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(54) Title: TERMINAL PHOSPHATE BLOCKED NUCLEOSIDE POLYPHOSPHATES

(57) Abrégé/Abstract:

The present invention describes terminal phosphate blocked nucleoside polyphosphates that are stable at high temperature and their use in nucleic acid amplification and analysis. Current invention further describes charge modified terminal phosphate blocked nucleoside polyphosphates for improved incorporation and direct loading of nucleic acid sequencing reactions onto separating media.



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(54) Title: TERMINAL PHOSPHATE BLOCKED NUCLEOSIDE POLYPHOSPHATES

(57) Abstract: The present invention describes terminal phosphate blocked nucleoside polyphosphates that are stable at high temperature and their use in nucleic acid amplification and analysis. Current invention further describes charge modified terminal phosphate blocked nucleoside polyphosphates for improved incorporation and direct loading of nucleic acid sequencing reactions onto separating media.

WO 2004/020602 A3

30323-45

TERMINAL PHOSPHATE BLOCKED NUCLEOSIDE POLYPHOSPHATES**Field of Invention**

[0002] The present invention relates to terminal phosphate blocked nucleoside polyphosphates that are stable at high temperature and their use in nucleic acid amplification and analysis. Current invention further describes charge modified terminal phosphate blocked nucleoside polyphosphates for improved incorporation and direct loading of nucleic acid sequencing reactions onto separating media.

Background of Invention

[0003] DNA amplification by a number of amplification methods is performed at high temperatures. For example, in PCR, repeated cycles of denaturation at 95°C, annealing around 60°C and extension around 70°C causes significant breakdown of the dNTP's. This may significantly affect the yield of product in later cycles. Other amplification methods such as RCA and NASBA, although isothermal, also are conducted at higher temperatures. In case of NASBA, which is performed at 41°C, the stability of nucleotides may not be very critical. However RCA may be conducted at higher temperature depending upon the polymerase used and the complexity of sequence to be amplified. Stability of nucleotides can be an issue under these conditions. It is therefore desirable to have nucleotides that can survive this repeated cycling of temperature or prolonged heating at a constant yet high temperature and hence continue to give high product yields even in later cycles of amplification and possibly cut down the number of cycles/time required to achieve desirable amplification.

30323-45

[0004] The sequence of nucleotide bases in a DNA molecule can be determined in a variety of ways. The chain termination method generally involves synthesizing DNA complementary to the template strand to be sequenced by extending a primer able to hybridize to a portion of that template strand with a DNA polymerase. During the synthesis reaction, deoxynucleoside triphosphates (dNTP's) are incorporated to form a DNA fragment until a chain terminating agent, for example, a dideoxynucleoside triphosphate (ddNTP) is incorporated. Incorporation of a ddNTP prevents further DNA synthesis (a process called chain termination). The size of each DNA fragment synthesized in this procedure is then determined by gel electrophoresis and this information used to determine the sequence of nucleotides in the original template DNA. For example, Tabor and Richardson, U.S. Patent No. 4,795,699, describes a two step sequencing method in which an unlabeled primer is labeled in a labeling step, and then extended in the presence of excess dNTPs and a ddNTP in a chain termination step. In the labeling step, a low concentration of dNTPs is provided (one being labeled) to allow a small amount of primer extension.

[0005] In the dideoxy sequencing method, the primer may be labeled, for example with ^{32}P , by a process using a polynucleotide kinase. Such labeling allows detection of extended primers after gel electrophoresis by auto-radiography of the resulting gel. Alternatively, a labeled dNTP may be incorporated during the process of DNA synthesis, and the presence of such labeled dNTPs detected by autoradiography or other means. To this end, the dNTP may be labeled either radioactively with ^{32}P or ^{35}S . In another procedure, the primer can be labeled with one or more fluorescent moieties for detection by fluorescence. In yet another procedure, the ddNTP may be labeled, for example, with a fluorescent marker.

[0006] In a sequencing reaction, the labeled dNTPs or ddNTPs partially decompose, most likely due to the thermocycling conditions, and generate labeled by-products which migrate in the separating media, thus interfering with interpretation of the true sequencing fragments. For example, labeled dNTP or ddNTP decomposition products and unreacted terminators may appear on sequencing gels or electropherogram as peaks or blobs (Figure 1, Lanes 3 and 4, blobs result when

sequencing products containing conventional terminators are directly loaded onto, an electrophoretic gel). At the present time, this problem is addressed by precipitation of the sequencing products using e.g., ethanol precipitation prior to loading (Figure 1, lanes 1 and 2). While this reduces the contamination somewhat, the procedure is time consuming and creates a bottleneck for high throughput sequencing applications.

[0007] Thus, a process is needed for improving the clarity of sequencing data. Ideally, such a process would reduce sample preparation time and result in improved sequencing throughput. Moreover, such a method would also be economical to use. These and other concerns are addressed in greater detail below.

[0008] Recently, charge modified nucleoside-triphosphates that are either highly negatively charged so that they (or any fragmentation products) move well ahead of the sequence product fragments or highly positively charged so that they (or any fragmentation products) move in the opposite direction of the sequencing fragment when separated on a sequencing gel, have been described (WO 01/19841). These nucleotides have a string of negatively or positively charged moieties attached to the base. These nucleotides once incorporated, due to the presence of string of charges on the base, significantly affect the mobility of sequencing fragments. It is desirable to have modified nucleoside triphosphates that are either highly negatively charged or net positively charged, but after incorporation have same charge as the natural nucleotides. Therefore, mobility of the sequencing products is not affected. Even when mobility is not an issue, it is desirable to have more stable nucleoside triphosphate so that any possible complications from breakdown products are prevented.

Summary of Invention

[0009] One aspect of the instant disclosure pertains to use of terminal phosphate blocked nucleoside polyphosphates (Structure 1) in high temperature amplification methods such as PCR to enhance yield of amplified product. Another aspect describes labeled nucleoside polyphosphates with a blocking group on the terminal

30323-45

phosphate and their use in sequencing and other genotyping methods requiring high temperature or temperature cycling.

[0010a] Hence, in one embodiment, the present invention relates to a method for nucleic acid analysis, which includes a polymerase reaction at
5 temperatures between 60°C and 95°C, of a nucleic acid template, a primer, a nucleic acid polymerase, and at least one nucleoside polyphosphate, further comprising conducting said polymerase reaction in the presence of at least one thermally stable, terminal-phosphate-blocked nucleoside polyphosphate, wherein said terminal-phosphate-blocked nucleoside polyphosphate is represented by the
10 formula



wherein

X is a polyphosphate chain with at least 3 phosphate or modified phosphate groups;

15 S is a natural or modified sugar, a carbocycle, or an acyclic linker;

B is a natural or modified heterocyclic base; and

L is H or a linker moiety selected from the group consisting of substituted or unsubstituted, linear or branched cyclic or acyclic alkyl, alkenyl, alkynyl, aromatic, and heterocyclic.

30323-45

[0010b] The present invention further includes a nucleic acid amplification and/or detection kit wherein the kit includes: at least one thermally stable terminal-phosphate-blocked nucleotides according to the following formula:



wherein Z is a terminal block consisting of an organic moiety. The terminal block may be linear or branched acyclic or cyclic alkyl, alkenyl, alkynyl, aromatic, heterocyclic moiety or a detectable label with or without a linker and may contain atoms such as C, H, N, O, P, S and halogen. Z may also be optionally modified to contain additional negative charges or positively charged moieties. In latter case amount of positive charge added in conjunction with any other positive charge on the molecule is sufficient to make the whole entity net positively charged;

X is a polyphosphate chain with at least 3 phosphate or modified phosphate groups with the proviso that such a modification does not prevent the incorporation of this nucleoside polyphosphate into a DNA or RNA polymer;

S is a natural or modified sugar, a carbocycle or an acyclic linker;

B is a natural or modified heterocycle. Suitable base analogs include but are not limited to those disclosed in WO 99/06422 and WO 97/28177;

L is H or a linker moiety. The linker may be H, linear or branched, cyclic or acyclic alkyl, alkenyl, or alkynyl, aromatic, heterocyclic and may contain atoms such as C, H, N, O, S and halogen; and

L, B, S, X, or Z are substituted with a moiety which may impart additional negative charge or a net positive charge to Structure 1 at physiological or nucleic acid sequencing conditions.

[0011] The linker may optionally be substituted with a label, (also referred to as a "reporter or signal moiety"). The label may be a moiety such as a fluorescent tag, an energy transfer (ET) label, a radioisotope, an electrochemical tag, a mass

30323-45

spectrometry tag, a Raman tag, a hapten, a chemiluminescent group, an enzyme, a chromophore, and two or more labels. The label may also be charged, e.g. Cy3.5, Cy5.5, carboxyfluorescein, or a dye attached to a charged moiety, e.g., carboxyfluorescein attached to cysteic acid or similar charged species. Methods for making these and other similar compounds are known in the art and are disclosed in Alexandrova LA et. al., Nucleic Acids Research, 1998, 26, 778-786; Arzumanov AA et. al., J. Biological Chemistry, 1996, 271, 24389-24394; and PCT patent application GB98/00978 (WO 1998/043991).

[0012] The molecule may be modified with a moiety which imparts an additional negative charge or a net positive charge to Structure 1 at physiological or nucleic acid sequencing or amplification conditions. The moiety may be any charged species that alters the electrophoretic mobility of the Structure, e.g., α -sulfo- β -alanine, cysteic acid, sulfonic acids, carboxylates, phosphates, phosphodiesteres, phosphonates, amines, quarternized amines, and phosphonium moieties. The moiety (referred to as a "mobility modifier") may be attached between the linker and label, between the base and linker, and may be attached only to the sugar or only to the linker. It may also be attached between terminal phosphate and may in fact be the terminal block. It may also be attached between a label and the terminal block or only to the terminal block or only to the label on terminal block. The molecule may also contain multiple linkers and moieties that are alternatively spaced together.

Brief Description of the Drawings

[0013] Figure 1 is a gel image of an ET terminator DNA sequencing reaction loaded either after ethanol precipitation (Lanes 1 and 2) or directly loaded (Lanes 3 and 4) onto the sequencing gel.

[0014] Figure 2 shows the stability of normal terminator and terminal phosphate blocked terminator on heating at 95°C for 20 minutes.

[0015] Figure 3 shows the sequencing ladder obtained using either the normal energy transfer terminator or the terminal phosphate blocked terminator

[0016] Figure 4 shows the stability of normal and gamma blocked nucleoside triphosphates on heating at 95°C for 2 hours.

[0017] Figure 5 shows the stability of γ -DDAO-ddTTP.

Detailed Description of Invention

[0018] The term “nucleoside” as defined herein is a compound including a purine deazapurine, or pyrimidine base linked to a sugar or a sugar substitute, such as a carbocyclic or acyclic linker at the 1' position or equivalent position and includes 2'-deoxy and 2'-hydroxyl, 2', 3'-dideoxy forms, as well as other substitutions.

[0019] The term “nucleotide” as used herein refers to a phosphate ester of a nucleoside, wherein the esterification site typically corresponds to the hydroxyl group attached to the C-5 position of the pentose sugar.

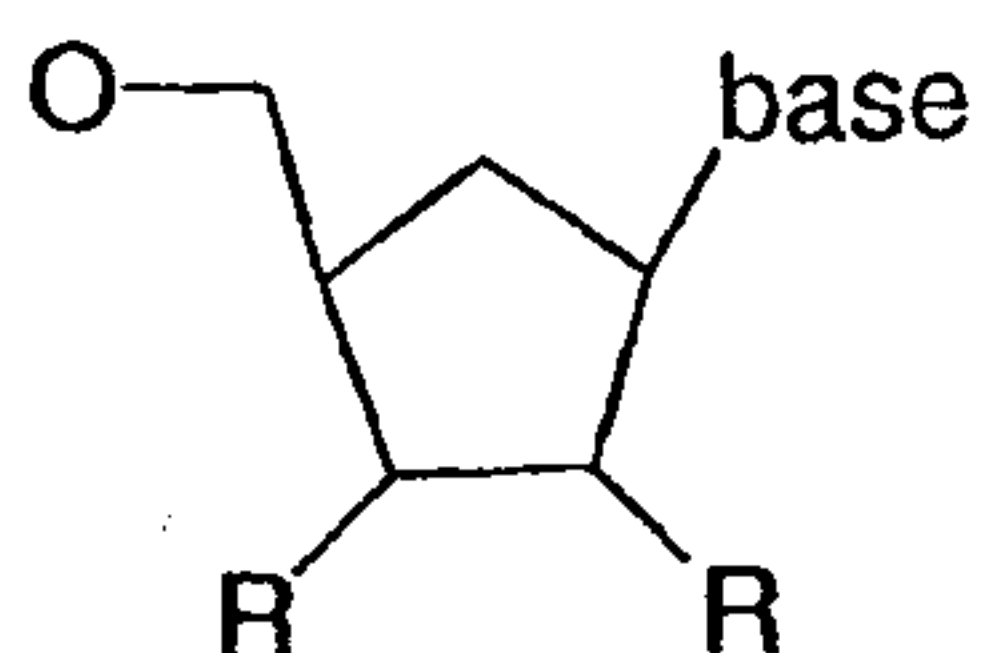
[0020] The term “oligonucleotide” includes linear oligomers of nucleotides or derivatives thereof, including deoxyribonucleosides, ribonucleosides, and the like. Throughout the specification, whenever an oligonucleotide is represented by a sequence of letters, the nucleotides are in the 5' $\rightarrow$ 3' order from left to right where A denotes deoxyadenosine, C denotes deoxycytidine, G denotes deoxyguanosine, and T denotes thymidine, unless noted otherwise.

[0021] The term “primer” refers to a linear oligonucleotide that anneals in a specific way to a unique nucleic acid template sequence and allows for amplification of that unique sequence.

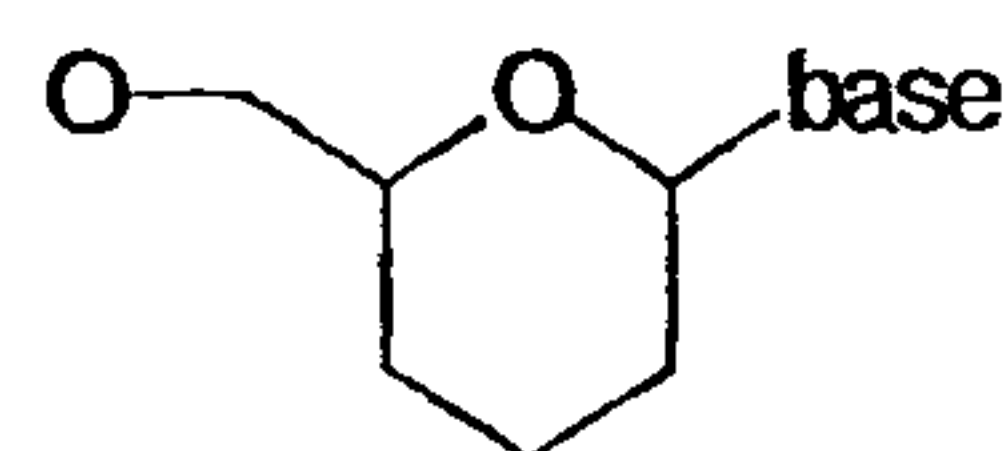
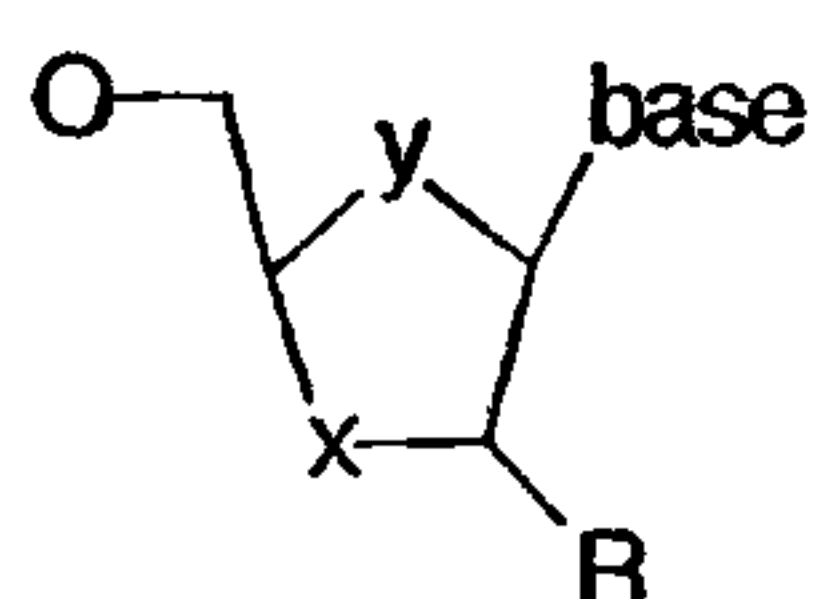
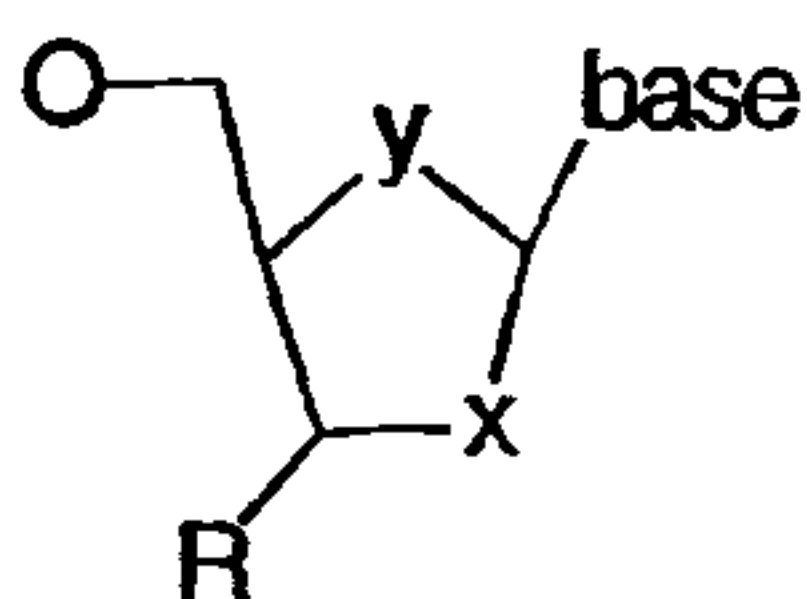
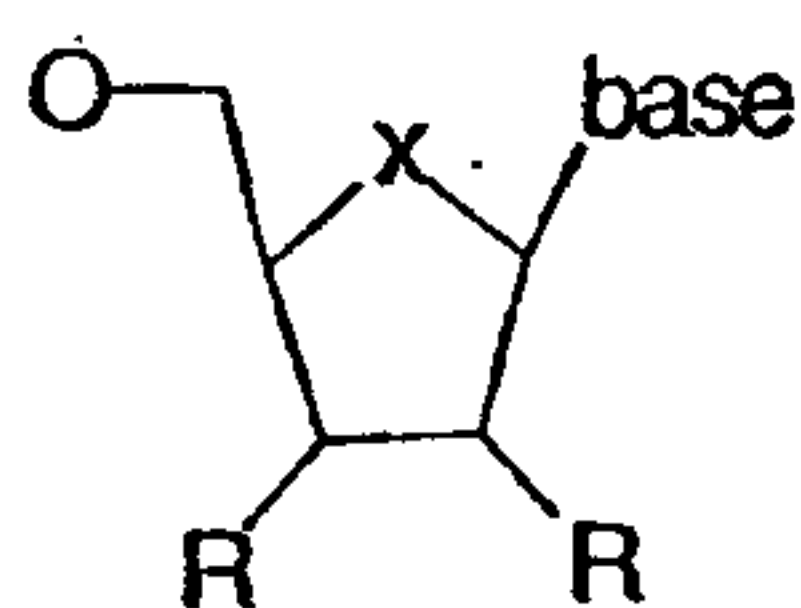
[0022] For purposes of the methods of the present invention, useful carbocyclic moieties have been described by Ferraro, M. and Gotor, V. in Chem Rev. 2000, volume 100, 4319-48. Suitable sugar moieties are described by Joeng, L.S. et al., in J

30323-45

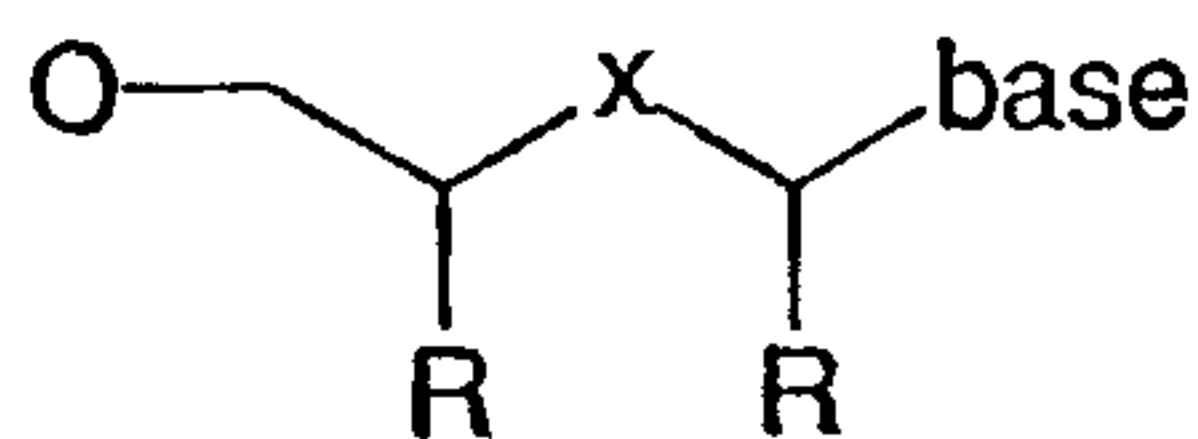
Med. Chem. 1993, vol. 356, 2627-38; by Kim H.O. et al., in J Med. Chem. 193, vol. 36, 30-7; and by Eschenmosser A., in Science 1999, vol. 284, 2118-2124. Moreover, useful acyclic moieties have been described by Martinez, C.I., et al., in Nucleic Acids Research 1999, vol. 27, 1271-1274; by Martinez, C.I., et al., in Bioorganic & Medicinal Chemistry Letters 1997, vol. 7, 3013-3016; and in U.S. Patent 5,558,991 to Trainor, G.L. Structures for these moieties are shown below, where for all moieties R may be H, OH, NHR, lower alkyl and aryl; for the sugar moieties X and Y are independently O, S, or NH; and for the acyclic moieties, X = O, S, NH, NR.



Carbocyclic Moieties



Sugar Moieties



Acyclic Moieties

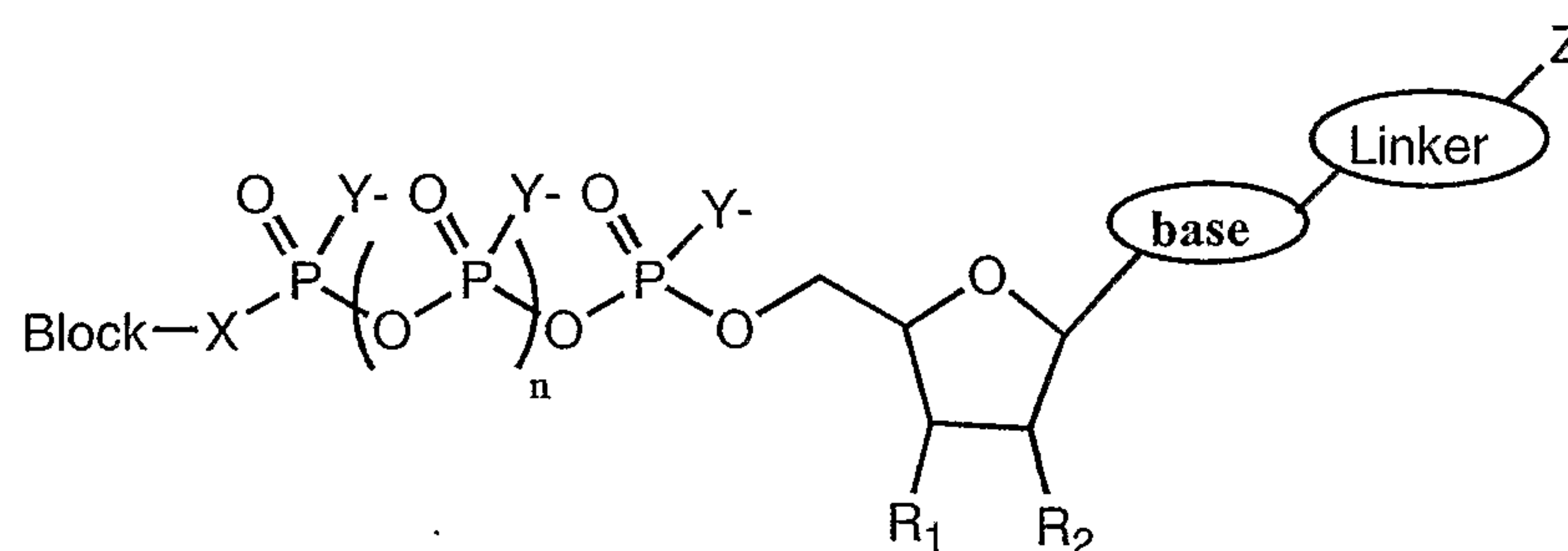
[0023] In certain embodiments, the sugar moiety may be selected from the following: ribosyl, 2'-deoxyribosyl, 3'-deoxyribosyl, 2',3'-dideoxyribosyl, 2', 3'-didehydrodideoxyribosyl, 2'-alkoxyribosyl, 2'-azidoribosyl, 2'-aminoribosyl, 2'-fluororibosyl, 2'-mercaptoriboxyl, 2'-alkylthioribosyl, 3'-alkoxyribosyl, 3'-azidoribosyl, 3'-aminoribosyl, 3'-fluororibosyl, 3'-mercaptoriboxyl, 3'-alkylthioribosyl

carbocyclic, acyclic and other modified sugars. In other embodiments, the 3'-position has a hydroxyl group, required for chain elongation.

[0024] Moreover, in Structure 1 above, the base may include uracil, thymine, cytosine, 5-methylcytosine, guanine, 7-deazaguanine, hypoxanthine, 7-deazahypoxanthine, adenine, 7-deazaadenine, 2,6-diaminopurine or analogs thereof.

[0025] The present invention pertains to the use of terminal phosphate blocked nucleic acid polyphosphates which have enhanced stability at high temperature than the corresponding unblocked nucleic acid polyphosphates. These include deoxynucleoside polyphosphates and ribonucleoside polyphosphates blocked at the terminal position. These also include terminal phosphate blocked dideoxynucleoside polyphosphates or nucleoside terminators, which do not break down significantly during sequencing reactions and migrate on separation media at different rates than the sequencing reaction products. This results in improved sequence data. Such nucleic acid terminators also allow for the direct loading of nucleic acid sequencing reactions onto separating media. To achieve this goal, the terminator phosphate moiety is modified to stabilize the terminator molecule. The unreacted terminators move faster (negatively charged). It is further possible to affect mobility by adding additional negative charges to the terminator or making the terminator overall positively charged by adding a number of positive charges to the structure by modification. The latter is also desirable as it has been found that positively charged nucleoside triphosphates are better substrates for polymerases than the parent compounds (Finn et. al., Nucleic Acids Research (2003) 31, 4769-4778).

[0026] One embodiment of the terminal phosphate blocked nucleoside polyphosphates useful in the instant disclosure is depicted in Structure 2 below,



[0027] In the Structure above, n is 1 or greater; R1 and R2 are independently H, Cl, Br, F, I, SH, SR, N₃, NH₂, NHR, OR or OH; 'base' is a natural or modified nucleoside base; X is CH₂, O, S or NH; Y is O, S or BH₃; and 'Block' is an organic moiety containing at least one carbon atom and may contain heteroatoms as well as a detectable moiety. 'Block' may also be H when X is CH₂. The linker may be H, alkyl, alkenyl, alkynyl, aromatic, or heterocyclic and may contain atoms such as C, H, N, O, S, P and halogen. Z may be H or a detectable moiety such as a radioisotope, an electrochemical tag, a fluorescent tag, an energy transfer (ET) label, a mass spectrometry tag, a Raman tag, a hapten, a chemiluminescent group, an enzyme, a chromophore, and two or more labels. The label may also be charged, e.g. Cy3.5, Cy5.5, carboxyfluorescein, or a dye attached to a charged moiety, e.g., carboxyfluorescein attached to cysteic acid or similar charged species.

[0028] It has been discovered that when n is 2 or greater, the nucleotides are significantly better substrates for polymerases than when n is 1. Therefore, in preferred embodiments of the present invention, n is 2, 3 or 4. In more preferred embodiments of the present invention, X and Y are O, R1 and R2 are independently H or OH and Z is either H or a fluorescent label.

[0029] The molecule may be modified with a moiety which imparts an additional negative charge or a net positive charge to Structure 2 at physiological or nucleic acid sequencing conditions. The moiety may be any charged species which alters the electrophoretic mobility of the Structure, e.g., α -sulfo- β -alanine, cysteic acid, sulfonic acids, carboxylates, phosphates, phosphodiesteres, phosphonates, amines, quarternized amines, and phosphonium moieties. The moiety (referred to as a "mobility modifier") may be attached between the linker and Z, between the base and linker, and may be attached only to the sugar or only to the linker. It may also be attached between terminal phosphate and block and may in fact be the terminal block. It may also be attached to the terminal block, if terminal block is labeled, between the label and terminal block or only to the label on terminal block. The molecule may also contain multiple linkers and moieties which are alternatively spaced together.

30323-45

[0030] When the terminal phosphate blocked nucleic acid polyphosphate is a terminator, it migrates on separation media at different rate than the sequencing reaction products and result in improved sequence data (i.e., no blobs which obscure true data) and permit direct loading of nucleic acid sequencing reactions onto separating media.

[0031] Another embodiment of current invention involves the use of terminal phosphate blocked nucleoside polyphosphates in DNA or RNA amplification methods at high temperatures. Examples of such methods include polymerase chain reaction (PCR), rolling circle amplification (RCA), and nucleic acid sequence based amplification (NASBA). For e.g., wherein the target molecule is a nucleic acid polymer such as DNA, it may be amplified by PCR incorporation of a terminal phosphate blocked nucleotide base such as adenine, thymine, cytosine, guanine or other nitrogen heterocyclic bases into the DNA molecule. The polymerase chain reaction (PCR) method is described by Saiki et al in Science Vol. 239, page 487, 1988, Mullis et al in U.S. Patent 4,683,195 and by Sambrook, J. et al. (Eds.), Molecular Cloning, second edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY (1980), Ausubel, F.M. et al. (Eds.), Current Protocols in Molecular Biology, John Wiley & Sons, Inc., NY (1999), and Wu, R. (Ed.), Recombinant DNA Methodology II, Methods in Enzymology, Academic Press, Inc., NY, (1995). Using PCR, the target nucleic acid for detection such as DNA is amplified by placing it directly into a reaction vessel containing the PCR reagents and appropriate primers. Typically, a primer is selected which is complimentary in sequence to at least a portion of the target nucleic acid.

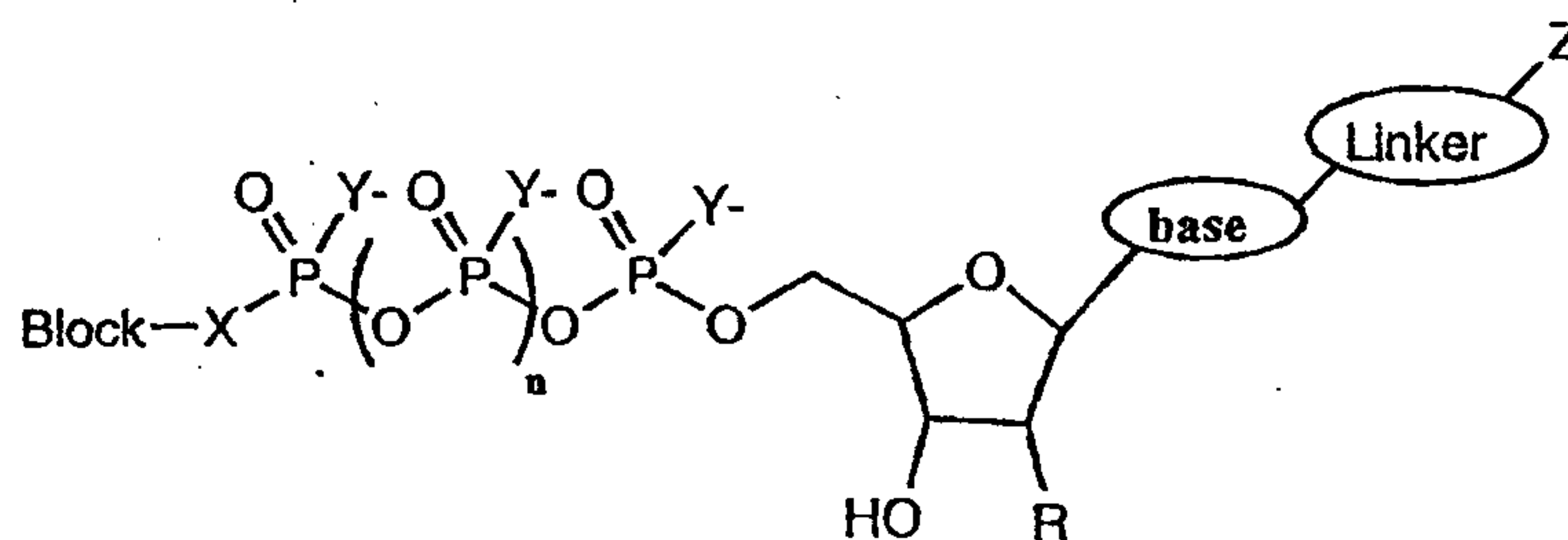
[0032] It is noted that nucleic acid polymerase reactions suitable for amplifying nucleic acids may further include various RCA methods of amplifying nucleic acid sequences. For example, those disclosed in U.S. Patent 5,854,033 to Lizardi, Paul M. are useful. Polymerase reactions may further include the nucleic acid sequence based amplification (NASBA) wherein the system involves amplification of RNA, not DNA, and the amplification is iso-thermal, taking place at one temperature (41°C). Amplification of target RNA by NASBA involves the coordinated activities of three enzymes: reverse transcriptase, Rnase H, and T7

30323-45

RNA polymerase along with oligonucleotide primers directed toward the sample target RNA. These enzymes catalyze the exponential amplification of a target single-stranded RNA in four steps: extension, degradation, DNA synthesis and cyclic RNA amplification.

[0033] The DNA sequence for amplification may include DNA isolated from cells, chemically treated DNA such as bisulfite treated methylated DNA or DNA chemically or enzymatically synthesized according to methods known in the art. Such methods include those described in DNA Structure Part A: Synthesis and Physical analysis of DNA, Lilley, D.M.J. and Dahlberg, J.E. (Eds.), Methods Enzymol., 211, Academic Press, Inc., New York (1992). The DNA sequence may further include chromosomal DNA and natural or synthetic oligonucleotides. The DNA may be either double- or single-stranded.

[0034] Another embodiment of the thermally stable terminal phosphate blocked nucleoside polyphosphates useful in the instant disclosure is depicted in Structure 3:



[0035] In the Structure above, n is 1 or greater; R is H, Cl, Br, F, I, SH, SR, N₃, NH₂, NHR, OR or OH; 'base' is a natural or modified nucleoside base; X is CH₂, O, S or NH; Y is O, S or BH₃; and 'Block' is an organic moiety containing at least one carbon atom and may contain heteroatoms as well as a detectable moiety. 'Block' may also be H when X is CH₂. The linker may be H, alkyl, alkenyl, alkynyl, aromatic, or heterocyclic and may contain atoms such as C, H, N, O, S, P and halogen. Z may be H or a detectable moiety such as a radioisotope, an electrochemical tag, a fluorescent tag, an energy transfer (ET) label, a mass spectrometry tag, a Raman tag, a hapten, a chemiluminescent group, an enzyme, a chromophore, and two or more labels. The label may also be charged, e.g. Cy3.5,

Cy5.5, carboxyfluorescein, or a dye attached to a charged moiety, e.g., carboxyfluorescein attached to cysteic acid or similar charged species.

[0036] It has been discovered that when n is 2 or greater, the nucleotides are significantly better substrates for polymerases than when n is 1. Therefore, in preferred embodiments of the present invention, n is 2, 3 or 4. In more preferred embodiments of the present invention, X and Y are O, R is H or OH and Z is either H or a fluorescent label.

[0037] In another preferred embodiment of the terminal phosphate blocked nucleotides of Structure 3 useful in the current invention, n is 2, 3 or 4, X and Y are O, block is a small C1-C10 alkyl, aryl with or without substituents, base is a naturally occurring base, linker is H and has no label attached to it, R is H or OH.

[0038] The molecule may be modified with a moiety that imparts an additional negative charge or a net positive charge to Structure 3 at physiological or nucleic acid sequencing conditions. The moiety may be any charged species which alters the electrophoretic mobility of the Structure, e.g., α -sulfo- β -alanine, cysteic acid, sulfonic acids, carboxylates, phosphates, phosphodiesteres, phosphonates, amines, quarternized amines, and phosphonium moieties. The moiety (referred to as a "mobility modifier") may be attached between the linker and Z , between the base and linker, and may be attached only to the sugar or only to the linker. It may also be attached between terminal phosphate and block and may in fact be the terminal block. It may also be attached to the terminal block, if terminal block is labeled, between the label and terminal block or only to the label on terminal block. The molecule may also contain multiple linkers and moieties which are alternatively spaced together.

[0039] The methods of the present invention described above may include conducting the polymerase reaction in the presence of at least one of DNA or RNA polymerase. Suitable nucleotides for addition as substrates in the polymerase reaction include nucleoside polyphosphates, deoxynucleoside polyphosphates, and dideoxynucleoside polyphosphates, carbocyclic nucleoside polyphosphates and acyclic nucleoside polyphosphates and analogs thereof. Particularly desired are

nucleotides containing 3, 4, or 5 phosphoryl groups in the polyphosphate chain, where the end phosphate is blocked.

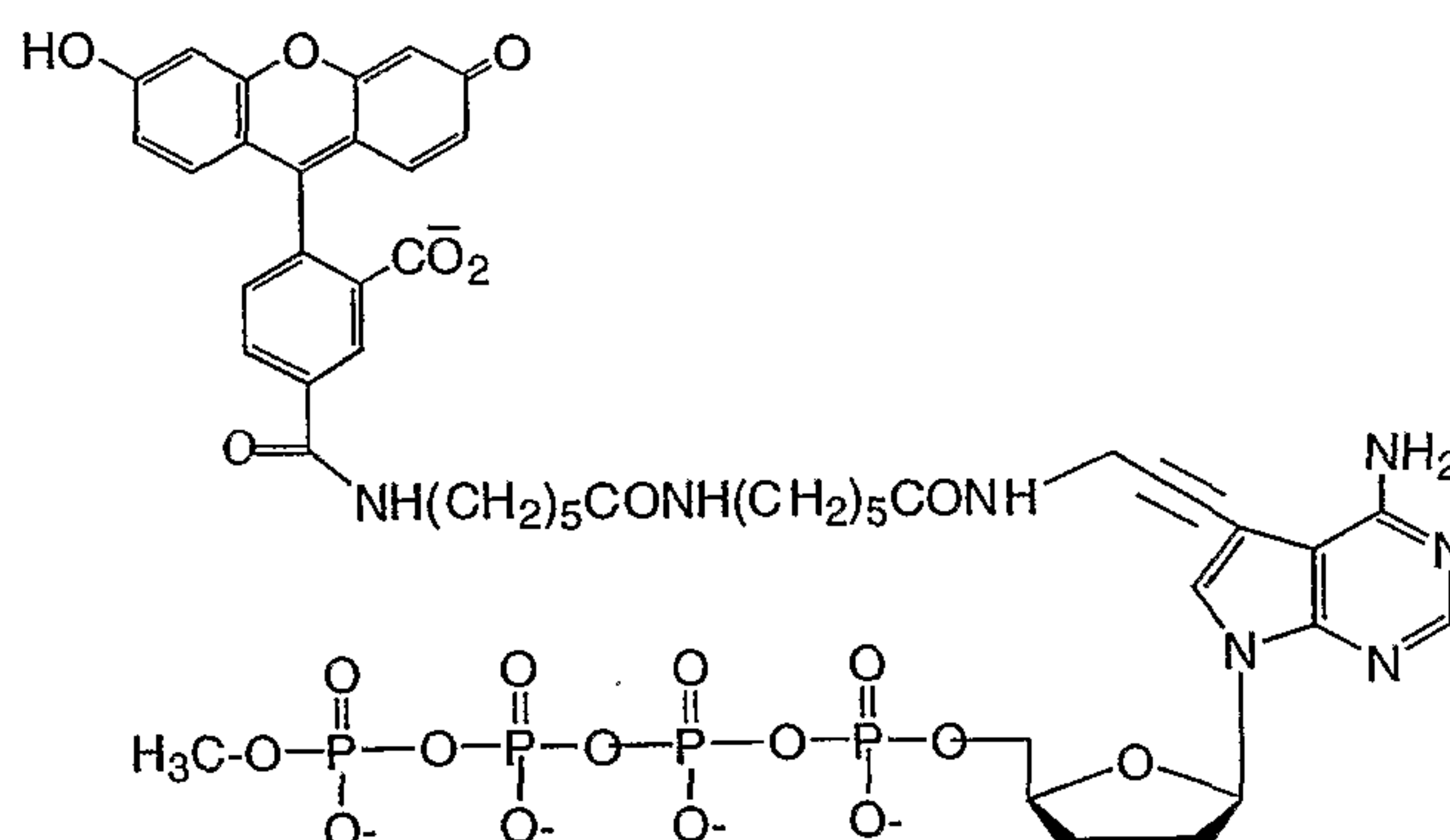
EXAMPLES

The following examples illustrate certain preferred embodiments of the illustration but are not intended to be illustrative of all embodiments.

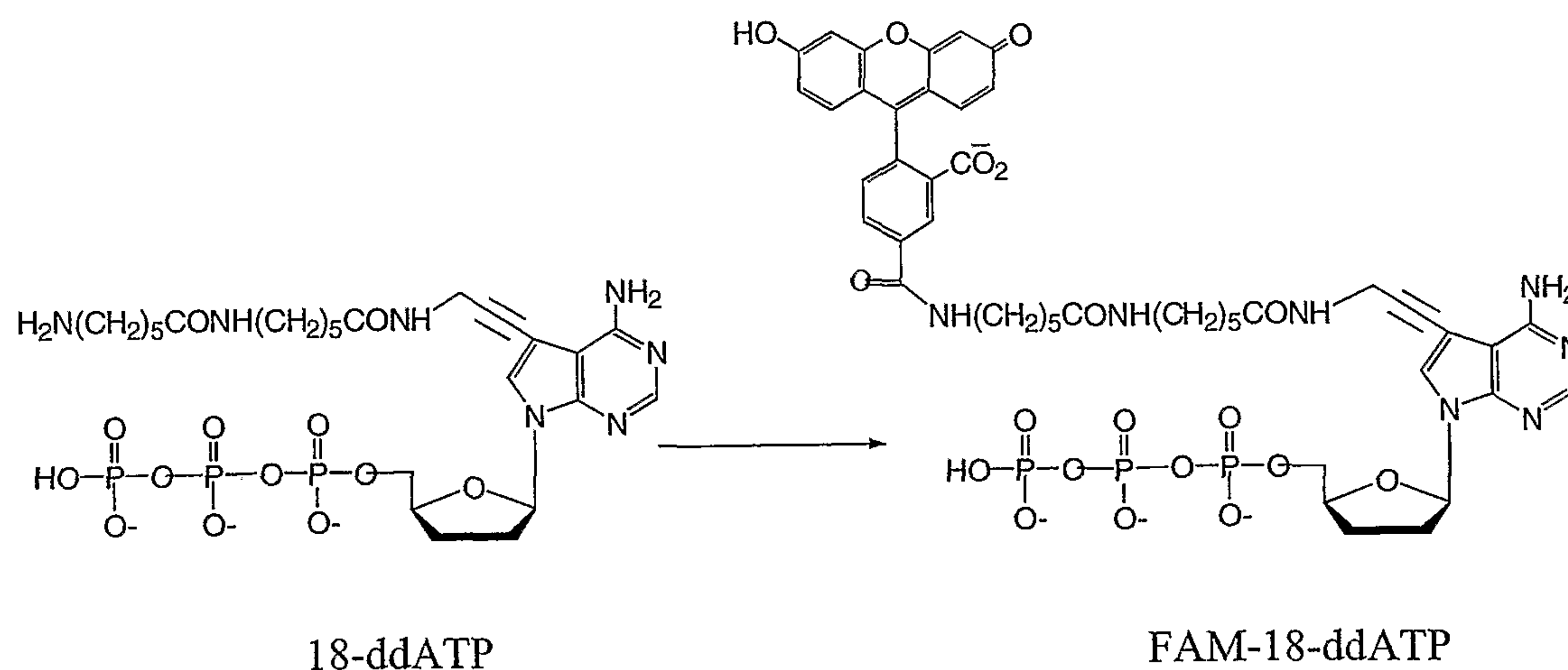
Example 1

Synthesis of Methyl-block Dye-labeled-2', 3'-Dideoxynucleoside-5'- tetraphosphates:

Synthesis of Fluorescein-18-ddA4P-Methyl



A. Preparation of FAM-18-ddATP



[0040] A solution of 18-ddATP (60 μ moles, in 5ml 0.1M NaHCO₃/Na₂CO₃, pH 8.5) was cooled on an ice/water bath. To the solution was added 5-carboxy-

fluorescein-NHS ester (35 mg, 1eq.) in DMF (5 ml). The reaction flask was removed from the cooling bath and the reaction mixture was stirred at room temperature for 16 hrs. The product purified by anion exchange chromatography and HPLC. The product containing fractions were concentrated then lyophilized to yield a yellow solid.

B. Preparation of Methyl-Phosphoimidazolidate

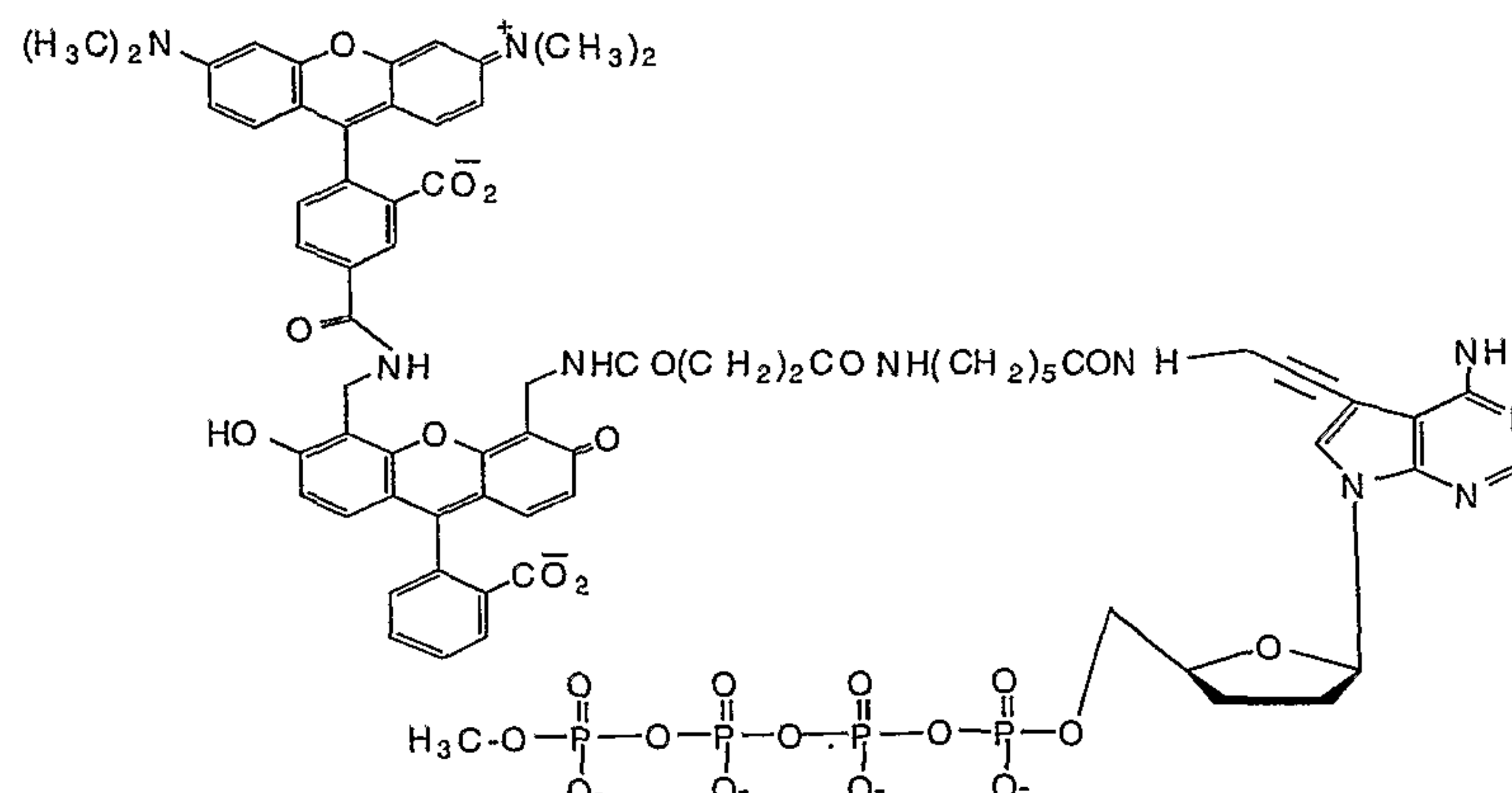
[0041] Methyl-monophosphate (50 μ mol) was coevaporated with anhydrous DMF (2x 2ml) and tributylamine (50 μ mol). This was redissolved in anhy. DMF (0.5 ml) and treated with carbonyldiimidazole (200 μ mol, 5 eq.) for overnight. The reaction mixture was quenched by addition of methanol (50 μ l). After 1 hr. the mixture was evaporated to dryness in vacuo and redissolved in anhy. DMF (500 μ l).

C. Synthesis of Fluorescein-18-ddA4P-Methyl

[0042] FAM-18-ddATP (3 μ mol) was coevaporated with anhy. DMF and tributylamine and redissolved in anhy. DMF (400 μ l). To this solution, 100 μ l of methyl phosphoimidazolidate was added and the reaction mixture was stirred for overnight. The mass spectral analysis indicated the complete conversion of triphosphate to the required methyl tetraphosphate. The reaction mixture was concentrated and purified first on anion exchange column followed by X-terra C18 RP HPLC column. The required fraction were collected, concentrated in vacuo and redissolved in water. The yield was monitored spectroscopically as 2.5 μ mol. UV max 501 nm, ESMS: 1204 (M-1).

Example 2

Synthesis of energy transfer dye based blocked dideoxynucleoside-5'-tetraphosphate:FAM-TAMRA-ddA4P-Methyl



[0043] FAM-TAMRA-18-ddATP was converted to the methyl tetraphosphate essentially the same way as reported above for the synthesis of FAM-18-ddA4P-Methyl. The yield from 10 μmol of starting material was 8.5 μmol . UV 495 and 556 nm. ESMS: 1644 (M-1).

Example 3

Stability of Normal and Methyl blocked energy transfer terminator

[0044] A sequence reaction containing 25 mM HEPES 8.0, 3 mM MgCl_2 , 1 mM MnSO_4 , 200 micromolar dNTP, 0.01% tween-20, 20 units Thermo Sequenase I, 0.8 milliunits pyrophosphatase, 100 ng M13mp18, 5 pmoles universal -40 primer, and 3.5 micromolar FAM-TAM-18-ddATP was cycled 25 times from 95 degrees C, 15 seconds to 60 degrees C, 2 minutes. The reaction was then ethanol precipitated and electrophoresed on a MegaBACE 1000 sequencing machine (Figure 2, Panel 1). If it was not ethanol precipitated, the breakdown products would appear as blobs on electropherogram and would interfere with fragments between 50-100 nucleotides long.

[0045] On the same MegaBACE run, 10 micromolar FAM-TAM-18-ddATP or 10 micromolar FAM-TAM-18-ddA4P-methyl in 25 mM HEPES 8.0, 3 mM MgCl_2 , 1 mM MnSO_4 , 0.01% tween-20 was electrophoresed directly (without precipitation) with or without heating at 95 degrees C for 20 minutes (Panel 2-5). It is clear from Figure 2, Panels 2 & 3 that the normal terminator degrades on heating while the same

30323-45

terminator with methyl block at the terminal phosphate remain mostly intact, panels 4 and 5.

Example 4

DNA sequencing using normal and terminal phosphate blocked terminator

[0046] Sequence reactions contained 25 mM HEPES 8.0, 3 mM MgCl₂, 1 mM MnSO₄, 200 micromolar dNTP, 0.01% tween-20, 20 units Thermo Sequenase^{*} I, 0.8 milliunits pyrophosphatase, 100 ng M13mp18, 5 pmoles universal -40 primer, and either 3.5 micromolar FAM-TAM-18-ddATP or 50 micromolar FAM-TAM-18-ddA4P-methyl as indicated. Reactions were cycled 25 times from 95 degrees C, 15 seconds to 60 degrees C, 2 minutes. Reactions were then ethanol precipitated and electrophoresed on an ABI377 DNA sequencing machine. It is clear from Figure 3 that the methyl blocked terminator gave similar sequence ladder in comparison with the normal terminator.

Example 5

Stability of γ -blocked nucleoside triphosphates

[0047] dATP and γ -methyl-dATP were separately dissolved in 100 μ l buffer (25 mM Tris, pH 8, 5 mM MgCl₂, 2 mM DTT and 10% glycerol) at 50 μ M concentration and heated at 95°C for 2h. Reaction mixture was analyzed by reverse phase HPLC for any decomposition products and by LCMS for the identification of products. Both HPLC and LCMS showed no decomposition of γ -methyl-dATP, while dATP had decomposed by ca 75% to dADP (69.0%) and dAMP (5.7%) (Figure 4).

Example 6

Stability of γ -DDAO-ddTTP

[0048] Three sets of two samples (100 μ l each) were prepared by dissolving γ -DDAO-ddTTP in a Tris buffer (25 mM Tris, pH 8, 5 mM MgCl₂, 2mM DTT and 10% Glycerol) at 50 μ M concentration. Each set was heated at 37°C, 60°C or 95°C for 10 minutes. To one sample from each set, one unit of Calf Intestinal Alkaline

*Trade-mark

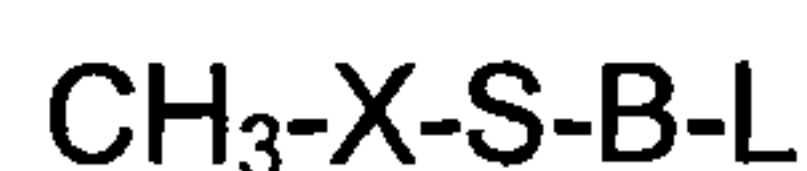
Phosphatase (CIAP) was added and mixture was incubated at 37°C for 5 minutes. A unit of CIAP hydrolyzes 1 μ mol of p-nitrophenyl-phosphate per minute. Samples without CIAP were also incubated at 37°C for 5 minutes. All samples were then analyzed by HPLC. Neither temperature nor CIAP had any significant affect on the stability of γ -DDAO-ddTTP. Slight increase in free dye formation in the presence of CIAP compared to non-CIAP treated sample is probably due to the decomposition of impurities in the starting material (Figure 5).

[0049] Having described the particular, desired embodiments of the invention herein, it should be appreciated that modifications may be made there through without departing from the contemplated scope of the invention. The true scope of the invention is set forth in the claims appended hereto.

30323-45

CLAIMS:

1. A method for nucleic acid analysis, which includes a polymerase reaction at temperatures between 60°C and 95°C, of a nucleic acid template, a primer, a nucleic acid polymerase, and at least one nucleoside polyphosphate, further comprising conducting said polymerase reaction in the presence of at least one thermally stable, terminal-phosphate-blocked nucleoside polyphosphate, wherein said terminal-phosphate-blocked nucleoside polyphosphate is represented by the formula



10 wherein

X is a polyphosphate chain with at least 3 phosphate or modified phosphate groups;

S is a natural or modified sugar, a carbocycle, or an acyclic linker;

B is a natural or modified heterocyclic base; and

15 L is H or a linker moiety selected from the group consisting of substituted or unsubstituted, linear or branched cyclic or acyclic alkyl, alkenyl, alkynyl, aromatic, and heterocyclic.

2. The method of claim 1, wherein said nucleic acid analysis is DNA sequencing.

20 3. The method of claim 2, wherein said terminal-phosphate-blocked nucleoside polyphosphate is a labeled terminator.

4. The method of claim 1, wherein said nucleic acid analysis is polymerase chain reaction (PCR).

25 5. The method of claim 1, wherein said at least one terminal-phosphate-blocked nucleoside polyphosphate is net positively charged.

30323-45

6. The method of claim 1, wherein L is labeled with a detectable moiety selected from the group consisting of radioisotopes, electrochemical tags, fluorescent tags, energy transfer (ET) labels, mass spectrometry tags, Raman tags, haptens, chemiluminescent groups, enzymes, chromophores, and any combinations thereof.

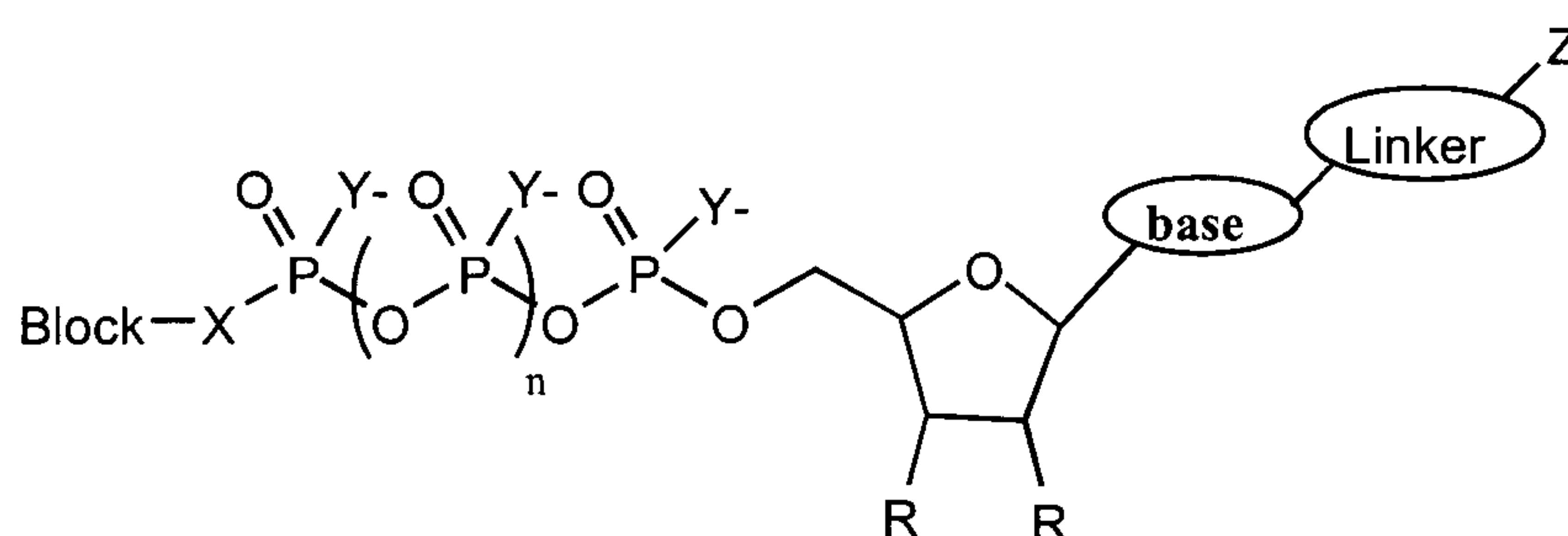
5 7. The method of claim 1, wherein B is selected from the group consisting of uracil, cytosine, guanine, adenine, thymine, 7-deazaguanine, 7-deazaadenine, hypoxanthine, 7-deazahypoxanthine and 2,6-diaminopurine or derivatives thereof.

8. The method of claim 1, wherein X is a polyphosphate chain of 3, 4
10 or 5 phosphate groups.

9. The method of claim 1 for sequencing, wherein S is selected from the group consisting of 2'-deoxyribosyl, 3'-deoxyribosyl, 2',3'-dideoxyribosyl, 2',3'-dideoxy-2',3'-didehydroribosyl, 3'-alkoxyribosyl, 3'-azidoribosyl, 3'-aminoribosyl, 3'-fluororibosyl, 3'-mercaptoribosyl, 3'-alkylthioribosyl,
15 2'-alkoxyribosyl, 2'-azidoribosyl, 2'-aminoribosyl, 2'-fluororibosyl, 2'-mercaptoribosyl, 2'-alkylthioribosyl, carbocyclic and acyclic.

10. The method of claim 1 for nucleic acid amplification, wherein S is selected from the group consisting of ribosyl, 2'-deoxyribosyl, 2'-alkoxyribosyl, 2'-azidoribosyl, 2'-aminoribosyl, 2'-fluororibosyl, 2'-mercaptoribosyl, and
20 2'-alkylthioribosyl.

11. The method of claim 1, wherein said terminal-phosphate-blocked nucleoside polyphosphate is represented by the formula



wherein

30323-45

n is 1, 2 or 3;

Block is H;

X is CH₂;

Y is O, S, or BH₃;

5

R is H or OH;

Base is a natural or modified nucleoside base;

Linker is H, alkyl, aryl, alkylaryl, alkenyl, alkynyl, aromatic, or heterocyclic and may optionally be charged; and

10 Z is a fluorescent dye, an energy transfer dye, a chemiluminescent compound, a colored compound, a mass tag or is absent.

1 2 3 4

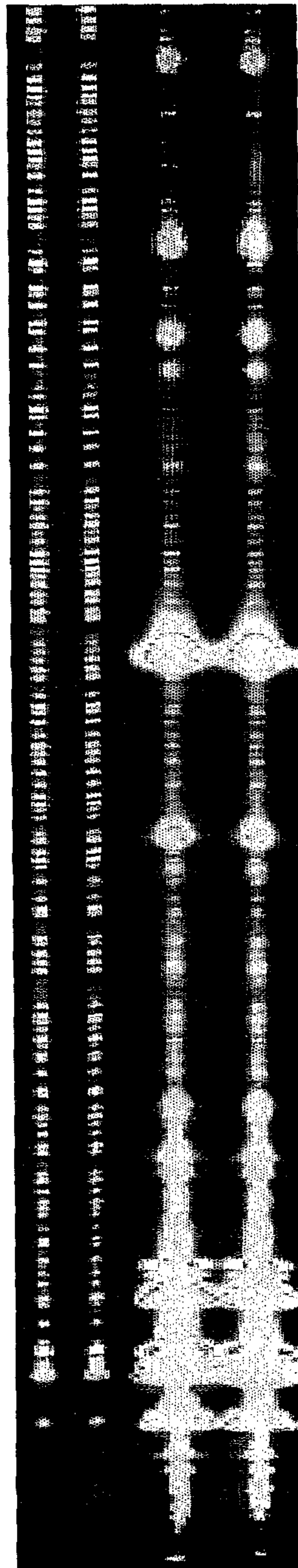
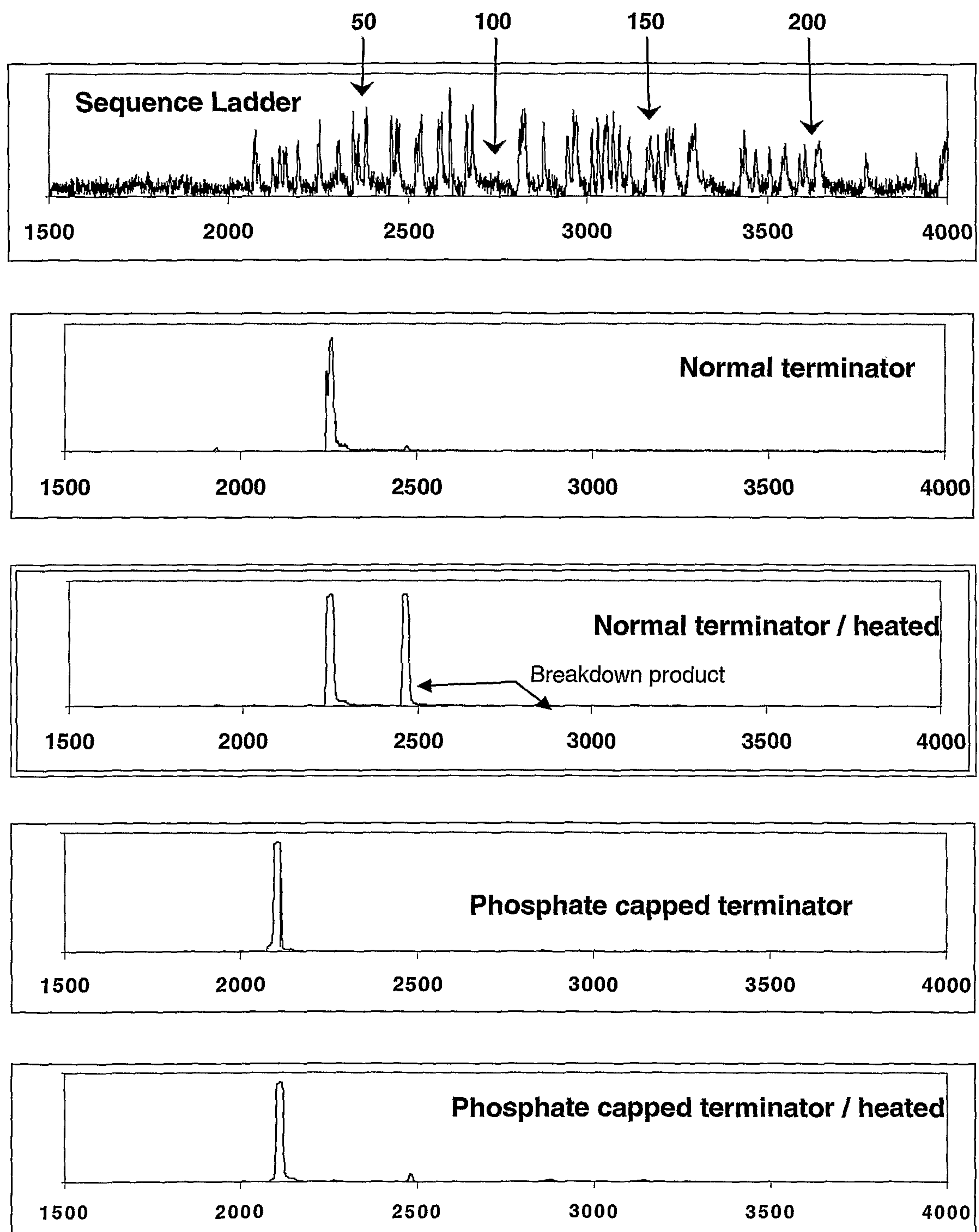
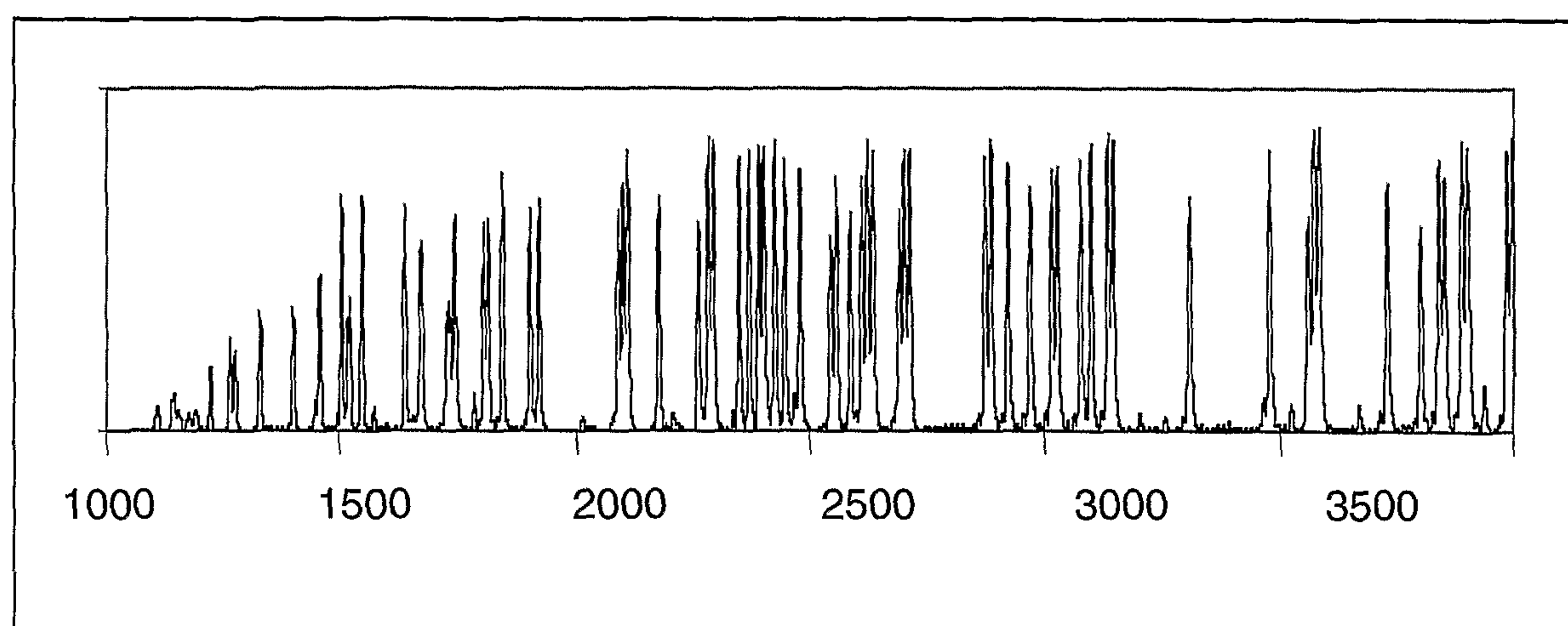
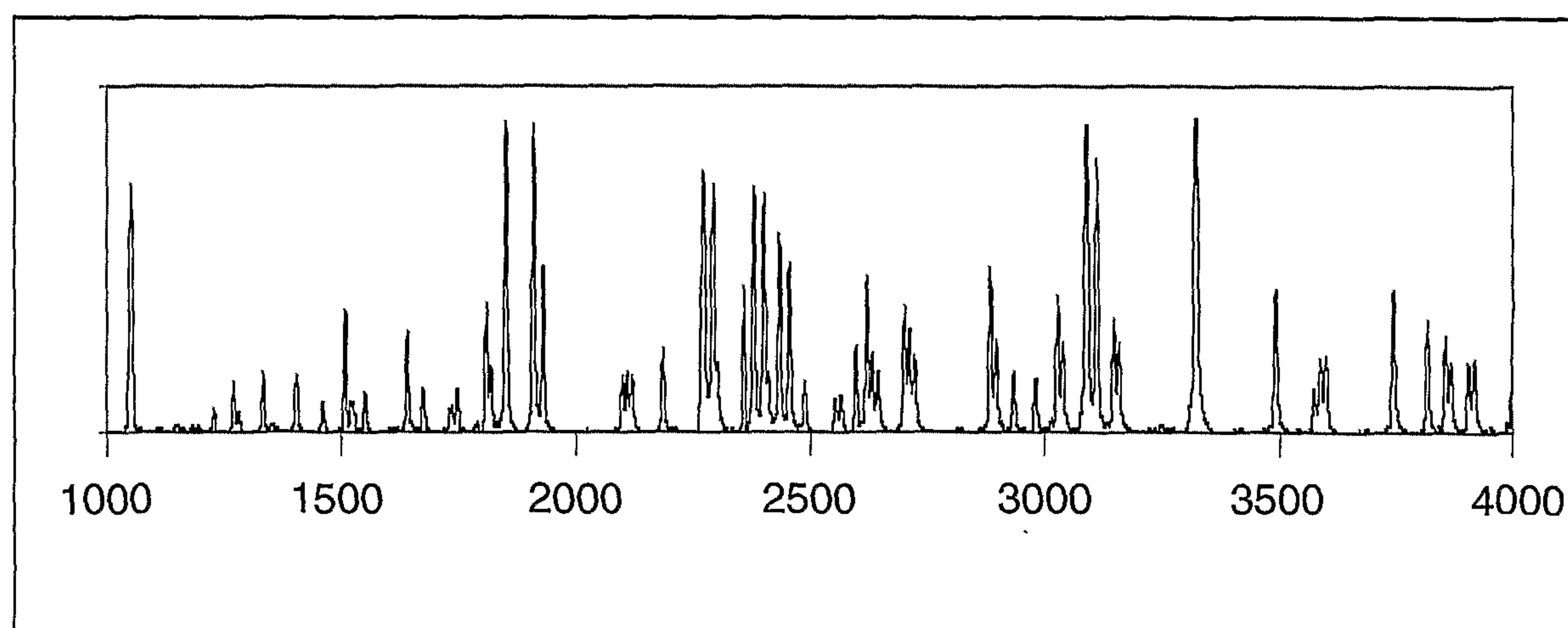
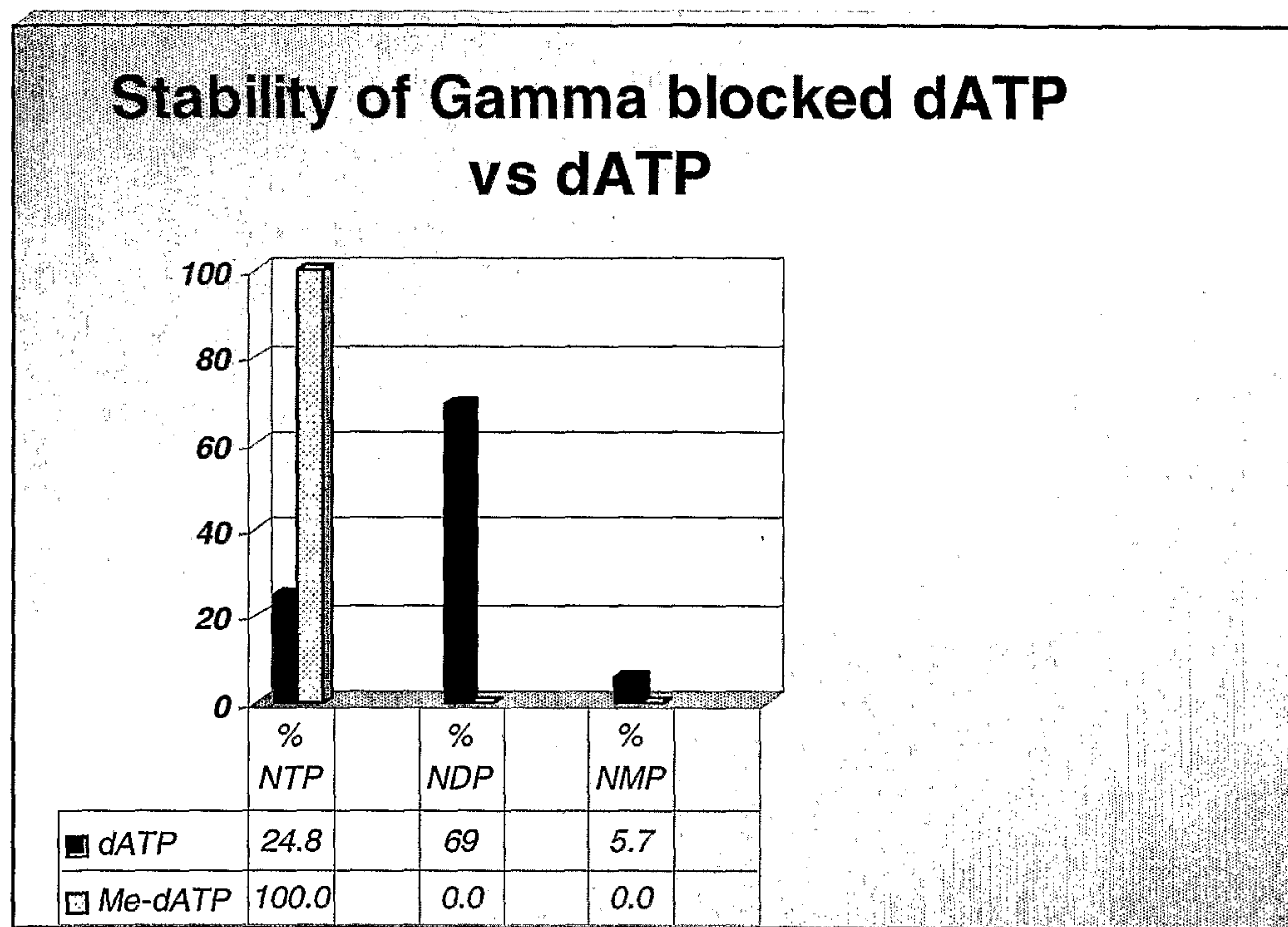
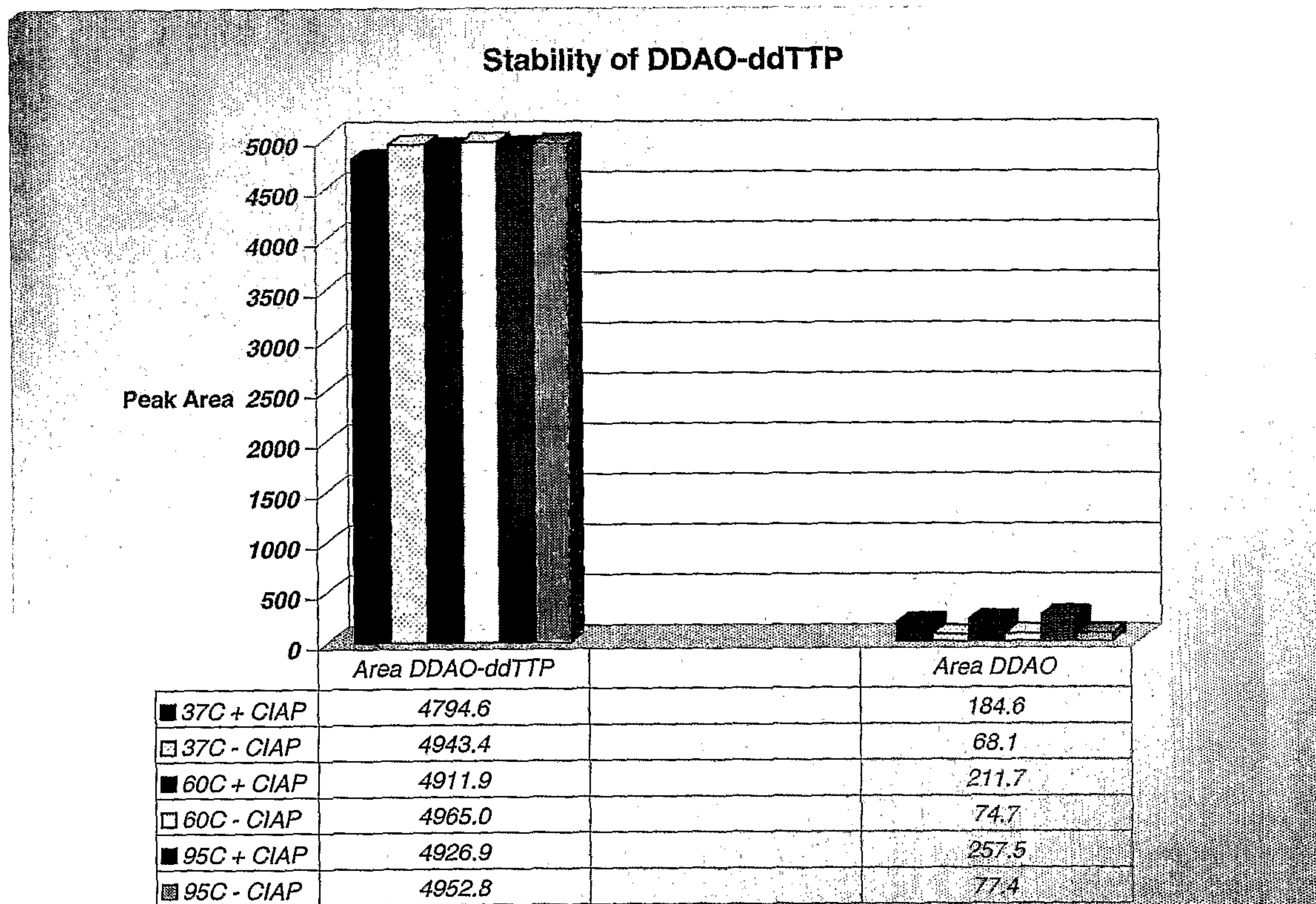


FIGURE 1

**FIGURE 2**

Normal terminator sequence ladder**Phosphate blocked terminator sequence ladder****FIGURE 3**

**FIGURE 4**

**FIGURE 5**