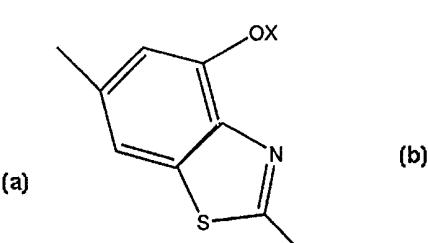
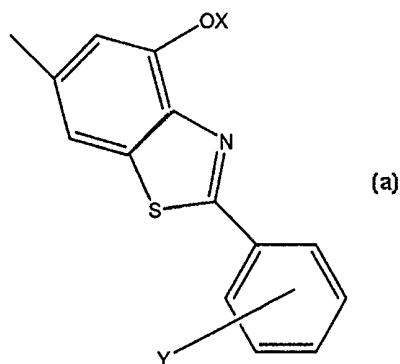
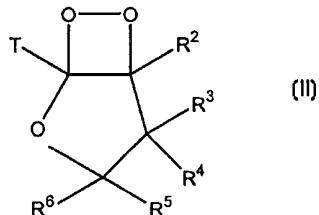
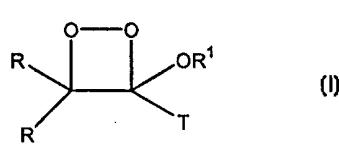


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(54) Title: BENZOTHIAZOLE DIOXETANES



(57) Abstract

Chemiluminescent 1,2-dioxetane compounds capable of producing light energy when decomposed, substantially stable at room temperature, represented by formula (I) or (II), wherein T is (a) or (b).

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**TITLE OF THE INVENTION****BENZOTHIAZOLE DIOXETANES**

This application is a regular National application claiming priority from Provisional Application, U.S. Application Serial No. 60/094,336 filed July 28, 1998. The entirety of that 5 provisional application is incorporated herein by reference.

**BACKGROUND OF THE INVENTION****Field of the Invention**

This invention relates to improved chemiluminescent 1,2-dioxetane compounds. More particularly, this invention relates to improved enzymatically cleavable 10 chemiluminescent 1,2-dioxetane compounds that contain enzymatically removable labile groups. Such labile groups prevent the molecule from decomposing to produce light, i.e. visible light or light detectable by appropriate instrumentation, until an appropriate enzyme is added to remove the labile group.

One enzyme molecule can affect the removal, though a catalytic cycle, of its 15 complimentary labile group from thousands of enzymatically cleavable chemiluminescent 1,2-dioxetane molecules. This is a marked contrast to the situation with chemically cleavable chemiluminescent 1,2-dioxetanes, where one molecule of chemical cleaving agent is needed to remove the complimentary labile group from each dioxetane molecule.

Enzymatically cleavable light-producing 1,2-dioxetane compounds will usually also 20 contain stabilizing groups, such as an adamantylidene group spiro bonded to the dioxetane ring's 3-carbon atom, that will aid in preventing the dioxetane compound from undergoing spontaneous decomposition at room temperature (about 25°C) before the bond by which the

enzymatically cleavable labile group is attached to the remainder of the molecule is intentionally cleaved. Wieringa, et al., Tetrahedron Letters, 169 (1972), and McCapra, et al., J. Chem. Soc., Chem. Comm., 944 (1977). These stabilizing groups thus permit such dioxetanes to be stored for exceptionally long periods of time before use, e.g., for from about 5 12 months to as much as about 12 years at temperatures ranging from about 4°C to about as much as 30°C without undergoing substantial decomposition.

This invention further relates to the incorporation of its dioxetane molecules in art-recognized immunoassays, chemical assays and nucleic acid probe assays, and to their use as direct chemical/physical probes for studying the molecular structure or micro structures of 10 various micro molecules, synthetic polymers, proteins, nucleic acids, catalytic antibodies, and the like, to permit an analyte-to chemical or biological substance whose presence, amount or structure is being determined to be identified or quantified.

### Background of the Invention

Applications naming one or more of the inventors herein, as inventors, and assigned 15 to Tropix, Inc., have clearly established 1,2-dioxetanes as chemiluminescent compounds which can be used as reporters and labels in ultra sensitive assays that can be conducted quickly, without resort to exotic conditions or elaborate apparatus, for the detection of a variety of biological materials. Among these are U.S. Patent numbers 4,931,223; 4,931,569; 4,952,707; 4,956,477; 4,978,614; 5,032,381; 5,145,772; 5,220,005; 5,225,584; 5,326,882; 20 5,330,900; 5,336,596; and 5,871,938. All of the foregoing are incorporated herein by reference. Other patents commonly assigned with this application have issued, and other applications are pending. Together this wealth of patent literature addresses 1,2-dioxetanes, stabilized by a typically polycyclic group, such as spiroadamantane bonded to one of the

carbons of the dioxetane ring, and a moiety bonded to the remainder carbon of the dioxetane ring which is electron sensitive, such that the protection of the electron sensitive moiety, typically an aryl group, leads to an anion, generally an oxyanion, which is unstable, and decomposes. Through decomposition, the O-O bond is broken and a photon is generated. The 5 same carbon atom to which this electron sensitive moiety is bonded may bear an alkoxy or other electron-active group.

The first of the dioxetanes of this class commercialized was 3-(4-methoxy-spiro(1,2-dioxetane-3, 2'-tricyclo(3.3.1.1<sup>3,7</sup>) decan)-4-yl)phenyl phosphate, particularly the disodium salt, generally known as AMPPD®. This compound has been commercialized by assignee of 10 this application, Tropix, Inc., as well as a company of Detroit, Mich., Lumigen, Inc. Superior performance of the above described compounds can be obtained by selective substitution on the spiroadamantane ring. Substitution, at either bridgehead carbon with an electron active species, such as chlorine, improves reaction speed and signal to noise ratio (s/n). The 15 chlorine substituted counterpart of AMPPD®, CSPD®, has been widely commercialized by Tropix, Inc. of Bedford, Mass. "Third-generation" dioxetane compounds of similar structure, wherein the aryl moiety also bears an electron active substituent, such as chlorine, offer further improvements in performance, and have been commercialized by Tropix, Inc. The phosphate moieties are available under the trademarks CDP® and CDP-*Star*®.

However, it has been observed that AMPPD® in aqueous solution, and also in the 20 presence of chemiluminescent enhancers, e.g., a polymeric ammonium, phosphonium or sulphonium salt such as poly[vinyl benzothiazole(benzothiazole dimethyl ammonium choride)] ("BDMQ") and other hetero polar polymers may exhibit longer than optimum periods of time to reach constant light emission characteristics ("t  $\frac{1}{2}$ ", defined as the time necessary to obtain one-half of the maximum chemiluminescence intensity at constant,

steady-state light emission levels; this emission half-life varies as a function of the stability of the dioxetane oxyanion in various environments).

Statistically, approximately seven  $t_{1/2}$  periods are required to reach steady-light emission kinetics. The  $t_{1/2}$  of AMPPD® at concentrations above  $2 \times 10^{-5}$  M in an aqueous 5 solution at pH 9.5 in the presence of BDMQ have been found to be 7.5 minutes. At  $4 \times 10^{-3}$  M in the absence of BDMQ, the  $t_{1/2}$  has been found to be approximately 30-60 minutes, while at  $2 \times 10^{-5}$  M in an aqueous solution, the  $t_{1/2}$  for AMPPD® has been found to be 2.5 minutes.

10 In rapid bioassays that employ enzymatically cleavable chemiluminescent 1,2-dioxetanes as reporter molecules, it is desirable to reach steady-state light emission kinetics as quickly as possible so as to detect an “endpoint” in the assay. While chemiluminescent intensity can be measured before achieving steady state kinetics, sophisticated, thermally controlled luminometry instrumentation must be used if one wishes to acquire precise data prior to steady-state emission kinetics.

15 Furthermore, AMPPD®, in an aqueous buffered solution both in the presence and absence of chemiluminescent enhancers such as BDMQ, exhibits higher than desirable thermal and non-enzymatically activated light emission, or “noise”. Such noise can be attributed to emission from the excited state adamantane and of the methyl m-oxybenzoate anion derived from the aromatic portion of the AMPPD® molecule. This noise can limit the 20 levels of detection, and thus prevent the realization of ultimate sensitivity, as the measured noise level of AMPPD® is approximately two orders of magnitude above the dark current in a standard luminometer.

Importantly, various instruments for detecting chemiluminescent emission such as CCD cameras have greater detection sensitivities in the green and red wavelengths.

AMPPD® and related dioxetanes typically emit in the blue wavelengths of the visible spectrum. Heretofore it has been necessary to use polymeric enhancers to "shift" the emission wavelength. It would be desirable to obtain dioxetanes which emit in wavelengths closer to the "red or green end" of the visible spectrum, to enhance detection sensitivity.

5 It is, therefore, an object of this invention to decrease the time necessary to conduct assays, and particularly bioassays, in which enzymatically cleavable chemiluminescent 1,2-dioxetanes are used as reporter molecules.

It is also an object of this invention to provide new and improved enzymatically cleavable chemiluminescent 1,2-dioxetanes which, when used as reporter molecules in assays, and in particular bioassays, reduce the time required to complete the assay.

10 A further object of this invention is to provide a new and improved enzymatically cleavable chemiluminescent 1,2-dioxetane for use as substrates for enzyme-based assays, and particularly bioassays, which provide improved signal to background behavior and thus provide improved detection levels.

15 A further object of this invention is the provision of dioxetane whose emission wavelengths are shifted toward the green and red wavelengths.

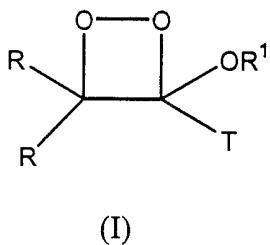
A still further object of this invention is to provide novel intermediates useful in synthesizing these improved enzymatically cleavable 1,2-dioxetanes.

20 Another object of this invention is to provide methods of preparing these enzymatically cleavable chemiluminescent 1,2-dioxetanes and intermediates thereof.

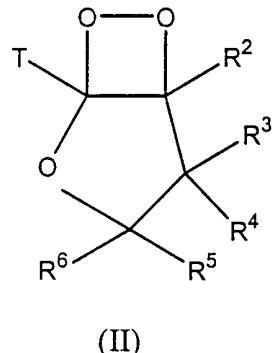
These and other objects, as well as the nature, scope and utilization of this invention, will become readily apparent to those skilled in the art from the following description and the appended claims.

SUMMARY OF THE INVENTION

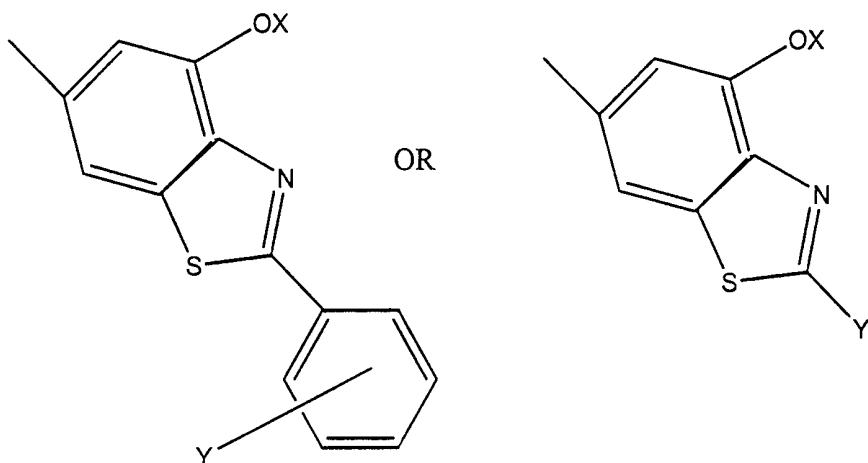
The above objects, and others, made clear by the discussion set forth below, is met by a new family of dioxetanes of the general formula(s):



OR



wherein T is:



10

wherein each R may independently be any branched alkyl or cycloalkyl group which provides stabilization for the dioxetane, or both R groups may be joined in a cycloalkyl or polycycloalkyl moiety spiro bound to the dioxetane ring wherein the R group or groups may be unsubstituted or substituted with a halogen atom, an alkoxy group, or an electron-withdrawing organic group, and wherein R<sup>1</sup> is an aryl group, or an alkyl group of 1-20 carbon atoms, which may be optionally substituted with 1 or more halogen atoms, and wherein Y

may be H, or an electron donating or withdrawing group, or an organic linker group attached to an ancillary fluorophore, or to any biological moiety, and wherein X may be any protecting group which is removable by chemical or enzymatic means, wherein R<sup>2</sup> - R<sup>6</sup> are independently H, alkyl, or branched alkyl, substituted alkyl, aryl, substituted aryl, wherein R<sup>3</sup> and R<sup>4</sup> may be joined as a spiro-fused cycloalkyl group.

5 The above dioxetanes may be synthesized by way of the fused benzothiazole aldehyde, or toluene derivative using permanganate oxidation to provide a carboxylic acid. Esters of this acid may be used to prepare dioxetane precursors for the above compounds according to methodology described in U.S. Patent 5,731,445 which is incorporated herein by 10 reference.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a fused(heteroaryl)benzothiazole 1,2-dioxetane phosphate.

Figure 2 (omitted).

Figures 3 and 4 show the synthesis of the dioxetane of formula I of the invention.

15 Figure 5 illustrates a synthesis of an intermediate for the dioxetanes of formula I of the invention.

Figure 6 (omitted).

Figures 7 and 8 illustrate the synthesis and structure of a red-emitting dioxetane system using energy transfer.

20 Figures 9 and 10 reflect the emission spectrum of the dioxetane of this invention.

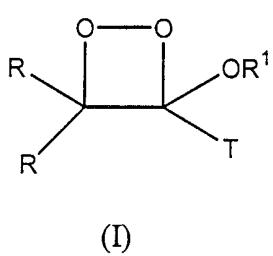
Figures 11-14 illustrate the speed of chemiluminescent kinetics, and sensitivity, of the inventive dioxetanes as opposed to commercial prior art dioxetanes.

DETAILED DESCRIPTION

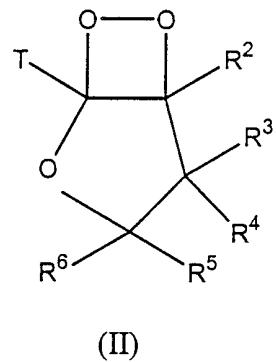
We now describe the structure, synthesis, and use of preferred embodiments of the present invention.

Structure

5 The invention employs dioxetanes having the general formula(s):

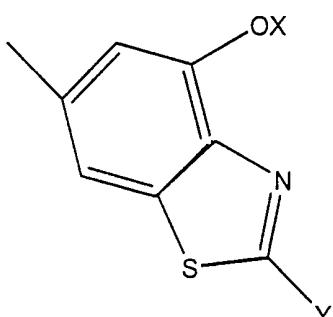
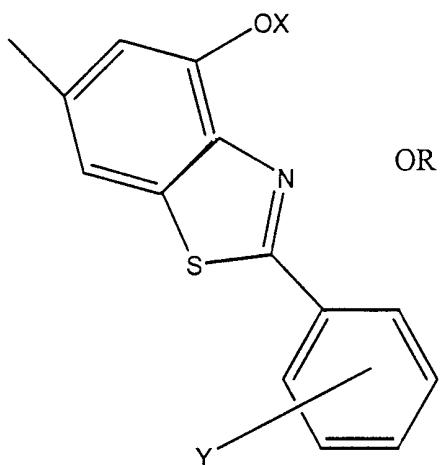


OR



(II)

10 wherein T is:



15 wherein each R may independently be any branched alkyl or cycloalkyl group which provides stabilization for the dioxetane, or where both R groups together form a cycloalkyl or polycycloalkyl moiety spiro bound to the dioxetane ring wherein each R or the spiro bound

cyclic group may be unsubstituted or substituted with a halogen atom, an alkoxy group, or an electron-withdrawing organic group, and wherein R<sup>1</sup> is an aryl group, or an alkyl group of 1-20 carbon atoms, which may be optionally substituted with 1 or more halogen atoms, and wherein Y may be H, or an electron donating or withdrawing group, or an organic linker 5 group which may be attached to an ancillary fluorophore or to any biological moiety, and wherein X may be any protecting group which is removed by chemical or enzymatic means, wherein R<sup>2</sup>-R<sup>6</sup> are independently H, alkyl, substituted alkyl, aryl, substituted aryl, wherein R<sup>3</sup> and R<sup>4</sup> may be joined as a spiro-fused cycloalkyl group.

Representative identities for each of the substituents of formulas I and II will be 10 familiar to those of skill in the art, given the novel chemical formulas herein, and the earlier patents of Tropix incorporated herein by reference. Preferred identities for R include straight or branched chain alkyls of 2-12 carbon atoms, with a preference for branched alkyl groups. Each alkyl group may be substituted with one or more electron-withdrawing or electron- 15 donating groups, and/or each alkyl moiety R may be substituted with one or more groups which increase the solubility of the overall dioxetane, which is generally quite hydrophobic. Preferred solubilizing groups include carboxylic acid moieties, sulfonic acid moieties, phosphoric acid moieties, trifluoromethyl moieties, etc.

In a preferred embodiment, both R groups together form a spiroadamantyl group, which may be unsubstituted, or substituted at either head carbon, or both, with an electron 20 active (electron withdrawing or electron donating) group, including alkoxy of 1-7 carbon atoms, halo, alkyl, etc. Exemplary substituents on the adamantyl group are set forth in U.S. Patent 5,112,960, incorporated herein by reference. Beyond spiroadamantyl groups, the identity of each group R is selected so as to provide steric stabilization for the dioxetane, to prevent premature decomposition.

$R^2 - R^6$  are each independently selected, save that  $R^3$  and  $R^4$  may be joined to form a spiro-fused cycloalkyl group, as described above for groups R. Otherwise,  $R^2 - R^6$  are independently selected from hydrogen, alkyl unsubstituted or substituted with one or more halogen groups, particularly fluorine, such as trifluoroalkyl of 1-6 carbon atoms, hydroxy, phenyl, naphthyl, etc. Each and/or all, or any combination, of moieties  $R^2 - R^6$  may be further substituted with groups calculated to enhance the water solubility of the dioxetane, as described above. Each moiety  $R^2 - R^6$  may bear one or two water solubility-enhancing groups. Instead of alkyl, each and/or all of  $R^2 - R^6$  may be aryl, preferably phenyl.

Substituent Y may serve one or more functions. Y may be hydrogen, or, to effect the decomposition kinetics of the unprotected dioxetane (see the identities for X, below) Y may be an electron withdrawing group (e.g., any heteroaryl group). Y may be an electron donating group (e.g., any alkyl group). Additionally, a wide variety of other electron-active substitutents for substitution on aryl moieties for dioxetanes are set forth for the substituent "Z" in U.S. Patent 5,538,847, incorporated herein by reference. As set forth therein, electron 10 donating groups, such as a methoxy group, enhance anion decomposition process, whereas electron-withdrawing groups, such as chlorine, may retard the same decomposition reaction. Surprisingly, the influence of substituents on the aryl ring may be quite opposite that on the adamantly or other steric stabilizing group. In the alternative, Y may be an organic linker 15 group, of 1-20 carbon atoms, providing a covalent linkage between the dioxetane of the invention and a biological moiety to be studied, as described in U.S. Patent 5,800,999, incorporated herein by reference. In this embodiment, the dioxetane or its precursor serves as 20 a direct label, rather than indirect, and may be effectively triggered by agents other than enzymes, such as pH, heat, etc. In these embodiments, the identity of X (described below) may be other than an enzyme-label group.

In another alternative, Y may be OX'. As discussed herein below, X is the triggering group, that is, the group whose activation or removal leads to decomposition of the dioxetane through cleavage of the C-C and O-O bonds of the ring. The OX group meta with respect to the point of attachment of the benzothiazole group to the dioxetane is the primary triggering agent. Additional triggering, or reduced triggering, may be effected by setting Y equal to OX'. In the event this selection is made, X' is selected, independently, from the same set of variables that may characterize X.

5 In classic embodiments, X is an enzyme-labile group. Although preferred groups include phosphate moieties and galactoside moieties, virtually any enzyme-cleavable group, 10 which, upon cleavage, leaves the oxyanion, is suitable for use in this invention. A large variety of enzyme-cleavable groups are set forth in U.S. Patent 5,605,795, which is incorporated herein by reference. In general, in addition to the phosphate esters, moiety X may be any of the moieties identified for group Z in U.S. Patent 5,605,795, incorporated 15 herein by reference, including substrates for esterases, decarboxylases, phospholipases,  $\alpha$ - or  $\beta$ -xylosidase, fucosidases, glucosidases, and thioglucosidases, galactosidases,mannosidases, fructofuranosidases, glucosiduronases, trypsin, etc. Additionally, moiety OX can be replaced by any of a wide variety of peptides cleavable by proteolytic enzymes, as set forth in U.S. Patent 5,591,591, incorporated herein by reference.

20 As previously noted, there are situations where non-enzymatic chemical triggering, as opposed to enzymatic triggering, may be preferable. In these instances, X is preferably H, trialkylsilyl, etc. Various chemical triggering, and identities for X, are set forth, e.g., in U.S. Patent 5,652,345, also incorporated herein by reference.

In monitoring, and measuring (quantifying) chemiluminescence, a wide variety of apparatus have been developed. Among the most sensitive, and particularly suited to high

throughput screening applications and the like, are CCD cameras. Typical luminescent emission from dioxetanes is in the blue wavelengths of the visible spectrum. CCD cameras have difficulty "seeing", that is, registering, blue emission. Typically, only the "edge" of the longer wavelengths of the blue emission are observed by the camera. By employing a fused 5 benzothiazole resonating moiety on the dioxetane, the light is green-shifted, that is, the emission is shifted toward the green end of the visible spectrum. Prior art dioxetanes are typically used with enhancement agents, which are configured so as to sequester the dioxetane in hydrophobic regions, to avoid the chemiluminescent quenching that can be observed in the presence of water. These enhancement molecules are preferably onium 10 quaternary polymers, including phosphonium, sulfonium and ammonium polymers. Representative polymers, and their effects, are set forth in U.S. Patent 5,330,900, which is incorporated herein by reference. These polymers may be used alone, or together with a surfactant additive, to further improve the enhancement value, as disclosed in U.S. Patent 5,547,836, also incorporated herein by reference. Because of the green shifting of the 15 dioxetane emission, and the enhanced hydrophobicity of the dioxetanes due to the presence of the fused benzothiazole, less enhancement agents, and if necessary, additives need be employed. As previously noted, moiety Y of the dioxetane can be used in a variety of functions. One function is as a linking arm. In addition to being a linker to a biological 20 moiety of interest, Y may be an organic linking group (typically alkyl or alkoxy) attached to an energy transfer fluorophore, a fluorescent moiety which absorbs the energy emission of the dioxetane on decomposition, and fluoresces in response thereto. Energy transfer fluoresensce is well established, and illustrated in Figure 7 and Figure 8.

Referring more particularly to the figures of the application, Figure 1 presents the chemical structure of a preferred embodiment of the invention, benzothiazole dioxetane

phosphate. This molecule is referred to, herein, as BZPD. The synthesis of this dioxetane is illustrated in Figures 3 and 4, and the necessary reactions for synthesis are set forth below. Although conventional starting materials may be used to synthesize the dioxetanes of the claimed invention, novel isothiocyanates are set forth as an aspect of the invention, and 5 illustrated in Figure 5.

Figure 9 illustrates the "green shifting" of the wavelength emission of BZPD, showing a peak wavelength above 550 nm, in the absence of any enhancement agent. As shown in Figure 10, in the presence of an enhancement agent (Sapphire-II™), long wavelength intensity is further enhanced. The relative chemiluminescent performance of 10 BZPD is compared with other commercially successful dioxetanes in Figures 11-14. Thus, the relatively "quick" or short  $T_{1/2}$  of BZPD is illustrated in Figure 11-A, compared with CSPD® (phenyl dioxetane bearing a chlorine substituent on the adamanyl group) and CDP-*Star*® (further bearing a chlorine on the phenyl moiety). The inventive dioxetanes also have an excellent S/N performance, as shown in Figure 11-B. S/N values are of importance, 15 because if the noise background is too high (a low S/N), no matter how rapidly the peak intensity is developed, the assay is relatively insensitive.

Figure 12-A and 12-B reflect similar performance after 24 minutes, showing the continued heightened sensitivity and emission profile of BZPD.

Sensitivity, is an essential characteristic of dioxetane detection agents. In Figures 13-20 A and 14-A, sensitivity after four minutes and 24 minutes, respectively, at various concentrations of alkaline phosphatase, for BZPD is measured. As clearly set forth, BZPD offers superior detection sensitivities (greater signal) even at very low concentrations of enzyme ( $10^{-17}$  moles or less). As shown in Figures 13-B and 14-B, the S/N ratio of BZPD is

comparable to previously developed dioxetanes, such that the heightened sensitivity can be used to detect very small amounts of material.

Direct synthesis of BZPD is described below.

The above dioxetanes may be synthesized by way of the fused benzothiazole 5 aldehyde, or toluenene derivative using permanganate oxidation. Esters of this acid may be used to prepare dioxetane precursors for the above compounds according to methodology described in U.S. Patent 5,731,445 which is incorporated herein by reference.

#### Synthesis of Benzothiazole Dioxetanes Substrates

The following example is a representative synthesis of benzothiazole dioxetane 10 substrates and their precursors, and should not limit the scope of the claims.

4,6-dibromo-o-anisidine was obtained according to the literature:

Fuchs, Monatshefte fur Chemie, 36, 130, 1915.

A Varian Unity 300 NMR Spectrometer was used. All NMR data is proton(<sup>1</sup>H)NMR

#### Example 1: 2-Benzamido-3,5-dibromoanisole

15 4,5-dibromo-o-anisidine (11.3g; 40.2 mmol), was dissolved in 75 ml dichloromethane and 6.7 ml pyridine. The mixture was stirred at room temperature, under argon. Benzoyl chloride (4.8 ml; 1.03 equivalents), was added dropwise by syringe. The mixture was stirred for 8 hours to obtain an orange-brown suspension. The reaction mixture was then concentrated to one-third volume on the rotary evaporator. The thick slurry was filtered on a Buchner funnel, 20 washing the flask and solid with 50:50 dichloromethane/hexanes. The resulting white solid was then washed liberally with water to remove any pyridine hydrochloride. The solid product was dried in vacuo to obtain 13.56 grams of the above-titled product. The biphasic filtrate was washed with water in a funnel, separating the organic layer which was then rotary

evaporated to yield a purple brown solid. Trituration with 50:50 dichloromethane/hexanes, and recrystallization from minimal ethyl acetate gave a second crop, weighing 1.43 grams. NMR(300 MHz/DMSO-d6); $\delta$  3.81(s, 3H), 7.36(1H), 7.44-7.71(m, 4H), 7.88-8.11(m, 2H) 9.88(s, 1H).

5 IR(CH<sub>2</sub>Cl<sub>2</sub>/cm<sup>-1</sup>): 3420, 2980, 2940, 1691, 1585, 1487, 1400, 1041, 875, 837.

**Example 2: N-(2,4-dibromo-6-methoxy)phenylthiobenzamide**

The product of the preceding example (14.4g; 37.4 mmol), was dissolved in 35 ml dry pyridine with slight warming. Phosphorous pentasulfide (11g; 49.5 mmol), was added in portions under argon. A thick, light yellow complex formed exothermically. This mixture 10 was stirred for 2 hours in an oil bath at 90°C to give a thinner, darker yellow suspension. The mixture was then refluxed for 15 minutes, and cooled to room temperature. The mixture was treated with 125 ml ethyl acetate to precipitate a gum. Water, 1 ml, was added with swirling to agglomerate the gum prior to decantation of the supernate. The gum was then triturated with 2 X 25 ml ethyl acetate. The combined organics were rotary evaporated to yield an 15 orange oil which contained pyridine. A 7% solution of sodium hydroxide in water was added to the oil with vigorous stirring for 20 minutes. The solution was filtered to remove insolubles rinsing with minimal hydroxide solution. The filtrate was then acidified to pH 1 with 3M HCl, to precipitate a flocky, light yellow solid, which was dissolved in the minimal 20 quantity of dichloromethane. The organic layer was separated and rotary evaporated to yield 12.6g of the above-titled product as a lemon-yellow solid. Analytical samples could be obtained by recrystallization from ethanol to yield a one-spot material on TLC (Kieselgel 60-dichloromethane; Rf=0.56).

NMR(300 MHz/DMSO-d6); $\delta$  3.81(s, 3H), 7.40-7.59(m, 6H), 7.90-7.93(m, 2H), 11.36(s, 1H).

IR(CHCl<sub>3</sub>/cm<sup>-1</sup>): 3380, 2990, 1584, 1490, 1400, 1345, 1040, 878, 838, 695.

**Example 3: 2-Phenyl-4-methoxy-6-bromobenzothiazole**

12.6 grams of the thioamide from the preceding example (31.4 mmol) was warmed in 30 ml of methanol. The suspension was swirled during the addition of 7.35 ml of 4.3 M sodium methoxide in methanol (31.6 mmol). During the addition the solid dissolved and the yellow 5 color faded to light amber. Rotary evaporation of the solvent and pumping in vacuo gave an amber, glassy solid which coated the glass. This thioamide salt was kept under argon during the addition of 20 ml of N-methylpyrrolidone. The flask was capped with a septum and connected to a bubbler as it was placed in an oil bath at 110-120°C. Upon stirring for 30 minutes, a solid developed as the color became green-brown. The flask was then cooled 10 toward room temperature before 100 ml of water was added to produce an off-white solid. The mixture was filtered and the solid washed liberally with water. After drying in vacuo, the solid was recrystallized from 50:50 ethyl acetate:hexanes to yield 7.05g of white, hair-like 15 needles. TLC showed the blue fluorescent product spot at  $R_f$ =0.47, while a trace UV absorbing impurity was present at a higher RF (Kieselgel 60-dichloromethane). The impurity could be removed by silica gel chromatography to obtain an analytical sample. NMR and IR data were consistent with the structure of the above-titled product.

NMR(300 MHz/CDCl<sub>3</sub>): $\delta$  4.10(s, 3H), 7.07(d, 1H), 7.49-7.52(m, 3H), 7.66(d, 1H), 8.11-8.14(m, 2H).

IR(CHCl<sub>3</sub>/cm<sup>-1</sup>): 3003, 2940, 1590, 1562, 1517, 1440, 1400, 1387, 1322, 1260, 1055, 978, 20 830, 690.

**Example 4: 2-Phenyl-4-methoxy-6-formylbenzothiazole**

3 grams of the chromatographed product from the preceding example (9.37 mmol), was dissolved in 70 ml of dry THF under argon. In another flask, 60 ml dry THF was cooled and stirred at -78° under argon. To this flask, 5.6 ml of 2.5 M n-Butyllithium (14.1 mmol) was

added by syringe. The solution of bromobenzothiazole starting material was then added dropwise under argon from an addition funnel over 25 minutes. THF, 7 ml, was used to rinse the funnel at the conclusion of the addition. The red-brown solution was stirred for another 10 minutes at low temperature. Dry DMF, 1.8 ml, was then added dropwise by syringe.

5 After 10 minutes the solution was slowly warmed to room temperature over 1 hour. The reaction was quenched by the rapid addition of 20 ml of 1 M aqueous ammonium chloride solution. The THF was removed on the rotovap, and the product was partitioned between ethyl acetate and the remaining water. The ethyl acetate layer was washed four times with water to remove any DMF. The organics were dried over sodium sulfate and the solvent 10 removed to yield a semi-solid paste. This was triturated with 20 ml of 20% dichloromethane in hexanes to yield a dry solid after decantation and pumping in vacuo. The resulting peach-colored product weighed 1.81 g TLC showed essentially one spot at an R<sub>f</sub> value of 0.62 (Kieselgel 60 – 10% ethyl acetate/hexanes). Spectral data for a similarly obtained product were identical, and consistent with that expected for the above-titled compound.

15 NMR(300 MHz/CDCl<sub>3</sub>): $\delta$  4.18(s, 3H), 7.48-7.56(m, 4H), 8.04(d, 1H), 8.17-8.20(m, 2H), 10.08(s, 1H).  
IR(CHCl<sub>3</sub>/cm<sup>-1</sup>): 3010, 2840, 2740, 1695, 1595, 1572, 1480, 1470, 1395, 1290, 1270, 1145, 1057, 983, 850, 690.

**Example 5: 2-Phenyl-4-methoxy-6-formylbenzothiazole dimethyl acetal**

20 Under argon, 1.8 grams of the aldehyde from the previous example (6.7 mmol) was treated with 11 ml dichloromethane, 0.9 ml of trimethylorthoformate, and 0.7 ml of anhydrous methanol. The suspension was stirred as 105 mg of toluenesulfonic acid monohydrate was added all at once. The flask was closed with a septum after purging it with argon. The solid soon dissolved to give a yellow-orange solution. Stirring was continued overnight at room

temperature. The reaction mixture was neutralized with excess triethylamine (0.15 ml) using a syringe. The mixture was stripped of all volatiles, dissolved in minimal dichloromethane, and plug-chromatographed on a 2 cm X 1.5 inch column of Alumina. The eluant was rotary evaporated and pumped to an oil which slowly solidified. A sample was taken for immediate 5 IR analysis, which showed the absence of any carbonyl absorption. This indicated that acetal formation was complete, and the crude product was used immediately for the next reaction.

IR(CH<sub>2</sub>Cl<sub>2</sub>/cm<sup>-1</sup>): 2940, 2840, 1602, 1580, 1468, 1410, 1355, 1198, 1155, 1060, 996, 837.

**Example 6: Diethyl-1-methoxy-1-(2-phenyl-4-methoxybenzothiazol-6-yl)methanephosphonate**

10 The crude product obtained in the previous step was dissolved in 11 ml of sieve-dried dichloromethane and 1.5 ml of triethylphosphite under argon. The flask was sealed with a septum, and the stirred solution was cooled to -78°C in a dry ice/acetone bath. The pressure was equilibrated at this temperature with an argon balloon. The mixture, which became a suspension, was then treated dropwise with 1.0 ml of borontrifluoride etherate. The 15 suspended solid dissolved as the contents were slowly warmed to about -20°C. The solution was stored in the refrigerator for one hour, and then slowly warmed to room temperature for an overnight stirring period. In the morning, 0.7 grams of solid sodium bicarbonate was added, followed by 15 ml of saturated, aqueous sodium bicarbonate solution. The biphasic 20 was stirred vigorously to expel carbon dioxide. Water was added as necessary over 3 hours to dissolve any inorganics. The dichloromethane layer was separated, and the aqueous layer was back-extracted with 15 ml of the same solvent. The combined organics were subjected to TLC to show a single, UV/blue fluorescent spot at approximately Rf 0.15, tailing back to the origin (Kieselgel 60-ethyl acetate). The solution was evaporated and vacuum pumped at 40°C. The viscous yellow oil was then dissolved in a minimal amount of 50/50

dichloromethane/ethyl acetate and passed over a very short plug of silica gel. The eluant was stripped and chased several times with a mixture of dichloromethane/hexanes. The oily product weighed 2.7 grams. NMR and IR spectroscopy showed a substantially pure product, but the presence of moisture was indicated.

5 NMR(300 MHz/CDCl<sub>3</sub>): $\delta$  1.21-1.36(m, 6H), 3.46(s, 3H), 3.93-4.21(m, 7H), 4.59-4.64(d, 1H), 7.07(s, 1H), 7.47-7.52(m, 3H), 7.57(s, 1H), 8.11-8.14(m, 2H).  
IR(CH<sub>2</sub>Cl<sub>2</sub>/cm<sup>-1</sup>): 3660 & 3460(H<sub>2</sub>O), 2980, 2935, 2860, 1597, 1570, 1510, 1480, 1460, 1445, 1408, 1342, 1245-1285(br), 1100, 1040(br), 965(br), 865, 840, 610.

Example 7: 6-(Methoxytricyclo[3.3.1.1<sup>3,7</sup>]dec-2-ylidenemethyl)-2-phenyl-4-

10 methoxybenzothiazole

2.7 grams of the pumped phosphonate ester from the previous step (6.4 mmol), was dissolved in 25 ml of dry THF under argon. The solution was cooled to -78°C with stirring in a flask outfitted with a septum and an argon balloon. The solution was treated dropwise with enough 2.5 M n-BuLi in hexanes to achieve a just permanent, red-purple color. In this process, all 15 moisture and protic impurities have been titrated. Subsequently 2.7 ml of the same n-BuLi solution (6.75 mmol) were added dropwise to yield a deep burgundy solution. After 10 minutes stirring at low temperature, 2-adamantanone (0.95 grams, 6.33 mmol) was added as a solid under strong argon flow to exclude moisture. The solid dissolved over 10 minutes. The solution was then allowed to warm slowly to room temperature. A reflux condenser was 20 attached while maintaining an argon atmosphere. The mixture was refluxed for 1.5 hours to obtain a light orange solution. THF was then stripped on the rotary evaporator taking care to avoid foaming. The product was partitioned between 25 ml ethyl acetate and 50 ml 1:1 saturated sodium bicarbonate/water. The organic layer was then washed with 25 ml of water. The organic layer was dried over sodium sulfate and stripped to yield a light yellow gum.

The gum was plug-chromatographed on a short column of silica gel, eluting with dichloromethane to remove trace polar contaminants. The appropriate fractions were pumped and chased with dichloromethane-hexanes. The pumped product, weighing 2.14 grams, became a semi-solid upon storage in the freezer. IR spectroscopy revealed a small 2-5 adamantanone carbonyl band, indicating minor contamination which would be eliminated in the next step.

IR(CH<sub>2</sub>Cl<sub>2</sub>/cm<sup>-1</sup>): 2920, 2850, 1597, 1567, 1450, 1402, 1330, 1320, 1310, 1252, 1165, 1100, 1057, 978, 865, 640, 620. Trace AD=0 at 1720 and 1710.

10 **Example 8: 6-(Methoxytricyclo[3.3.1.1<sup>3,7</sup>]dec-2-ylidenemethyl)-2-phenyl-4-hydroxybenzothiazole**

A sodium ethanethiolate solution in DMF was made from 60% sodium hydride and ethanethiol: 240 mg of 60% sodium hydride (6 mmol) was washed three times with hexanes under an argon atmosphere, removing the mineral oil. DMF, 11 ml, was added. The resulting suspension was cooled to 0°C with stirring for the dropwise addition of ethanethiol (0.45 ml, 6 mmol). After hydrogen evolution ceased, the solution was warmed to room 15 temperature, and delivered by pipett to 1.64 grams of methoxy[2-phenyl-4-methoxy(benzothiazol-6-yl)methylidene adamantane, in a separate flask (3.9 mmol) under argon. The resulting solution was stirred in an oil bath at 130°C. After one hour the solution was deep orange, and contained suspended solid. The reaction mixture was cooled and 20 partitioned between 50 ml each of 1 M ammonium chloride and 75% ethyl acetate/hexanes. The organic layer was washed 3 times with 25 ml of water. The combined aqueous layers were back-extracted with the same solvent mixture, which was then washed several times with water. The combined organics were dried over sodium sulfate. TLC (Kieselgel 60-dichloromethane) showed product at Rf=0.23, but also starting material at Rf=0.39. Column

chromatography (silica gel: 50% dichloromethane-hexanes to pure dichloromethane) allowed one pure fraction of the lower R<sub>f</sub> product to be isolated. Repeat chromatography of the mixed fractions allowed additional product to be isolated. After stripping the solvents, a total of 245 mg of the above-entitled product was obtained.

5 NMR(300 MHz/CD<sub>2</sub>Cl<sub>2</sub>): $\delta$  1.74-2.07(m, 14H), 2.71(s, 1H), 3.26 (s, 1H), 3.32(s, 3H), 6.76(s, 1H), 6.94(d, 1H), 7.38(d, 1H), 7.44-759(m, 3H), 7.99-8.16(m, 2H).  
IR(CH<sub>2</sub>Cl<sub>2</sub>/cm<sup>-1</sup>): 3520, 2910, 2850, 1612, 1575, 1480, 1445, 1302, 1284, 1175, 1080, 980, 860.

10 **Example 9: Disodium 6-(methoxytricyclo[3.3.1.1<sup>3,7</sup>]dec-2-ylidenemethyl)-2-**

**phenylbenzothiazolyl-4-phosphate**

Molecular sieve-dried pyridine, 4.0 ml, was placed in a flask under argon. The flask was outfitted with a magnetic stir bar and placed in an ice bath. Distilled phosphorus oxychloride, 0.112 ml (1.2 mmol), was added dropwise by syringe. In another flask, 245 mg of the hydroxybenzothiazole derivative from the previous example was dissolved in 15 ml of anhydrous THF under argon. The THF solution was then added slowly and dropwise to the stirred solution of phosphorylating agent. During the addition, a precipitate developed. At the end of the addition, the flask and syringe were rinsed with 2 ml of THF which was also added slowly to the reaction flask. The reaction mixture was then warmed to room temperature and stirred for three hours. A cotton-tipped needle on a 20 ml syringe was used to draw up the supernate, leaving the pyridine hydrochloride behind. This supernate was added dropwise to a solution of 15 ml 0.5 M sodium hydroxide, which had been diluted to a volume of 75 ml with water, while being stirred at ice-bath temperature. The slightly cloudy solution cleared upon warming to room temperature. The solution was carefully pumped to remove THF and the volume adjusted to 110 ml with 5.0 ml acetonitrile and water. This

solution was injected in two portions onto a Polymer Laboratories 2 inch polystyrene reverse-phase HPLC column. A gradient of 5% to 10% acetonitrile was used to allow separation of the major peak absorbing at 270 nm. This gradient will require optimization for any specific equipment. The appropriate fractions were pooled and lyophilized to obtain 294 mg of a light 5 yellow solid. Spectral data were in concert with the above-titled structure. An analytical HPLC chromatogram on a similar support, using an acetonitrile gradient against 0.1% aqueous sodium bicarbonate, showed a single product eluting at 13.2 minutes (approximately 50% acetonitrile).

10 NMR(300 MHz/D<sub>2</sub>O): $\delta$  1.38-2.02(m, 14H), 2.51(s, 1H), 3.00(s, 1H), 3.24(s, 3H), 7.26-7.53(m, 5H), 7.75-8.04(m, 2H).

**Example 10: Disodium 6-(4-methoxyspiro-[1,2-dioxetane-3.2'-tricyclo[3.3.1.1<sup>3,7</sup>]decan]-4-yl)2-phenylbenzothiazolyl-4-phosphate**

285 milligrams of the enol ether phosphate from the previous step was placed in a tube. The solid was wet down with 1.0 ml of methanol and then dissolved by adding 25 ml of 15 dichloromethane. The solution was then treated with 0.5 ml of a solution of 5, 10, 15, 20-tetraphenyl-21 H, 23 H-porphine (2 mg/ml in CHCl<sub>3</sub>). The contents of the tube were cooled to 0°C while the solution was sparged with oxygen gas. After 5 minutes, while continuing to bubble oxygen through the solution, the tube was irradiated with light from a cooled, 400 watt sodium vapor lamp while maintaining the temperature at 5°C. A 5 mil thick piece of 20 Kapton polyimide film, placed between the lamp and the tube filtered out unwanted UV radiation. The irradiation was continued for 17 minutes. Analytical HPLC [0.1% NaHCO<sub>3</sub>, (H<sub>2</sub>O)-acetonitrile gradient] showed that the conversion of the starting material, eluting at 13.2 minutes, to the 1,2-dioxetane, which eluted at 12.94 minutes, was substantially complete. The reaction mixture was stripped of solvents to give a red gum. Acetonitrile, 5 ml, and 0.05

M aqueous sodium hydroxide, 20 ml, were added with swirling and occasional cooling to dissolve the gum. DI water was then added to give a total volume of 70 ml. This solution was filtered through highly retentive filter paper, rinsing carefully with water in small portions, to give a filtrate volume of 110 ml. This solution was injected in two portions onto a Polymer Laboratories 1 inch polystyrene reverse-phase HPLC column. A gradient of 5% to 100% acetonitrile (against water) was used to allow separation of the major peak absorbing at 270 nm. This gradient will require optimization for any specific equipment. An analytical HPLC chromatogram of the combined product fractions on a similar support, using an acetonitrile gradient against 0.1% aqueous sodium bicarbonate, showed a single product eluting at 12.96 minutes (approximately 50% acetonitrile). The appropriate fractions were pooled and lyophilized to obtain 287 mg of a light yellow solid. The product 1,2-dioxetane produced green light at 558 nm when triggered with alkaline phosphatase in an aqueous buffer at pH 8.5.

UV: 213, 260.5, and 304 nm in 50/50 CH<sub>3</sub>CN/H<sub>2</sub>O

15 **Example 11: 2-Methoxy-4,6-dibromophenylisothiocyanate**

19.75 grams of 4,6-dibromo-o-anisidine (70 mmol) and 20 grams of solid bicarbonate were placed in a flask under argon. A large, heavy-duty magnetic stir bar was added, followed by 120 ml acetonitrile and 50 ml dichloromethane. The suspension was stirred at 0°C as 6.0 ml of thiophosgene was added rapidly by syringe. A thick precipitate developed immediately.

20 This was stirred vigorously as the contents of the flask were slowly warmed to room temperature. The carbon dioxide generated was led to a bubbler with a needle vent. The mixture thinned slightly as it warmed, and was more easily stirred. Vigorous stirring was continued for two hours. The suspension was then recooled to 0°C. The solid was filtered off on a Buchner funnel, rinsing the flask and transferring any remaining solid with 30 ml of

cold acetonitrile. The filtrate was rotary evaporated to a solid containing areas of orange discoloration. This solid was triturated with hexanes, pumped dry, and transferred to the Buchner funnel containing the white, original filter cake. This solid was washed with 5 X 100 ml portions of a 0.5 M aqueous solution of  $\text{NaH}_2\text{PO}_4$  in order to neutralize the inorganic bicarbonate present (carbon dioxide was released). The solid was broken up during each rinse. The white product was then washed liberally with water and dried in vacuo. The dry product weighed 21.8 grams. Analytical data obtained from a similarly synthesized product were in agreement with the above-titled structure.

$\text{NMR}(300 \text{ MHz}/\text{CDCl}_3): \delta$  3.92(s, 3H), 6.98(d, 1H), 7.31(d, 1H).

$\text{IR}(\text{CH}_2\text{Cl}_2/\text{cm}^{-1}): 3020, 2970, 2940, 2030(\text{br}), 1575, 1555, 1470, 1400, 1040, 935, 870, 840.$

**Example 12: 2-Phenyl-4-methoxy-6-bromobenzothiazole[One Pot Method]**

15.5 grams of the isothiocyanate from the preceding example (48 mmol), was dissolved in 50 ml of dry THF under argon. The solution was cooled to 0°C with stirring in an ice bath. A solution of phenylmagnesium bromide (Aldrich, 1.0 M in THF), 50 ml (50 mmol), was added by syringe in a thin stream. After stirring in the cold for 10 minutes, the solution was slowly warmed to room temperature. At this point a precipitate began to appear as a minor exotherm occurred. The light orange-brown suspension became thicker over 2 hours. The solvent was removed by rotary evaporation at 30°C to obtain a moist, peach-colored solid coating the glass. This material was protected from air as 50 ml of sieve-dried DMF was added. The solid dissolved with a slight exotherm. The flask was placed in an oil bath at 125°C. Over 45 minutes, any residual THF was allowed to distill from the flask using a short path distillation head. The mixture darkened during this time, and a suspended solid was produced. Upon cooling to room temperature, the contents of the flask solidified. Aqueous 1 M HCl, 100 ml was added, breaking up the solid. Water, 100 ml, was added subsequently.

The mixture was macerated to remove any coordinated magnesium ion. The mixture was then filtered and washed well with water. The moist solid was taken up in 2 X 250 ml warm ethyl acetate, separating the supernate from insoluble flock. The combined organics were dried over sodium sulfate and stripped to give 13.27 grams of a light brown solid. TLC 5 showed a major blue fluorescent product spot at  $R_f$ =0.47, while a trace UV absorbing impurity was present at a higher  $R_f$  (Kieselgel 60-dichloromethane). A small, colored origin spot was removed by plug chromatography over silica gel (dichloromethane). Combining the appropriate fractions gave 12.29 grams of the product, essentially identical to that of Example 3, but still containing a trace amount of the higher  $R_f$  impurity. The reaction of this example 10 may also be acidified and worked up after the phenyl magnesium bromide has reacted with the isothiocyanate to obtain the thioamide product of Example 2.

The following were also synthesized according to the general synthetic methodology described above. One of skill in the art may easily invoke minor modifications as necessary. Any other route to the benzothiazole system may be employed as well.

15 **Example 13: 2-(p-benzyloxybenzamido)-3,5-dibromoanisole**

NMR(300 MHz/DMSO-d6): $\delta$  3.79(s, 3H), 5.21(2H), 7.11-7.14(d, 2H), 7.34-7.52(m, 7H), 7.93-7.96(d, 2H), 9.70(s, 1H).

**Example 14: N-(2,4-dibromo-6-methoxy)-p-benzyloxypheylthiobenzamide**

NMR(300 MHz/DMSO-d6): $\delta$  3.80(s, 3H), 5.22(2H), 7.08-7.11(d, 2H), 7.32-7.55(m, 7H), 7.95-7.98(d, 2H), 11.12(s, 1H).

**Example 15: 2-(p-benzyloxy)phenyl-4-methoxy-6-bromobenzothiazole**

NMR(300 MHz/DMSO-d6): $\delta$  4.00(s, 3H), 5.21(2H), 7.17-7.22(m, 3H), 7.34-7.50(m, 5H), 7.93-8.01(m, 3H).

**Example 16: 2-(p-benzyloxy)phenyl-4-methoxy-6-formylbenzothiazole**

NMR(300 MHz/DMSO-d<sub>6</sub>): $\delta$  4.05(s, 3H), 5.23(2H), 7.20-7.23(d, 2H), 7.33-7.50(m, 6H), 8.05-8.08(d, 2H), 8.31-8.32(d, 1H), 10.04(s, 1H).

**Example 17: 2-(p-benzyloxy)phenyl-4-methoxy-6-formylbenzothiazole dimethyl acetal**

5 IR(CHCl<sub>3</sub>/cm<sup>-1</sup>): 3000, 2940, 2840, 1611, 1580, 1530, 1490, 1470, 1355, 1180, 1155, 1060, 1020, 980, 838, 700.

**Example 18: diethyl-1-methoxy-1-[2-(p-benzyloxy)phenyl-4-methoxybenzothiazol-6-vl]methanephosphonate**

10 NMR(300 MHz/CDCl<sub>3</sub>): $\delta$  1.19-1.37(m, 6H), 3.43(s, 3H), 3.86-4.18(m, 7H), 4.51-4.75(m, 1H), 5.12(s, 2H), 7.02-7.03(m, 2H), 7.30-7.52(m, 7H), 8.02-8.06(m, 2H).

**Example 19: 6-(Methoxytricyclo[3.3.1.1<sup>3,7</sup>]dec-2-ylideneethyl)-2-(p-benzyloxy)phenyl-4-methoxybenzothiazole**

NMR(300 MHz/CDCl<sub>3</sub>): $\delta$  1.78-2.1(m, 14H), 2.74(s, 1H), 3.30(s, 1H), 3.35(s, 3H), 4.06(s, 3H), 5.12(s, 2H), 6.85-6.96(m, 1H), 6.99-7.12(m, 2H), 7.29-7.50(m, 6H), 7.99-8.14(m, 2H).

15

**Table 1**

Half-life of Dephosphorylated dioxetanes pH 10.

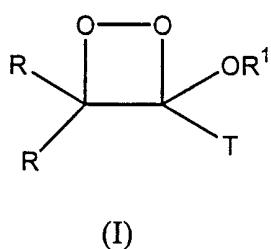
Dioxetane	t $\frac{1}{2}$ , sec
BZPD	2.3
CSPD®	57.6
CDP- <i>Star</i> ®	96

20

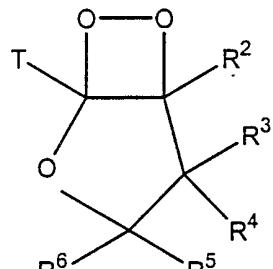
Plus Sapphire-II™	t $\frac{1}{2}$ , sec
BZPD	54.9
CSPD®	228
CDP- <i>Star</i> ®	420

## IN THE CLAIMS:

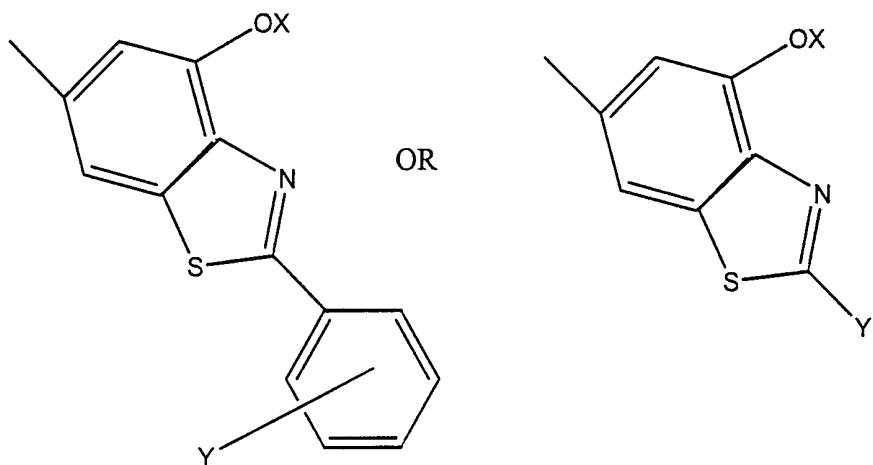
1. A 1,2-dioxetane compound capable of producing light energy when decomposed, represented by the formula:



OR



5 wherein T is:



and wherein R may independently be any branched alkyl or cycloalkyl group which provides stabilization for the dioxetane or where both R groups together form a cycloalkyl or polycycloalkyl moiety spiro bound to the dioxetane ring, wherein each R group or the spiro bound moiety may be unsubstituted or substituted with one or more electron-withdrawing groups or electron donating groups, and wherein R<sup>1</sup> is an aryl group, or an alkyl group of 1-

20 carbon atoms, which may be optionally substituted with 1 or more halogen atoms, and wherein Y may be H, or an electron donating or withdrawing group, or an organic linker group which may be attached to (1) an ancillary fluorophore, or (2) any biological moiety, and wherein X may be any protecting group which is removed by non-enzymatic chemical or 5 enzymatic means, where R<sup>2</sup> - R<sup>6</sup> are each independently H, alkyl of 1-20 carbon atoms, or an aryl group, where each of R<sup>2</sup> - R<sup>6</sup> may be unsubstituted or substituted one or more with electron-donating groups or electron-withdrawing groups, wherein R<sup>3</sup> and R<sup>4</sup> may be joined as a spiro-fused cycloalkyl group.

2. A compound of Claim 1, wherein X is phosphate, both R groups together form a 10 spiroadamantyl group, and R<sup>1</sup> is methyl, and Y is hydrogen.

3. A compound of Claim 1, wherein at least one of an R group, R<sup>2</sup> - R<sup>6</sup> and Y bear a substituent which improves the solubility of said dioxetane in aqueous solution.

4. A compound of Claim 2, wherein each substituent improving solubility is a carboxylic acid moiety, a sulfonic acid moiety or a phosphoric acid moiety.

15 5. A compound of Claim 1, wherein at least one of R<sup>2</sup> - R<sup>6</sup> is substituted with an electron-active group.

6. A compound of Claim 1, wherein X is an enzyme removable group.

7. A compound of Claim 1, wherein X is a moiety which is removed by change in pH or heat.

20 8. A compound of Claim 1, wherein Y is an alkyl or alkoxy moiety linked to a fluorophore in an energy transfer relationship with said dioxetane.

9. A kit for detecting a first substance in a sample, comprising a cleavable chemiluminescent 1,2-dioxetane compound of Claim 1.

10. The kit of Claim 9, further comprising an enzyme which, in the presence of said dioxetane, causes said dioxetane to decompose.

11. The kit of Claim 9, further comprising a water soluble enhancing substance which enhances the chemiluminescence detectable from decomposition of said dioxetane.

5 12. The kit of Claim 11, wherein said enhancing substance is a quaternary onium polymer.

13. The kit of Claim 11, wherein said kit further comprises an additive which improves the enhancement of chemiluminescence detected by said enhancement agent.

14. The kit of Claim 9, wherein said 1,2-dioxetane compound is the dioxetane of  
10 Claim 3.

15. A method for detecting a first substance in a sample, comprising adding the compound of Claim 1 to said sample, wherein X is removed by said substance, incubating said sample and inspecting said sample for the generation of light, wherein light so generated is indicative of the presence, and the amount of light detected is indicative of the amount, of  
15 said first substance.

16. The method of Claim 15, wherein said method further comprises adding an enhancement agent to said sample, to enhance the amount of light detected.

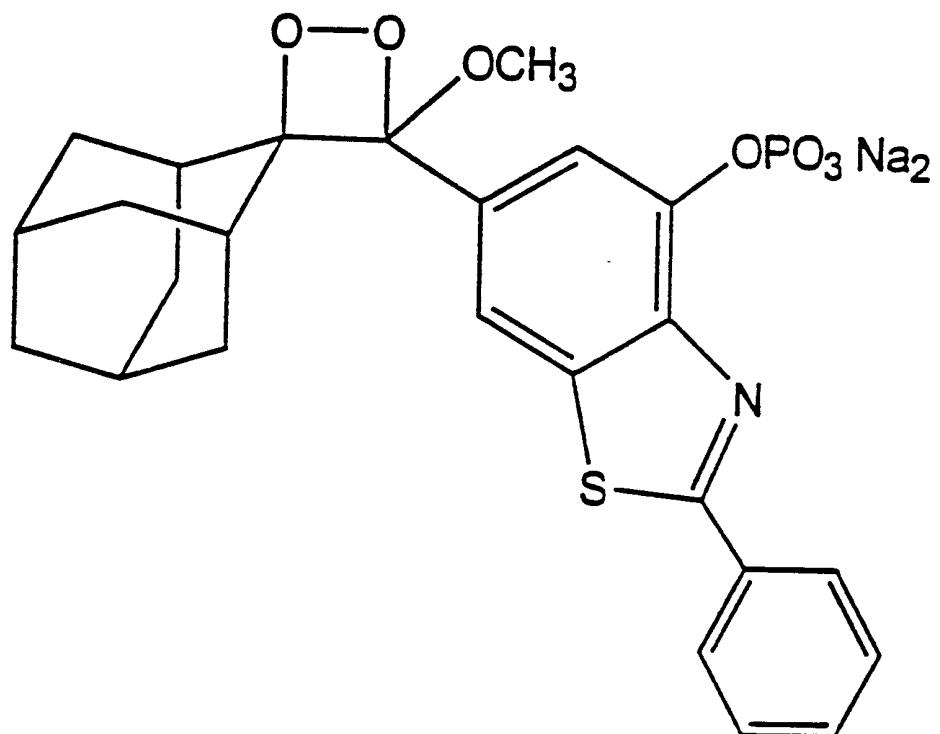
17. The method of Claim 15, wherein said light is detected by a CCD camera.

18. The method of Claim 16, wherein said enhancement agent is an onium quaternary  
20 polymer.

19. The method of Claim 18, wherein said method further comprises the addition of an enhancement additive, to improve the enhancement of detected chemiluminescent emission effected by said enhancement agent.

20. The method of Claim 15, wherein said substance is an enzyme.

21. The method of Claim 20, wherein said enzyme is complexed with a biological moiety of interest.

**FIGURE 1**

**FUSED(HETEROARYL)BENZOTIAZOLE  
1,2-DIOXETANE PHOSPHATE**

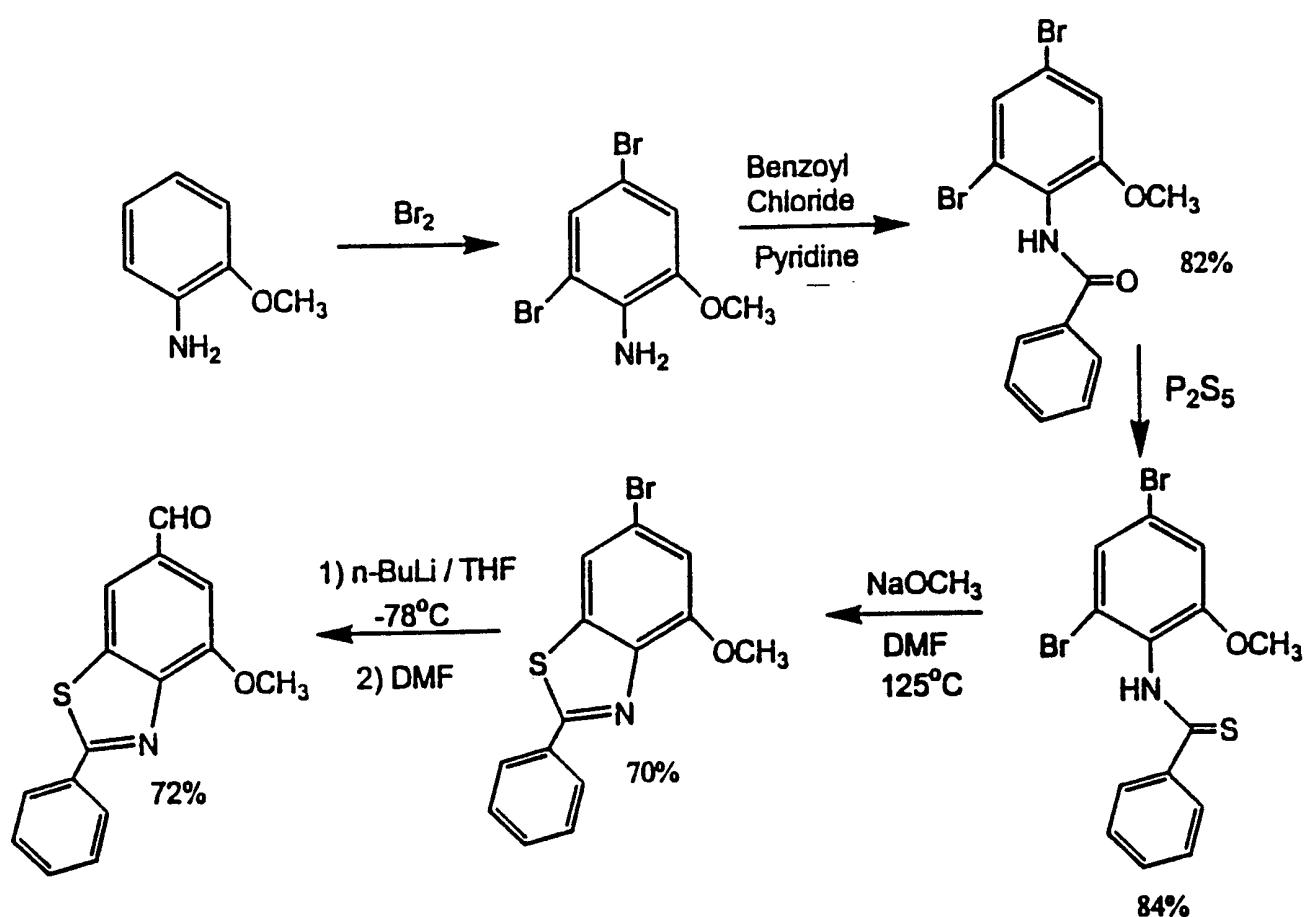
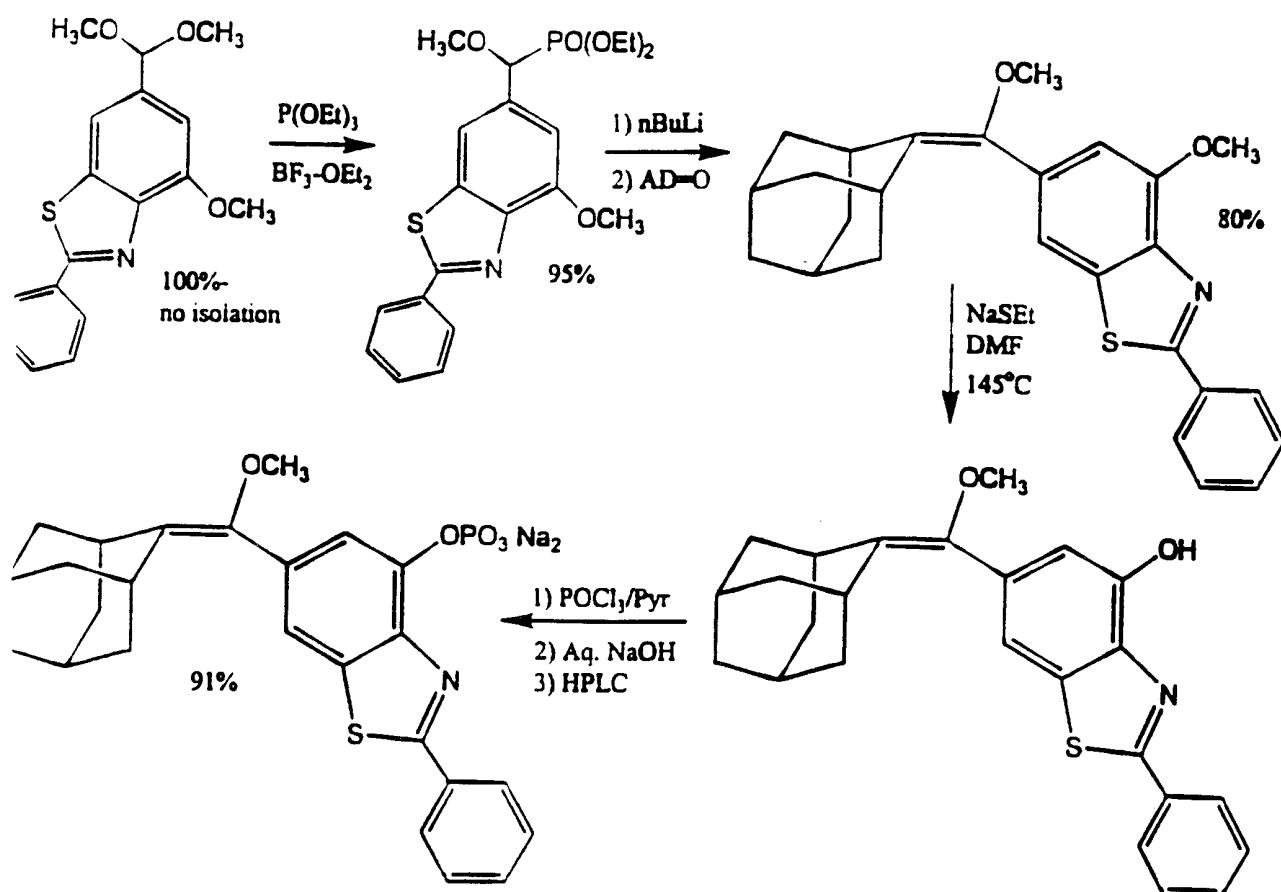
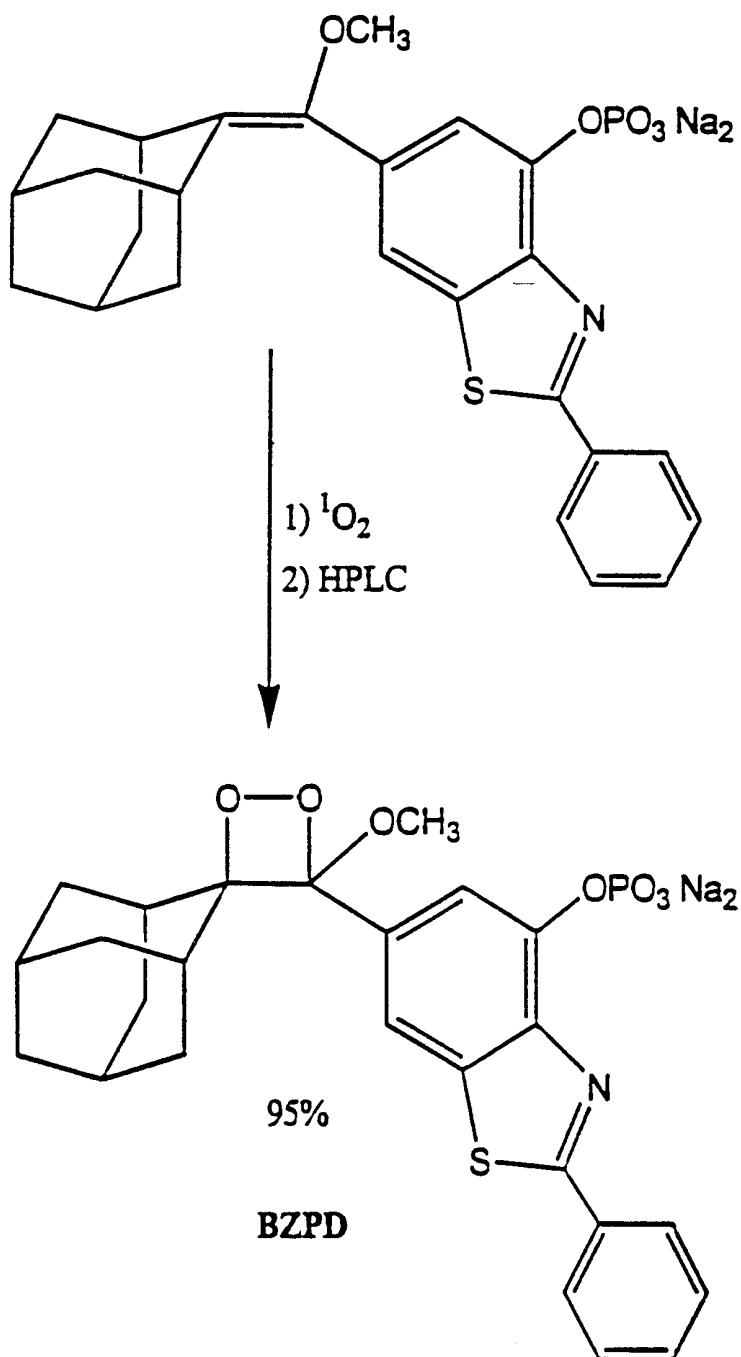
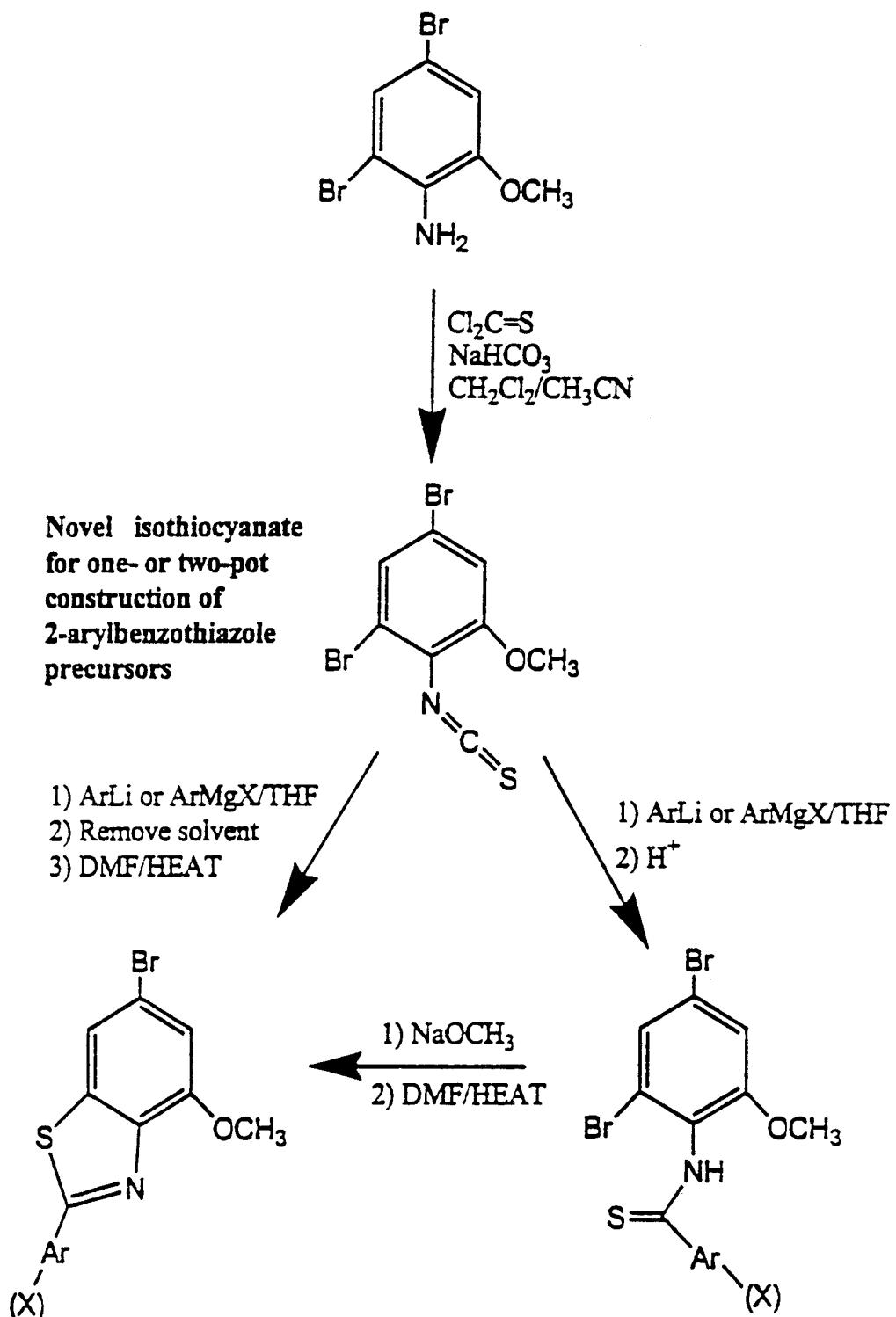
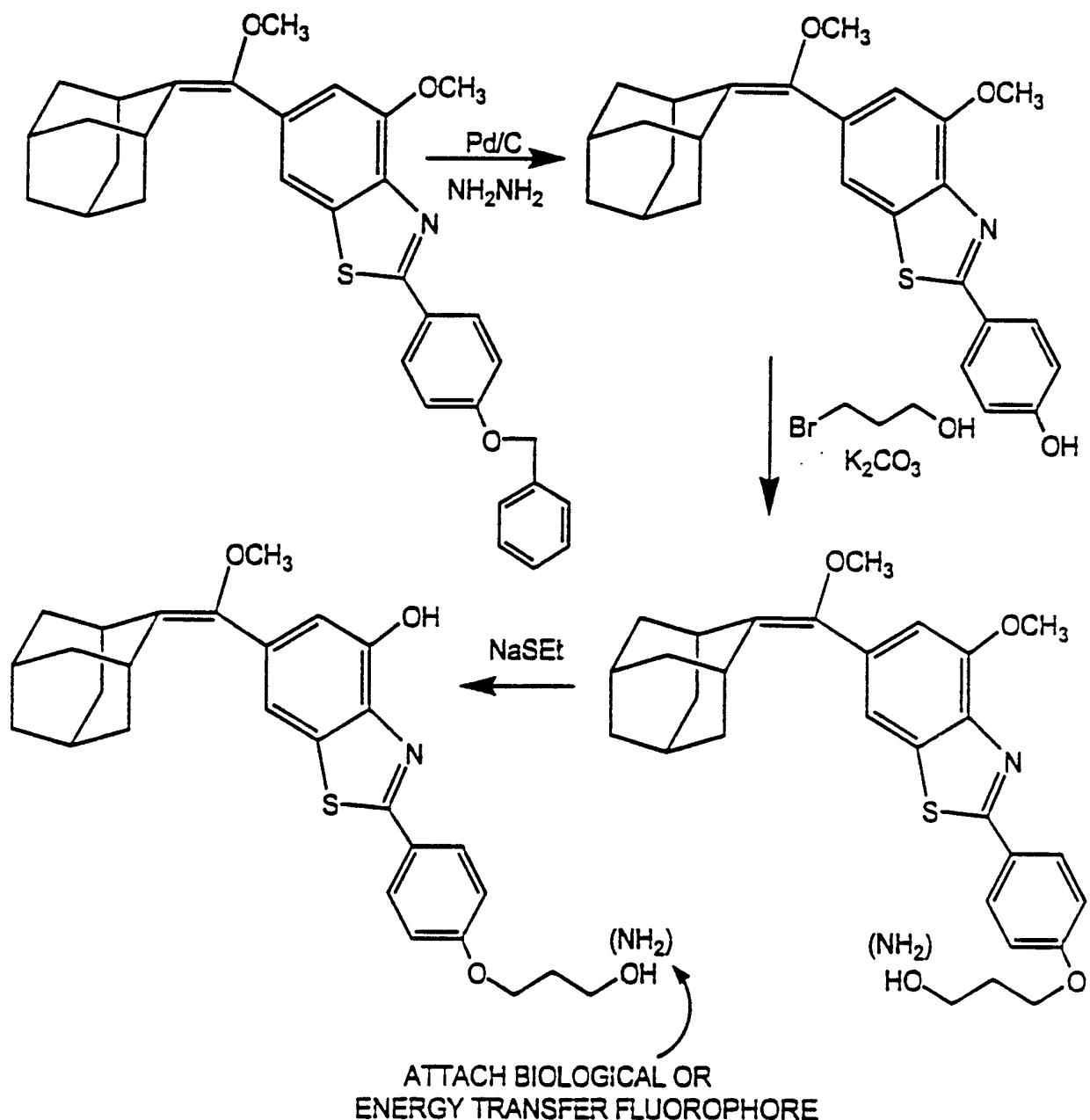
**FIGURE 3****SYNTHESIS OF THE FUSED BENZOTHIAZOLE 1,2-DIOXETANE BZPD**

FIGURE 3 (CONTINUED)

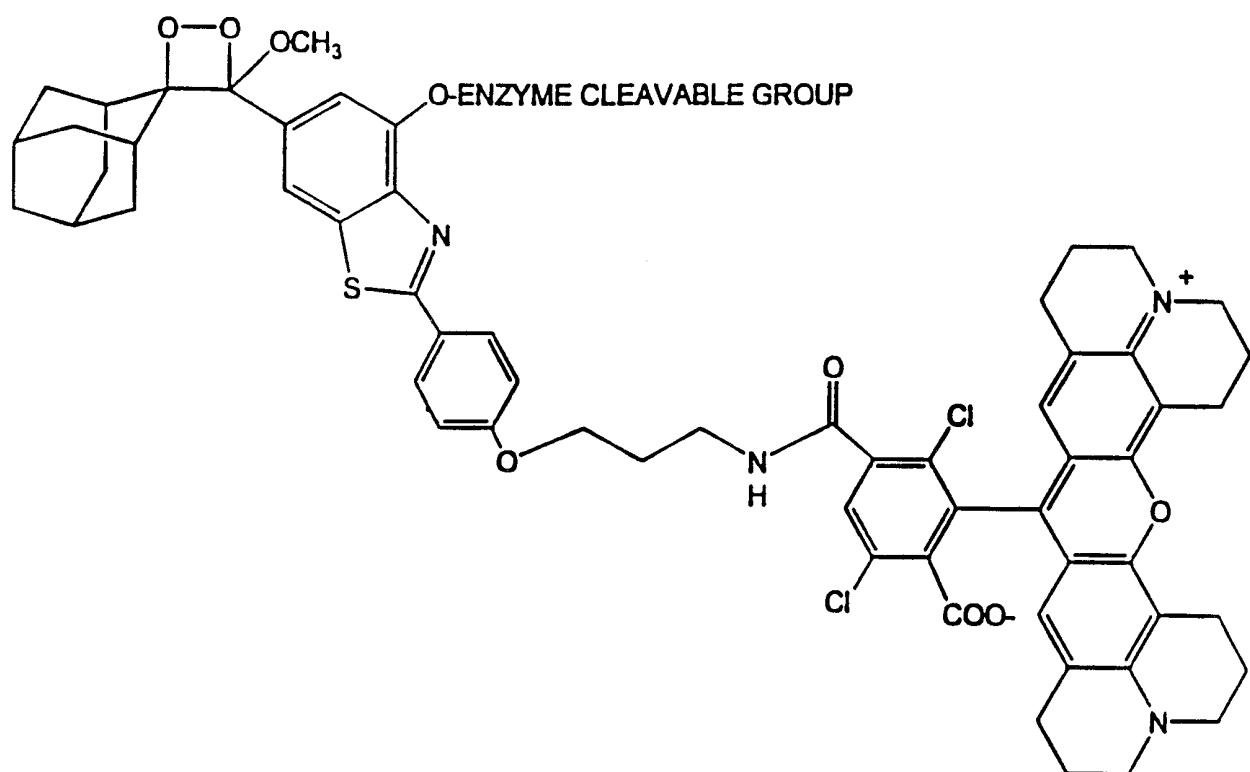
**PHOTOXYGENATION OF BENZOTHIAZOLE ENOL ETHER PHOSPHATE**

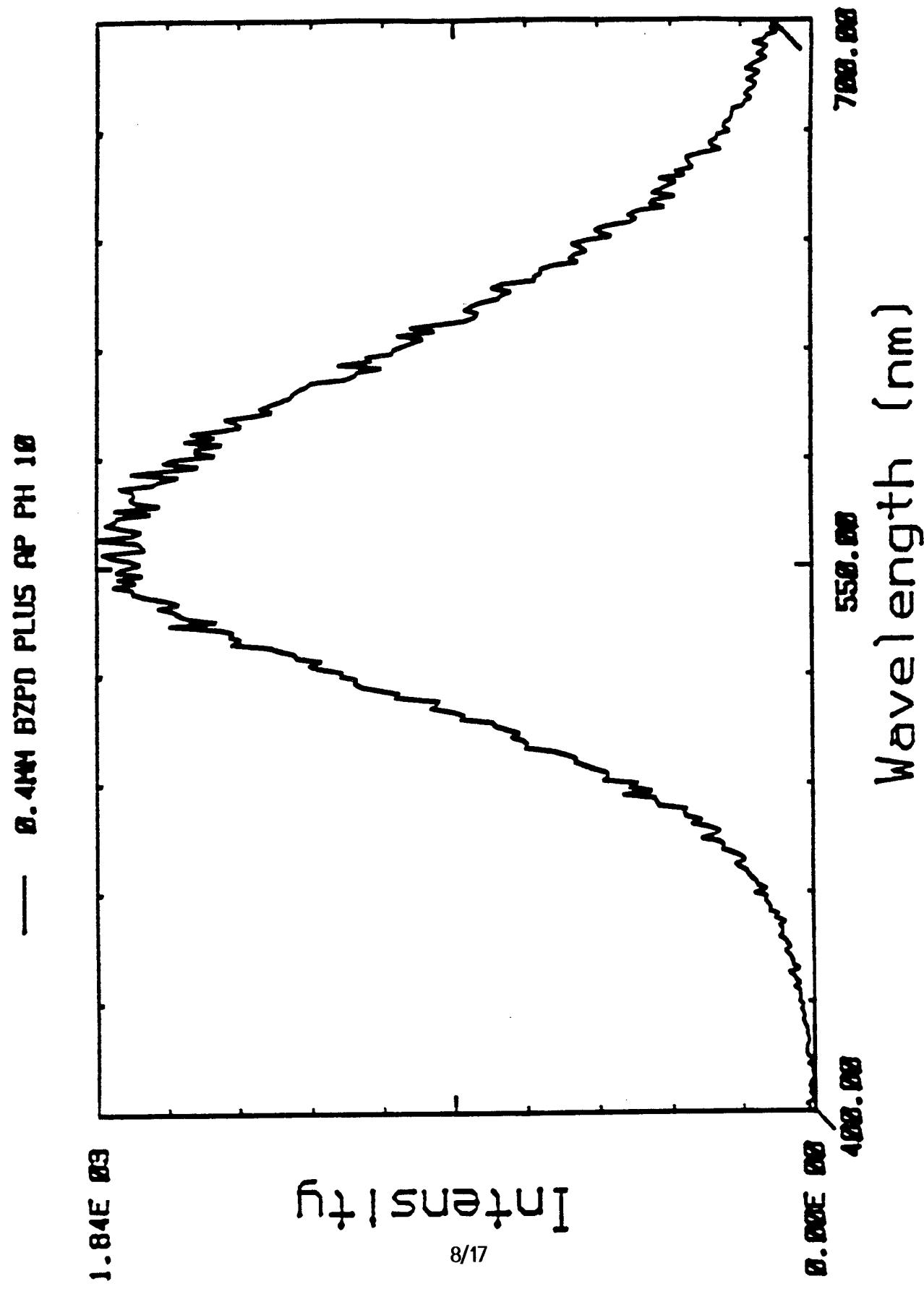
**FIGURE 5**

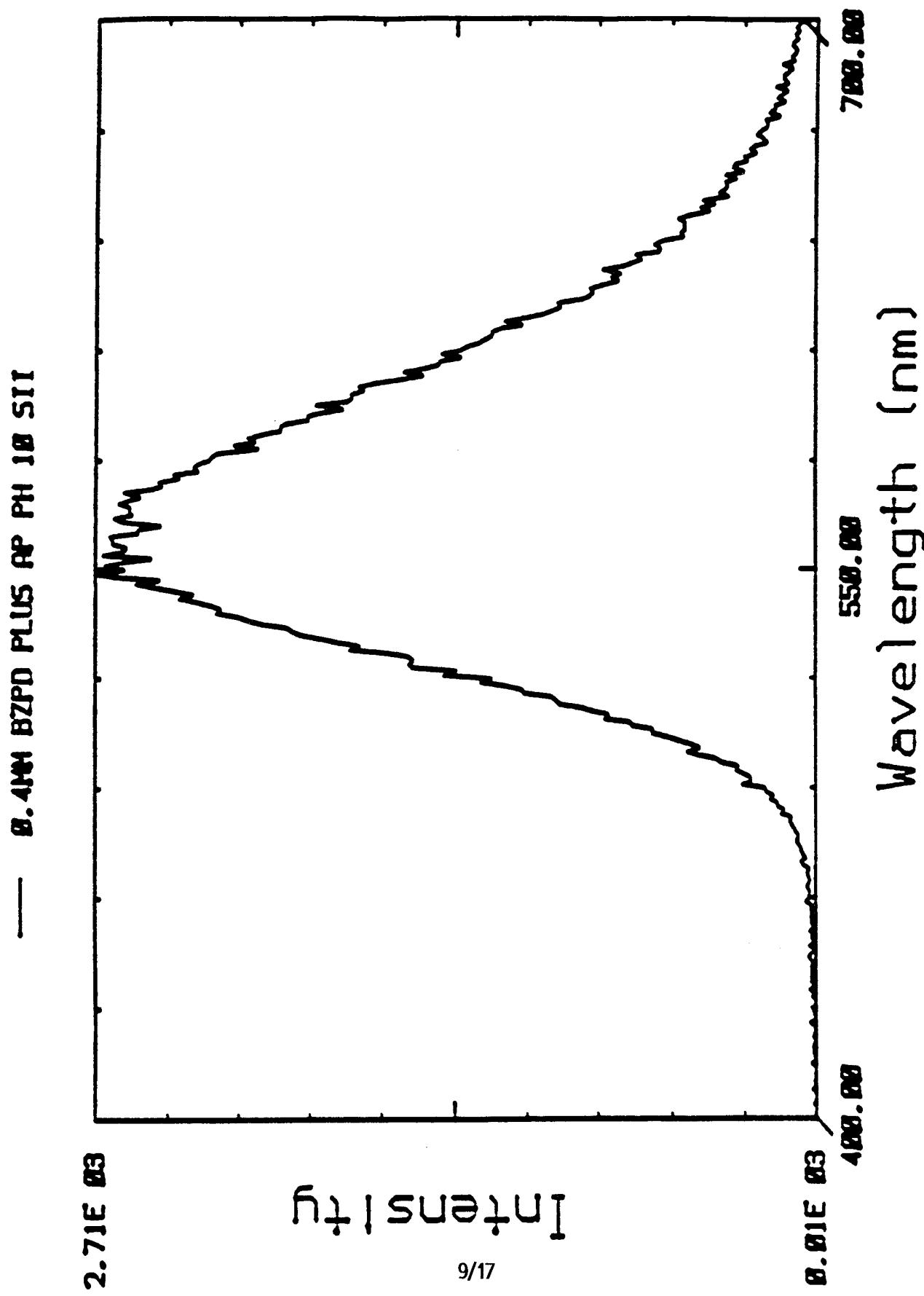
**BENZYLOXY ENOL ETHER DERIVATIVES ALLOW REGIOSELECTIVE LIBERATION  
OF A PHENOL TO CREATE A LINKABLE GREEN-EMITTING SYSTEM**

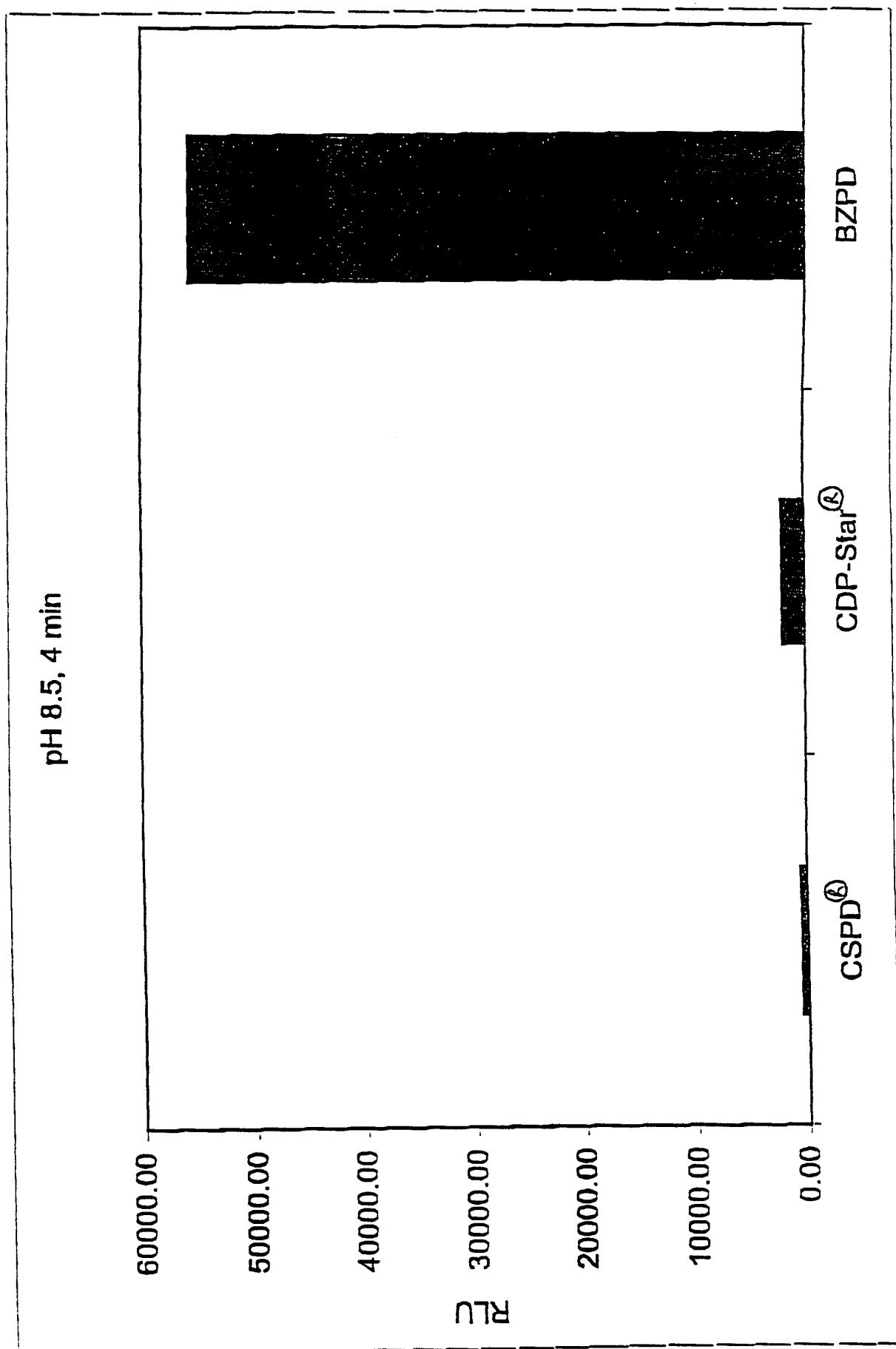


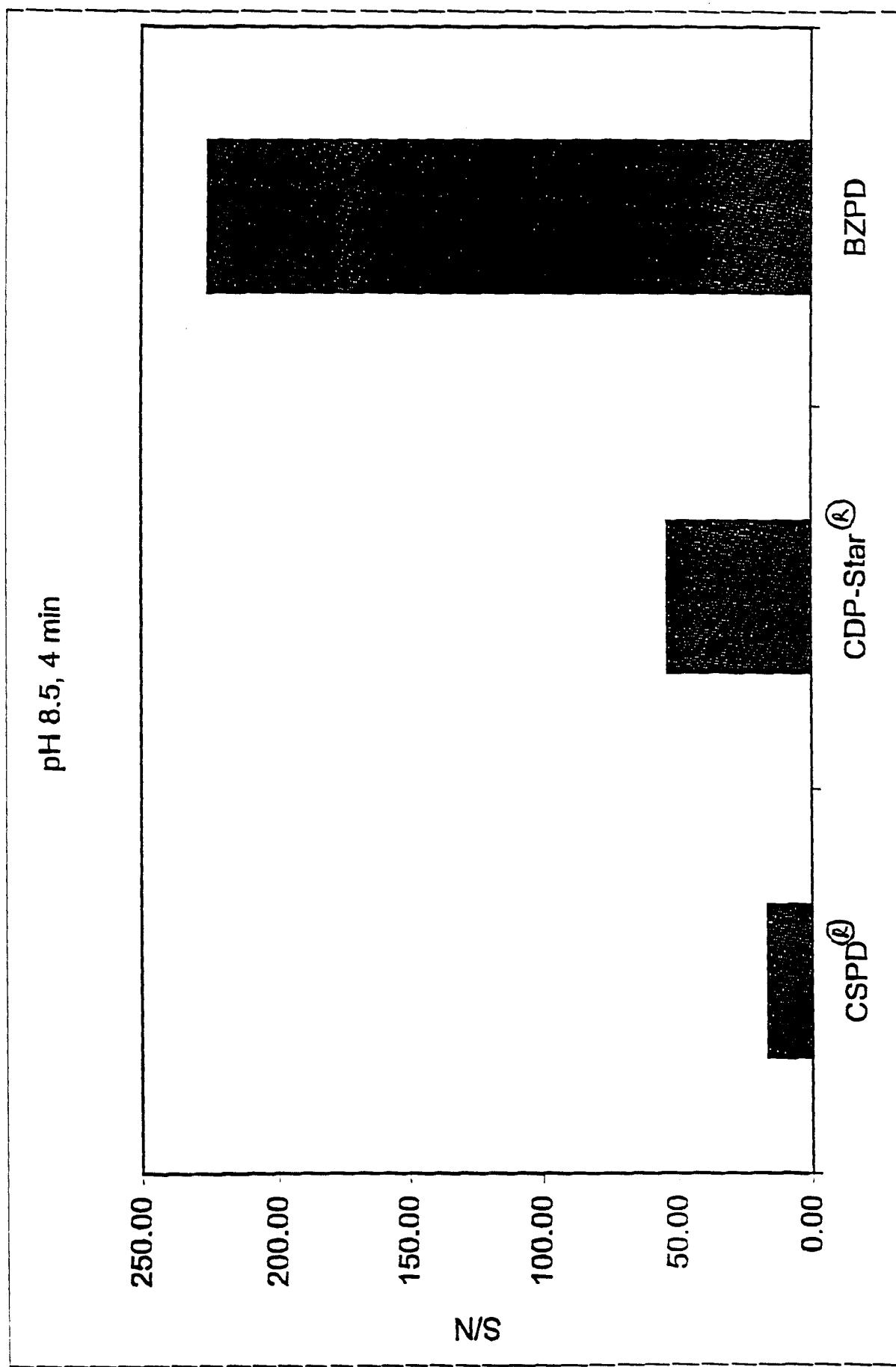
ATTACH BIOLOGICAL OR  
ENERGY TRANSFER FLUOROPHORE

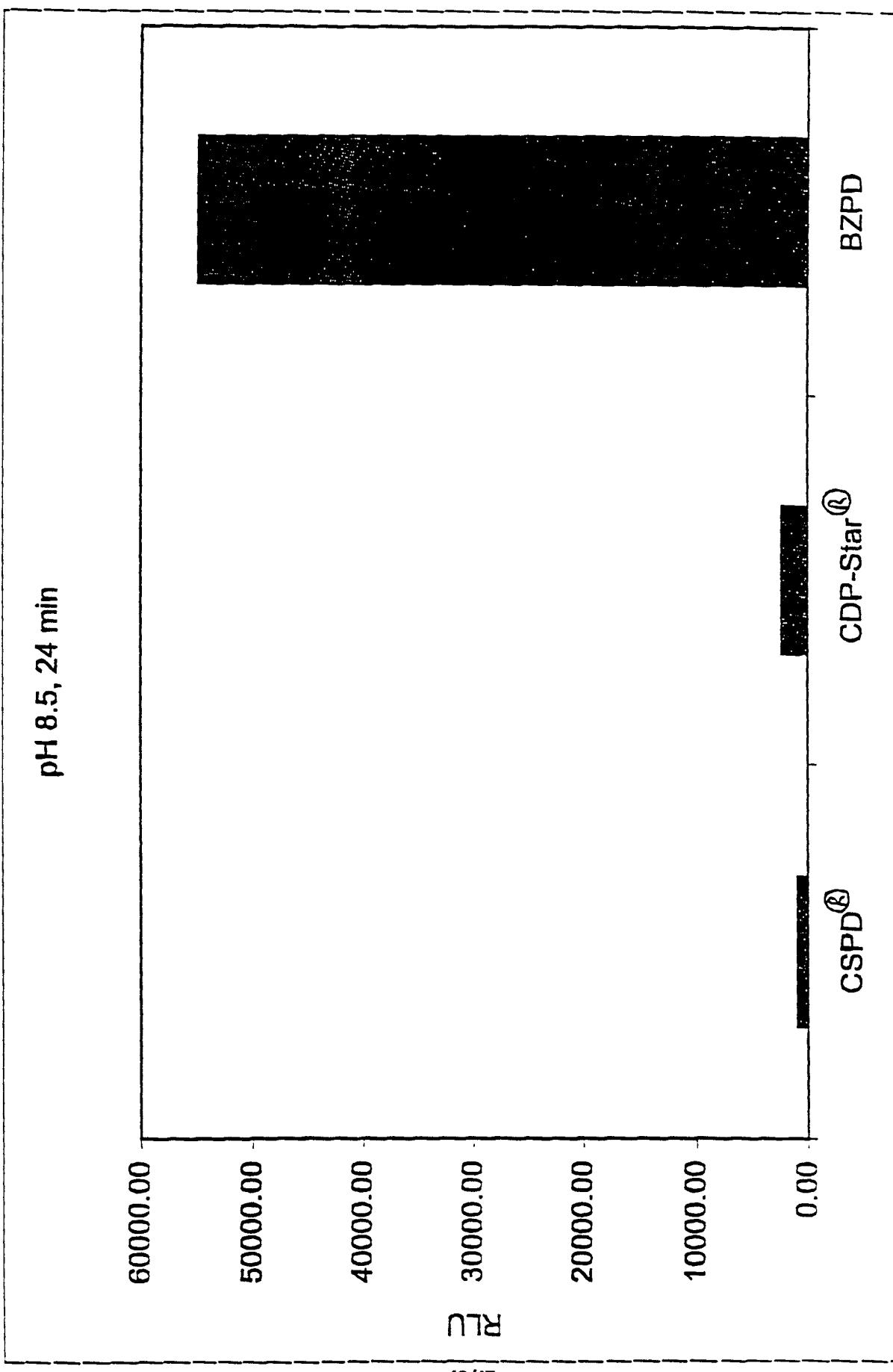
**FIGURE 8****BENZOTHIAZOLE-DROX ENERGY TRANSFER ENZYME SUBSTRATE**

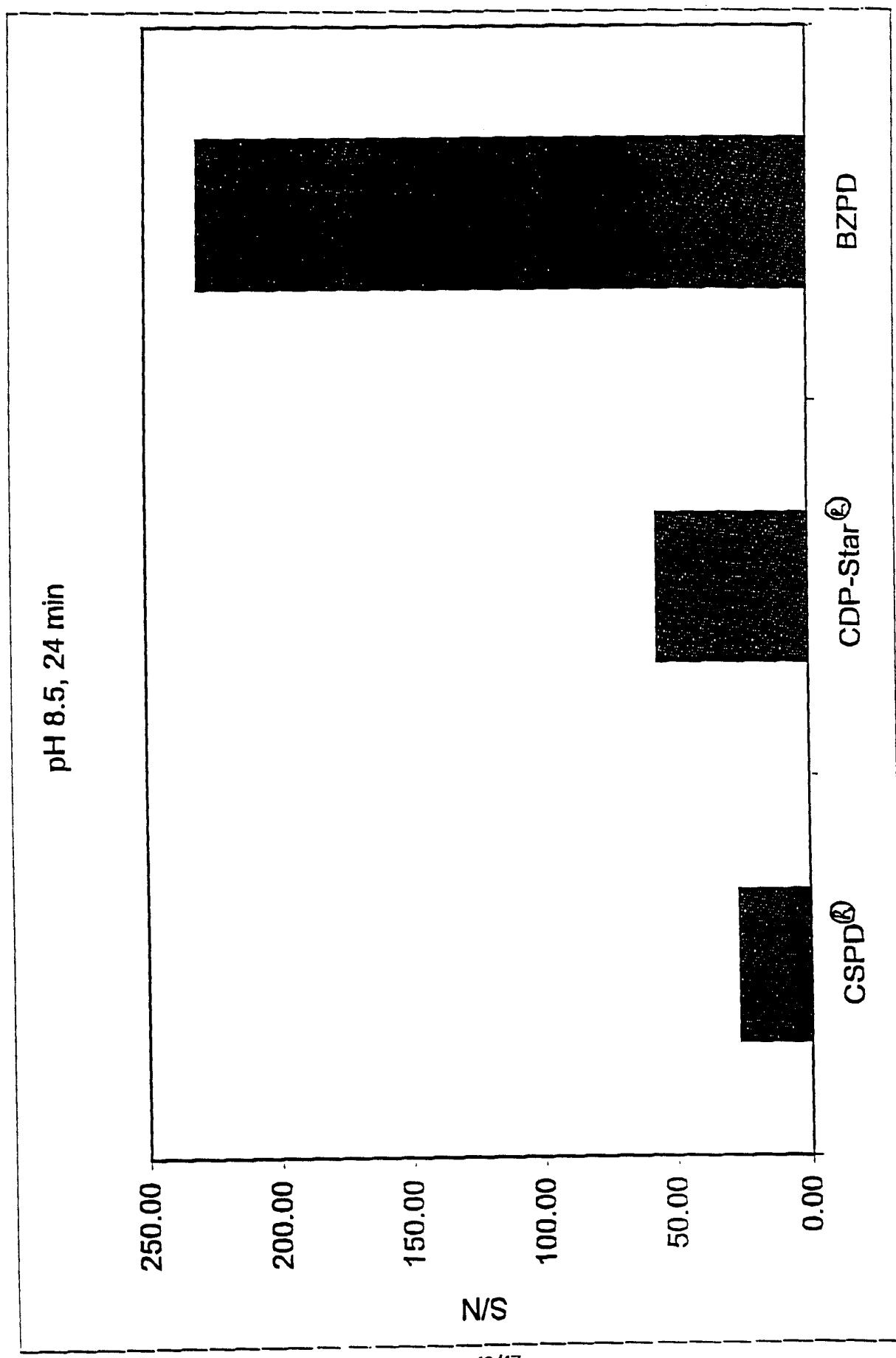
**FIGURE 9**

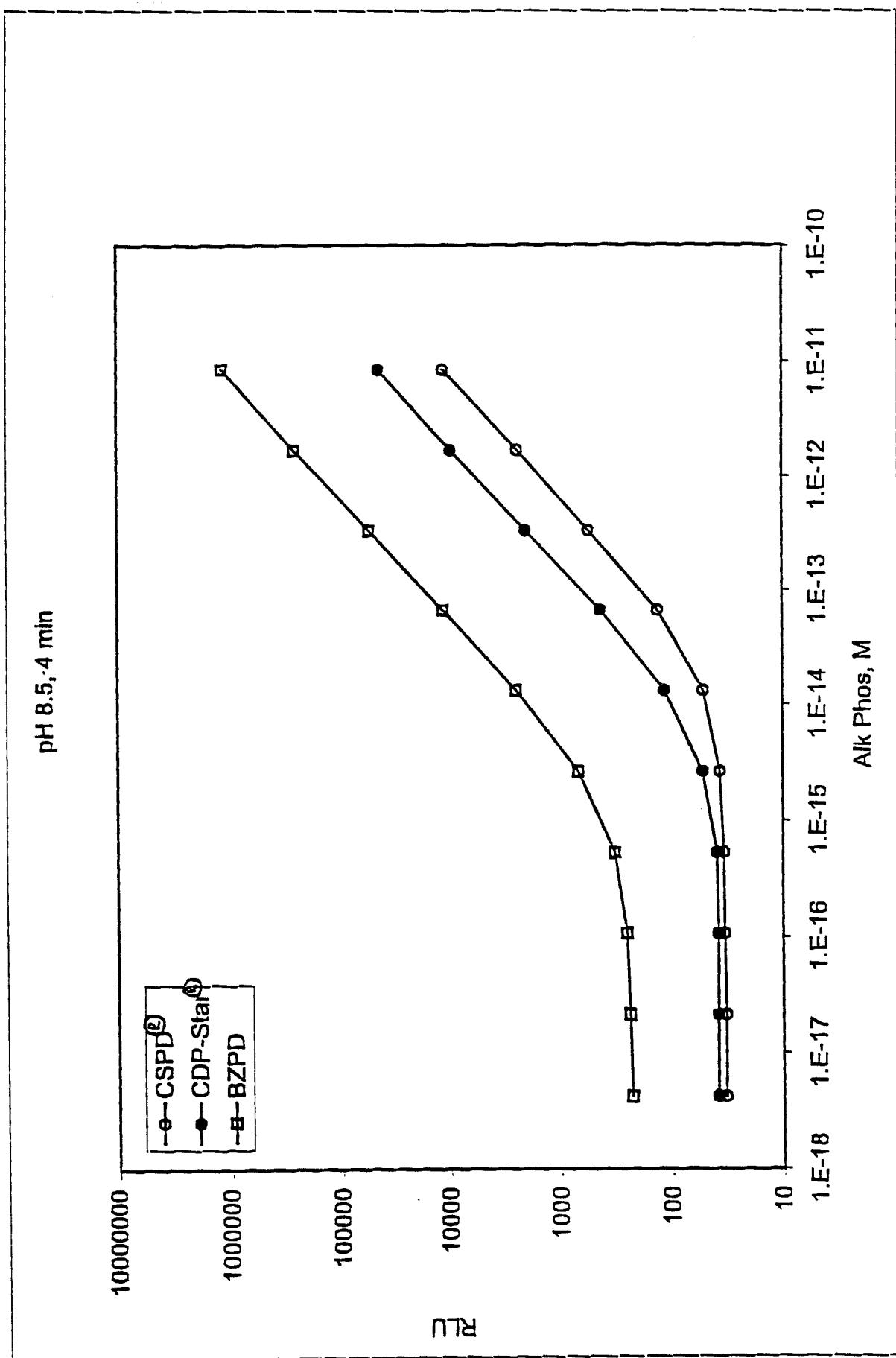
**FIGURE 10**

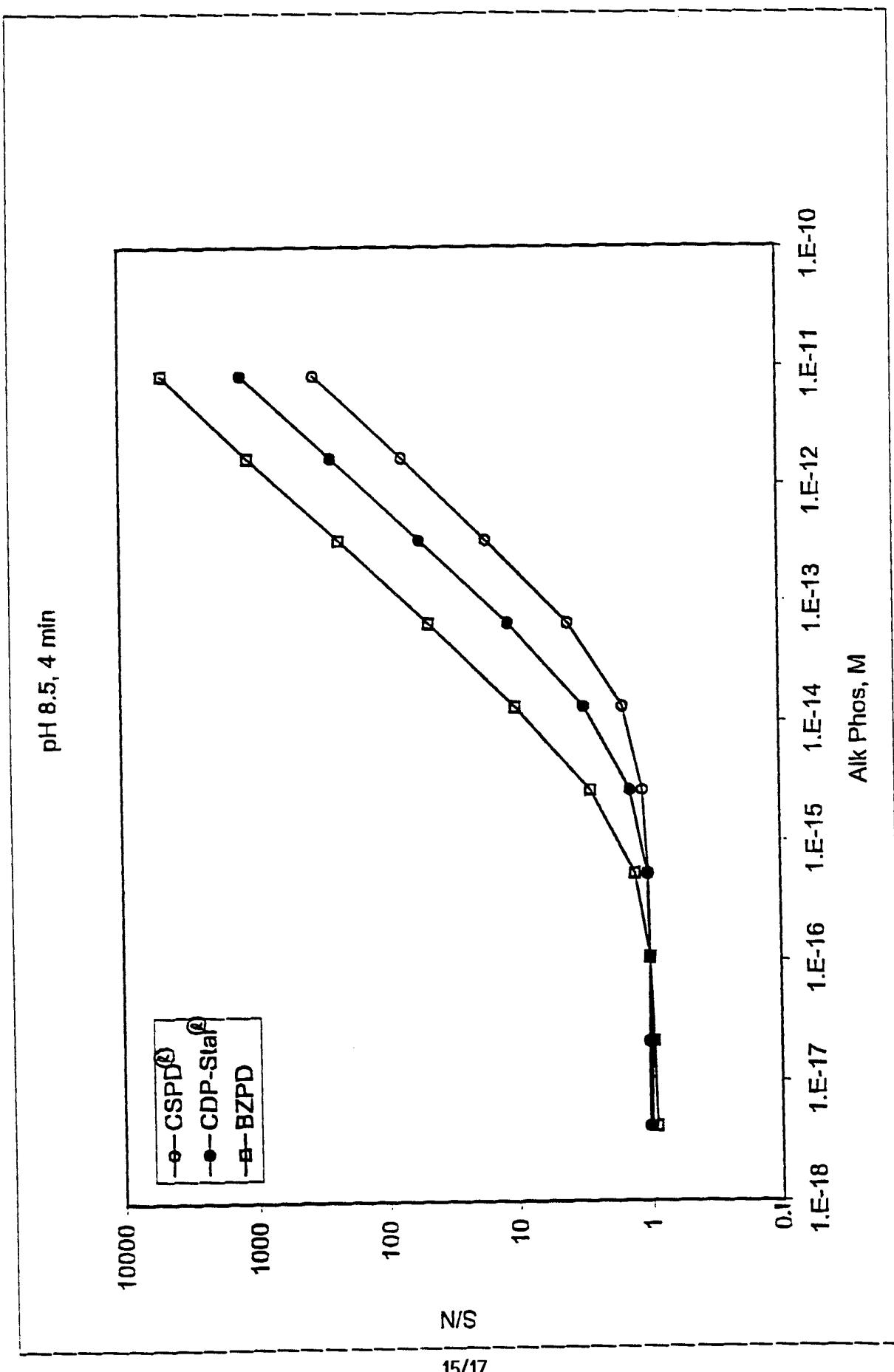
**FIGURE 11-A**

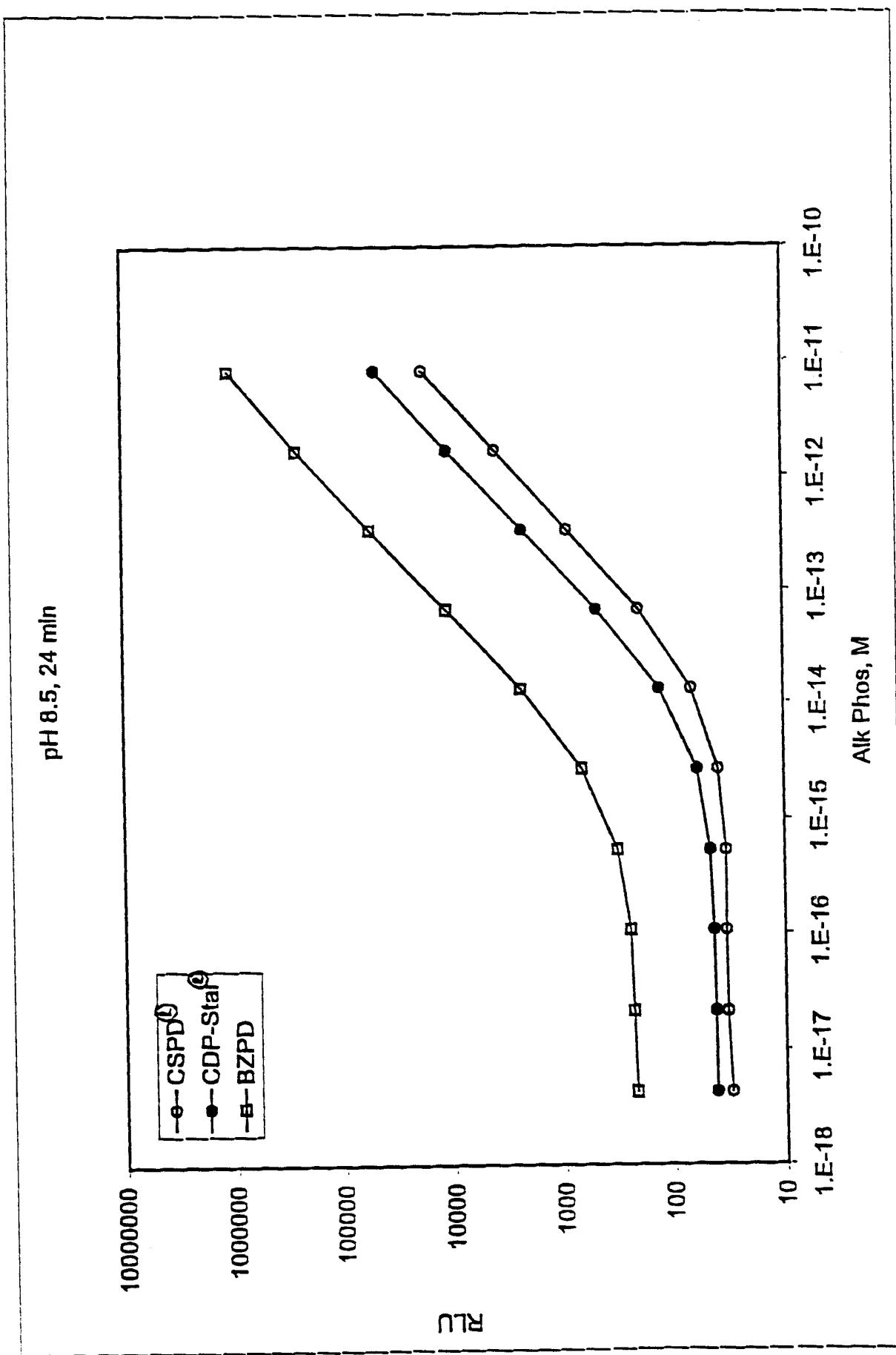
**FIGURE 11-B**

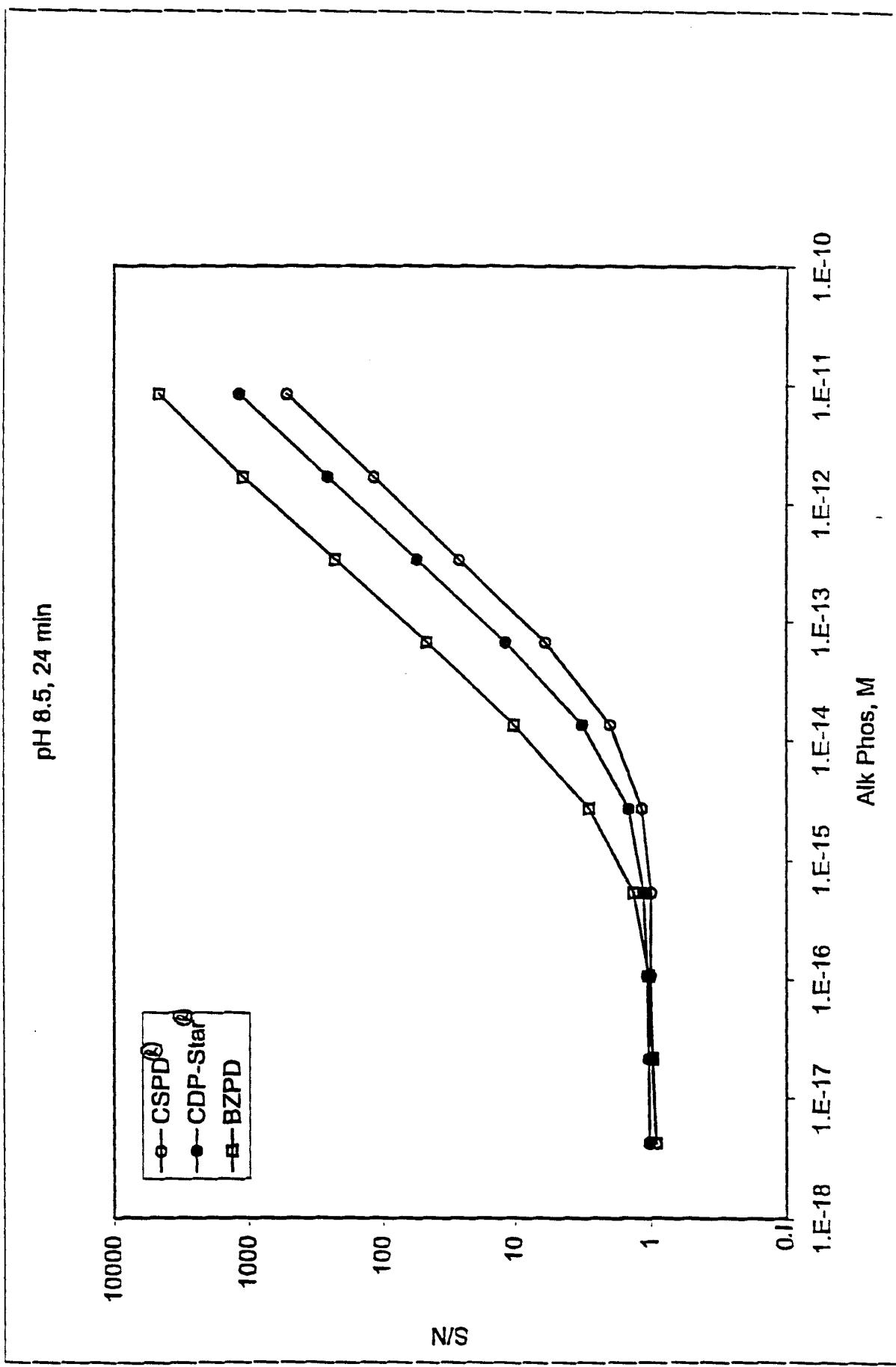
**FIGURE 12-A**

**FIGURE 12-B**

**FIGURE 13-A**

**FIGURE 13-B**

**FIGURE 14-A**

**FIGURE 14-B**

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US99/17094

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : A61K 31/425, 31/435; C07D 498/14, 513/04  
 US CL : 514/278, 367; 546/15; 548/114, 147, 159, 178

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 514/278, 367; 546/15; 548/114, 147, 159, 178

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CAS ONLINE, EAST

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,679,802 A (BRONSTEIN et al.) 21 October 1997 (21.10.97), see entire document, especially columns 3-5.	1-21

Further documents are listed in the continuation of Box C.  See patent family annex.

* Special categories of cited documents:	*T*	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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Date of the actual completion of the international search

01 NOVEMBER 1999

Date of mailing of the international search report

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