19}F -NMR (376 MHz, DMSO- d_6): -74.13, -74.51, -78.09, -78.47. ESI-LCMS: m/z 736 $[\text{M}+\text{H}]^+$.

[0155] Preparation of (15-33): To a solution of **15-32** (3 g, 4.1 mmol) and DCI (240.4 mg, 2.0 mmol) in dry DCM (30 mL) was added CEP[N(iPr) $_2$] $_2$ (1.5 g, 4.9 mmol) under N_2 . The mixture was allowed to stir at r.t. for 1h, quenched with sat NaHCO_3 , washed with brine, dried over Na_2SO_4 , concentrated to obtain a crude product which was purified by column chromatography. This resulted in to give **15-33** (3.1 g, 3.3 mmol, 81.2% yield) as a white solid. ^1H -NMR (400 MHz, DMSO- d_6): δ = 11.20 (s, 1H), 8.69-8.68 (d, J = 4.0Hz, 1H), 8.50-8.48 (d, J = 8.0Hz, 1H), 8.05-8.03 (m, 2H), 7.66-7.62 (m, 1H), 7.57-7.45 (m, 6H), 7.40- 7.33 (m, 2H), 7.30- 7.11 (m, 6H), 6.85- 6.76 (m, 2H), 6.45-6.30 (m, 1H), 4.77-4.74 (m, 0.5H), 4.00-3.99 (m, 0.5H), 3.86-3.84 (m, 0.5H), 3.77-3.70 (m, 5H), 3.67-3.59 (m, 4H), 3.56-3.51 (m, 1H), 3.50-3.34 (m, 3H), 3.32 (s, 3H), 3.08-3.06 (m, 0.5H), 2.77-2.65 (m, 2H), 1.08-0.99 (m, 12H). ^{19}F -NMR (376 MHz, DMSO- d_6): -73.92, -74.27, -74.30, -74.65, -77.64, -78.03, -78.55, 78.93. ESI-LCMS: m/z 936 $[\text{M}+\text{H}]^+$.

Example 12Scheme 14

[0156] Preparation of Intermediate (16-34): A solution of **16-1** (150.0 g, 397.5 mmol) and 6-Chloroguanine (101.1 g, 596.3 mmol) in dry ACN (1.5 L) was added BSA (259.5 g, 1.27 mol) under Ar. The resulting suspension was stirred at 50°C for 1 h. Then the mixture was cooled at -5°C and TMSOTf (590.5 g, 2.66 mol) was added by syringe. After that the mixture was stirred at 60°C for 5 h, concentrated to remove ACN and the residue was dissolved in EA (2.0 L), washed

with sat $\text{NaHCO}_3(\text{aq.})$ and brine, dried over Na_2SO_4 , concentrated to give the crude product **16-34** (265.0 g) as a yellow solid. ESI-LCMS: m/z 487 $[\text{M}+\text{H}]^+$.

[0157] Preparation of Intermediate (16-35): A solution of **16-34** (crude, 265 g, 353.8 mmol) and TEA (107.4 g, 1.06 mol, 148 mL) in DCM (2.5 L) was added MMTrCl (164.0 g, 530.7 mmol) and DMAP (8.6 g, 70.8 mmol), the mixture was stirred at r.t. for 5 h, washed with water and brine, dried over Na_2SO_4 , concentrated to obtain the residue which was purified by column chromatography to give **16-35** (160.0 g, 210.8 mmol, 53.0% yield over 2 steps) as a yellow solid. ESI-LCMS: m/z 759 $[\text{M}+\text{H}]^+$.

[0158] Preparation of Intermediate (16-36): To a solution of **35** (20.0 g, 26.39 mmol) in Benzyl alcohol (200 mL) was added NaH (5.3 g, 131.93 mmol) at 0 °C. The resulting mixture was allowed to stir at r.t. for 2 h, quenched with cold water, extracted with EA, washed with water and brine, dried over Na_2SO_4 , concentrated to obtain a residue which was purified by column chromatography to give **16-36** (11.2 g, 16.72 mmol, 63.1% yield) as white solid. ESI-LCMS: m/z 671 $[\text{M}+\text{H}]^+$.

[0159] Preparation of Intermediate (16-37): A solution of **16-36** (49.0 g, 73.1 mmol) and pyridine (28.9 g, 365.3 mmol, 29 mL) in DCM (500 mL) was added DMTrCl (27.2 g, 80.4 mmol) at r.t.. The mixture was stirred at r.t. for 3 h, washed with water and brine, dried over Na_2SO_4 , concentrated to obtained a residue which was purified by column chromatography to give **16-37** (58.9 g, 60.6 mmol, 82.9% yield) as a white solid. ESI-LCMS: m/z 973 $[\text{M}+\text{H}]^+$.

[0160] Preparation of Intermediate (16-38): A solution of **16-37** (58.9 g, 60.6 mmol) in dry THF (300 mL) were added NaH (5.1 g, 127.8 mmol, 60% purity) and Methyl p-toluenesulfonate (19.5 g, 127.8 mmol) at 0°C, the mixture was allowed to stirred at r.t., and TBAI (4.7 g, 12.8 mmol) was added. After that the mixture was stirred at 80°C for 24 h, and quenched with sat $\text{NH}_4\text{Cl}(\text{aq.})$, extracted with EA, washed with brine, dried over Na_2SO_4 , concentrated to obtain a residue which was purified by column chromatography to give the crude product **16-38** (30.9 g) as a blank solid. ESI-LCMS: m/z 1067 $[\text{M}+\text{H}]^+$.

[0161] Preparation of Intermediate (16-39): A solution of the crude **16-38** (30.9 g) and K_2CO_3 (8.0 g, 58.1 mmol) in DMF (200 mL) was added Sodium chlorodifluoroacetate (5.4 g, 29.1 mmol) at r.t.. The mixture was stirred at r.t. for 15 h, quenched with sat $\text{NH}_4\text{Cl}(\text{aq.})$, extracted

with EA, washed with brine, dried over Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography to give **16-39** (9.8 g, 9.1 mmol, 15.0% yield over 2 steps) as a yellow solid. ESI-LCMS: m/z 1081 [M+H]⁺.

[0162] Preparation of Intermediate (16-40): A solution of **16-39** (9.3 g, 8.6 mmol) in THF (180 mL) was added NaBH₄ (488 mg, 12.9 mmol) and EtOH (15 mL) at 0°C. The mixture was stirred at 0°C for 1 h, quenched with sat NH₄Cl (aq.), extracted with EA, washed with brine, dried over Na₂SO₄, concentrated to obtain a residue which was purified by column chromatography. This resulted in to give **16-40** (8.5 g, 7.0 mmol, 81.63% yield, 87% purity) as a white solid. ESI-LCMS: m/z 1053 [M+H]⁺.

[0163] Preparation of Intermediate (16-41): A solution of **16-40** (8.3 g, 7.9 mmol) in THF (80 mL) was added NaH (472 mg, 11.8 mmol, 60% purity) and Methyl p-toluenesulfonate (2.9 g, 15.8 mmol) at 0°C. The mixture was allowed to stir at r.t. for 15 h, and poured into cold water, extracted with EA, washed with brine, dried over Na₂SO₄, concentrated to obtained the crude product **16-41** (9.1 g) as a yellow oil. ESI-LCMS: m/z 1067 [M+H]⁺.

[0164] Preparation of Intermediate (16-42): A solution of crude **16-41** (9.1 g) in DCM (100 mL) was added a solution of p-TsOH (10 g) in MeOH (10 mL). The mixture was stirred at r.t. for 0.5 h, and neutralized with TEA to give pH = 7, concentrated to obtain a residue which was purified by column chromatography. This resulted in to give **16-42** (3.2 g, 6.5 mmol, 82.3% yield over 2 steps) as a yellow solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 8.14 (s, 1H), 7.52-7.50 (m, 2H), 7.42-7.33 (m, 3H), 6.62 (s, 2H, exchanged with D₂O), 6.01 (d, *J* = 6.4 Hz, 1H), 5.62 (t, *J* = 6.0 Hz, 1H), 5.49 (t, *J* = 12.8 Hz, 2H), 5.39 (t, *J* = 5.6 Hz, 1H, exchanged with D₂O), 4.64 (dd, *J* = 3.6, 5.6 Hz, 1H), 4.02 (dd, *J* = 3.6, 7.2 Hz, 1H), 3.74-3.66 (m, 3H), 3.64-3.59 (m, 1H), 3.32 (s, 3H). ¹⁹F-NMR (376 MHz, DMSO-*d*₆): -77.52, -77.91, -78.17, -78.55). ESI-LCMS: m/z 493 [M+H]⁺.

[0165] Preparation of Intermediate (16-43): A solution of **16-42** (3.2 g, 6.5 mmol) in pyridine (30 mL) was added i-BuCl (2.1 g, 19.5 mmol) drop wise at 0°C. The mixture was stirred at 0°C for 1 h, quenched with MeOH and concentrated to obtain a residue which was purified by column chromatography. This resulted in to give **16-43** (3.2 g, 5.5 mmol, 84.59% yield) as a yellow oil. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 10.60 (s, 1H, exchanged with D₂O), 8.42 (s, 1H), 7.57-7.54 (m, 2H), 7.44-7.35 (m, 3H), 6.20 (d, *J* = 2.8 Hz, 1H), 5.71 (dd, *J* = 2.4, 5.6 Hz, 1H), 5.68-5.64

(m, 3H), 4.41 (dd, $J = 3.6, 12.0$ Hz, 1H), 4.24 (dd, $J = 5.6, 12.0$ Hz, 1H), 4.19-4.15 (m, 1H), 3.80 (t, $J = 10.4$ Hz, 2H), 3.38 (s, 3H), 3.35 (s, 3H), 2.45-2.38 (m, 1H), 1.12 (dd, $J = 2.4, 6.8$ Hz, 6H), 0.97 (dd, $J = 6.8, 16.4$ Hz, 6H). ^{19}F -NMR (376 MHz, DMSO- d_6): -76.48, -76.87, -77.62, -78.01). ESI-LCMS: m/z 633 $[\text{M}+\text{H}]^+$.

[0166] Preparation of Intermediate (16-44): A solution of **16-43** (1.6 g, 2.5 mmol) in THF (20 mL) was added Pd/C (200 mg), the mixture was stirred at r.t. for 5 h under H_2 . The reaction was filtered and the filtrate was concentrated to give **16-44** (1.2 g, 2.3 mmol, 91.86% yield) as a white solid. ^1H -NMR (400 MHz, DMSO- d_6): $\delta = 11.60$ (s, 1H, exchanged with D_2O), 8.22 (s, 1H), 6.05 (d, $J = 2.8$ Hz, 1H), 5.14 (dd, $J = 3.2, 5.6$ Hz, 1H), 4.40 (dd, $J = 2.4, 12.0$ Hz, 1H), 4.17 (dd, $J = 5.6, 12.0$ Hz, 1H), 3.93-3.73 (m, 4H), 3.38 (s, 3H), 1.14 (d, $J = 7.2$ Hz, 6H), 1.04 (dd, $J = 7.2, 12.4$ Hz, 6H). ^{19}F -NMR (376 MHz, DMSO- d_6): -75.73, -76.12, -77.46, -77.84). ESI-LCMS: m/z 517 $[\text{M}+\text{H}]^+$.

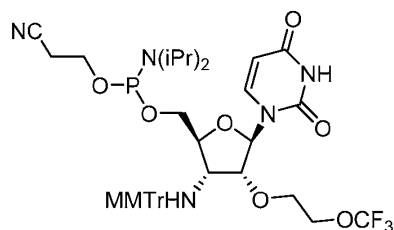
[0167] Preparation of Intermediate (16-45): A solution of **16-44** (3.0 g, 5.8 mmol) and collidine (1.8 g, 14.5 mmol) in DCM (40 mL) was added MMTrCl (2.7 g, 8.7 mmol) and AgNO_3 (986 mg, 5.8 mmol), the mixture was stirred at r.t. for 1 h, filtered and the filtrate was washed with water and dried over anhydrous Na_2SO_4 , concentrated to obtain a residue which was purified by column chromatography to give **16-45** (3.8 g, 4.8 mmol, 82.94% yield) as a white solid. ^1H -NMR (400 MHz, DMSO- d_6): $\delta = 12.16$ (s, 1H, exchanged with D_2O), 11.48 (s, 1H, exchanged with D_2O), 7.86 (s, 1H), 7.50 (dd, $J = 5.2, 7.2$ Hz, 4H), 7.37 (d, $J = 8.8$ Hz, 2H), 7.28 (t, $J = 7.2$ Hz, 4H), 7.20 (t, $J = 7.2$ Hz, 2H), 6.83 (d, $J = 9.2$ Hz, 2H), 6.11 (d, $J = 3.2$ Hz, 1H), 4.18 (dd, $J = 5.2, 8.8$ Hz, 1H), 4.08 (t, $J = 4.4$ Hz, 1H), 4.44-3.97 (m, 1H), 3.74 (dd, $J = 7.6, 10.4$ Hz, 2H), 3.70 (s, 3H), 3.46-3.41 (m, 1H), 3.16 (d, $J = 8.0$ Hz, 1H, exchanged with D_2O), 2.86-2.79 (m, 1H), 2.33-2.26 (m, 1H), 1.13 (t, $J = 7.2$ Hz, 6H), 0.89 (dd, $J = 7.2, 14.8$ Hz, 6H). ^{19}F -NMR (376 MHz, DMSO- d_6): -74.01, -74.39, -78.00, -78.38). ESI-LCMS: m/z 789 $[\text{M}+\text{H}]^+$.

[0168] Preparation of Intermediate (16-46): A solution of **16-45** (3.8 g, 4.8 mmol) in pyridine (40 mL) was added 2N NaOH (MeOH: H_2O =4:1) (15 mL) at 0°C , the mixture was stirred at 0°C for 1 h. Then the reaction was neutralized with saturated NH_4Cl (aq) to pH = 7~8, extracted with EA, washed with brine, dried over anhydrous Na_2SO_4 , concentrated to obtain a residue which was purified by column chromatography. This resulted in to give **16-46** (3.0 g, 4.2 mmol, 87.50% yield) as a white solid. ^1H -NMR (400 MHz, DMSO- d_6): $\delta = 12.16$ (s, 1H, exchanged

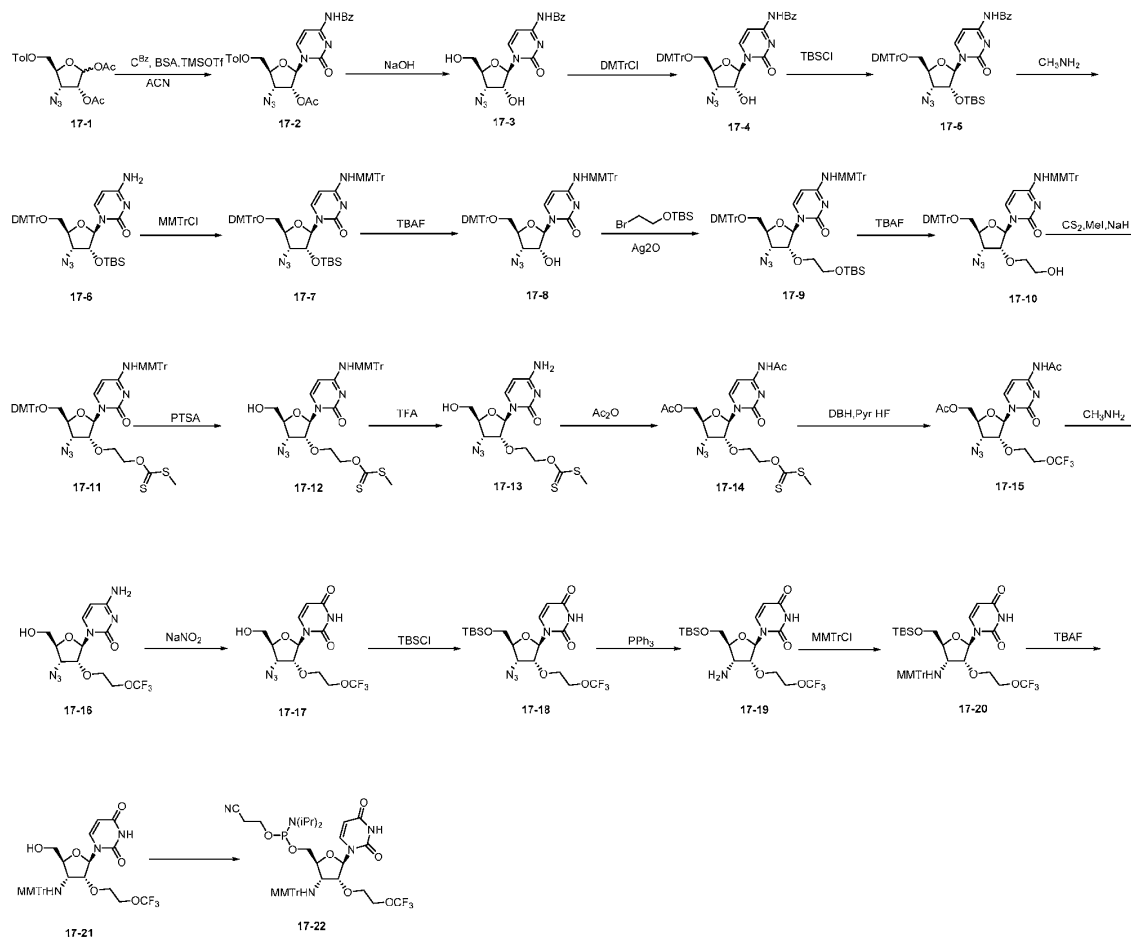
with D₂O), 11.68 (s, 1H, exchanged with D₂O), 8.19 (s, 1H), 7.51 (dd, $J = 5.2, 7.2$ Hz, 4H), 7.38 (d, $J = 8.8$ Hz, 2H), 7.31 (t, $J = 7.2$ Hz, 4H), 7.21 (t, $J = 7.2$ Hz, 2H), 6.87 (d, $J = 8.8$ Hz, 2H), 6.26 (d, $J = 6.0$ Hz, 1H), 5.15 (t, $J = 4.4$ Hz, 1H), 4.76 (t, $J = 6.0$ Hz, 1H, exchanged with D₂O), 3.75-3.70 (m, 5H), 3.42 (d, $J = 2.4$ Hz, 1H), 3.38-3.28 (m, 5H), 3.23 (d, $J = 6.4$ Hz, 1H, exchanged with D₂O), 3.16-3.10 (m, 1H), 2.88-2.81 (m, 1H), 1.15 (dd, $J = 6.4, 7.2$ Hz, 6H). ¹⁹F-NMR (376 MHz, DMSO-*d*₆): -74.73, -75.12, -78.79, -79.17. ESI-LCMS: m/z 719 [M+H]⁺.

[0169] Preparation of (16-47): A solution of **16-46** (3.0 g, 4.2 mmol) and DCI (394 mg, 3.3 mmol) in dry DCM (50 mL) was added CEP[N(iPr)₂]₂ (1.5 g, 5.0 mmol) under Ar. The mixture was stirred at r.t. for 1 h. The reaction was washed with 10% NaHCO₃ (aq) and water, dried over Na₂SO₄ and concentrated to obtain the crude product which was purified by column chromatography. This resulted in to give **16-47** (3.0 g, 3.2 mmol, 77.81% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 12.13 (s, 1H), 11.65 (d, $J = 5.6$ Hz, 1H), 8.11 (s, 0.35H), 7.95 (s, 0.65H), 7.50 (t, $J = 7.2$ Hz, 4H), 7.38-7.26 (m, 6H), 7.20 (dd, $J = 8.4, 16.0$ Hz, 2H), 6.88 (d, $J = 9.2$ Hz, 0.7H), 6.82 (d, $J = 8.8$ Hz, 1.3H), 6.31 (d, $J = 6.8$ Hz, 0.35H), 6.14 (d, $J = 4.4$ Hz, 0.65H), 4.97 (t, $J = 6.4$ Hz, 0.35H), 3.97 (t, $J = 4.4$ Hz, 0.65H), 3.82-3.54 (m, 9H), 3.48-3.14 (m, 9H), 2.86-2.69 (m, 2H), 1.24-0.92 (m, 18H). ³¹P-NMR (162 MHz, DMSO-*d*₆): 148.35, 148.24. ESI-LCMS: m/z 919 [M+H]⁺.

Example 13



Scheme 15



[0170] **Preparation of Intermediate (17-2):** To a solution of 17-1 (120 g, 318 mmol) in ACN (1.2 L) was added BSA (208 g, 1016 mmol) and N⁴-Benzoylcytosine (102 g, 474 mmol). The mixture was stirred at 50°C for 1 h until clear. Then the solution was cooled to -10°C. TMSOTf (84 g, 381 mmol) was slowly added to the mixture. Then warmed up. The reaction mixture was stirred at 60°C for 12 h. The mixture was cooled to 0°C and saturated NaHCO₃ was added until pH = 7.5. The mixture was filtered and the filtrate was concentrated to give the residue. The residue was dissolved in EA and washed with water and brine, dried over Na₂SO₄. The organic solution was concentrated to give the crude 17-2 (160 g) as a yellow oil. ESI-LCMS: m/z 533 [M+H]⁺.

[0171] Preparation of Intermediate (17-3): A solution of crude **17-2** (160 g) in Pyridine (1.5 L) was added to 600 mL 2N NaOH solution in Methanol and Water at 0 °C. The suspension was stirred at 0 °C for 30 min. The reaction mixture was quenched by addition of sat. NH₄Cl solution (1 L). The solution was added to water (15 L) to give the solid. The solid was filtered and washed with (PE: EA=3:1) to give **17-3** (80 g, 214 mmol, 67% over two steps) as white solid. ESI-LCMS: m/z 373 [M+H]⁺.

[0172] Preparation of Intermediate (17-4): To a solution of **17-3** (80 g, 214 mmol) in Pyridine (1 L) was added DMTrCl (87 g, 257 mmol). The reaction mixture was stirred at r.t. for 1 h. MeOH (50 ml) was added to the mixture. The solution was concentrated to give the crude. The crude was dissolved in EA and washed with water and brine. The organic layer was dried over Na₂SO₄. The organic solution was concentrated to give the crude **17-4** (160 g) as a yellow oil which was used directly for the next step. ESI-LCMS: m/z 675 [M+H]⁺.

[0173] Preparation of Intermediate (17-5): To a solution of crude **17-4** (160 g) in DCM (1 L) was added Imidazole (22 g, 332 mmol) and TBSCl (46 g, 310.62 mmol). The reaction mixture was stirred at r.t. for 12 h. The mixture was diluted with DCM (1 L). Water was added. The organic layer was washed with brine and concentrated to give the crude **17-5** (200 g) which was used directly for the next step. ESI-LCMS: m/z 789 [M+H]⁺.

[0174] Preparation of Intermediate 17-6: A solution of crude **17-5** (200 g) in Methylamine (1 L) was stirred at r.t. for 2 h. The solution was concentrated and purified by column chromatography to give **17-6** (130 g, 204.42 mmol, 94.8% yield) as a white solid. ESI-LCMS: m/z 685 [M+H]⁺.

[0175] Preparation of Intermediate (17-7): To a solution of **17-6** (142 g, 207.34 mmol) in DCM (1 L) was added collidine (50.25 g, 414.69 mmol) and MMTrCl (95.79 g, 311.01 mmol). Then AgNO₃ (52.83 g, 311.01 mmol) was added to the solution. The reaction mixture was stirred at r.t. for 1h. The mixture was filtered. The organic solution was washed with water. The organic layer was concentrated to give the crude **17-7** (190 g, 198.50 mmol, 95.73% yield) as a yellow solid which was used directly for the next step. ESI-LCMS: m/z 957.4 [M+H]⁺.

[0176] Preparation of Intermediate (17-8): To a solution of **17-7** (190 g, 198.50 mmol) in THF (1 L) was added TBAF (77.85 g, 297.74 mmol). The mixture was stirred at r.t. for 12 h. Water was added. The product was extracted with EA. The organic layer was washed with brine and dried

over Na₂SO₄. The organic solution was concentrated and purified by column chromatography to give **17-8** (160 g, 189.81 mmol, 95.6% yield) as a white solid. ESI-LCMS: m/z 843.4 [M+H]⁺.

[0177] Preparation of Intermediate (17-9): To a solution of **17-8** (154 g, 182.70 mmol) in DMF (1 L) was added Ag₂O (84.68 g, 365.39 mmol, 11.86 mL), (2-Bromoethoxy)-*tert*-butyldimethylsilane (78.67 g, 328.85 mmol) and NaI (41.08 g, 274.04 mmol). The reaction mixture was stirred at 45°C for 12 h. Water was added. The mixture was filtered and product was extracted with EA. The organic solution was concentrated and purified by column chromatography to give **17-9** (90 g, 89.89 mmol, 49.2% yield) as a black solid. ESI-LCMS: m/z 1001.4 [M+H]⁺.

[0178] Preparation of Intermediate (17-10): To a solution of **17-9** (90 g, 89.89 mmol) in THF (500 mL) was added TBAF (35.25 g, 134.83 mmol). The reaction mixture was stirred at r.t. for 12 h. Water was added to the mixture. The product was extracted with EA. The organic layer was concentrated and purified by column chromatography to give **17-10** (75 g, 84.56 mmol, 94.1% yield) as a yellow solid. ESI-LCMS: m/z 887.2 [M+H]⁺.

[0179] Preparation of Intermediate (17-11): To a solution of **17-10** (54 g, 60.88 mmol) in THF (400 mL) was added NaH (1.75 g, 73.06 mmol) at 0°C. After stirred at r.t. for 30 min, the reaction was cooled to 0°C, CS₂ (9.50 g, 121.76 mmol) was added to the mixture. After 10 min at this temperature, MeI (15.45 g, 109.58 mmol) was added to the mixture. And then the mixture was stirred at r.t. for 12 h. Water was added. The product was extracted with EA. The organic layer was washed with brine and dried over Na₂SO₄. The organic solution was concentrated and purified by column chromatography to obtain **17-11** (50 g, 51.17 mmol, 84.1% yield) as a white solid. ESI-LCMS: m/z 977.2 [M+H]⁺.

[0180] Preparation of Intermediate (17-12): To a solution of **17-11** (17 g, 17.40 mmol) in DCM (100 mL) was added PTSA (5.99 g, 34.79 mmol) in Methanol (10 mL). The mixture was stirred at r.t. for 1 h. Cooled to 0°C. Con. NH₄OH was added to give pH = 7.5. Water was added and the product was extracted with DCM. The organic layer was concentrated and purified by column chromatography to give **17-12** (10 g, 14.82 mmol, 85.2% yield) as a white solid. ESI-LCMS: m/z 675.1 [M+H]⁺.

[0181] Preparation of Intermediate (17-13): To a solution of **17-12** (40 g, 59.28 mmol) in DCM (800 mL) was added TFA (150 mL). The mixture was stirred at r.t. for 1 h. Cooled to 0°C. Con. NH₄OH was added to the solution to give pH = 7.5. Water was added and the product was extracted with DCM. The organic layer solution was dried over Na₂SO₄ and concentrated to give the crude product which was purified by column chromatography to give **17-13** (21 g, 52.18 mmol, 88.0% yield) as a white solid. ESI-LCMS: m/z 403.0 [M+H]⁺.

[0182] Preparation of Intermediate (17-14): To a solution of **17-13** (26 g, 64.60 mmol) in Pyridine (500 mL) was added Ac₂O (19.79 g, 193.81 mmol). The reaction mixture was stirred at 40°C for 1 h. Water was added. The solution was concentrated to give the crude. The crude was purified by column chromatography and MPLC to give **17-14** (21 g, 43.16 mmol, 66.8% yield) as a white solid. ESI-LCMS: m/z 487.0 [M+H]⁺.

[0183] Preparation of Intermediate (17-15): To a solution of DBH (4.19 g, 14.64 mmol) in DCM (75 mL) was added HF/Pyridine (10 mL) slowly at -60°C. Then SM-1 (2.5 g, 5.14 mmol) dissolved in DCM was slowly added to the mixture. The reaction mixture was stirred at -40°C for 1 h. DCM was added to the mixture. Sat. NaHCO₃ was slowly added to the mixture to give the pH = 7.0. The solution was concentrated to give the crude product. The crude was purified by column chromatography and MPLC to give **17-15** (1.1 g, 2.37 mmol, 46.1% yield) as a white solid. ESI-LCMS: m/z 465.1 [M+H]⁺. ¹⁹F NMR (376 MHz, Chloroform-*d*) δ -55.49.

[0184] Preparation of Intermediate (17-16): A solution of **17-15** (4.6 g, 9.91 mmol) in Methylamine (30 mL) was stirred at r.t. for 1 h. The solution was concentrated and purified by column chromatography to **17-16** (3.7 g, 9.73 mmol, 98.2% yield) as a white solid. ESI-LCMS: m/z 381.1 [M+H]⁺.

[0185] Preparation of Intermediate (17-17): To a solution of **17-16** (1.7 g, 4.47 mmol) in AcOH (5 mL) and Water (5 mL) was added NaNO₂ (30.40 g, 447.04 mmol). The mixture was stirred at r.t. for 3 h. LC-MS showed 70% conversion. EA and water was added. The organic layer was concentrated and purified by MPLC to give **17-17** (1.5 g, 3.93 mmol, 88.0% yield) as a white solid. ESI-LCMS: m/z 382.2 [M+H]⁺.

[0186] Preparation of Intermediate (17-18): To a solution of **17-17** (2.23 g, 5.85 mmol) in DCM (30 mL) was added Imidazole (796.36 mg, 11.70 mmol) and TBSCl (1.32 g, 8.77 mmol). The

reaction mixture was stirred at r.t. for 12 h. Water was added. The organic layer was washed with brine and dried over Na₂SO₄. The organic layer was concentrated to give the crude **17-18** (2.8 g, 5.65 mmol, 96.6% yield) as a white solid. ESI-LCMS: m/z 496.4 [M+H]⁺.

[0187] Preparation of Intermediate (17-19): To a solution of **17-18** (2.8 g, 5.65 mmol) in THF (30 mL) was added PPh₃ (1.78 g, 6.78 mmol) and water (203.59 mg, 11.30 mmol). The mixture was stirred at 50°C for 2 h under N₂ atmosphere. The mixture was concentrated and purified by column chromatography to give **17-19** (2.5 g, 5.32 mmol, 94.2% yield) as a white solid. ESI-LCMS: m/z 470.3 [M+H]⁺.

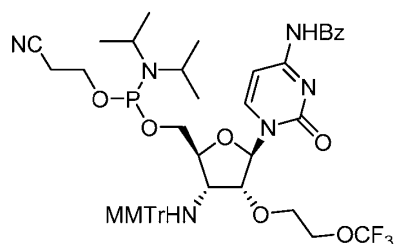
[0188] Preparation of Intermediate (17-20): To a solution of **17-19** (2.8 g, 5.96 mmol) in DCM (40 mL) was added TEA (1.21 g, 11.93 mmol, 1.66 mL) and MMTrCl (2.76 g, 8.95 mmol). The mixture was stirred at r.t. for 1 h. Water was added. The organic layer was dried over Na₂SO₄ and concentrated, the residue was purified by column chromatography to give **17-20** (3.1 g, 4.18 mmol, 70.1% yield) as a white solid. ¹H NMR (400 MHz, DMSO-*d*₆) δ 11.36 (d, *J* = 2.2 Hz, 1H), 7.67 (d, *J* = 8.0 Hz, 1H), 7.46 (td, *J* = 8.6, 1.3 Hz, 4H), 7.37-7.30 (m, 2H), 7.25 (t, *J* = 7.5 Hz, 4H), 7.22 – 7.14 (m, 2H), 6.84 – 6.77 (m, 2H), 5.54 (s, 1H), 5.44 (dd, *J* = 8.0, 2.2 Hz, 1H), 4.17 – 4.01 (m, 4H), 3.90 (dd, *J* = 9.8, 2.4 Hz, 1H), 3.70 (s, 4H), 3.07 (td, *J* = 10.1, 4.5 Hz, 1H), 3.03 – 2.93 (m, 1H), 2.82 (d, *J* = 10.3 Hz, 1H), 1.51 (d, *J* = 4.5 Hz, 1H), 0.84 (s, 9H), 0.12 (s, 3H), -0.03 (s, 3H). ¹⁹F NMR (376 MHz, DMSO-*d*₆) δ -58.72.

[0189] Preparation of Intermediate (17-21): To a solution of **17-20** (3.1 g, 4.18 mmol) in THF (30 mL) was added TBAF (1.64 g, 6.27 mmol). The mixture was stirred at r.t. for 15 h. The mixture was concentrated and purified by column chromatography to give **17-21** (2.2 g, 3.51 mmol, 83.9% yield) as a white solid. ¹H NMR (400 MHz, DMSO-*d*₆) δ 11.30 (d, *J* = 2.0 Hz, 1H), 7.98 (d, *J* = 8.1 Hz, 1H), 7.52-7.42 (m, 4H), 7.37-7.30 (m, 2H), 7.30-7.23 (m, 4H), 7.23-7.14 (m, 2H), 6.87-6.79 (m, 2H), 5.52 (d, *J* = 2.0 Hz, 1H), 5.50 (d, *J* = 1.5 Hz, 1H), 5.17 (t, *J* = 3.8 Hz, 1H), 4.13 (t, *J* = 4.2 Hz, 2H), 4.05 (dd, *J* = 4.2, 2.1 Hz, 2H), 3.90 (dt, *J* = 10.0, 2.2 Hz, 1H), 3.72 (s, 3H), 3.67 (dt, *J* = 11.4, 3.7 Hz, 1H), 3.39 (td, *J* = 6.4, 5.1 Hz, 1H), 3.10 (td, *J* = 10.3, 4.3 Hz, 1H), 2.97 (dt, *J* = 11.8, 4.7 Hz, 1H), 2.68 (d, *J* = 10.6 Hz, 1H), 1.44 (d, *J* = 4.3 Hz, 1H). ¹⁹F NMR (376 MHz, DMSO-*d*₆) δ -58.82.

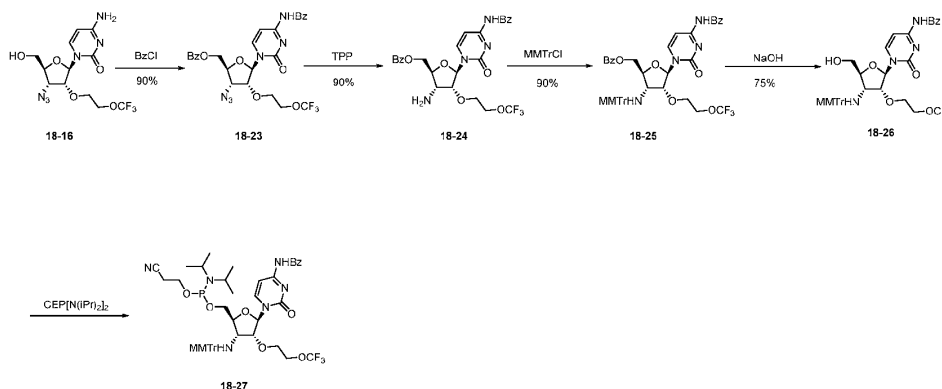
[0190] Preparation of (17-22): To a solution of **17-21** (1.4 g, 2.23 mmol) in DCM (10 mL) was added DCI (318.88 mg, 2.23 mmol) and CEP[N(iPr)₂]₂ (872.87 mg, 2.90 mmol). The mixture

was stirred at r.t. for 1 h. The solution was diluted with DCM. The organic layer was washed with sat. NaHCO_3 , water and brine. The organic layer was dried over Na_2SO_4 and purified by column chromatography to give 1.3 g crude product. The product was drying in vacuum at 40°C overnight. This resulted in (1.15 g, 1.39 mmol, 62.28% yield) to give **17-22** as a white solid. MS m/z $[\text{M}-\text{H}]^-$ (ESI): 826.4; ^1H NMR (400 MHz, $\text{DMSO}-d_6$) δ 11.37 (s, 1H), 7.78 (d, $J = 8.1$ Hz, 0.6 H), 7.59-7.44 (m, 4.4 H), 7.41-7.33 (m, 2H), 7.27 (m, 4H), 7.24-7.14 (m, 2H), 6.88-6.79 (m, 2H), 5.57-5.48 (m, 1.4H), 5.44 (d, $J = 8.0$ Hz, 0.6H), 4.25-4.13 (m, 2H), 4.13-3.90 (m, 3H), 3.79 – 3.38 (m, 8H), 3.03 (m, 2H), 2.86 (dd, $J = 26.4, 10.4$ Hz, 1H), 2.79-2.67 (m, 2H), 1.67 (d, $J = 4.5$ Hz, 0.4 H), 1.26 (d, $J = 4.5$ Hz, 0.6 H), 1.18 (d, $J = 6.7$ Hz, 3H), 1.15 – 1.02 (m, 9H). ^{31}P NMR (162 MHz, $\text{DMSO}-d_6$) δ 148.03, 146.68.

Example 14



Scheme 16



[0191] **Preparation of Intermediate (18-23):** To a solution of **18-16** (1.2 g, 3.16 mmol) in Pyridine (10 mL) was added BzCl (971.92 mg, 6.94 mmol) at 0°C . The mixture was stirred at r.t. for 1 h. Water was added. The product was extracted with EA. The organic layer was washed

with brine and dried over Na₂SO₄. The organic layer was concentrated and purified by column chromatography to give **18-23** (1.58 g, 2.68 mmol, 85.1% yield) as a white solid. ESI-LCMS: m/z 589.1 [M+H]⁺

[0192] Preparation of Intermediate (18-24): To a solution of **18-23** (1.47 g, 2.50 mmol) in THF (20 mL) was added water (90.00 mg, 5.00 mmol) and PPh₃ (786.20 mg, 3.00 mmol). The mixture was stirred at 50°C under N₂ atmosphere. The mixture was concentrated and purified by column chromatography to give **18-24** (1.35 g, 2.40 mmol, 96.1% yield) as a white solid. ESI-LCMS: m/z 563.2 [M+H]⁺.

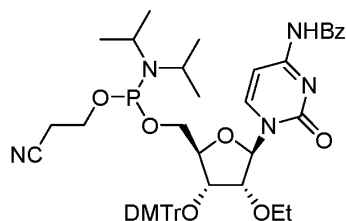
[0193] Preparation of Intermediate (18-25): To a solution of **18-24** (1.4 g, 2.49 mmol) in DCM (40 mL) was added TEA (503.71 mg, 4.98 mmol, 694.29 uL) and MMTrCl (1.15 g, 3.73 mmol). The mixture was stirred at r.t. for 1 h. Water was added. The organic layer was dried over Na₂SO₄ and concentrated, the residue was purified by column chromatography to give **18-25** (2 g, 2.40 mmol, 96.3% yield) as a white solid. ¹⁹F NMR (376 MHz, DMSO-d₆) δ -58.72.

[0194] Preparation of Intermediate (18-26): To a solution of **18-25** (2 g, 2.40 mmol) in Pyridine (30 mL) was added NaOH (287.46 mg, 7.19 mmol) in Methanol (12 mL) and Water (3 mL) at 0°C. The mixture was stirred at r.t. for 0.5 h. Sat. NH₄Cl was added to give pH = 8. The product was extracted with EA. The organic layer was concentrated and purified by MPLC to give **18-26** (1.5 g, 2.05 mmol, 85.69% yield) as a white solid. ¹H NMR (400 MHz, DMSO-d₆) δ 11.27 (s, 1H), 8.55 (d, *J* = 7.5 Hz, 1H), 8.11-7.94 (m, 2H), 7.77-7.57 (m, 1H), 7.57-7.40 (m, 6H), 7.40-7.10 (m, 9H), 6.97-6.76 (m, 2H), 5.56 (s, 1H), 5.36-5.18 (m, 1H), 4.15 (dd, *J* = 9.7, 5.4 Hz, 4H), 4.01 (d, *J* = 10.2 Hz, 1H), 3.84 (d, *J* = 11.7 Hz, 1H), 3.72 (s, 3H), 3.18-2.97 (m, 2H), 2.66 (d, *J* = 10.9 Hz, 1H), 1.48 (d, *J* = 4.1 Hz, 1H). ¹⁹F NMR (376 MHz, DMSO-d₆) δ -58.75.

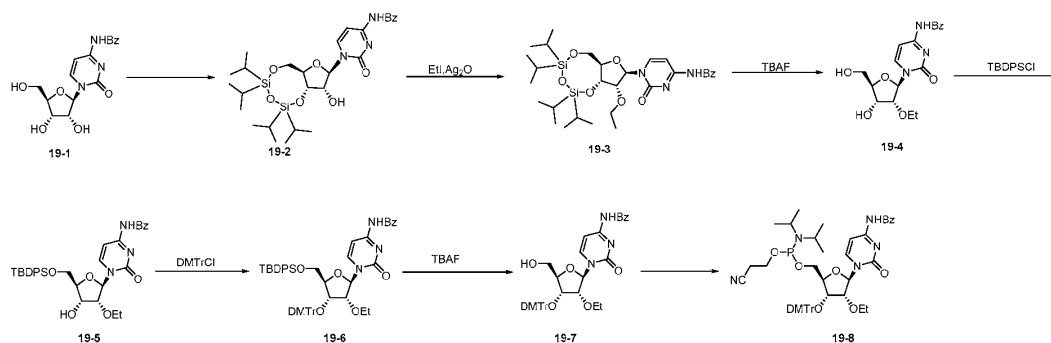
[0195] Preparation of (18-27): To a solution of **18-26** (1.4 g, 1.92 mmol) in DCM (30 mL) was added DCI (226.08 mg, 1.92 mmol) and CEP[N(iPr)₂]₂ (749.69 mg, 2.49 mmol). The mixture was stirred at r.t. for 1 h. The solution was diluted with DCM. The organic layer was washed with water and brine. The organic layer was dried over Na₂SO₄ and concentrated to the crude product. The crude was purified by HPLC. The product was drying in vacuum at 40°C overnight. This resulted in (1.65 g, 1.77 mmol, 92.51% yield) to give **18-27** as a white solid. ESI-LCMS: m/z 877 [M+H]⁺. ¹H NMR (400 MHz, DMSO-d₆) δ 11.33 (s, 1H), 8.34 (d, *J* = 7.4 Hz, 0.6H), 8.20 (d, *J* = 7.4 Hz, 0.6H), 8.02 (dt, *J* = 8.3, 1.2 Hz, 2H), 7.73-7.57 (m, 1H), 7.57-7.40 (m, 6H),

7.40-7.30 (m, 3H), 7.30-7.10 (m, 6H), 6.86-6.71 (m, 2H), 5.60 (d, $J = 1.1$ Hz, 1H), 4.41-4.03 (m, 5H), 4.00-3.39 (m, 8H), 3.05 (m, 2H), 2.92-2.70 (m, 3H), 1.53 (d, $J = 4.2$ Hz, 0.4H), 1.29 (d, $J = 4.2$ Hz, 0.6H), 1.26-1.00 (m, 12H). ^{31}P NMR (162 MHz, DMSO- d_6) δ 148.41, 146.88.

Example 15



Scheme 17



[0196] **Preparation of Intermediate (19-2):** To a solution of **19-1** (48.0 g, 138.2 mmol) in anhydrous pyridine (500 mL) was added TIPDSCl (52.2 g, 165.8 mmol) at 0°C, the mixture was allowed to stir at r.t. for 5 h. Upon of completion, the mixture was poured into cold water, extracted with EA, washed brine, dried over anhydrous Na_2SO_4 , and concentrated to obtain a residue which was purified by column chromatography to give **19-2** (67 g, 113.6 mmol, 82.2% yield) as a white solid. ^1H -NMR (400 MHz, DMSO- d_6): δ = 11.29 (s, 1H, exchanged with D_2O), 8.21 (d, $J = 7.2$ Hz, 1H), 8.02-8.00 (m, 2H), 7.65-7.61 (m, 1H), 7.54-7.50 (m, 2H), 7.38 (d, $J = 7.2$ Hz, 1H), 5.83 (d, $J = 3.6$ Hz, 1H, exchanged with D_2O), 5.64 (s, 1H), 4.24 (d, $J = 13.2$ Hz, 1H), 4.11 (s, 3H), 3.95 (d, $J = 12.8$ Hz, 1H), 1.09-0.96 (m, 28H). ESI-LCMS: m/z 590 $[\text{M}+\text{H}]^+$.

[0197] **Preparation of Intermediate (19-3):** A solution of **19-2** (54 g, 91.5 mmol) and EtI (285.6 g, 1.8 mol, 146 mL) in toluene (500 mL) was added Ag_2O (63.6 g, 274.6 mmol), the mixture was stirred at 50°C for 4 h, filtered and the filtrate was concentrated to obtain a residue which was

purified by column chromatography to give **19-3** (41.2 g, 66.4 mmol, 72.5% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 11.34 (s, 1H, exchanged with D₂O), 8.19 (d, *J* = 7.2 Hz, 1H), 7.97 (d, *J* = 7.6 Hz, 2H), 7.63 (t, *J* = 7.2 Hz, 1H), 7.51 (t, *J* = 7.6 Hz, 2H), 7.38 (d, *J* = 7.2 Hz, 1H), 5.67 (s, 1H), 4.22 (d, *J* = 13.6 Hz, 1H), 4.14 (dd, *J* = 4.0, 9.6 Hz, 1H), 4.08 (d, *J* = 9.6 Hz, 1H), 3.95-3.91 (m, 2H), 3.82 (dd, *J* = 6.8, 13.6 Hz, 2H), 1.17 (t, *J* = 6.8 Hz, 3H), 1.04-0.94 (m, 28H). ESI-LCMS: *m/z* 618 [M+H]⁺.

[0198] Preparation of Intermediate (19-4): A solution of **19-3** (41.2 g, 66.4 mmol) in THF (400 mL) was added TBAF (1 M in THF) (132.7 mmol, 133 mL), the mixture was stirred at r.t. for 1 h, poured into cold water, extracted with EA, washed brine, dried over anhydrous Na₂SO₄, and concentrated to obtain a solid which was washed with (PE:EA=1:1) to give **19-4** (19.1 g, 50.6 mmol, 76.3% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 11.29 (s, 1H, exchanged with D₂O), 8.57 (d, *J* = 7.6 Hz, 1H), 8.01 (d, *J* = 7.6 Hz, 2H), 7.63 (t, *J* = 7.6 Hz, 1H), 7.52 (t, *J* = 8.0 Hz, 2H), 7.36 (d, *J* = 7.6 Hz, 1H), 5.87 (d, *J* = 2.8 Hz, 1H), 5.26 (t, *J* = 5.2 Hz, 1H, exchanged with D₂O), 5.05 (d, *J* = 7.2 Hz, 1H, exchanged with D₂O), 4.11-4.06 (m, 1H), 3.94-3.91 (m, 1H), 3.86-3.74 (m, 3H), 3.71-3.61 (m, 2H), 1.17 (t, *J* = 7.6 Hz, 3H). ESI-LCMS: *m/z* 376 [M+H]⁺.

[0199] Preparation of Intermediate (19-5): A solution of **19-4** (19.1 g, 50.6 mmol) and imidazole (5.2 g, 75.9 mmol) in pyridine (200 mL) was added TBDPSCl (7.1 g, 60.7 mmol), the mixture was stirred at r.t. for 1 h, poured into cold water, extracted with EA, washed brine, dried over anhydrous Na₂SO₄, and concentrated to obtain a solid which was purified by column chromatography to give **19-5** (20.2 g, 32.6 mmol, 64.4% yield) as a white solid. ESI-LCMS: *m/z* 614 [M+H]⁺.

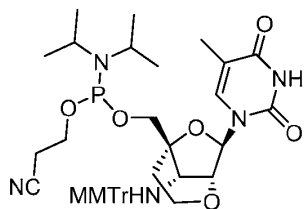
[0200] Preparation of Intermediate (19-6): A solution of **19-5** (14.0 g, 22.8 mmol) and collidine (6.9 g, 57.0 mmol) in DCM (150 mL) were added DMTrCl (11.6 g, 34.2 mmol) and AgNO₃ (3.9 g, 22.8 mmol) under Ar. The mixture was stirred at r.t. for 15 h, filtered and the filtrate was washed with water, dried over anhydrous Na₂SO₄, and concentrated to give the crude product **19-6** (26.2 g) as a yellow oil. ESI-LCMS: *m/z* 916 [M+H]⁺.

[0201] Preparation of Intermediate (19-7): A solution of **19-6** (26.2 g (crude)) in THF (200 mL) was added TBAF (1 M in THF) (23 mL), the mixture was stirred at 50°C for 3 h, poured into cold water, extracted with EA, washed brine, dried over anhydrous Na₂SO₄, and concentrated to

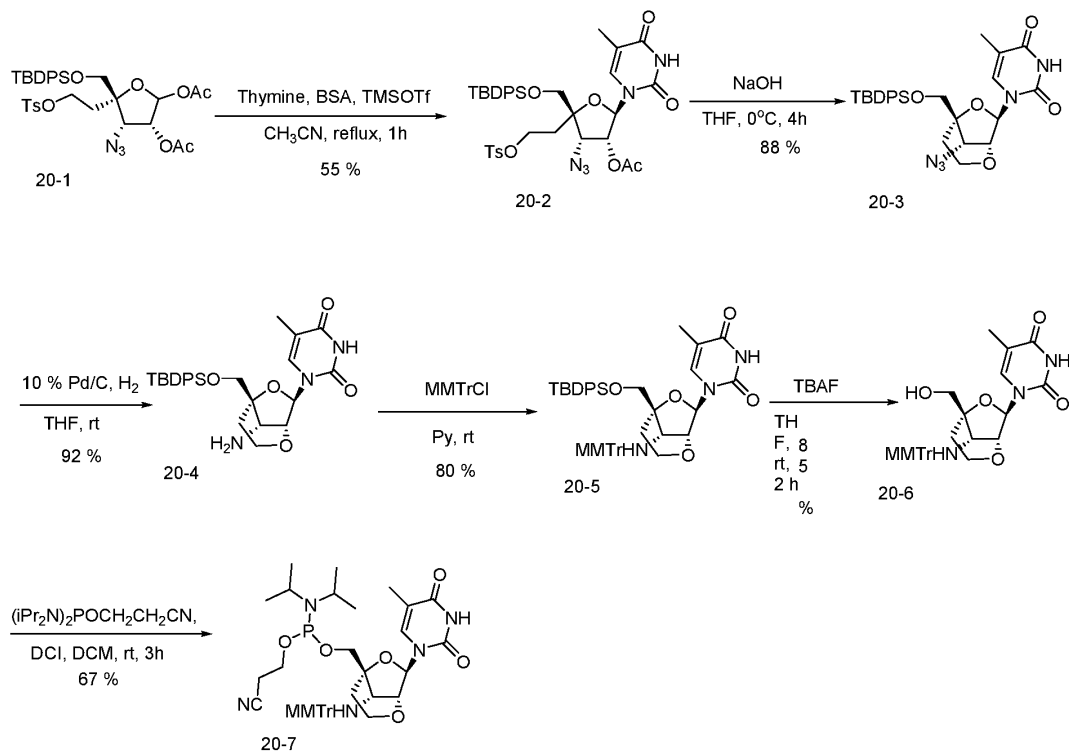
obtain a residue which was purified by column chromatography to give **19-7** (11.2 g, 16.5 mmol, 72.37% yield over two steps) as a white solid. $^1\text{H-NMR}$ (400 MHz, $\text{DMSO-}d_6$): δ = 11.30 (s, 1H, exchanged with D_2O), 8.40 (d, J = 7.6 Hz, 1H), 8.02 (d, J = 7.6 Hz, 2H), 7.65-7.61 (m, 1H), 7.54-7.49 (m, 4H), 7.35-7.30 (m, 6H), 7.26-7.23 (m, 1H), 6.89-6.86 (m, 4H), 5.96 (d, J = 3.2 Hz, 1H), 5.08 (t, J = 4.4 Hz, 1H, exchanged with D_2O), 4.01 (t, J = 5.2 Hz, 1H), 3.79-3.78 (m, 1H), 3.73 (d, J = 1.2 Hz, 6H), 3.66-3.55 (m, 2H), 3.40-3.38 (m, 1H), 3.25-3.17 (m, 1H), 2.97-2.95 (m, 1H), 1.17 (t, J = 6.8 Hz, 3H). ESI-LCMS: m/z 678 $[\text{M}+\text{H}]^+$.

[0202] Preparation of (19-8): A solution of **19-7** (5.0 g, 7.4 mmol) and DCI (2.2 g, 7.4 mmol) in dry DCM (50 mL) was added $\text{CEP}[\text{N}(\text{iPr})_2]_2$ (2.7 g, 8.8 mmol) under Ar. The mixture was stirred at r.t. for 1 h. The reaction was washed with 10% NaHCO_3 (aq) and water, dried over Na_2SO_4 and concentrated to obtain the crude product which was purified Flash-Prep-HPLC. This resulted in to give **19-8** (5.5 g, 6.26 mmol, 84.91% yield) as a white solid. $^1\text{H-NMR}$ (400 MHz, $\text{DMSO-}d_6$): δ = 11.34 (s, 1H), 8.16 (dd, J = 7.6, 39.2 Hz, 1H), 8.03-8.00 (m, 2H), 7.65-7.61 (m, 2H), 7.54-7.45 (m, 4H), 7.35-7.24 (m, 8H), 6.88-6.82 (m, 4H), 5.89 (dd, J = 3.2, 88.8 Hz, 1H), 4.25-3.86 (m, 3H), 3.75-3.66 (m, 9H), 3.62-3.38 (m, 4H), 3.26-3.05 (m, 1H), 2.78 (dd, J = 5.6, 10.4 Hz, 2H), 1.20-1.11 (m, 9H), 1.04 (dd, J = 6.4, 27.6 Hz, 6H). $^{31}\text{P-NMR}$ (162 MHz, $\text{DMSO-}d_6$): 148.09, 147.84. ESI-LCMS: m/z 878 $[\text{M}+\text{H}]^+$.

Example 16



Scheme 18



[0203] Preparation of Intermediate (20-2): To a solution of Thymine (8.15 g, 64.68 mmol, 1.5 eq.) in Acetonitrile (300 mL) with an inert atmosphere of nitrogen, was added N,O-Bis(trimethylsilyl)acetamide (39 g, 194.2 mmol, 4.5 eq.) at room temperature. The resulting solution was stirred for 2 h at 80 °C. The reaction mixture was cooled to 0 °C and **20-1** (30 g, 43.16 mmol, 1.00 eq.) was added. Then trimethylsilyl trifluoromethanesulfonate (57.48g, 258.95 mmol, 6.0 eq.) was added dropwise with stirring at 0 °C. The resulting solution was allowed to react, with stirring, for an additional 1 h at 80 °C. The reaction mixture was cooled to 0 °C, quenched by the addition of saturated sodium bicarbonate. The resulting solution was extracted ethyl acetate and the organic layers combined. The organic layer was washed with water and saturated sodium chloride respectively. The residue was purified by column chromatography. This resulted in 18 g (55%) of **20-2** as a brown solid. MS m/z [M+H]⁺ (ESI): 762.

[0204] Preparation of Intermediate (20-3): To a solution of **20-2** (18 g, 23.9 mmol, 1.00 eq.) in Tetrahydrofuran (180 mL) with an inert atmosphere of nitrogen, was added sodium hydroxide

(47 mL, 2N in water, 4.0 eq.) at 0 °C. The resulting solution was stirred for 4 h at 0 °C. The resulting mixture was extracted with ethyl acetate, and the organic layers combined. The organic layer was dried over anhydrous sodium sulfate and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 11.4 g (88%) of **20-3** as a white solid. MS m/z [M+H]⁺ (ESI): 548.

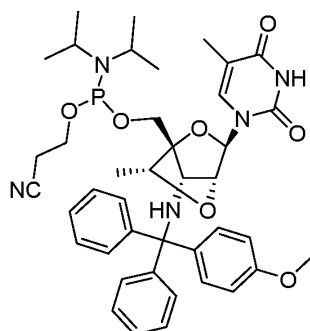
[0205] Preparation of Intermediate (20-4): To a solution of **20-3** (11.4 g, 20.84 mmol, 1.00 eq.) in Tetrahydrofuran (100 mL) was added 10% Palladium on activated carbon (1.4 g). The flask was evacuated and flushed five times with hydrogen. The resulting solution was stirred for 8 h at room temperature. The solids were filtered out. The resulting mixture was concentrated under reduced pressure. This resulted in 10 g (92%) of **20-4** as a white solid. MS m/z [M+H]⁺ (ESI): 522.

[0206] Preparation of Intermediate (20-5): To a solution of **20-4** (10 g, 19.19 mmol, 1.00 eq.) in pyridine (50 mL) with an inert atmosphere of nitrogen, was added 1-(chlorodiphenylmethyl)-4-methoxybenzene (8.8 g, 28.79 mmol, 1.5 eq.) at room temperature. The resulting solution was stirred for 12 h at room temperature. The reaction was then quenched by the addition of methanol (20 mL). The crude product was purified by Flash-Prep-HPLC. The fractions (500 mL) was diluted with dichloromethane and dried over anhydrous sodium sulfate. The solid was filtered out. The filtrate was concentrated under reduced pressure. This resulted in 12.2 g (80%) of **20-5** as a white solid. MS m/z [M-H]⁻ (ESI): 792.

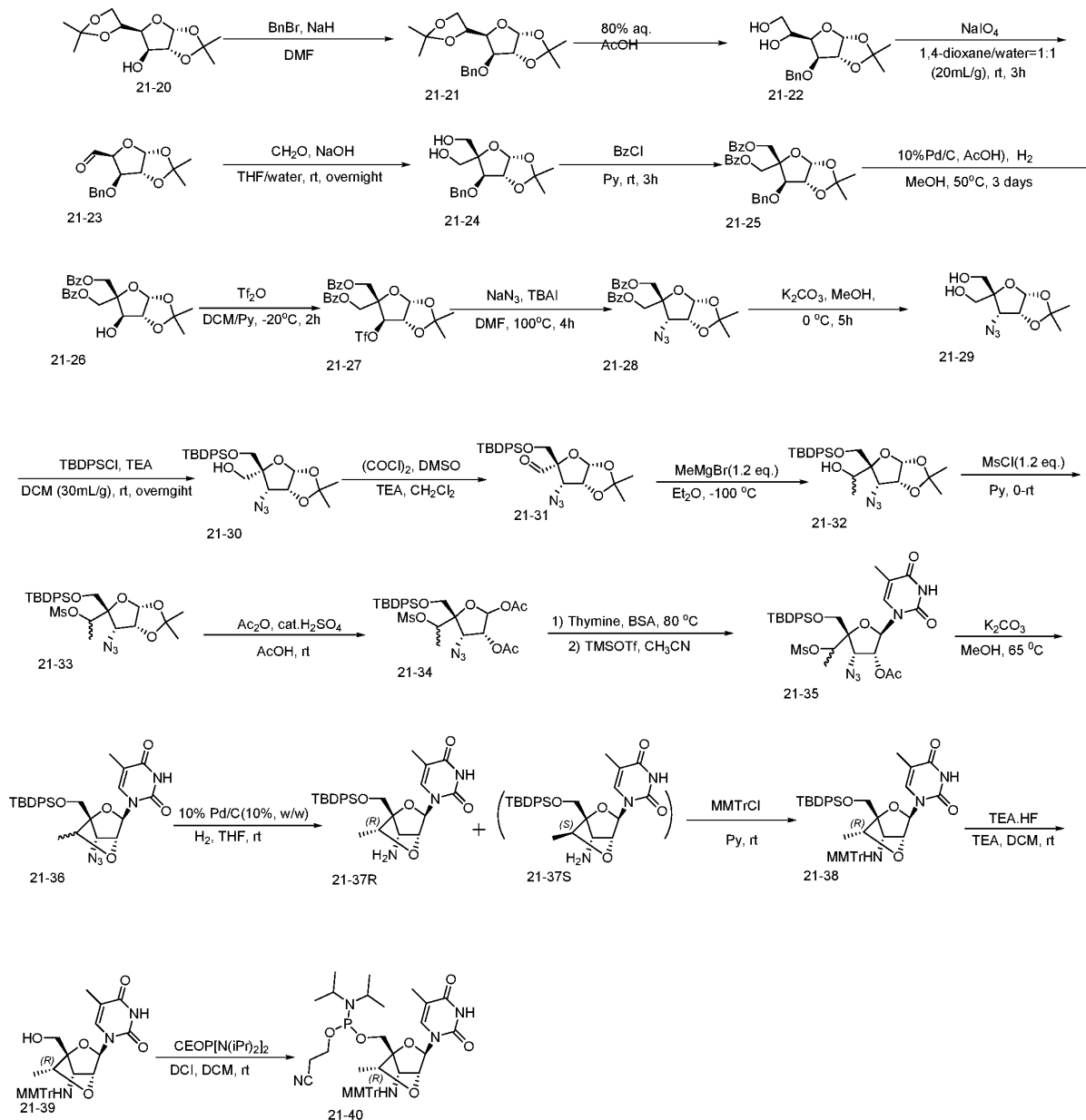
[0207] Preparation of Intermediate (20-6): To a solution of **20-5** (4.2 g, 5.29 mmol, 1.00 eq.) in dichloromethane (40 mL) with an inert atmosphere of nitrogen, was added Tetrabutylammonium fluoride (1M in THF, 13.0 mL, 2.5 eq.) at room temperature. The resulting solution was stirred for 10 h at room temperature. The crude product was purified by Flash-Prep-HPLC. The fractions were diluted with dichloromethane and dried over anhydrous sodium sulfate. The solid was filtered out. The filtrate was concentrated under reduced pressure. This resulted in 2.5 g (85%) of **20-6** as a white solid. MS m/z [M-H]⁻ (ESI): 554. ¹H NMR: (DMSO-d₆, 300Hz, ppm): δ 11.25 (s, 1H), 7.95 (s, 1H), 7.46 (m, 4H), 7.31-7.11 (m, 8H), 6.76 (m, 2H), 5.61 (s, 1H), 5.22 (t, *J*=3.0 Hz, 1H), 3.95 (m, 1H), 3.85-3.61 (m, 6H), 2.85 (m, 1H), 2.45 (d, *J*=9.0 Hz, 1H), 2.23-2.06 (m, 1H), 1.61 (m, 4H), 1.34 (d, *J*=12.0 Hz, 1H).

[0208] Preparation of (20-7): To a solution of **20-6** (2.5 g, 3.78 mmol, 1.00 eq.) in dichloromethane (20 mL) with an inert atmosphere of nitrogen, was added Bis(diisopropylamino)(2-cyanoethoxy)phosphine (1.7 g, 5.67 mmol, 1.5 eq.) at room temperature. To this was added 4, 5-Dicyanoimidazole (440 mg, 4.15 mmol, 1.10 eq.) at room temperature. The resulting solution was stirred for 3 h at room temperature and diluted with dichloromethane, washed with water. The crude product was purified by Flash-Prep-HPLC. The fractions were diluted with dichloromethane and dried over anhydrous sodium sulfate. The solid was filtered out. The filtrate was concentrated under reduced pressure. This resulted in 2.3 g (67%) of **20-7** as a white solid. MS m/z [M-H]⁻ (ESI): 754. H-NMR: (DMSO- d_6 , 300Hz, *ppm*): δ 11.31 (s, 1H), 7.76-7.41 (m, 5H), 7.37-7.10 (m, 8H), 6.87-6.68 (m, 2H), 5.66 (m, 1H), 4.04 (m, 1H), 3.83 (m, 2H), 3.70 (m, 3H), 3.69-3.45 (m, 4H), 3.30-3.00 (m, 1H), 2.88-2.54 (m, 3H), 2.45-2.12 (m, 2H), 1.87-1.64 (m, 4H), 1.51 (m, 1H), 1.17 (m, 12H). P NMR (DMSO- d_6 , 300Hz, *ppm*): 152.69, 150.53.

Example 17



Scheme 19



[0209] **Preparation of Intermediate (21-21):** To a solution of (3aR,5S,6S,6aR)-5-(2,2-dimethyl-1,3-dioxolan-4-yl)-2,2-dimethyl-tetrahydro-2H-furo[2,3-d][1,3]dioxol-6-ol (500 g, 1.92 mol, 1.00 eq.) in N,N-dimethylformamide (5000 mL) with an inert atmosphere of nitrogen was added

(bromomethyl) benzene (345 g, 2.02 mol, 1.05 eq.) at room temperature. Sodium hydride (123 g, 3.08 mol, 1.60 eq. 60%) was added for several batches at 0 °C. The resulting solution was stirred for 2 h at 25 °C. The reaction was then quenched by the addition of ammonium chloride (aq). The resulting solution was extracted with ethyl acetate and the organic layers combined and dried over anhydrous sodium sulfate and concentrated under reduced pressure. This resulted in 670 g (crude) of **21-21** as yellow oil. MS m/z [M+H]⁺ (ESI): 351.

[0210] Preparation of Intermediate (21-22): **21-21** (500 g, 1.43 mol, 1.00 eq.) was dissolved 80% acetic acid (5000 mL). The resulting solution was stirred overnight at room temperature. The resulting mixture was concentrated under reduced pressure. The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with sodium bicarbonate (aq). The mixture was dried over anhydrous sodium sulfate and concentrated under reduced pressure. This resulted in 440 g (crude) of **21-22** as yellow oil. MS m/z [M+Na]⁺ (ESI): 333.

[0211] Preparation of Intermediate (21-23): To a solution of **21-22** (500 g, 1.61 mol, 1.00 eq.) in 1,4-dioxane (5000 mL) was added a solution of sodium periodate (345 g, 1.61 mol, 1.00 eq.) in water (5000 mL) dropwise with stirring at 0 °C. The resulting solution was stirred for 2 h at room temperature. The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with water. The mixture was dried over anhydrous sodium sulfate and concentrated under reduced pressure. This resulted in 400 g (crude) of **21-23** as yellow oil. MS m/z [M+H]⁺ (ESI): 279.

[0212] Preparation of Intermediate (21-24): To a solution of **21-23** (250 g, 898.3 mmol, 1.00 eq.) in tetrahydrofuran/water (1250/1250 mL) was added formaldehyde solution (37%, 600 mL) at room temperature. To this was added 2N sodium hydroxide (1500 mL, 3.12 eq.) dropwise with stirring at 0 °C. The resulting solution was stirred overnight at room temperature. The resulting solution was extracted with ethyl acetate and the organic layers combined. The resulting mixture was washed with water. The mixture was dried over anhydrous sodium sulfate and concentrated under reduced pressure. This resulted in 191 g (crude) of **21-24** as yellow oil. MS m/z [M+Na]⁺ (ESI): 333.

[0213] Preparation of Intermediate (21-25): To a solution of **21-24** (300 g, 966.7 mmol, 1.00 eq.) in pyridine (3000 mL) with an inert atmosphere of nitrogen was added benzoyl chloride (409.4 g, 2.91 mol, 3.01 eq.) dropwise with stirring at 0 °C and then stirred for 2 h at room temperature.

The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with sodium bicarbonate (aq). The mixture was dried over anhydrous sodium sulfate and concentrated under reduced pressure. The residue was purified by column chromatography. This resulted in 410 g (82%) of **21-25** as yellow oil.

[0214] Preparation of Intermediate (21-26): To a solution of **21-25** (250 g, 482.11 mmol, 1.00 eq.) in methanol (2500 mL) was added 10% Palladium carbon (125 g) and acetic acid (29 g, 482.11 mmol, 1.00 eq.). Then H₂ (gas) was inserted. The resulting solution was stirred for 72 h at 50 °C. The solids were filtered out. The resulting mixture was concentrated under reduced pressure. The resulting solution was diluted with dichloromethane and washed with Sat. sodium bicarbonate (aq). The mixture was dried over anhydrous sodium sulfate and concentrated under reduced pressure. This resulted in 185 g (90%) of **21-26** as light yellow oil.

[0215] Preparation of Intermediate (21-27): To a solution of **21-26** (128 g, 299.06 mmol, 1.00 eq.) in dichloromethane (900 mL) with an inert atmosphere of nitrogen was added pyridine (300 mL) at room temperature. To this was added trifluoromethane sulfonic anhydride (109.4 g, 387.9 mmol, 1.30 eq.) dropwise with stirring at -20 °C. The resulting solution was stirred for 2 h at -20 °C. The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with water and brine. The mixture was dried over anhydrous sodium sulfate and concentrated under reduced pressure. This resulted in 158 g (crude) of **21-27** as yellow oil.

[0216] Preparation of Intermediate (21-28): To a solution of **21-27** (158 g, 281.89 mmol, 1.00 eq.) in N,N-dimethylformamide (1500 mL) with an inert atmosphere of nitrogen was added Sodium azide (55 g, 846.02 mmol, 3.00 eq.) and Tetrabutylammonium iodide (10.4 g, 28.18 mmol, 0.10 eq.) at room temperature. The resulting solution was stirred overnight at 100 °C. The reaction was then quenched by the addition of water/ice. The resulting solution was extracted with ethyl acetate and the organic layers combined. The resulting mixture was washed with water and brine. The mixture was dried over anhydrous sodium sulfate and concentrated under reduced pressure. The residue was purified by column chromatography. This resulted in 58 g (45%) of **21-28** as yellow oil.

[0217] Preparation of Intermediate (21-29): To a solution of **21-28** (70 g, 154.4 mmol, 1.00 eq.) in methanol/water (850/150 mL) was added potassium carbonate (6.4 g, 46.0 mmol, 0.30 eq.). The resulting solution was stirred for 5 h at 0 °C. The pH value of the solution was adjusted to 7

with 10% hydrochloric acid. The resulting mixture was concentrated under reduced pressure. The resulting solution was diluted with ethyl acetate and washed with water. The mixture was dried over anhydrous sodium sulfate and concentrated under reduced pressure. The residue was purified by column chromatography. This resulted in 26.7 g (71%) of **21-29** as a white solid.

[0218] Preparation of Intermediate (21-30): To a solution of **21-29** (12 g, 48.93 mmol, 1.00 eq.) in dichloromethane (360 mL) with an inert atmosphere of nitrogen was followed by the addition of Triethylamine (14.85 g, 146.75 mmol, 3.00 eq.) at room temperature. To this was added tert-butyl (chloro)diphenylsilane (13.5 g, 49.12 mmol, 1.00 eq.) dropwise with stirring at 0 °C. The resulting solution was stirred overnight at room temperature. The resulting solution was diluted with dichloromethane and washed with water. The mixture was dried over anhydrous sodium sulfate and concentrated under reduced pressure. The residue was purified by column chromatography. This resulted in 12.8 g (54%) of **21-30** as a white solid. MS m/z [M+Na]⁺ (ESI): 506.

[0219] Preparation of Intermediate (21-31): To a solution of oxalyl chloride (5.1 mL, 1.50eq.) in dichloromethane (300 mL) with an inert atmosphere of nitrogen was added dimethyl sulfoxide (8.1 mL, 3.00eq.) dropwise with stirring at -78 °C. The resulting solution was stirred at -78 °C for 30 min. To this was added a solution of **21-30** (26 g, 43mmol, 1.00eq.) in dichloromethane (100 mL) dropwise with stirring at -78 °C, stirred for an additional 45 min at -78 °C. Then triethylamine (23.5 mL, 4.50eq.) was added, and allowed to react, with stirring, for an additional 1 h at 25 °C. The resulting solution was diluted with dichloromethane, and was washed with hydrogen chloride, saturated sodium bicarbonate, and saturated sodium chloride respectively. The mixture was dried over anhydrous sodium sulfate, filtered, and concentrated under vacuum. This resulted in 20 g (80%) of **21-31** as colorless oil.

[0220] Preparation of Intermediate (21-32): To a solution of **21-31** (20 g, 41.53 mmol, 1.00 eq.) in ether (200 mL) with an inert atmosphere of nitrogen, was added methylmagnesium bromide (3M) (28 mL, 62.30 mmol, 1.50 eq.) dropwise with stirred at -100 °C. The resulting solution was stirred for 2 hours at -100 °C. The reaction was then quenched by the addition of saturated ammonium chloride (50 mL) and diluted with ethyl acetate. The resulting mixture was washed with water and saturated sodium chloride respectively. The organic layer was dried over

anhydrous sodium sulfate, filtered, and concentrated under reduced pressure. This resulted in 14.5 g (70%) of **21-32** as colorless oil. MS m/z [M+Na]⁺ (ESI): 520.

[0221] Preparation of Intermediate (21-33): To a solution of **PH21-32** (15 g, 30.14 mmol, 1.00 eq.) in pyridine (150 mL) with an inert atmosphere of nitrogen, was added methanesulfonyl chloride (4.5 g, 39.28 mmol, 1.30 eq.) dropwise with stirred at 0-5 °C. The resulting solution was stirred for 3 hours at 0-5 °C. The reaction was then quenched by the addition of methanol (20 mL) and diluted with ethyl acetate. The resulting mixture was washed with water and saturated sodium chloride. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated under reduced pressure. This resulted in 13.8 g (70%) of **21-33** as a brown solid. MS m/z [M+Na]⁺ (ESI): 598.

[0222] Preparation of Intermediate (21-34): To a solution of **21-33** (10 g, 17.37 mmol, 1.00 eq.) in acetic acid (150 mL) with an inert atmosphere of nitrogen, was added acetyl acetate (19.5 g, 191.01 mmol, 11.00 eq.) and sulfuric acid (170 mg, 1.73 mmol, 0.10 eq.). The resulting solution was stirred for 1 hour at room temperature. The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with water and Sat. sodium chloride. The mixture was dried over anhydrous sodium sulfate and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 6.5 g (60%) of **21-34** as a yellow solid. MS m/z [M+Na]⁺ (ESI): 642.

[0223] Preparation of Intermediate (21-35): To a solution of 5-methyl-1, 2, 3, 4-tetrahydropyrimidine-2, 4-dione (1.5 g, 11.90 mmol, 1.50 eq.) in Acetonitrile (125 mL) with an inert atmosphere of nitrogen, was added N, O-Bis(trimethylsilyl)acetamide (5.75 g, 28.19 mmol, 3.50 eq.) at room temperature. The resulting solution was stirred for 2 h at 80 °C. To this was added **21-34** (5 g, 8.07 mmol, 1.00 eq.) at 0 °C, and then trimethylsilyl trifluoromethanesulfonate (2.34 g, 10.53 mmol, 1.30 eq.) was added dropwise with stirring at 0 °C. The resulting solution was allowed to react, with stirring, for an additional 6 h at 80 °C. The reaction mixture was cooled to 0 °C, quenched by the addition of Sat. ammonium chloride. The resulting solution was extracted with ethyl acetate and the organic layers combined and dried over anhydrous sodium sulfate and concentrated. The residue was purified by column chromatography. This resulted in 4.5 g (81%) of **21-35** as a white solid. MS m/z [M+H]⁺ (ESI): 686.

[0224] Preparation of Intermediate (21-36): To a solution of **21-35** (9 g, 13.12 mmol, 1.00 eq.) in methanol (90 mL) with an inert atmosphere of nitrogen, was added potassium carbonate (5.4 g,

38.79 mmol, 3.00 eq.). The resulting solution was stirred for 2 hours at 65 °C and diluted with ethyl acetate. The resulting mixture was washed with water and Sat. sodium chloride. The organic layer was dried over anhydrous sodium sulfate and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 5 g (70%) of **21-36** as a white solid. MS m/z [M+H]⁺ (ESI): 548.

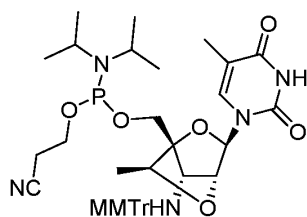
[0225] Preparation of Intermediate (21-37): To a solution of **21-36** (6 g, 10.96 mmol, 1.00 eq.) in tetrahydrofuran (60 mL) was added 10% Palladium on activated carbon (2 g). The flask was evacuated and flushed five times with hydrogen. The resulting solution was stirred for 8 hours at room temperature. The solids were filtered out. The resulting mixture was concentrated under reduced pressure. This resulted in 5.3 g (93%) of **21-37R** and **21-37S** as a white solid. Then the mixture was separated by Prep-SFC. This resulted in 3.5 g as a white solid. MS m/z [M+H]⁺ (ESI): 522.

[0226] Preparation of Intermediate (21-38): To a solution of **21-37** (3.5 g, 6.71 mmol, 1.00 eq.) in pyridine (35 mL) with an inert atmosphere of nitrogen was added 1-(chlorodiphenylmethyl)-4-methoxybenzene (2.7 g, 8.74 mmol, 1.30 eq.) at room temperature. The resulting solution was stirred for 2 hours at room temperature. The reaction was then quenched by the addition of methanol (20 mL). The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with Sat. sodium bicarbonate and brine. The organic layer was dried over anhydrous sodium sulfate and concentrated. The residue was purified by column chromatography. This resulted in 4 g (75%) of **21-38** as a white solid. MS m/z [M-H]⁻ (ESI): 792.

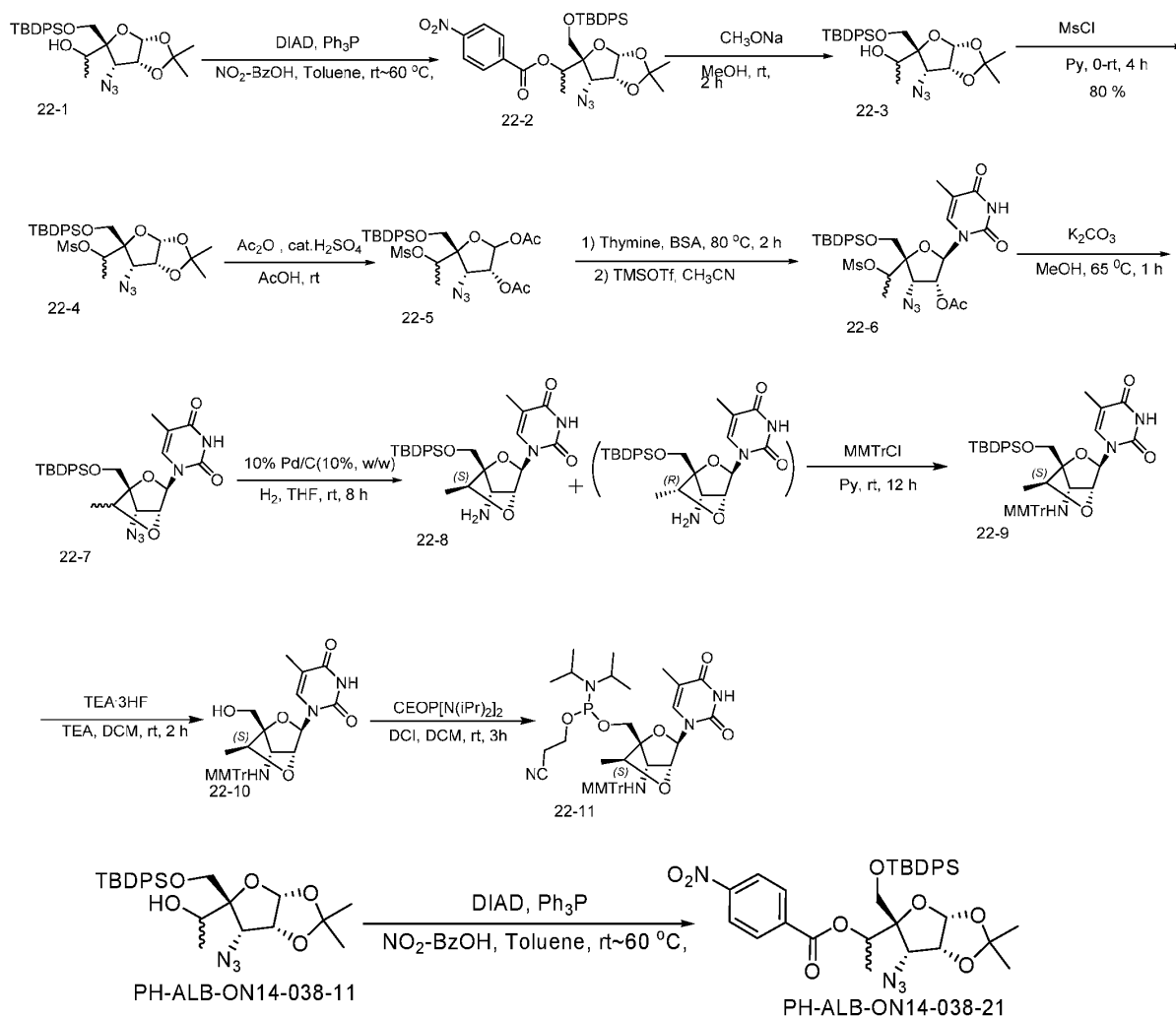
[0227] Preparation of Intermediate (21-39): To a solution of **21-38** (4 g, 5.04 mmol, 1.00 eq.) in dichloromethane (40 mL) with an inert atmosphere of nitrogen, was added triethylamine (1 g, 9.9 mmol, 2.0 eq.) at room temperature. To this was added Triethylamine trihydrofluoride (0.97 g, 7.56 mmol, 1.50 eq.) at room temperature. The resulting solution was stirred for 12 hours at room temperature and diluted with dichloromethane. The resulting mixture was washed with water. The mixture was dried over anhydrous sodium sulfate and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 2.3 g (80%) of **21-39** as a white solid. ¹H NMR (DMSO-d₆, 300Hz, ppm): δ 11.33 (s, 1H), 7.45 (m, 5H), 7.20 (m, 8H), 6.80 (m, 2H), 5.35 (t, J=5.1 Hz, 1H), 5.15 (s, 1H), 4.23 (m, 1H), 4.05 (m, 1H), 3.81 (m, 1H), 3.73 (s, 3H), 2.92 (d, J=9.7 Hz, 1H), 2.25 (d, J=9.8 Hz, 1H), 2.05 (s, 1H), 1.54 (s, 3H), 1.12 (d, J=6.1 Hz, 3H).

[0228] Preparation of (21-40): To a solution of **21-39** in dichloromethane (23 mL) with an inert atmosphere of nitrogen was added Bis(diisopropylamino)(2-cyanoethoxy)phosphine (1.62 g, 5.38 mmol, 1.30 eq.) at room temperature. To this was added 4, 5-Dicyanoimidazole (490 mg, 4.15 mmol, 1.10 eq.) at room temperature. The resulting solution was stirred for 1 hour at room temperature and diluted with dichloromethane. Then the mixture was washed with water. The organic layer was dried over anhydrous sodium sulfate and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 2.3 g (70%) of **21-40** as a white solid. MS m/z [M-H]⁻(ESI): 754. ¹H NMR (DMSO- d_6 , 400Hz, ppm) δ 11.37 (s, 1H), 7.45 (m, 4H), 7.28 (m, 9H), 6.80 (m, 2H), 5.18 (d, $J=6.3$ Hz, 1H), 4.35 (m, 1H), 4.21 (m, 1H), 4.01 (m, 1H), 3.7 (m, 6H), 3.6 (m, 1H), 2.90 (m, 3H), 2.33 (m, 1H), 2.13 (m, 1H), 1.59 (d, $J=21.6$ Hz, 3H), 1.20 (m, 15H). P NMR (DMSO- d_6 , 400Hz, ppm): 147.45, 147.08.

Example 18



Scheme 20



[0229] Preparation of Intermediate (22-2): To a solution of triphenylphosphane (10.5 g, 40.03 mmol, 2.00 eq.) in Toluene (100 mL) with an inert atmosphere of nitrogen, was added diisopropyl azodicarboxylate (8.10 g, 40.03 mmol, 2.00 eq.) at room temperature. To this was added p-nitrobenzoic acid (6.70 g, 40.03 mmol, 2.00 eq.) at 0°C . The resulting solution was stirred for 2 h at room temperature. To this was added **22-1** (10 g, 20.09 mmol, 1.00 eq.) at room temperature. The resulting solution was allowed to react for an additional 8 h at 60°C . The reaction mixture was diluted with ethyl acetate. The resulting mixture was washed with water

and saturated sodium chloride respectively. The mixture was dried over anhydrous sodium sulfate and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 5 g (38%) of **22-2** as a yellow solid.

[0230] Preparation of Intermediate (22-3): To a solution of **22-2** (27.5 g, 42.52 mmol, 1.00 eq.) in methanol (300 mL), with an inert atmosphere of nitrogen, was added sodium hydroxide (4.6 g, 85 mmol, 2.0 eq.) at 0 °C. The resulting solution was stirred for 2 hours at 25 °C. The pH value of the solution was adjusted to 8 with acetic acid. The resulting mixture was concentrated and then diluted with ethyl acetate. The resulting mixture was washed with water and saturated sodium chloride. The organic layer was dried over anhydrous sodium sulfate and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 16.5 g (78%) of **22-3** as yellow oil.

[0231] Preparation of Intermediate (22-4): To a solution of **22-3** (16.5 g, 33.15 mmol, 1.00 eq.) in pyridine (160 mL) with an inert atmosphere of nitrogen, was added methanesulfonyl chloride (4.95 g, 43.23 mmol, 1.30 eq.) dropwise with stirred at 0-5 °C. The resulting solution was stirred for 3 hours at 0-5 °C. The reaction was then quenched by the addition of methanol (30 mL) and diluted with ethyl acetate. The resulting mixture was washed with water and Sat. sodium chloride. The mixture was dried over anhydrous calcium chloride and concentrated under reduced pressure. This resulted in 15.3 g (70%) of **22-4** as a brown solid. MS m/z [M+Na]⁺ (ESI): 598.

[0232] Preparation of Intermediate (22-5): To a solution of **22-4** (15.3 g, 26.57 mmol, 1.00 eq.) in acetic acid (150 mL) with an inert atmosphere of nitrogen, was added acetyl acetate (30 g, 292.2 mmol, 11.00 eq.) and sulfuric acid (260 mg, 2.65 mmol, 0.10 eq.). The resulting solution was stirred for 1 hour at room temperature and diluted with ethyl acetate. The resulting mixture was washed with water and Sat. sodium chloride. The organic layer was dried over anhydrous sodium sulfate and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 10 g (60%) of **22-5** as a yellow solid. MS m/z [M+Na]⁺ (ESI): 642.

[0233] Preparation of Intermediate (22-6): To a solution of 5-methyl-1, 2, 3, 4-tetrahydropyrimidine-2, 4-dione (3.0 g, 23.8 mmol, 1.50 eq.) in Acetonitrile (250 mL) with an inert atmosphere of nitrogen, was added N, O-Bis (trimethylsilyl) acetamide (11.5 g, 56.1 mmol, 3.50 eq.) at room temperature. The resulting solution was stirred for 2 h at 80 °C. To this was

added **22-5** (10 g, 16.14 mmol, 1.00 eq.) at 0 °C, and then trimethylsilyl trifluoromethanesulfonate (4.68 g, 21.06 mmol, 1.30 eq.) was added dropwise with stirring at 0 °C. The resulting solution was allowed to react, with stirring, for an additional 6 h at 80 °C. The reaction mixture was cooled to 0 °C, quenched by the addition of Sat. ammonium chloride. The resulting solution was extracted with ethyl acetate and the organic layers combined and dried over anhydrous sodium sulfate and concentrated. The residue was purified by column chromatography. This resulted in 9 g (81%) of **22-6** as a white solid. MS m/z [M+H]⁺ (ESI): 686.

[0234] Preparation of Intermediate (22-7): To a solution of **22-6** (9 g, 13.12 mmol, 1.00 eq.) in methanol (90 mL) with an inert atmosphere of nitrogen, was added potassium carbonate (5.4 g, 38.79 mmol, 3.00 eq.) at room temperature. The resulting solution was stirred for 2 hours at 65 °C. The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with water and Sat. sodium chloride. The organic layer was dried over anhydrous sodium sulfate and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 5 g (70%) of **22-7** as a white solid. MS m/z [M+H]⁺ (ESI): 548.

[0235] Preparation of Intermediate (22-8): To a solution of **22-7** (5 g, 9.13 mmol, 1.00 eq.) in tetrahydrofuran (50 mL) was added 10% Palladium on activated carbon (2 g). The flask was evacuated and flushed five times with hydrogen. The resulting solution was stirred for 8 hours at room temperature. The solids were filtered out. The resulting mixture was concentrated under reduced pressure. This resulted in 4.4 g (93%) of **22-8R** and **22-8** as a white solid. Then the mixture was separated by Prep-SFC. This resulted in 1.9 g **22-8** as a white solid. MS m/z [M+H]⁺ (ESI): 522.

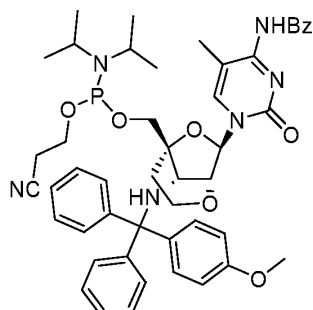
[0236] Preparation of Intermediate (22-9): To a solution of **22-8** (1.9 g, 3.64 mmol, 1.00 eq.) in pyridine (20 mL) with an inert atmosphere of nitrogen, was added 1-(chlorodiphenylmethyl)-4-methoxybenzene (1.23 g, 4.01 mmol, 1.10 eq.) at room temperature. The resulting solution was stirred for 2 hours at room temperature. The reaction was then quenched by the addition of methanol (10 mL). The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with Sat. sodium bicarbonate and Sat. sodium chloride. The organic layer was dried over anhydrous sodium sulfate and concentrated. The residue was purified by column

chromatography. This resulted in 2.3 g (80%) of **22-9** as a white solid. MS m/z [M-H]⁻ (ESI): 792.

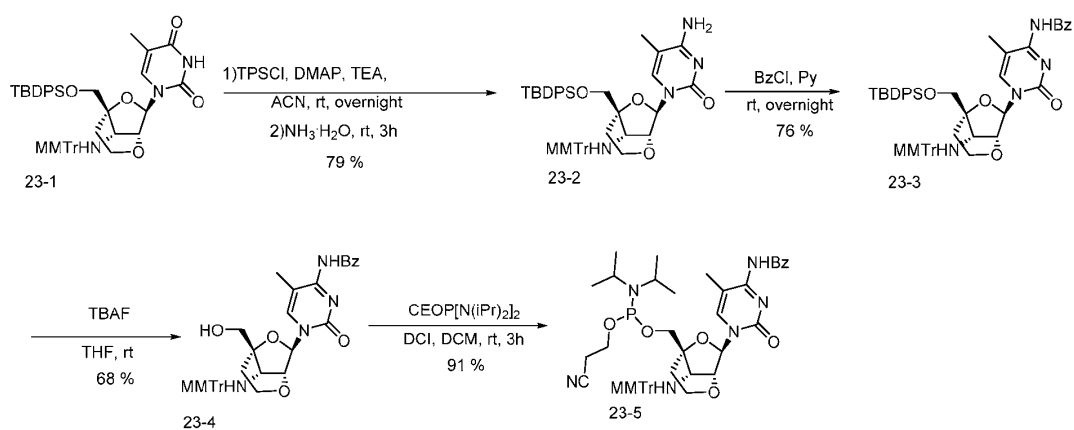
[0237] Preparation of Intermediate (22-10): To a solution of **22-9** (2.3 g, 2.90 mmol, 1.00 eq.) in dichloromethane (20 mL) with an inert atmosphere of nitrogen, was added triethylamine (723 mg, 7.25 mmol, 2.50 eq.) at room temperature. To this was added triethylamine trihydrofluoride (2.8 g, 17.4 mmol, 6.00 eq.) at room temperature and the resulting solution was stirred for 2 hours at 25 °C. The resulting solution was diluted with dichloromethane, washed with water and saturated sodium chloride respectively. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 1.7 g (80%) of **22-10** as a white solid. ¹H NMR (DMSO-d₆, 400Hz, *ppm*) δ 11.33 (s, 1H), 7.41 (m, 4H), 7.20 (m, 7H), 7.19 (m, 2H), 6.80 (m, 2H), 5.25 (t, *J*=5.2 Hz, 1H), 5.15 (s, 1H), 4.15 (m, 2H), 3.91 (q, *J*=6.7 Hz, 1H), 3.73 (s, 3H), 2.73 (d, *J*=9.5 Hz, 1H), 2.25 (m, 1H), 2.05 (m, 1H), 1.55 (s, 3H), 1.38 (d, *J*=6.8 Hz, 3H).

[0238] Preparation of (22-11): To a solution of **22-10** (1.77 g, 3.19 mmol, 1.00 eq.) in dichloromethane (20 mL) with an inert atmosphere of nitrogen, was added Bis(diisopropylamino)(2-cyanoethoxy)phosphine (1.35 g, 4.3 mmol, 1.4 eq.) at room temperature. To this was added 4, 5-Dicyanoimidazole (451 mg, 3.6 mmol, 1.20 eq.) at room temperature. The resulting solution was stirred for 2 hours at 25 °C and diluted with dichloromethane. The resulting mixture was washed with water and saturated sodium chloride respectively. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 1.82 g (76%) of **22-11** as a white solid. MS m/z [M-H]⁻ (ESI): 754. ¹H NMR (DMSO-d₆, 400Hz, *ppm*) δ 11.4 (d, *J*=9.8 Hz, 1H), 7.40 (m, 4H), 7.28 (m, 8H), 7.07 (m, 1H), 6.79 (m, 2H), 5.22 (d, *J*=4.0 Hz, 1H), 4.38 (m, 1H), 4.27 (m, 1H), 4.01 (q, *J*=6.7 Hz, 1H), 3.7 (m, 7H), 2.82 (m, 1H), 2.70 (m, 1H), 2.13 (m, 1H), 2.32 (d, *J*=60.2 Hz, 1H), 2.13 (dd, *J*=28.6 Hz and 6.0 Hz, 1H), 1.60 (d, *J*=18.0 Hz, 3H), 1.45 (t, *J*=6.9 Hz, 3H), 1.20 (m, 12H). ³¹P NMR (DMSO-d₆, 400Hz, *ppm*): δ 148.03, 147.53.

Example 19



Scheme 21



[0239] Preparation of Intermediate (23-2): To a solution of **23-1** (7.2 g, 9.07 mmol, 1.0 eq.) in Acetonitrile (70 mL) with an inert atmosphere of nitrogen, was added Triethylamine (2.75 g, 27.24 mmol, 3.0 eq.), 4-(dimethylamino)-pyridin (3.4 g, 27.24 mmol, 3.0 eq.) and 2, 4, 6-Triisopropylbenzenesulfonyl chloride (8.226 g, 27.24 mmol, 3.0 eq.). The resulting solution was stirred for 12 h at room temperature. Then ammoniumhydroxide (20 mL) was added and stirred for 1 hour at room temperature. The resulting solution was extracted with dichloromethane. The organic layers combined and washed with water, dried over anhydrous sodium sulfate, concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 5.7 g (79%) of **23-2** as a yellow solid MS m/z [M-H]⁻(ESI):791.

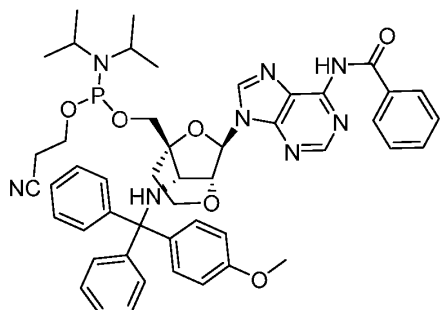
[0240] Preparation of Intermediate (23-3): To a solution of **23-2** (5.7 g, 7.20 mmol, 1.00 eq.) in Pyridine (70 mL) with an inert atmosphere of nitrogen, was added Benzoyl chloride (1.14 g, 1.2

eq.) dropwise at 0 °C. The resulting solution was stirred for 12 h at room temperature. The reaction was then quenched by the addition of methanol. The resulting mixture was concentrated. The residue was purified by column chromatography. This resulted in 5 g (76%) of **23-3** as a light yellow solid. MS m/z [M-H]⁻ (ESI): 895.

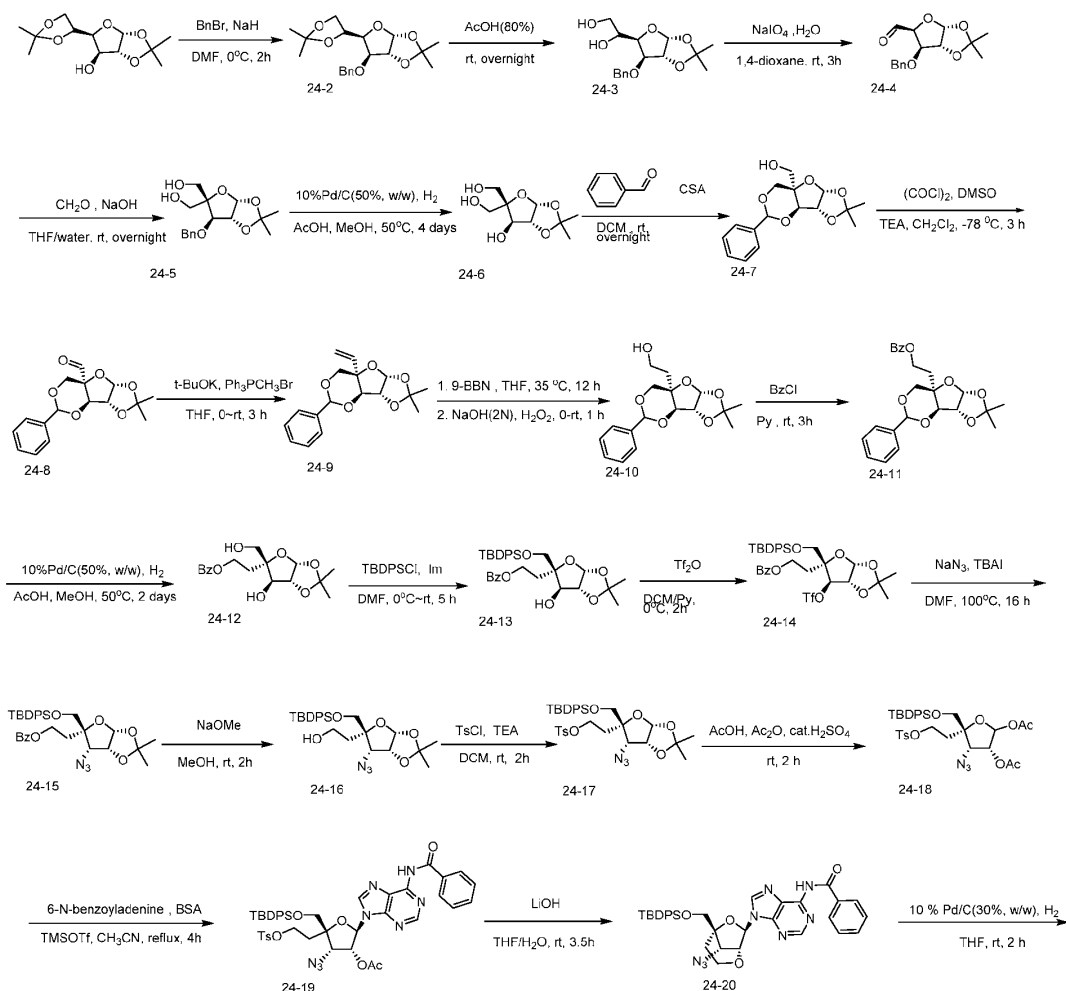
[0241] Preparation of Intermediate (23-4): To a solution of **23-3** (5 g, 5.58 mmol, 1.00 eq.) in Tetrahydrofuran (50 mL) was added tetrabutylammonium fluoride (1M in tetrahydrofuran, 11 mL, 2.0 eq.). The resulting solution was stirred for 4 h at room temperature. The resulting mixture was concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 2.5 g (68%) of **23-4** as a white solid. MS m/z [M-H]⁻ (ESI): 657. ¹H NMR (DMSO-d₆, 300Hz, ppm): δ 13.08 (s, 1H), 8.32-8.18 (m, 2H), 7.70-7.35 (m, 8H), 7.31-7.08 (m, 8H), 6.75 (m, 2H), 5.68 (s, 1H), 5.33 (s, 1H), 4.01-3.91 (m, 1H), 3.79 (m, 3H), 3.69 (s, 3H), 2.85 (m, 1H), 2.46-2.05 (m, 2H), 1.88 (s, 3H), 1.70 (s, 1H), 1.36 (m, 1H).

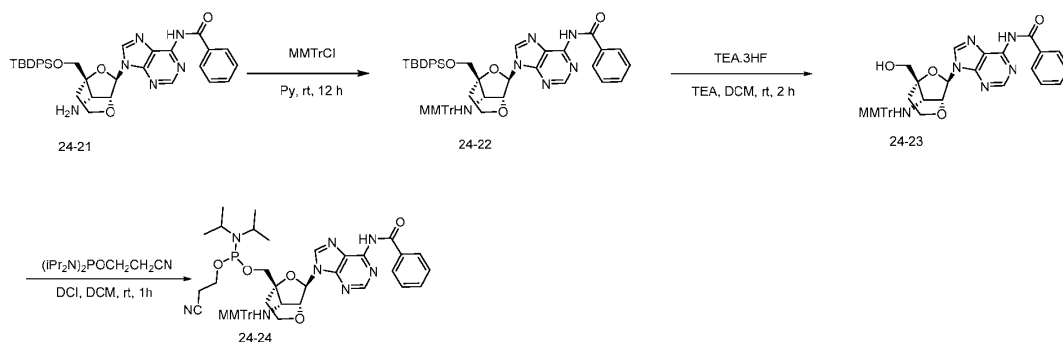
[0242] Preparation of (23-5): To a solution of **23-4** (2.5 g, 3.80 mmol, 1.00 eq.) in dichloromethane (25 mL) with an inert atmosphere of nitrogen was added Bis(diisopropylamino)(2-cyanoethoxy)phosphine (1.7 g, 5.70 mmol, 1.50 eq.) at room temperature. To this was added 4, 5-Dicyanoimidazole (490 mg, 4.17 mmol, 1.10 eq.) at room temperature. The resulting solution was stirred for 3 h at room temperature and diluted with dichloromethane. The resulting mixture was washed with water. The organic layer was dried over anhydrous sodium sulfate and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 2.9710 g (91%) of **23-5** as a white solid. MS m/z [M+H]⁺ (ESI): 859. ¹H NMR (DMSO-d₆, 300Hz, ppm): δ 13.07 (s, 1H), 8.15 (m, 2H), 7.70-7.42 (m, 8H), 7.23 (m, 8H), 6.75 (m, 2H), 5.81-5.68 (m, 1H), 4.17-3.97 (m, 1H), 3.96-3.55 (m, 9H), 3.10-2.55 (m, 4H), 2.38-2.19 (m, 1H), 1.98 (m, 4H), 1.81-1.38 (m, 2H), 1.20 (m, 12H). ³¹P NMR (DMSO-d₆, 300Hz, ppm): 148.11, 145.59.

Example 20



Scheme 22





[0243] Preparation of Intermediate (24-2): To a solution of (3aR,5S,6S,6aR)-5-(2,2-dimethyl-1,3-dioxolan-4-yl)-2,2-dimethyl-tetrahydro-2H-furo[2,3-d][1,3]dioxol-6-ol (500 g, 1.92 mol, 1.00 eq.) in N,N-dimethylformamide (5000 mL) with an inert atmosphere of nitrogen, was added (bromomethyl) benzene (345 g, 2.02 mol, 1.05 eq.) at room temperature. Sodium hydride (123 g, 3.0 mol, 1.60 eq.) was added for several batches at 0 °C. The resulting solution was stirred for 2 h at 25 °C. The reaction was then quenched by the addition of Saturated ammoniumchloride (2000 mL). The resulting solution was extracted with ethyl acetate and the organic layers combined, dried over anhydrous sodium sulfate, filtered and concentrated. This resulted in 670 g (crude) of **24-2** as yellow oil. This crude product was used in the next step without further purification. MS m/z [M+H]⁺ (ESI): 351.

[0244] Preparation of Intermediate (24-3): **24-2** (300 g, 856.14 mmol, 1.00 eq.) was dissolved acetic acid (80% in water, 3000 mL). The resulting solution was stirred overnight at room temperature. The resulting mixture was concentrated and diluted with ethyl acetate. The resulting mixture was washed with Saturated sodium bicarbonate respectively. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. This resulted in 237 g (crude) of **24-3** as yellow oil. This crude product was used in the next step without further purification. MS m/z [M+Na]⁺ (ESI): 333.

[0245] Preparation of Intermediate (24-4): To a solution of **24-3** (200 g, 644.44 mmol, 1.00 eq.) in 1,4-dioxane (2000 mL) was added a solution of sodium periodate (138 g, 644.44 mmol, 1.00 eq.) in water(2000 mL) dropwise with stirring at 0 °C. The resulting solution was stirred for 2 h at room temperature. The resulting solution was diluted with ethyl acetate and washed with water. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated.

This resulted in 160 g (crude) of **24-4** as yellow oil. This crude product was used in the next step without further purification. MS m/z $[M+H]^+$ (ESI): 279.

[0246] Preparation of Intermediate (24-5): To a solution of **24-4** (200 g, 718.64 mmol, 1.00 eq.) in tetrahydrofuran/water (1000 mL/1000 mL) was added Formaldehyde Solution (37%, 480 mL) at room temperature. To this was added 2N sodium hydroxide (1200 mL, 3.12 eq.) dropwise with stirring at 0 °C. The resulting solution was stirred overnight at room temperature. The reaction mixture was extracted with ethyl acetate and the organic layers combined. The organic layer was washed with water. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. This resulted in 152.8 g (crude) of **24-5** as yellow oil. This crude product was used in the next step without further purification. MS m/z $[M+Na]^+$ (ESI): 333.

[0247] Preparation of Intermediate (24-6): To a solution of **24-5** (500 g, 1.61 mmol, 1.00 eq.) in methanol/ Acetic acid (5000/500 mL) in a 20-L pressure tank reactor with an inert atmosphere of nitrogen, was added 10% Palladium on activated carbon (250 g). The pressure tank was evacuated and flushed five times with hydrogen. The resulting solution was stirred for 4 days at 50 °C (8 atm). The solids were filtered out. The resulting mixture was concentrated. The residue was purified by column chromatography. This resulted in 280 g (79%) of **24-6** as a white solid.

[0248] Preparation of Intermediate (24-7): To a solution of **24-6** (200 g, 908.2 mmol, 1.00 eq.) in dichloromethane (6000 mL) with an inert atmosphere of nitrogen, was added benzaldehyde (436.0 g, 2722.9 mmol, 3.00 eq.) dropwise with stirring at 0 °C. Then camphorsulfonic acid (2 g) was added at 0 °C. The resulting solution was stirred overnight at room temperature. The reaction was then quenched by the addition of 2000 mL Saturated sodium bicarbonate. The resulting solution was extracted with dichloromethane and the organic layers combined. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The residue was purified by column chromatography. This resulted in 13.5 g (48%) of **24-7** as a white solid. MS m/z $[M+Na]^+$ (ESI): 331. **¹H NMR** (DMSO-*d*₆, 400Hz, *ppm*): δ 7.44-7.30 (m, 6H), 5.97 (d, *J*=4.1Hz, 1H), 5.46 (s, 1H), 5.06 (t, *J*=5.4Hz, 1H), 4.64-4.52 (m, 2H), 4.14 (d, *J*=13.0Hz, 1H), 4.08-3.93 (m, 1H), 3.74-3.65 (m, 1H), 3.38 (m, 1H), 1.46 (s, 3H), 1.23 (s, 3H).

[0249] Preparation of Intermediate (24-8): To a solution of oxalyl chloride (30.9 g, 243.31 mmol, 1.50 eq.) in dichloromethane (1000 mL) with an inert atmosphere of nitrogen, was added of dimethyl sulfoxide (37.9 g, 485.09 mmol, 3.00 eq.) dropwise with stirring at -78 °C. The

resulting solution was stirred for 30 min at -78 °C. To this was added a solution of **24-7** (50 g, 162.17 mmol, 1.00 eq.) in dichloromethane (200 mL) dropwise with stirring at -78 °C. The resulting solution was allowed to react, with stirring, for an additional 1.5 h at -78 °C. Then was added triethylamine (73.9 g, 730.31 mmol, 4.50 eq.) dropwise with stirring at -78 °C. The resulting solution was allowed to react, with stirring, for an additional 2 h at -78 °C. The resulting solution was diluted with dichloromethane and washed with 5% hydrochloric acid, Saturated sodium bicarbonate, and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. This resulted in 49 g (crude) of **24-8** as a white solid. This crude product was used in the next step without further purification. MS m/z [M+H]⁺ (ESI): 307.

[0250] Preparation of Intermediate (24-9): To a solution of methyltriphenylphosphonium bromide (139.8 g, 2.00 eq.) in tetrahydrofuran (600 mL) with an inert atmosphere of nitrogen, was added Potassium tert-butoxide (43.8 g, 390.33 mmol, 2.00 eq.). The resulting solution was stirred for 30 min at room temperature. To this a solution of **24-8** (60 g, 195.87 mmol, 1.00 eq.) in tetrahydrofuran (150 mL) was added dropwise with stirring at 0 °C. The resulting solution was allowed to react, with stirring, for an additional 2 h at room temperature. The reaction was then quenched by the addition of Saturated Ammonium chloride (400 mL). The resulting solution was extracted with ethyl acetate and the organic layers combined. The organic layer was washed with water, and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The residue was purified by column chromatography. This resulted in 38.7 g (65%) of **24-9** as a white solid. MS m/z [M+H]⁺ (ESI): 305.

[0251] Preparation of Intermediate (24-10): To a solution of **24-9** (60 g, 197.16 mmol, 1.00 eq.) in tetrahydrofuran (600 mL) with an inert atmosphere of nitrogen, was added 9-Borabicyclo[3.3.1]nonane (0.5M in tetrahydrofuran, 789 mL, 2.00 eq.). The resulting solution was stirred overnight at 35 °C. Then sodium hydroxide (2N in water, 591 mL, 6.00 eq.) was added at room temperature. To this was added hydrogen peroxide (30%, 120 mL, 6.00 eq.) dropwise with stirring at room temperature. The resulting solution was allowed to react. The resulting solution was extracted with dichloromethane and the organic layers combined. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The residue

was purified by column chromatography. This resulted in 43.5 g (68%) of **24-10** as a white solid. MS m/z [M+Na]⁺ (ESI): 345.

[0252] Preparation of Intermediate (24-11): To a solution of **24-10** (100 g, 310.2 mmol, 1.00 eq.) in pyridine (1000 mL) with an inert atmosphere of nitrogen, was added benzoyl chloride (130 g, 924.8 mmol, 3.00 eq.) dropwise with stirring at 0 °C. The resulting solution was stirred for 3 h at room temperature. The reaction was then quenched by the addition of methanol (200 mL). The resulting mixture was concentrated. The solid was diluted with ethyl acetate. The resulting mixture was washed with water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The residue was purified by column chromatography. This resulted in 110 g (83%) of **24-11** as a white solid. MS m/z [M+Na]⁺ (ESI): 449.

[0253] Preparation of Intermediate (24-12): To a solution of **24-11** (200 g, 469 mmol, 1.00 eq.) in methanol/ tetrahydrofuran (500/100 mL) was added 10% Palladium on activated carbon (100 g). The flask was evacuated and flushed five times with hydrogen. The resulting solution was stirred for 48 h at 40 °C. The solids were filtered out. The resulting mixture was concentrated. The residue was purified by column chromatography. This resulted in 35 g (88%) of **24-12** as colorless oil. MS m/z [M+Na]⁺ (ESI): 361.

[0254] Preparation of Intermediate (24-13): To a solution of **24-12** (50 g, 147.77 mmol, 1.00 eq.) and imidazole (19.5 g, 286.43 mmol, 2.00 eq.) in N,N-dimethylformamide (500 mL) with an inert atmosphere of nitrogen, was added tert-Butyldiphenylsilane (44.5 g, 1.10 eq.) dropwise with stirring at 0 °C. The resulting solution was stirred for 2 h at room temperature. The reaction was then quenched by the addition of methanol (100 mL). The resulting mixture was concentrated. The residue was dissolved in dichloromethane. The resulting mixture was washed with water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The residue was purified by column chromatography. This resulted in 60 g (70%) of **24-13** as a solid. MS m/z [M+Na]⁺ (ESI): 599. **1H NMR** (DMSO-*d*₆, 300Hz, ppm): 7.90-7.80 (m, 2H), 7.72-7.54 (m, 5H), 7.49-7.30 (m, 8H), 5.85 (d, *J*=4.4Hz, 1H), 5.59 (d, *J*=4.9Hz, 1H), 4.54 (m, 1H), 4.37 (t, *J*=7.0Hz, 2H), 4.09 (m, 1H), 3.29 (s, 2H), 2.22 (m, 2H), 1.42 (s, 3H), 1.21 (s, 3H), 0.96 (s, 9H).

[0255] Preparation of Intermediate (24-14): To a solution of **24-13** (64 g, 110.97 mmol, 1.00 eq.) in dichloromethane/pyridine(448/134 mL) with an inert atmosphere of nitrogen, was added Trifluoromethanesulfonic anhydride (46.9 g, 166.23 mmol, 1.50 eq.) dropwise with stirring at 0 °C. The resulting solution was stirred for 2 h at 0 °C. The resulting solution was diluted with dichloromethane. The resulting mixture was washed with water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. This resulted in 78 g (crude) of **24-14** as a solid. This crude product was used in the next step without further purification. MS m/z [M+Na]⁺ (ESI): 731.

[0256] Preparation of Intermediate (24-15): To a solution of **24-14** (78 g, 110.04 mmol, 1.00 eq.) and Tetrabutylammonium iodide (4 g, 10.83 mmol, 0.10 eq.) in N,N-dimethylformamide (800 mL) with an inert atmosphere of nitrogen, was added Sodium azide (21.5 g, 330.72 mmol, 3.00 eq.). The resulting solution was stirred overnight at 100 °C. The reaction was then quenched by the addition of ice water (200 mL). The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The residue was purified by column chromatography. This resulted in 45 g (68%) of **24-15** as brown oil. MS m/z [M+Na]⁺ (ESI):624.

[0257] Preparation of Intermediate (24-16): To a solution of **24-15** (91 g, 151.22 mmol, 1.00 eq.) in methanol(900 mL) with an inert atmosphere of nitrogen, was added sodium methoxide (30% in methanol, 50 mL, 2.00 eq.). The resulting solution was stirred for 2 h at room temperature. The resulting solution was extracted with ethyl acetate and the organic layers combined. The organic layer was washed with water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The residue was purified by column chromatography. This resulted in 55g (73%) of **24-16** as a white solid. MS m/z [M+Na]⁺ (ESI):520.

[0258] Preparation of Intermediate (24-17): To a solution of **24-16** (56 g, 112.53 mmol, 1.00 eq.) and triethylamine (67.2 g, 664.10 mmol, 6.00 eq.) in dichloromethane(825 mL) with an inert atmosphere of nitrogen, was added 4-dimethylaminopyridine (1 g, 8.19 mmol, 0.31 eq.) and 4-toluene sulfonyl chloride (31.5 g, 165.22 mmol, 1.50 eq.) in order at room temperature. The resulting solution was stirred for 2 h at room temperature. The resulting solution was diluted with

dichloromethane. The resulting mixture was washed with water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The residue was purified by column chromatography. This resulted in 55 g (75%) of **24-17** as colorless oil. MS m/z [M+Na]⁺ (ESI):674.

[0259] Preparation of Intermediate (24-18): To a solution of **24-17** (100 g, 153.4 mmol, 1.00 eq.) in acetic acid(1000 mL) with an inert atmosphere of nitrogen, were added acetyl acetate (17.2 g, 168.48 mmol, 11.00 eq.) and sulfuric acid (300 mg, 3.08 mmol, 0.20 eq.). The resulting solution was stirred for 2 h at room temperature. The reaction was then quenched by the addition of ice water (600 mL). The resulting solution was extracted with ethyl acetate. The resulting mixture was washed water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The residue was purified by column chromatography. This resulted in 52 g (49%) of **24-18** as a brown solid. MS m/z [M+Na]⁺ (ESI):718.

[0260] Preparation of Intermediate (24-19): To a solution of 6-N-benzoyladenine(6.7 g, 1.50 eq.) in acetonitrile (100 mL) with an inert atmosphere of nitrogen, was added N,O-Bis(trimethylsilyl)acetamide (18.9 g, 92.91 mmol, 5.00 eq.). The resulting solution was stirred for 1 h at 85 °C. This was followed by the addition of **24-18** (13 g, 18.68 mmol, 1.00 eq.) in acetonitrile (100 mL) at 0 °C. To this trifluoromethanesulfonic acid trimethylsilyl ester (20.7 g, 92.91 mmol, 5.00 eq.) was added dropwise at 0 °C. The resulting solution was allowed to react, with stirring, for an additional 4h at 85 °C. The reaction was then quenched by the addition of Saturated sodium bicarbonate(100 mL). The resulting solution was extracted with ethyl acetate and the organic layers combined. The organic layer was washed with water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 8 g (49%) of **24-19** as a white solid. MS m/z [M+H]⁺ (ESI):875.

[0261] Preparation of Intermediate (24-20): To a solution of **24-19** (7.4 g, 8.46 mmol, 1.00 eq.) in tetrahydrofuran(55 mL) with an inert atmosphere of nitrogen, was added a solution of lithium hydroxide (1.01 g, 42.17 mmol, 5.00 eq.) in water (25 mL) at 0 °C. The resulting solution was stirred for 4 h at room temperature. The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The residue was purified by

column chromatography. This resulted in 4.3 g (77%) of **24-20** as a white solid. MS m/z [M+H]⁺ (ESI):661.

[0262] Preparation of Intermediate (24-21): To a solution of **24-20** (4 g, 6.05 mmol, 1.00 eq.) in tetrahydrofuran (40 mL), was added 10% Palladium on activated carbon (1.2 g). The flask was evacuated and flushed five times with hydrogen. The resulting solution was stirred for 3 h at 25 °C. The solids were filtered out. The resulting mixture was concentrated. This resulted in 3.8 g (99%) of **24-21** as a white solid. MS m/z [M+H]⁺ (ESI):635.

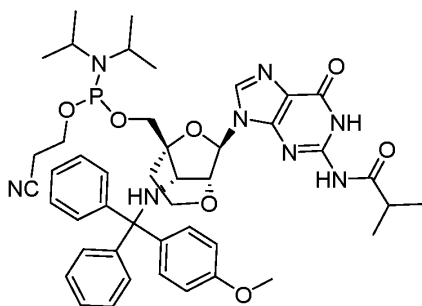
[0263] Preparation of Intermediate (24-22): To a solution of **24-21** (3.8 g, 5.99 mmol, 1.00 eq.) in pyridine(38 mL) with an inert atmosphere of nitrogen, was added 4-Methoxytriphenylmethyl chloride (2.0 g, 6.59 mmol, 1.10 eq.) at 0 °C. The resulting solution was stirred for 3 h at 25 °C. The reaction was then quenched by the addition of methanol (5 mL). The resulting mixture was concentrated. The residue was dissolved in dichloromethane. The resulting mixture was washed with water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 2.7 g (50%) of **24-22** as a white solid. MS m/z [M+H]⁺ (ESI):908.

[0264] Preparation of Intermediate (24-23): To a solution of **24-22**(2.7 g, 2.98 mmol, 1.00 eq.) in dichloromethane (27 mL) with an inert atmosphere of nitrogen, was added triethylamine(750 mg, 7.41 mmol, 2.50 eq.) and triethylamine trihydrofluoride (2.87 g, 17.80 mmol, 6.00 eq.) in order. The resulting solution was stirred for 2 h at 25 °C. The resulting solution was diluted with dichloromethane. The resulting mixture was washed with water and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 1.8 g (90%) of **24-23** as a white solid. MS m/z [M+H]⁺ (ESI):669. ¹H NMR (DMSO-*d*₆, 300Hz, *ppm*): δ 11.18 (s, 1H), 8.63 (d, *J*=13.7 Hz, 2H), 8.13-8.03 (m, 2H), 7.71-7.49 (m, 3H), 7.42-7.29 (m, 4H), 7.23-6.92 (m, 8H), 6.62-6.51 (m, 2H), 6.25 (s, 1H), 5.27 (t, *J*=4.3 Hz, 1H), 4.04 (m, *J*=12.0 Hz, 4.6 Hz, 1H), 3.88 (t, *J*=5.5 Hz, 3H), 3.57 (s, 3H), 3.04 (d, *J*=10.6 Hz, 1H), 2.41 (d, *J*=10.8 Hz, 1H), 2.20 (m, *J*=12.2 Hz, 7.7 Hz, 1H), 1.57 (d, *J*=2.5 Hz, 1H), 1.44 (d, *J*=11.7 Hz, 1H).

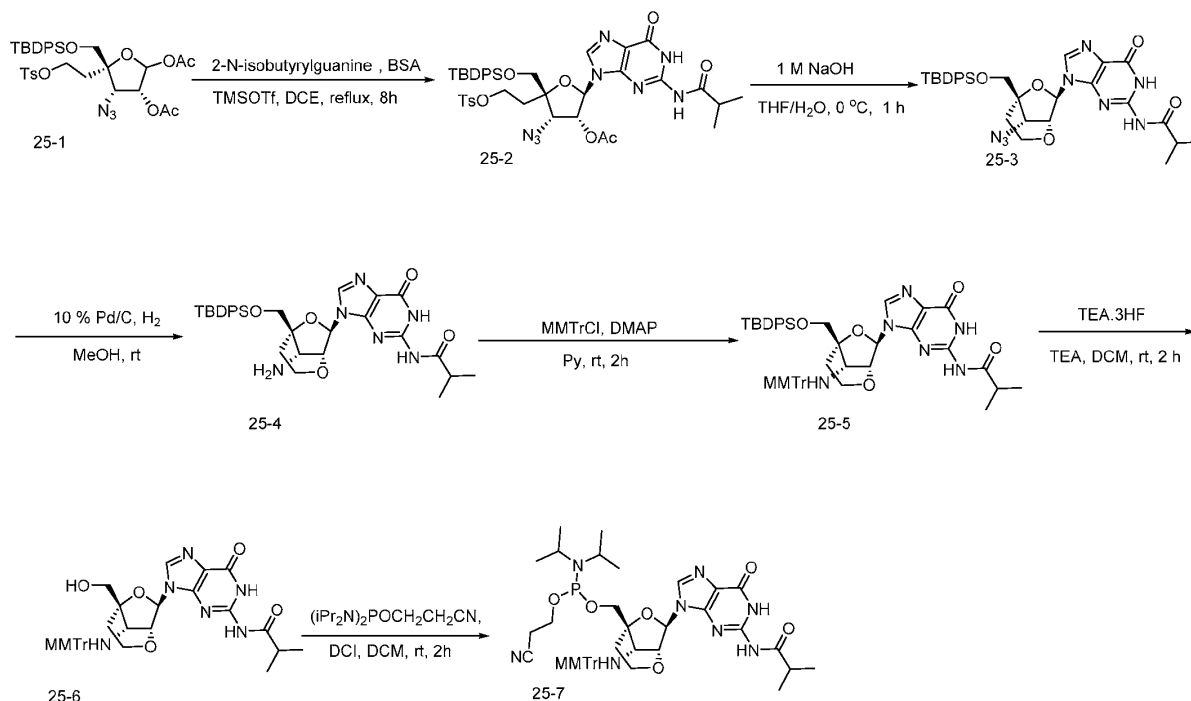
[0265] Preparation of (24-24): To a solution of **24-23** (1.8 g, 2.69 mmol, 1.00 eq.) in dichloromethane (20 mL) with an inert atmosphere of nitrogen, was added Bis(diisopropylamino)(2-cyanoethoxy)phosphine (1.26 g, 1.40 eq.) and added 4, 5-

Dicyanoimidazole (422 mg, 1.20 eq.) in order at 0 °C. The resulting solution was stirred for 1 h at 25 °C. The resulting solution was diluted with dichloromethane. The resulting mixture was washed with Saturated sodium bicarbonate and Saturated sodium chloride. The organic phase was dried over anhydrous sodium sulfate, filtered and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 2.1 g (77%) of **24-24** as a white solid. MS m/z $[M+H]^+$ (ESI): 869. **¹H NMR** (DMSO- d_6 , 300Hz, ppm): δ 11.20 (s, 1H), 8.62 (d, $J=17.2$ Hz, 1H), 8.40 (m, 1H), 8.13-8.03 (m, 2H), 7.65 (m, 1H), 7.56 (m, 2H), 7.47-7.33 (m, 4H), 7.21 (t, $J=8.3$ Hz, 2H), 7.15-6.92 (m, 6H), 6.59 (d, $J=8.5$ Hz, 2H), 6.31 (d, $J=3.6$ Hz, 1H), 4.22-4.02 (m, 1H), 4.00-3.37 (m, 9H), 3.04 (d, $J=10.6$ Hz, 1H), 2.92-2.67 (m, 2H), 2.55 (d, $J=11.3$ Hz, 1H), 2.31 (m, 1H), 1.73-1.47 (m, 2H), 1.27-0.99 (m, 13H), 0.93-0.76 (m, 1H). **P-NMR** (DMSO- d_6 , 300Hz, ppm): δ 148.21, 147.04.

Example 21



Scheme 23



[0266] Preparation of Intermediate (25-2): To a solution of N-2-acetylguanine (12.4 g, 56.36 mmol, 3.00 eq.) in 1, 2-dichloroethane (200 mL) with an inert atmosphere of nitrogen, was added N, O-Bis (trimethylsilyl) acetamide (19 g, 93.6 mmol, 5.00 eq.) at room temperature. The resulting solution was stirred for 3 h at 85 °C. To this was added **25-1** (13 g, 18.68 mmol, 1.00 eq.) at 0 °C, and then trimethylsilyl trifluoromethanesulfonate (20.8 g, 93.58 mmol, 5.00 eq.) was added dropwise with stirring at 0 °C. The resulting solution was allowed to react, with stirring, for an additional 2 h at 80 °C. The reaction mixture was cooled to 0 °C, quenched by the addition of saturated ammonium chloride (80 mL). The resulting solution was extracted with ethyl acetate and the organic layers combined and dried over anhydrous sodium sulfate, filtered, and concentrated. The residue was purified by column chromatography. This resulted in 5.6 g (35%) of **25-2** as a white solid. MS m/z $[M+H]^+$ (ESI): 857.

[0267] Preparation of Intermediate (25-3): To a solution of **25-2** (5.6 g, 6.53 mmol, 1.00 eq.) in tetrahydrofuran (56 mL) with an inert atmosphere of nitrogen, was added 1M sodium hydroxide (56 mL) at 0 °C. The resulting solution was stirred for 1 h at 0 °C. The pH value of the solution

was adjusted to 7 with acetic acid. The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with water and saturated sodium chloride respectively. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 2.9 g (69%) of **25-3** as a white solid.

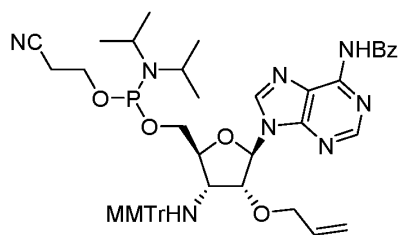
[0268] Preparation of Intermediate (25-4): To a solution of **25-3** (2.9 g, 4.51 mmol, 1.00 eq.) in tetrahydrofuran (30 mL) was added 10% Palladium on activated carbon (1.2 g). The flask was evacuated and flushed five times with hydrogen. The resulting solution was stirred for 5 hours at room temperature. The solids were filtered out. The resulting mixture was concentrated under reduced pressure. This resulted in 2.5 g (90%) of **25-4** as a white solid.

[0269] Preparation of Intermediate (25-5): To a solution of **25-4** (2.5 g, 4.05 mmol, 1.00 eq.) in pyridine (25 mL) with an inert atmosphere of nitrogen, was added 1-(chlorodiphenylmethyl)-4-methoxybenzene (1.9 g, 6.15 mmol, 1.50 eq.) and 4-dimethylaminopyridine (150 mg, 1.23 mmol, 0.30 eq.) in order at room temperature. The resulting solution was stirred for 2 h at room temperature and then quenched by the addition of methanol (10 mL). The resulting solution was diluted with ethyl acetate. The resulting mixture was washed with water and saturated sodium chloride respectively. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 2.7 g (75%) of **25-5** as a white solid.

[0270] Preparation of Intermediate (25-6): To a solution of **25-5** (2.7 g, 3.04 mmol, 1.00 eq.) in dichloromethane (30 mL) with an inert atmosphere of nitrogen was added triethylamine (1 g, 9.88 mmol, 3.00 eq.) at room temperature. To this was added triethylamine trihydrofluoride (1.5 g, 9.32 mmol, 3.0 eq.) at room temperature. The resulting solution was stirred for 2 hours at 25 °C and diluted with dichloromethane. The resulting mixture was washed with water and saturated sodium chloride respectively. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 1.7 g (86%) of **25-6** as a white solid. MS m/z [M+H]⁺ (ESI): 651. ¹H NMR (DMSO-d₆, 400 Hz, ppm) δ 12.16 (s, 1H), 11.77 (s, 1H), 8.15 (s, 1H), 7.42 (m, 4H), 7.15 (m, 8H), 6.56 (d, J=8.4 Hz, 2H), 5.97 (s, 1H), 5.22 (t, J=4.3 Hz, 1H), 4.01 (m, 1H), 3.85 (m, 2H), 3.73 (m, 1H), 3.60 (s, 3H), 3.01 (m, 1H), 2.82 (m, 1H), 2.39 (d, J=10.9 Hz, 1H), 2.17 (m, 1H), 1.58 (d, J=2.6 Hz, 1H), 1.41 (m, 1H), 1.18 (d, J=6.8 Hz, 3H), 1.12 (d, J=6.8 Hz, 3H).

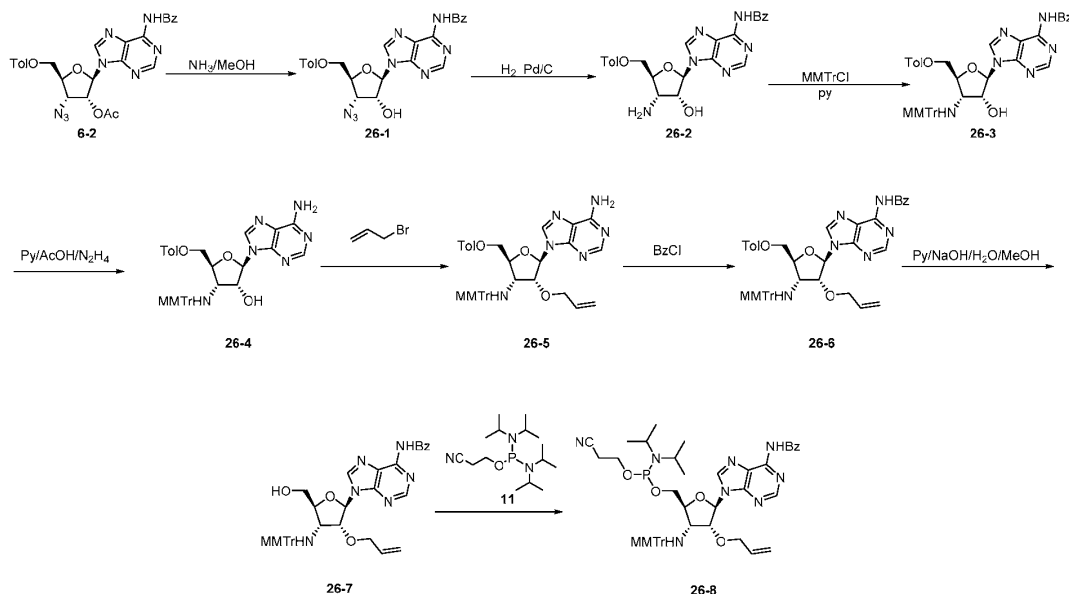
[0271] Preparation of (25-7): To a solution of **25-6** (1.7 g, 2.61 mmol, 1.00 eq.) in dichloromethane (17 mL) with an inert atmosphere of nitrogen was added Bis (diisopropylamino) (2-cyanoethoxy) phosphine (950 mg, 3.16 mmol, 1.30 eq.) at room temperature. To this was added 4, 5-Dicyanoimidazole (340 mg, 2.91 mmol, 1.10 eq.) at room temperature. The resulting solution was stirred for 2 hours at 25 °C and diluted with dichloromethane. The resulting mixture was washed with water and saturated sodium chloride respectively. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated. The crude product was purified by Flash-Prep-HPLC. This resulted in 1.8 g (81%) of **25-7** as a white solid. MS m/z $[M+H]^+$ (ESI): 851. H NMR (DMSO- d_6 , 400Hz, ppm) δ 12.18 (s, 1H), 11.80 (s, 1H), 7.98 (d, $J=64.4$ Hz, 1H), 7.47 (m, 4H), 7.15 (m, 8H), 6.56 (m, 2H), 6.01 (d, $J=10.0$ Hz, 1H), 3.95 (m, 3H), 3.77 (m, 2H), 3.66 (m, 1H), 3.59 (d, $J=9.8$ Hz, 3H), 3.38 (m, 2H), 2.91 (m, 4H), 2.30 (m, 1H), 1.55 (m, 2H), 1.15 (m, 14H), 1.04 (d, $J=6.7$ Hz, 4H). P NMR (DMSO- d_6 , 400Hz, ppm): 148.62, 147.09.

Example 22



[0272] The synthesis of the 2'-O-vinyl adenosine analog **26-8** was achieved as shown in scheme 26. Intermediate **6-2** was treated with $NH_3/MeOH$ to afford compound 26-1. To avoid side reactions of the vinyl moiety with the azide, the C3'-azide was reduced with a reducing agent such as H_2 , Pd/C to afford intermediate **26-2** whose free 3'- NH_2 was protected with MMTr protecting group to form **26-3**. After deprotection of the N6 position of the base to give **26-4**, alkylation was carried out with allyl bromide to obtain **26-5**. This approach used reduction of the C3'-azide prior to alkylation to avoid side reactions of the vinyl moiety with the azide. Reprotection of N6 position with benzyl chloride afforded compound **26-6** that was 5'-deprotected with Py/NaOH/MeOH/ H_2O to give **26-7**. Standard phosphitylation conditions were used to achieve target compound **26-8**.

Scheme 24



[0273] Preparation of Intermediate 26-1: To a solution of **6-2** (32.6 g, 58.6 mmol) in methanol (500 mL) was added $\text{NH}_3 \cdot \text{H}_2\text{O}$ (50 mL) at 0°C . The reaction mixture was stirred at 0°C for 2 h and concentrated, the residue was dissolved in EA, washed with brine, dried over anhydrous Na_2SO_4 , the solvent was removed and the residue was purified on silica gel to give **26-1** (28.5 g, 55.4 mmol, 94.62% yield) as a yellow solid. ESI-LCMS: m/z 515 $[\text{M}+\text{H}]^+$.

[0274] Preparation of Intermediate 26-2: To a solution of **26-1** (28.5 g, 55.4 mmol) in THF (400.00 mL) was added Pd/C (3.0 g), the mixture was stirred at r.t. for 6 h under H_2 . The mixture was filtered and the filtrate was concentrated to afford **26-2** (21.5 g, 44.1 mmol, 79.60% yield) as a gray solid. ESI-LCMS: m/z 489 $[\text{M}+\text{H}]^+$.

[0275] Preparation of Intermediate 26-3: MMTTrCl (20.4 g, 66.1 mmol) was added to a solution of **26-2** (21.5 g, 44.1 mmol) in pyridine (300 mL). The mixture was stirred at room temperature for 1 h. The reaction was quenched with MeOH and concentrated to obtained a residue which was purified on silica gel to give **26-3** (22.0 g, 28.9 mmol, 65.53% yield) as a white solid. ESI-LCMS: m/z 761 $[\text{M}+\text{H}]^+$.

[0276] Preparation of Intermediate 26-4: To a solution of **26-3** (22.0 g, 28.9 mmol) in a mixture of pyridine (200 mL) and AcOH (50 mL), was added hydrazine hydrate (80%) (173.5 mmol, 10 mL),

and the reaction was stirred at room temperature for 15 h. The reaction was poured into ice water, extracted with EA, washed with brine and dried over anhydrous Na₂SO₄, concentrated to obtain the crude product which was purified on silica gel to give **26-4** (18.0 g, 27.4 mmol, 94.79% yield) as a white solid. ESI-LCMS: m/z 657 [M+H]⁺.

[0277] Preparation of Intermediate 26-5: Ag₂O (9.5 g, 41.1 mmol, 1.33 mL) and NaI (8.2 g, 54.8 mmol) were added to a solution of **26-4** (18 g, 27.4 mmol) and vinyl bromide (6.6 g, 54.8 mmol) in dry DMF (250 mL) were added the mixture was stirred at room temperature for 1.5 h. The reaction was pured into ice water, extracted with EA, washed with brine and dried over anhydrous Na₂SO₄, concentrated to obtain the crude product which was purified by recrystallization (PE:EA=1:1) to give **26-5** (12.1 g, 17.3 mmol, 63.36% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 7.99 (d, *J* = 2.0 Hz, 1H), 7.53-7.48 (m, 6H), 7.40-7.37 (m, 2H), 7.28 (br s, 2H, exchanged with D₂O), 7.21-7.14 (m, 6H), 7.09-7.04 (m, 2H), 6.68 (d, *J* = 9.2 Hz, 2H), 5.93 (s, 1H), 5.87-5.77 (m, 1H), 5.22-5.16 (m, 1H), 5.10-5.07 (m, 1H), 4.81-4.78 (m, 1H), 4.68 (dd, *J* = 3.2, 12.4 Hz, 1H), 4.05-3.99 (m, 1H), 3.94-3.89 (m, 1H), 3.53 (s, 3H), 3.22-3.18 (m, 1H), 2.92 (d, *J* = 10.8 Hz, 1H, exchanged with D₂O), 2.49 (d, *J* = 4.8 Hz, 1H), 2.37 (s, 3H). ESI-LCMS: m/z 697 [M+H]⁺.

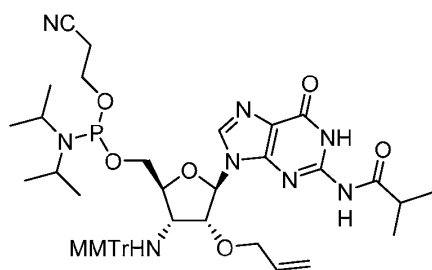
[0278] Preparation of Intermediate 26-6: BzCl (4.8 g, 34.4 mmol) was added dropwise to a solution of **26-5** (12 g, 17.2 mmol) in pyridine (120 mL) at 0°C. After the mixture was stirred for 1 h at r.t., 300 mL H₂O and 500 mL EA were added to separate the solution, the aqueous phase was extracted by EA. The combined organic layers were washed with brine, dried over Na₂SO₄, concentrated to obtain the crude product **26-6** (16.2 g) as a yellow oil. ESI-LCMS: m/z 801 [M+H]⁺.

[0279] Preparation of Intermediate 26-7: To a solution of the crude **26-6** (16.2 g) in pyridine (200 mL) was added 2N NaOH (MeOH:H₂O=4:1) (50 mL) dropwise at 0°C. The mixture was stirred at 0°C for 0.5 h and then neutralized with saturated NH₄Cl (aq) to give the pH=7~8, and 500 mL H₂O. 800 mL of EA were added to separate the solution, the aqueous was extracted with EA, the combined organic layers were washed with brine, dried over Na₂SO₄, and concentrated to obtain the crude product which was purified by MPLC to give **26-7** (9.3 g, 13.6 mmol, 79.07% yield over two steps) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 11.15 (s, 1 H, exchanged with D₂O), 8.68 (s, 1H), 8.65 (s, 1H), 8.07-8.05 (m, 2H), 7.67-7.63 (m, 1H), 7.57-7.53 (m, 2H), 7.44-7.41 (m, 4H), 7.27 (d, *J* = 9.2 Hz, 2H), 7.20-7.16 (m, 4H), 7.13-7.09 (m, 2H), 6.72 (d, *J* = 9.2 Hz,

2H), 6.08 (s, 1H), 5.93-5.83 (m, 1H), 5.27-5.22 (m, 1H), 5.18 (t, $J = 4.0$ Hz, 1H, exchanged with D_2O), 5.13-5.10 (m, 1H), 4.11-3.99 (m, 4H), 3.64 (s, 3H), 3.46-3.42 (m, 1H), 3.38-3.32 (m, 1H), 2.71 (d, $J = 10.8$ Hz, 1H, exchanged with D_2O), 1.91 (d, $J = 4.4$ Hz, 1H). ESI-LCMS: m/z 683 $[M+H]^+$.

[0280] Preparation of 26-8: Phosphitylation reagent (3.4 g, 11.4 mmol) was added under Ar to a solution of **26-7** (6.5 g, 9.5 mmol) and DCI (1.1 g, 9.5 mmol) in dry DCM (70 mL). The mixture was stirred at r.t. for 1 h. Then the reaction was washed with 10% $NaHCO_3$ (aq) and brine, dried over Na_2SO_4 , and concentrated to obtain the crude product which was purified by Flash-Prep-HPLC. This resulted in to give **26-8** (7.1 g, 8.0 mmol, 84.46% yield) as a white solid. 1H -NMR (400 MHz, $CDCl_3$): δ = 9.02 (br s, 1 H), 8.74 (d, $J = 10.4$ Hz, 1H), 8.37 (d, $J = 108.4$ Hz, 1H), 8.04 (t, $J = 7.2$ Hz, 2H), 7.65-7.61 (m, 1H), 7.57-7.53 (m, 2H), 7.51-7.48 (m, 4H), 7.41-7.38 (m, 2H), 7.21-7.10 (m, 6H), 6.73-6.70 (m, 2H), 6.03 (d, $J = 2.4$ Hz, 1H), 5.91-5.79 (m, 1H), 5.31-5.21 (m, 2H), 5.17-5.13 (m, 1H), 4.40-4.25 (m, 2H), 4.16-4.08 (m, 1H), 4.05-3.94 (m, 1H), 3.89-3.80 (m, 1H), 3.72 (dd, $J = 0.8, 10.8$ Hz, 3H), 3.70-3.47 (m, 4H), 3.42-3.35 (m, 1H), 2.86 (dd, $J = 10.8, 23.2$ Hz, 1H), 2.68-2.51 (m, 2H), 1.62 (dd, $J = 4.4, 210.8$ Hz, 1H), 1.26-1.18 (m, 12H). ^{31}P NMR (162 MHz, $CDCl_3$): 148.85, 148.24. ESI-LCMS: m/z 883 $[M+H]^+$.

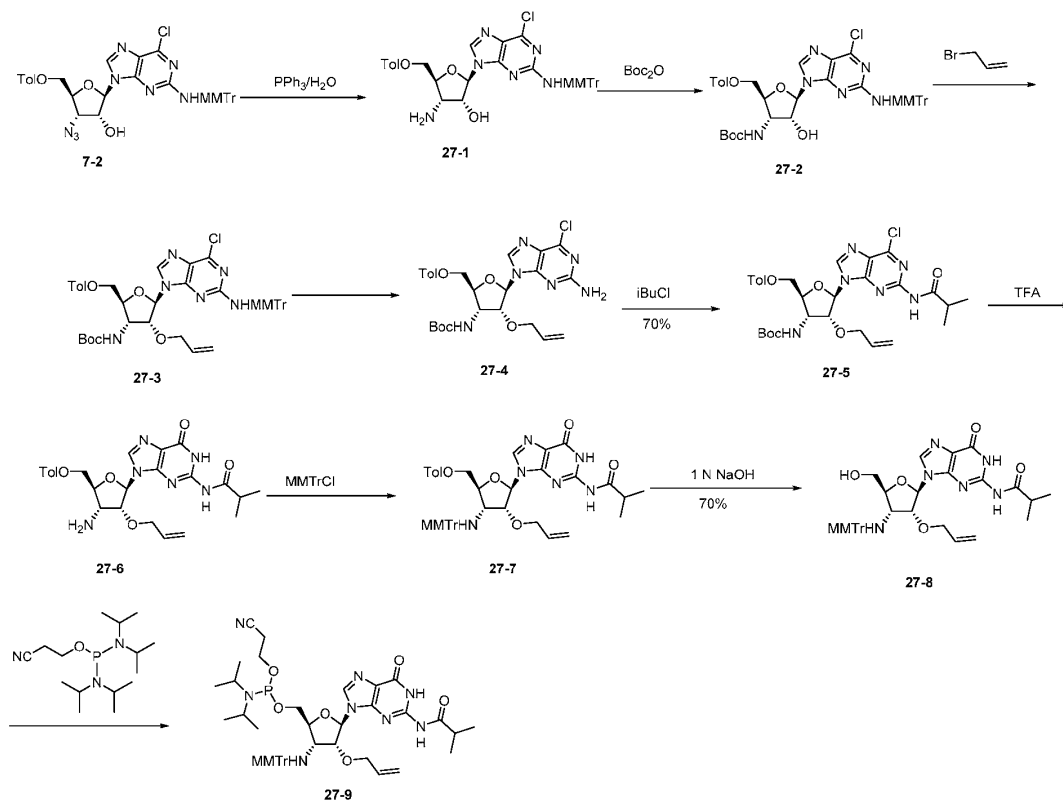
Example 23



[0281] The synthesis of guanosine-based 2'-vinyl phosphoramidate **27-9** was accomplished as shown in scheme 27. The C3'-azide of compound **7-2** was reduced to the corresponding amine to obtain **27-1**. 3'-amine protection with N-Boc yielded intermediate **27-2**. 2'-O-allylation was carried out by using allylbromide in the presence of Ag_2O and NaI to form intermediate **27-3**. Boc protection at the 3'-NH position was found to afford higher alkylation yields as compared to MMTTr

for this particular case. MMTr cleavage of the exocyclic amino to give **27-4** followed by deprotection with *i*BuCl gave compound **27-5**. Then, deprotection of the 3' amine gave **27-6** which after reprotection with MMTrCl yielded **27-7**. Cleavage of the 5'-tol group to form **27-8** and final phosphitylation gave target compound **27-9**.

Scheme 25



[0282] Preparation of Intermediate (27-1): To a solution of **7-2** (50.5 g, 69.7 mmol) in THF (500 mL) were added PPh_3 (27.4 g, 104.5 mmol) and H_2O (1.3 g, 69.7 mmol). The mixture was stirred at 60°C for 15 h. The reaction was concentrated and the residue was purified on silica gel to give **27-1** (41.1 g, 59.3 mmol, 85.08% yield) as a white solid. ESI-LCMS: m/z 691 $[\text{M}+\text{H}]^+$.

[0283] Preparation of Intermediate (27-2): To a solution of **27-1** (41.1 g, 59.3 mmol) in a mixture of THF (300 mL) and sat. NaHCO_3 (aq) (200 mL) was added Boc_2O (15.5 g, 71.2 mmol). The mixture was stirred at room temperature for 2 h, extracted with EA, washed with brine and dried over anhydrous Na_2SO_4 . Finally, it was concentrated to obtain the crude product which was

purified on silica gel to give **27-2** (46.2 g, 58.2 mmol, 98.00% yield) as a white solid. ESI-LCMS: m/z 791 [M+H]⁺.

[0284] Preparation of Intermediate (27-3): Vinyl bromide (45 g, 56.8 mmol) and **27-2** (10.3 g, 85.3 mmol) in dry DMF (400 mL), were added Ag₂O (19.7 g, 85.3 mmol) and NaI (12.8 g, 85.3 mmol), the mixture was stirred at room temperature for 0.5 h, poured into ice water, extracted with EA, washed with brine and dried over anhydrous Na₂SO₄, concentrated to obtain the crude product which was purified on silica gel to give **27-3** (35.3 g, 42.4 mmol, 74.66% yield) as a white solid. ESI-LCMS: m/z 831 [M+H]⁺.

[0285] Preparation of Intermediate (27-4): TCA (100 g, 42.1 mmol) was added to solution of **27-3** (35 g, 42.1 mmol) in DCM (400 mL) and the mixture was stirred at room temperature for 4 h. After this time, the reaction mixture was neutralized with saturated NaHCO₃ (aq) to give pH=8~9. EA was added and washed with brine. The organic layers were dried over Na₂SO₄ and concentrated to obtain the crude product which was purified on silica gel to give **27-4** (18.5 g, 33.1 mmol, 78.61% yield) as a white solid. ESI-LCMS: m/z 559 [M+Na]⁺.

[0286] Preparation of Intermediate (27-5): iBuCl (5.2 g, 48.3 mmol) was added dropwise to a solution of **27-4** (18 g, 32.2 mmol) in pyridine (200 mL) at 0°C. After the mixture was stirred at 0°C for 0.5 h, 500 mL H₂O and 800 mL EA were added to separate the solution. The aqueous phase was extracted with EA, the combined organic layer was washed with brine, dried over Na₂SO₄ and finally concentrated to obtain the crude product which was purified on silica gel to give **27-5** (18.1 g, 28.77 mmol, 89.35% yield) as a white solid. ESI-LCMS: m/z 629 [M+H]⁺.

[0287] Preparation of Intermediate (27-6): **27-5** (18 g, 28.6 mmol) was dissolved in a mixture of TFA (180 mL) and H₂O (60 mL). The reaction was stirred at room temperature for 15 h and neutralized with saturated NaHCO₃ (aq). The crude was extracted with EA, washed with brine, and dried over anhydrous Na₂SO₄. After concentration, purification on silica gel afforded **27-6** (12.5 g, 24.5 mmol, 85.57% yield) as a white solid. ESI-LCMS: m/z 511 [M+H]⁺.

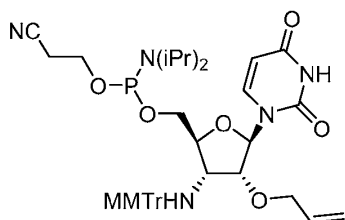
[0288] Preparation of Intermediate (27-7): To a solution of **27-6** (12.5 g, 24.5 mmol) in anhydrous DCM (150 mL), were added collidine (5.9 g, 49.0 mmol), AgNO₃ (6.2 g, 36.7 mmol), and MMTr-Cl (11.3 g, 36.7 mmol) and the mixture was stirred at r.t. for 1 h under N₂. After the reaction reached completion, the crude reaction mixture was filtered, washed with H₂O, dried over Na₂SO₄, and

concentrated to give a residue which was purified on silica gel to afford the crude product **27-7** (18.5 g, 23.6 mmol, 96.56% yield) as a white solid. ESI-LCMS: m/z 783 $[M+H]^+$.

[0289] Preparation of Intermediate (27-8): To a solution of crude **27-7** (18.5 g, 23.6 mmol) in pyridine (200 mL) 2N NaOH was added dropwise (in MeOH:H₂O=4:1) (50 mL) dropwise at 0°C, the mixture was stirred at 0°C for 15 min. The mixture was neutralized with saturated NH₄Cl (aq) to give pH=7~8, and 500 mL H₂O and 800 mL EA were added. The aqueous phase was extracted by EA, the combined organic layers were washed with brine, dried over Na₂SO₄, and concentrated to obtain the crude product which was purified by MPLC to give **27-8** (12.1 g, 18.2 mmol, 77.21%) as a white solid. ¹H-NMR (400 MHz, CDCl₃): δ = 12.13 (s, 1H, exchanged with D₂O), 11.34 (s, 1H, exchanged with D₂O), 8.11 (s, 1H), 7.47-7.43 (m, 4H), 7.28-7.21 (m, 6H), 7.17-7.13 (m, 2H), 6.77-6.75 (m, 2H), 5.89-5.80 (m, 2H), 5.25-5.20 (m, 1H), 5.13-5.09 (m, 1H), 4.03-3.92 (m, 4H), 3.65 (s, 3H), 3.46-3.41 (m, 1H), 3.31-3.24 (m, 1H), 2.87-2.80 (m, 1H), 2.73 (d, J = 10.0 Hz, 1H, exchanged with D₂O), 1.91 (d, J = 4.8 Hz, 1H), 1.16 (dd, J = 6.8, 11.2 Hz, 6H). ESI-LCMS: m/z 665 $[M+H]^+$.

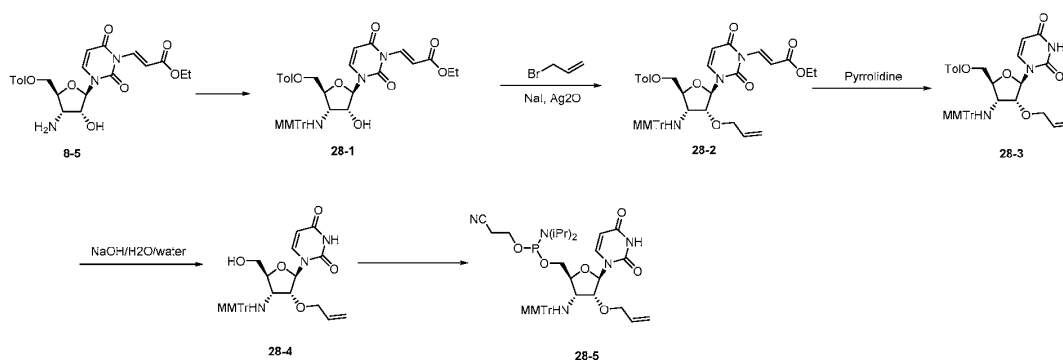
[0290] Preparation of (27-9): To a solution of **27-8** (7.5 g, 11.3 mmol) and DCI (1.5 g, 12.4 mmol) in dry DCM (80 mL) was added the phosphitylation reagent (4.4 g, 14.7 mmol) under Ar. The mixture was stirred at r.t. for 1 h, washed with 10% NaHCO₃ (aq) and brine, dried over Na₂SO₄ and concentrated to obtain the crude product which was purified by Flash-Prep-HPLC. This resulted in to give **27-9** (7.4 g, 8.5 mmol, 75.79% yield) as a white solid. ¹H-NMR (400 MHz, CDCl₃): δ = 7.90 (d, J = 119.2 Hz, 1H), 7.54-7.51 (m, 4H), 7.42-7.37 (m, 2H), 7.28-7.12 (m, 6H), 6.78-6.72 (m, 2H), 5.79-5.65 (m, 2H), 5.18-5.04 (m, 2H), 4.30-4.09 (m, 3H), 3.93-3.33 (m, 10H), 2.86 (dd, J = 10.0, 28.8 Hz, 1H), 2.72-2.52 (m, 3H), 2.10 (dd, J = 4.8, 211.6 Hz, 1H), 1.28-1.11 (m, 18H). ³¹P NMR (162 MHz, CDCl₃): 149.14, 148.15. ESI-LCMS: m/z 865 $[M+H]^+$.

Example 24



[0291] The synthesis of the 2'-O-allyl uridine phosphoramidite **28-5** was achieved as shown below in scheme 28. Briefly, MMTTrCl-mediated protection of the 3'-NH₂ group of **8-5** afforded compound **28-1** that was alkylated with allylbromide to give **28-2**. Deprotection of the propiolate group was accomplished with pyrrolidine leading to the formation of **28-3**. Then, cleavage of the 5'-ester gave intermediate **28-4** that was phosphitylated to afford target phosphoramidite **28-5**.

Scheme 26



[0292] Preparation of Intermediate (28-1): MMTTrCl (15.3 g, 49.6 mmol) was added under Ar to a solution of **8-5** (19.0 g, 41.3 mmol) in pyridine (300 mL), the mixture was stirred at room temperature for 1 h. Quenched with MeOH and concentrated to obtain a residue which was purified on silica gel to give **7** (24.5 g, 33.4 mmol, 80.97% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 8.08 (d, *J* = 14.8 Hz, 1H), 7.59-7.48 (m, 7H), 7.35-7.28 (m, 4H), 7.23-7.16 (m, 4H), 7.12-7.03 (m, 2H), 6.87 (d, *J* = 14.8 Hz, 1H), 6.73 (d, *J* = 4.8 Hz, 1H), 5.93 (d, *J* = 4.4 Hz, 1H, exchanged with D₂O), 5.42-5.40 (m, 2H), 4.73 (d, *J* = 12.4 Hz, 1H), 4.61 (dd, *J* = 2.8, 12.8 Hz, 1H), 4.28-4.19 (m, 3H), 3.58 (s, 3 H), 3.13-3.04 (m, 2H), 2.38 (s, 3 H), 2.15 (t, *J* = 4.0 Hz, 1H), 1.27 (t, *J* = 7.2 Hz, 3H). ESI-LCMS: *m/z* 732 [M+H]⁺.

[0293] Preparation of Intermediate (28-2): To a solution of **28-1** (22.5 g, 30.7 mmol) and allyl bromide (7.4 g, 61.5 mmol) in dry DMF (250 mL), were added NaI (9.2 g, 61.5 mmol) and Ag₂O (10.7 g, 46.1 mmol) under Ar, the mixture was stirred at room temperature for 0.5 h. The reaction was poured into ice water, extracted with EA, washed with brine and dried over anhydrous Na₂SO₄, concentrated to obtain the crude product which was purified on silica gel to give **28-2** (18.8 g, 24.3 mmol, 79.22% yield) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 8.06 (d, *J* = 14.8 Hz, 1H), 7.59 (t, *J* = 8.0 Hz, 3H), 7.50 (t, *J* = 8.4 Hz, 4H), 7.33 (d, *J* = 8.4 Hz, 2H), 7.27 (d, *J* = 8.0 Hz,

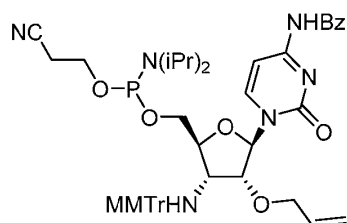
2H), 7.22-7.15 (m, 4H), 7.10 (t, $J = 7.2$ Hz, 1H), 7.04 (t, $J = 7.6$ Hz, 1H), 6.87 (dd, $J = 2.4$, 22.8 Hz, 1H), 6.72 (d, $J = 8.8$ Hz, 2H), 5.88-5.78 (m, 1H), 5.38 (d, $J = 8.0$ Hz, 1H), 5.22 (dd, $J = 1.6$, 17.2 Hz, 1H), 5.11-5.08 (m, 1H), 4.87-4.75 (m, 2H), 4.34 (d, $J = 10.4$ Hz, 1H), 4.20 (dd, $J = 7.2$, 14.4 Hz, 2H), 4.06-3.99 (m, 1H), 3.55 (s, 3H), 3.32-3.30 (m, 2H), 2.79 (d, $J = 10.4$ Hz, 1H, exchanged with D₂O), 2.37 (s, 3H), 1.84 (d, $J = 4.4$ Hz, 1H), 1.26 (t, $J = 7.2$ Hz, 3H). ESI-LCMS: m/z 772 [M+H]⁺.

[0294] Preparation of Intermediate (28-3): Pyrrolidine (1.8 g, 25.9 mmol) was added to a solution of **28-2** (20.0 g, 25.9 mmol) in acetonitrile (200 mL). The mixture was stirred at room temperature for 15 h. The solvent was evaporated and the residue was purified on silica gel to give **28-3** (15.5 g, 23.0 mmol, 88.81% yield) as a slightly yellow solid. ESI-LCMS: m/z 696 [M+Na]⁺.

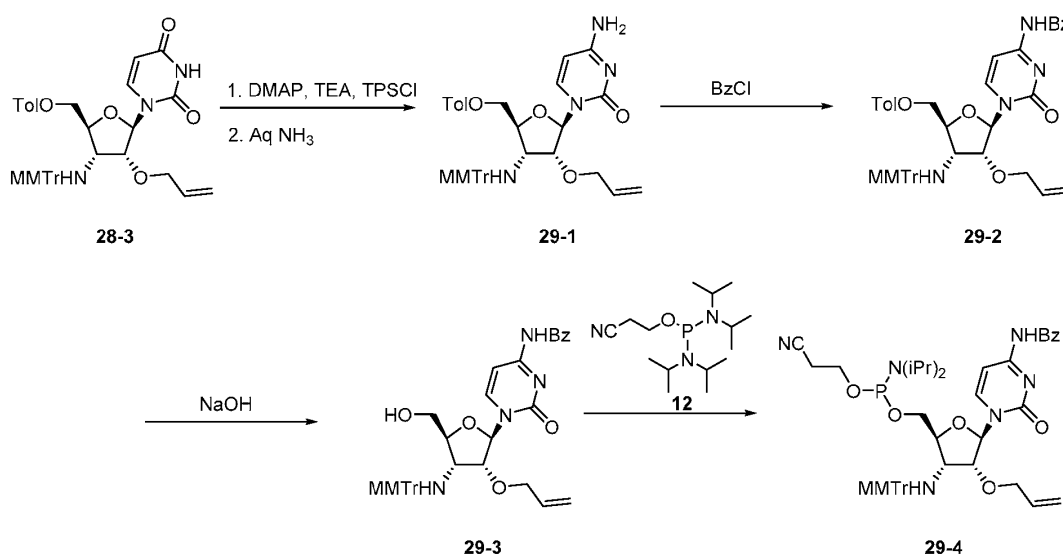
[0295] Preparation of Intermediate (28-4): A mixture of **28-3** (6.0 g, 8.9 mmol) and 2 N NaOH (in MeOH: H₂O=4:1) (60 mL) was stirred at r.t. for 0.5 h. After TLC showed that **28-3** was consumed completely, **28-4** was extracted with DCM and washed with brine, dried over Na₂SO₄, and concentrated to obtain the crude product which was purified by MPLC to give **28-4** (4.3 g, 7.7 mmol, 87.05%) as a white solid. ¹H-NMR (400 MHz, DMSO-*d*₆): δ = 11.27 (s, 1H, exchanged with D₂O), 7.97 (d, $J = 8.0$ Hz, 1H), 7.47-7.44 (m, 4H), 7.34 (d, $J = 8.8$ Hz, 2H), 7.27 (t, $J = 7.2$ Hz, 4H), 7.21-7.17 (m, 2H), 6.84 (d, $J = 8.8$ Hz, 2H), 5.86-5.76 (m, 1H), 5.25-5.49 (m, 2H), 5.20-5.15 (m, 1H), 5.08-5.05 (m, 1H), 4.06-4.01 (m, 2H), 3.96-3.90 (m, 2H), 3.72 (s, 3H), 3.30-3.25 (m, 1H), 3.16-3.09 (m, 1H), 2.69 (d, $J = 10.4$ Hz, 1H, exchanged with D₂O), 1.57 (d, $J = 4.4$ Hz, 1H). ESI-LCMS: m/z 556 [M+H]⁺.

[0296] Preparation of (28-5): To a solution of **28-4** (4.3 g, 7.7 mmol) and DCI (999 mg, 8.5 mmol) in dry DCM (40 mL) was added **28-4** (3.0 g, 10.0 mmol) under Ar. The mixture was stirred at r.t. for 1 h. The reaction was washed with 10% NaHCO₃ (aq.) and brine, dried over Na₂SO₄ and concentrated to obtain the crude product which was purified Flash-Prep-HPLC. **28-5** (4.4 g, 5.8 mmol, 75.68% yield) was obtained as a white solid. ¹H-NMR (400 MHz, CDCl₃): δ = 7.80 (dd, $J = 8.0$, 182.4 Hz, 1H), 7.55-7.43 (m, 6H), 7.30-7.18 (m, 6H), 6.82-6.78 (m, 2H), 5.84-5.74 (m, 1H), 5.66 (d, $J = 4.8$ Hz, 1H), 5.60 (d, $J = 8.0$ Hz, 1H), 5.22-5.17 (m, 1H), 5.11-5.08 (m, 1H), 4.32-4.29 (m, 1H), 4.19-4.01 (m, 3H), 3.89-3.81 (m, 1H), 3.78 (s, 3H), 3.66-3.46 (m, 3H), 3.39-3.35 (m, 1H), 3.22-3.01 (m, 1H), 2.94-2.88 (m, 1H), 2.64-2.44 (m, 1H), 1.52 (dd, $J = 4.8$, 140.0 Hz, 1H), 1.25-1.15 (m, 12H). ³¹P-NMR (162 MHz, CDCl₃): 149.16, 148.20. ESI-LCMS: m/z 756 [M+H]⁺.

Example 25



Scheme 27



[0297] **Preparation of Intermediate (29-1):** DMAP (3.6 g, 29.7 mmol), TEA (3.0 g, 29.6 mmol, 4 mL) and TPSCl (6.7 g, 22.2 mmol) were added under Ar to solution of **28-3** (10.0 g, 14.8 mmol) in dry acetonitrile (100 mL). After the mixture was stirred at r.t. for 1 h, conc. $\text{NH}_3 \cdot \text{H}_2\text{O}$ (25 mL) was added, and the reaction was stirred at r.t. for another 15 h. Upon completion, the solvent was removed, and the residue was dissolved in EA, washed with sat. NH_4Cl (aq) and brine, dried over anhydrous Na_2SO_4 , and concentrated to obtain the crude product which was purified on silica gel to give **29-1** (8.9 g, 13.2 mmol, 89.14% yield) as a pale yellow solid. $^1\text{H-NMR}$ (400 MHz, $\text{DMSO-}d_6$): δ = 7.59 (d, J = 7.6 Hz, 2H, exchanged with D_2O), 7.50-7.43 (m, 5H), 7.35-7.29 (m, 4H), 7.22-7.17 (m, 6H), 7.14-7.06 (m, 2H), 6.71 (d, J = 9.2 Hz, 2H), 5.88-5.79 (m, 1H), 5.55 (s, 1H), 5.39 (d, J = 7.2 Hz, 1H), 5.22 (dd, J = 1.6, 17.2 Hz, 1H), 5.08 (dd, J = 1.2, 10.4 Hz, 1H), 4.88-4.76 (m, 2H), 4.31-4.28 (m, 1H), 4.09-4.04 (m, 1H), 3.58 (s, 3H), 3.29-

3.25 (m, 1H), 3.20-3.14 (m, 1H), 2.79 (d, $J = 9.2$ Hz, 1H, changed with D₂O), 2.41 (s, 3H), 1.61 (d, $J = 4.4$ Hz, 1H). ESI-LCMS: m/z 673 [M+H]⁺.

[0298] Preparation of Intermediate (29-2): To a solution of **29-1** (8.5 g, 12.6 mmol) in pyridine (80 mL), BzCl was added dropwise at 0°C (2.1 g, 15.1 mmol). After the mixture was stirred for 1 h at r.t., 300 mL H₂O and 500 mL EA were added. The aqueous layer was extracted by EA, the combined organic layer was washed with brine, dried over Na₂SO₄, and concentrated to obtain the crude product **29-2** (11.30 g) as a yellow oil. ESI-LCMS: m/z 777 [M+H]⁺.

[0299] Preparation of Intermediate (29-3): 2N NaOH (60 mL, MeOH:H₂O=4:1) was added dropwise at 0°C to a solution of the crude product **29-2** (12.0 g, 15.4 mmol) in pyridine (120 mL). The mixture was stirred at 0°C for 15 min and then neutralized with saturated NH₄Cl (aq.). 500 mL H₂O and 800 mL EA were added. The aqueous phase was extracted by EA, the combined organic layers were washed with brine, dried over Na₂SO₄, and concentrated to obtain the crude product which was purified on silica gel to give **29-3** (6.5 g, 9.8 mmol, 66.2% yield over two steps) as a white solid. ¹H-NMR (400 MHz, CDCl₃): $\delta = 8.47$ (d, $J = 7.6$ Hz, 1H), 7.92 (d, $J = 7.6$ Hz, 1H), 7.65-7.60 (m, 1H), 7.54-7.50 (m, 6H), 7.47-7.44 (m, 2H), 7.29-7.22 (m, 6H), 6.85-6.78 (m, 2H), 5.90-5.80 (m, 1H), 5.74 (s, 1H), 5.28-5.23 (m, 1H), 5.14-5.11 (m, 1H), 4.30-4.25 (m, 3H), 4.18-4.15 (m, 1H), 3.79 (s, 3H), 3.54-3.48 (m, 1H), 3.13-3.07 (m, 1H), 2.84 (d, $J = 10.8$ Hz, 1H), 1.92 (d, $J = 4.4$ Hz, 1H). ESI-LCMS: m/z 659 [M+H]⁺.

[0300] Preparation of (29-4): CEP[N(iPr)₂]₂ (2.4 g, 8.1 mmol) was added under Ar to a solution of **29-3** (3.8 g, 5.8 mmol) and DCI (816 mg, 6.9 mmol) in dry DCM (40 mL). The mixture was stirred at r.t. for 1 h. The reaction mixture was washed with 10% NaHCO₃ (aq.) and brine, dried over Na₂SO₄ and concentrated to obtain the crude product which was purified Flash-Prep-HPLC. **29-4** (3.9 g, 4.5 mmol, 78.69% yield) was obtained as a white solid. ¹H-NMR (400 MHz, CDCl₃): $\delta = 8.67$ (d, $J = 7.6$ Hz, 1H), 7.94-7.91 (m, 2H), 7.64 (t, $J = 7.2$ Hz, 1H), 7.56-7.42 (m, 8H), 7.28-7.20 (m, 6H), 6.81-6.77 (m, 2H), 5.87-5.78 (m, 1H), 5.74 (d, $J = 4.0$ Hz, 1H), 5.25-5.20 (m, 1H), 5.11-5.08 (m, 1H), 4.43-4.34 (m, 1H), 4.27-4.21 (m, 2H), 4.15-4.09 (m, 1H), 3.94-3.84 (m, 1H), 3.79 (d, $J = 1.6$ Hz, 3H), 3.73-3.56 (m, 3H), 3.46-3.42 (m, 1H), 3.22-3.03 (m, 1H), 2.87 (t, $J = 10.0$ Hz, 1H), 2.69 (t, $J = 6.4$ Hz, 1H), 2.63-2.54 (m, 1H), 1.72 (dd, $J = 4.4, 105.6$ Hz, 1H), 1.30-1.22 (m, 12H). ³¹P-NMR (162 MHz, CDCl₃): 149.00, 148.08. ESI-LCMS: m/z 859 [M+H]⁺.

Example 26 – Synthesis of oligonucleotides

[0301] The modified oligonucleotides are synthesized on an ABI-394 synthesizer using the 93-step cycle written with modifications to deblock, coupling and wait steps. The solid support is 3'-NHTr-5'-LCAA-CPG. Each oligonucleotide is individually synthesized using methods described herein.

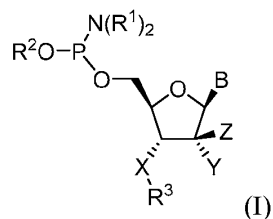
[0302] The modified oligonucleotides can be purified by anion-exchange HPLC. The buffers are, e.g., 20 mM sodium phosphate in 10 % CH₃CN, pH 8.5 (buffer A) and 20 mM sodium phosphate in 10% CH₃CN, 1.8 M NaBr, pH 8.5 (buffer B). Fractions containing full-length oligonucleotides are pooled, desalted, and lyophilized.

[0303] The purified dry oligomer are then desalted using Sephadex G-25 M (Amersham Biosciences). The cartridge is conditioned with 10 mL of deionized water thrice. Finally the purified oligomer is dissolved thoroughly in RNase free water is applied to the cartridge with very slow drop wise elution. The salt free oligomer is eluted with deionized water directly into a screw cap vial.

[0304] Approximately 0.10 OD of oligomer is dissolved in water and then pipetted in special vials for IEX-HPLC and LC/MS analysis. Analytical HPLC and ES LC-MS establishes the integrity of the oligonucleotides. The purity and molecular weight are determined by HPLC analysis (60 °C, IEX- Thermo DNAPac PA-100, A- 25 mM sodium phosphate 10% acetonitrile pH 11, B- 1.8 M NaBr 25 mM sodium phosphate 10% acetonitrile pH 11; RPIP- Waters XBridge OST C18, A- 100 mM HFIP 7 mM TEA B- 7:3 methanol/acetonitrile) and ESI-MS analysis using Promass Deconvolution for Xcalibur (Novatia, Newtown, PA).

WHAT IS CLAIMED IS:

1. A compound represented by Formula (I):



wherein

X is O or NH;

Y is selected from the group consisting of O-PG, $-\text{O}(\text{CR}^4_2)_a\text{CR}^4_3$, $-\text{O}(\text{CR}^4_2)_b\text{OCR}^4_3$ and $-\text{O}(\text{CR}^4_2)_b-\text{CR}^4=\text{CR}^4_2$;

Z is H;

PG is a protecting group;

B is a natural or an unmodified nucleobase or a modified nucleobase or a protected version thereof;

each R^1 is independently C_{1-6} alkyl or cycloalkyl;

R^2 is $\text{CH}_2\text{CH}_2\text{CN}$ or C_{1-6} alkyl;

or one R^1 and R^2 together form an optionally substituted C_{1-6} cycloalkyl;

R^3 is H or PG;

R^4 is independently in each instance H or F;

a is an integer of 0-2; and

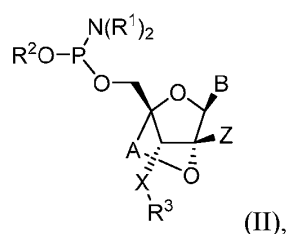
b is an integer of 1-3,

wherein when X is O, then Y is $-\text{O}(\text{CR}^4_2)_a\text{CR}^4_3$, $-\text{O}(\text{CR}^4_2)_b\text{OCR}^4_3$ or $-\text{O}(\text{CR}^4_2)_b-\text{CR}^4=\text{CR}^4_2$.

2. The compound of claim 1, wherein X is NH and Y is O-PG, OEt or O-methoxyethoxy.

3. The compound of claim 1 or 2, wherein R^1 is C_{2-3} alkyl.

4. The compound of claim 1 or 2, wherein R^1 is isopropyl.
5. The compound of any of claims 1-4, wherein R^3 is a trityl protecting group.
6. The compound of any of claims 1-4, wherein R^3 is monomethoxytrityl (MMTr) or tritoyl when X is NH and 4,4'-dimethoxytrityl (DMTr) or tritoyl when X is O.
7. The compound of any of claims 1-6, wherein B is selected from adenine (A), guanine (G), thymine (T), cytosine (C), uracil (U) and 5-methylcytosine (5-me-C), or a protected version thereof.
8. The compound of any of claims 1-6, wherein B is selected from 6-*N*-benzoyladenine (A^{Bz}), 4-*N*-Benzoylcytosine (C^{Bz}), and 2-*N*-isobutyrylguanosine (G^{iBu}).
9. A composition comprising the compound any of claims 1-8 and one or more reactants or solvents or impurities.
10. The composition of claim 9, wherein the amount of impurities is less than 1%.
11. A method of making an oligonucleotide comprising a modified nucleoside comprising reacting the compound any of claims 1-8 to form the oligonucleotide.
12. A compound represented by Formula (II):



wherein

X is O or NH;

Z is H;

B is a natural or an unmodified nucleobase or a modified nucleobase or a protected version thereof;

R^1 is independently a C_{1-6} alkyl or cycloalkyl;

R² is CH₂CH₂CN or a C₁₋₆ alkyl;

or one R¹ and R² together form an optionally substituted C₁₋₆ cycloalkyl;

R³ is H or a protecting group;

A is -(CR'R')₁₋₂-; and

R' is independently in each instance H or Me.

13. The compound of claim 12, wherein X is NH and Z is H.

14. The compound of claim 12 or 13, wherein R¹ is a C₂₋₃ alkyl.

15. The compound of claim 12 or 13, wherein R¹ is isopropyl.

16. The compound of any of claims 12-15, wherein R³ is a trityl protecting group.

17. The compound of any of claims 12-15, wherein R³ is monomethoxytrityl (MMTr) or tritoyl when X is NH and 4,4'-dimethoxytrityl (DMTr) or tritoyl when X is O.

18. The compound of any of claims 12-17, wherein B is selected from adenine (A), guanine (G), thymine (T), cytosine (C), uracil (U) and 5-methylcytosine (5-me-C), or a protected version thereof.

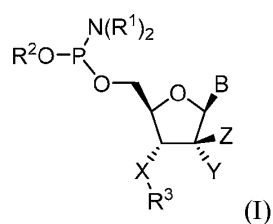
19. The compound of any of claims 11-17, wherein B is selected from 6-*N*-benzoyladenine (A^{Bz}), 4-*N*-Benzoylcytidine (C^{Bz}), and 2-*N*-isobutrylguanosine (G^{iBu}).

20. A composition comprising the compound of any of claims 12-19 and one or more reactants or solvents or impurities.

21. The composition of claim 20, wherein the compound has a purity of 99%, or more.

22. A method of making an oligonucleotide comprising a modified nucleoside, said method comprising reacting the compound of any of claims 12-19 to form the oligonucleotide.

23. A method of making a compound represented by Formula (I):



wherein

B is a natural or an unmodified nucleobase or a modified nucleobase or a protected version thereof;

Z is H;

Y is $-O(CR^4)_b-CR^4=CR^4_2$, wherein R^4 is independently in each instance H or F, and b is an integer of 1-3;

X is NH;

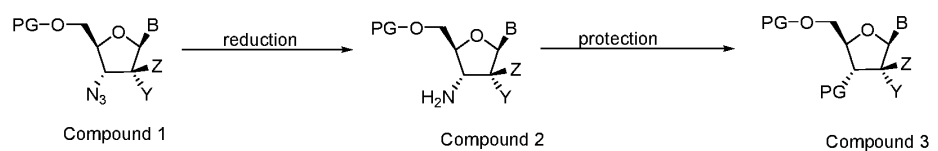
R^3 is H or PG, wherein PG is a protecting group;

each R^1 is independently C_{1-6} alkyl or cycloalkyl;

R^2 is CH_2CH_2CN or C_{1-6} alkyl;

or one R^1 and R^2 together form an optionally substituted C_{1-6} cycloalkyl,

said method comprising reducing compound 1 prior to protecting compound 2 to form compound 3



24. A method of making a compound represented by any of claims 1-10 said method comprising reducing compound 1 prior to protecting compound 2 to form compound 3

