# 4,4′-Dimethoxytrityl and 4,4′,4″-trimethoxytrityl as protecting groups for amino functions; selectivity for primary amino groups and application in $^{15}$N-labelling

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**4,4′-Dimethoxytrityl tetrafluoroborate (DMT$^+$ BF$_4^-$) and 4,4′,4″-trimethoxytrityl tetrafluoroborate (TMT$^+$ BF$_4^-$) are useful reagents for protecting primary and some secondary amines. Protected amines are obtained either by reaction of DMT$^+$ BF$_4^-$ or TMT$^+$ BF$_4^-$ with the amine or by alkylating DMT- or TMT-amine (available from DMT$^+$ BF$_4^-$ and TMT$^+$ BF$_4^-$ by treatment with ammonia). Alkylation of DMT- or TMT-amine stops after monoalkylation. Deprotection of the alkylated DMT- and TMT-amine is achieved by treatment with an acid of appropriate molarity (*e.g.* 0.1 M HCl in 1:1 tetrahydrofuran–water for TMT-amines). The value of the methodology described is illustrated by a synthesis of ($^{15}$NH$_2$) adenosine. X-Ray molecular structures of one DMT and two TMT derivatives are reported.**

## Introduction

Following our studies of 4,4′-dimethoxytrityl tetrafluoroborate (DMT$^+$ BF$_4^-$) as a convenient reagent for the selective protection of primary hydroxy groups with the DMT group,[1] we explored the application of this reagent and the corresponding mono- and trimethoxy-trityl tetrafluoroborate to the protection of amines. Although numerous protecting groups for amino functions have been described,[2] there is still a need for reagents that discriminate between different kinds of amino group and suppress amine reactivity within the protected moiety. This need has become more pressing with the establishment of 'combinatorial chemistry' as a tool in organic synthesis.[3] In this context, the recent introduction of phenylacetyl as an N-protecting group that is removable enzymically may be an advance.[4]

The application of 4,4′-dimethoxytrityl to the protection of the 5′-hydroxy groups in nucleotides was a breakthrough that led to the rational synthesis of oligonucleotides.[5] However, there have only been sporadic reports[6–10] of the application of methoxy-substituted trityl groups to the protection of nitrogen functions in amines, although the parent trityl group is well established for the N-protection of amino acids.[11,12] For example, the amino group of a guanine was protected with DMT,[7] whilst the primary amino groups of spermidine were selectively protected using 4-methoxytrityl (MMT), enabling the secondary amino group to be derivatised.[8] Methoxy-substituted trityl functions have also been used as N-protecting groups in pro-drugs, designed to release the amino function selectively in tumour cells because of the purported lower pH of these cells relative to normal cells.[9,10] Trityl functions have been attached to solid supports and then used as carriers of amino groups, which are eventually released by acid treatment.[13–19] Methoxy-substitution in the trityl group has been used to influence the rate of acid-induced cleavage.[20]

In this paper, we show the value of DMT$^+$ BF$_4^-$ and 4,4′,4″-trimethoxytrityl tetrafluoroborate (TMT$^+$ BF$_4^-$) for protecting amino functions as their N-DMT and N-TMT derivatives, respectively, especially in primary amines. Both N-protecting groups can be removed under acidic conditions, although a mechanistic subtlety in the H$^+$-induced pathway for detritylation makes these groups much harder to remove from nitrogen compared to oxygen.[21,22] The reagents DMT$^+$ BF$_4^-$ and TMT$^+$ BF$_4^-$ can directly react with amines, in which case there is a sharp preference for relatively unhindered amino groups (for some cases, primary amino ≫ secondary amino; *N.B. tert*-butylamine does not react). Alternatively, DMT or TMT can be attached to amino functions through the alkylation of 4,4′-dimethoxytritylamine (obtained from DMT$^+$ BF$_4^-$ and ammonia) or 4,4′,4″-trimethoxytritylamine (from TMT$^+$ BF$_4^-$ and ammonia). These alkylations stop at monoalkylation. X-ray molecular structure analyses of one DMT derivative and two TMT derivatives are presented and discussed in the light of these results. The value of the methodology described is illustrated by a synthesis of ($^{15}$NH$_2$)adenosine.

## Results and discussion

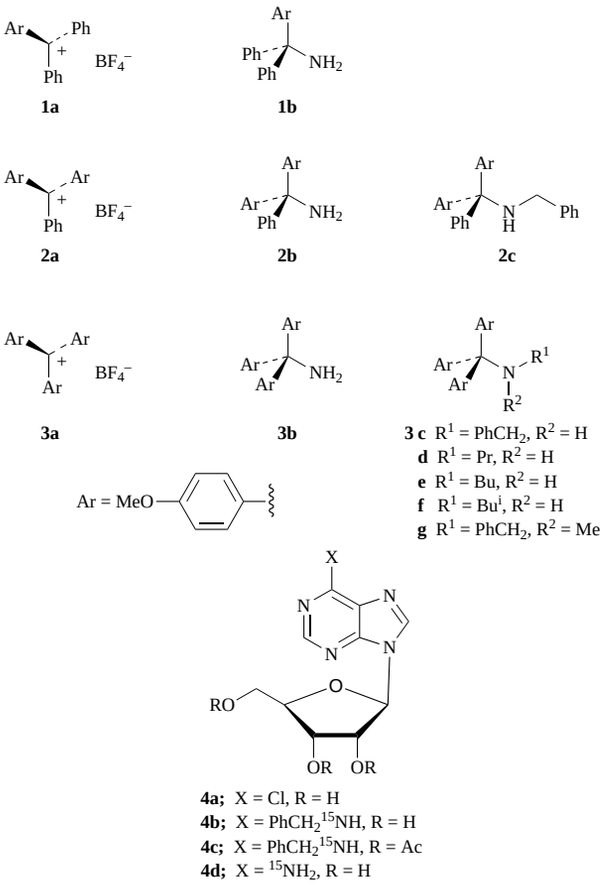
### Preparation of methoxytritylated amines

4-Methoxytrityl tetrafluoroborate (MMT$^+$ BF$_4^-$, **1a**) and DMT$^+$ BF$_4^-$ **2a** were recommended as reagents superior to the corresponding chlorides because of their ease of preparation in highly pure form and relative stability.[1] Similarly, TMT$^+$ BF$_4^-$ **3a** is easily prepared from the commercially available TMT-OH by treatment with tetrafluoroboric acid in acetic anhydride. It exists as purple crystals that are indefinitely stable in air.

Reactions of MMT$^+$ BF$_4^-$, DMT$^+$ BF$_4^-$ and TMT$^+$ BF$_4^-$ with ammonia gave the corresponding amines (**1b**, **2b** and **3b**, respectively), which for DMT and TMT are crystalline. DMT$^+$ BF$_4^-$ and TMT$^+$ BF$_4^-$ reacted rapidly with primary amines (RNH$_2$, where R = PhCH$_2$, Pr, Bu, Bu$^i$, but not Bu$^t$) to give the corresponding methoxytritylated derivatives (**2c**, **3c**–**3f**). Kinetic data for reactions of the TMT cation with several primary amines have been reported.[6] It was observed that most of the amines reacted at similar rates (*e.g.*, for benzylamine the second-order rate constant $k = 47 \times 10^3$ dm$^3$ mol$^{-1}$ s$^{-1}$ at 25 °C in water), although *tert*-butylamine reacted ~$10^5$-times slower than the norm. We also found that *N*-methylbenzylamine reacted with TMT$^+$ BF$_4^-$ to give product **3g**. Bunton and Huang[6] reported that dimethylamine and certain cyclic amines (*e.g.*, pyrrolidine and piperidine) reacted with the TMT cation at similar rates to those found for primary amines. However, we have observed that neither dibutylamine nor dibenzylamine reacts with TMT$^+$ BF$_4^-$, showing that the reactivity of some secondary amines with trityl cations is marginal.

The derivatives **2c** or **3c** and **3e** could also be obtained by alkylation of primary amine **2b** or **3b** with benzyl bromide or

1-bromobutane in dimethylformamide (DMF) in the presence of potassium carbonate. These monoalkylations did not proceed further even under forcing conditions. The X-ray crystal (molecular) structures of **2c** and **3e** show that approach to the nitrogen lone pair is severely impeded in each case by an aryl group (see below).




**Deprotection of methoxytritylated amines**

Khorana rejected TMT as an O-protecting group because of its extreme acidic lability.[5] However, removal of trityl groups from amino groups requires relatively strong acidic conditions, even for TMT. For the conversion of DMT-$NH_2$ into DMT-OH the need for two protonations has been demonstrated, one for the initial activation of the amino function and the other for the trapping of ammonia following cleavage of the DMT-$NH_3^+$ bond [see equations (1–3)].[21]

$$\text{DMT-NH}_2 + \text{H}^+ \longrightarrow \text{DMT-NH}_3^+ \qquad (1)$$

$$\text{DMT-NH}_3^+ \longrightarrow \text{DMT}^+ + \text{NH}_3 \qquad (2)$$

$$\text{NH}_3 + \text{H}^+ \longrightarrow \text{NH}_4^+ \qquad (3)$$

For the amines described in this paper, the conditions for acid-induced removal of MMT, DMT and TMT within a few hours at room temp. require an excess of hydrochloric acid of molarity in the range 4 to 0.05, with only TMT being removed at a satisfactory rate at lower HCl concentrations. For preparative-scale reactions we have generally used 0.5 M HCl in aq. tetrahydrofuran (THF) (1 : 1 v/v) for removal of TMT and 2 M HCl for removal of DMT. Alternative reagents for the removal of TMT are 0.5 M tetrazole or trifluoroacetic acid (TFA) in aq. THF (1 : 1 v/v). Using compound **3e** as a reference compound, the reaction times/yields for different acids were as follows: 17.5 h/74% (0.1 M HCl), 2.5 h/74% (0.5 M HCl), 2 h/74% (0.5 M tetrazole), immediate/88% (0.5 M TFA).

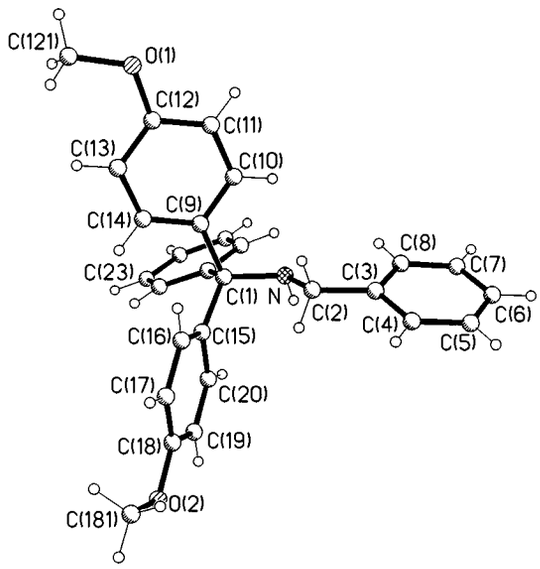



**Fig. 1** Molecular structure of DMT-$NHCH_2Ph$ with partial numbering scheme. The third trityl ring is numbered from C(21) to C(26). The minor methoxy disorder component is not shown.

**X-Ray molecular structures of DMT-$NHCH_2Ph$ 2c, TMT-NHBu 3e and TMT-$NMeCH_2Ph$ 3g**

The configuration of the trityl group is similar in all three structures. The aromatic rings do not adopt a propeller shape. Instead, two rings approach orthogonally with the plane of the three *ipso*-carbon atoms attached to C(1) (dihedral angles are 77.2 and 68.6°, 75.8 and 63.5°, 70.0 and 62.1° for the three structures), while the third is turned approximately 90° to such an orientation (dihedral angles 17.3, 10.1, 16.7°). In each case this third ring lies *transoid* to the nitrogen atom lone pair of electrons. This arrangement probably minimises steric interaction with the substituents on the nitrogen atom and blocks access to the lone pair by alkylating agents.

For structures **2c** and **3e**, the bond between nitrogen and the trityl centre C(1) is approximately 0.02 Å longer than the other N–C bond(s) [1.483(5) *vs*. 1.461(5) for **2c**, 1.482(2) *vs*. 1.462(2) for **3e**], probably as a result of steric interactions between the N-alkyl group(s) and the trityl moiety. Similar effects are seen across a range of 35 trityl-substituted amines in the Cambridge Structural Database.[23] For structure **3g** all of the N–C bonds are longer than the shorter N–C bonds in compounds **2c** and **3e**, with the N–C bond to TMT especially long [1.498(3) *vs*. 1.472(3) and 1.478(3) Å]. In this case the extra N-methyl group imposes an additional steric constraint. X-Ray molecular structures for the three compounds are presented in Figs. 1–3.

**Preparation of (6-$^{15}$N)adenosine**

To illustrate the value of the methodology described we have used it to prepare (6-$^{15}$N)adenosine, which we required for studies of DNA interactions with genotoxins (*cf.* ref. 24). ($^{15}$N)-Ammonium chloride was treated with an excess of aq. sodium hydroxide and the ($^{15}$N)ammonia thus produced was distilled onto dry DMT$^+$ $BF_4^-$ to give DMT-$^{15}NH_2$. This was alkylated with benzyl bromide and the resulting DMT-$^{15}NHCH_2Ph$ was hydrolysed using 2 M hydrochloric acid to give benzyl ($^{15}$N)amine in 68% overall yield. Reaction of the labelled benzylamine with 6-chloropurine riboside **4a** gave 6-*N*-benzyl (6-$^{15}$N)adenosine **4b**, which was O-acetylated to give triacetate **4c**. The benzyl group of the latter compound was removed by oxidation to benzoyl with ruthenium(IV)[25] followed by saponification to give (6-$^{15}$N)adenosine **4d**.

## Conclusions

The results described in this paper lead us to recommend the wider use of di- and especially tri-methoxytrityl as protecting

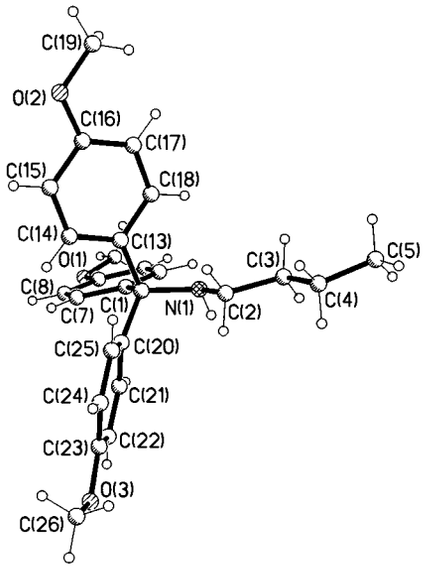



**Fig. 2** Molecular structure of TMT-NHBu with most atoms labelled

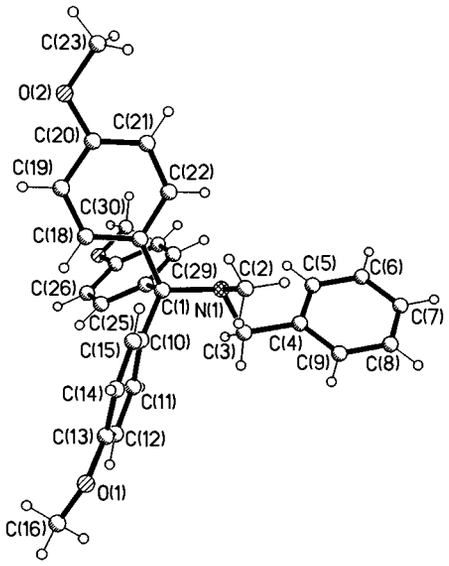



**Fig. 3** Molecular structure of TMT-N(Me)$CH_2$Ph with most atoms labelled

groups for primary amino groups. The reagent $TMT^+$ $BF_4^-$ is especially attractive because of its stability in air and the relative ease of removal of TMT from amino groups. Our demonstration that monoalkylated tritylamines cannot be alkylated further suggests the application of these derivatives as hindered bases, either as such or after conversion into the corresponding anion (*e.g.*, DMT-NLiR).

## Experimental

The primary sources of chemicals were the Aldrich Chemical Company, BDH Limited, and Lancaster Limited. Propylamine was distilled from calcium hydride. Tetrazole was 99+ % pure (Aldrich Gold Label). All other chemicals were used as supplied without further purification.

Acetonitrile was pre-dried over potassium carbonate and distilled from calcium hydride. THF was pre-dried by refluxing over sodium wire and distilled from lithium aluminium hydride. Dry DMF (anhydrous 99+ %, Aldrich) was used as obtained. Light petroleum refers to the fraction of boiling between 40 and 60 °C. All other solvents were used as received.

TLC was performed using TLC aluminium plates pre-coated with silica gel (Kieselgel 60 $F_{254}$, 0.2 mm). Silica gel (Kieselgel 60) was used for column chromatography. $^1$H NMR spectra were run on a Bruker WP-200E (200 MHz) spectrometer. *J*-Values are given in Hz. Residual proton signals from the deuteriated solvents were used as references [acetonitrile ($\delta$ 1.95), $D_2O$ ($\delta$ 4.81), chloroform ($\delta$ 7.25), dimethyl sulfoxide (DMSO) ($\delta$ 2.5), DMF ($\delta$ 2.75, 2.95 and 8.05)]. $^{13}$C Spectra were recorded on a Bruker WP-200E (50.3 MHz), the $^{13}$C signal from the deuteriated solvent being used as a reference [acetonitrile ($\delta_C$ 1.2 and 117.8), chloroform ($\delta_C$ 77.0), DMSO ($\delta_C$ 39.7), DMF ($\delta_C$ 28.9, 34.4 and 161.5)]. $^{15}$N Spectra were recorded on a Bruker WM300 spectrometer at 30.4 MHz using nitromethane ($\delta_N = 0$) as external reference. IR were recorded on a Nicolet 20-PC Fourier Transform IR spectrophotometer. Mass spectra were recorded on a Kratos MS80 RF spectrophotometer. Combustion analyses were performed using a Carlo Erba 1106 CHN analyser. UV spectra were recorded on a Uvikon Easy-10 spectrophotometer.

### X-Ray crystallography

Table 1 gives crystal data and other information on the structure determinations. A crystal of DMT-$NHCH_2$Ph was examined on a Stoe-Siemens four-circle diffractometer with graphite-monochromated MoKα radiation ($\lambda = 0.710\ 73$ Å) at 160 K. Cell parameters were refined from 2$\theta$-values of 30 reflections measured at ±$\omega$. Intensities were measured by $\omega/\theta$ scans. The measured data set consisted of just over one symmetry-independent quadrant. Five periodically monitored standard reflections showed no significant intensity variation. Crystals of TMT-NHBu and TMT-N(Me)$CH_2$Ph were examined at 160 K on a Siemens SMART CCD area-detector diffractometer with graphite-monochromated MoKα radiation. Cell parameters were refined from the observed $\omega$ angles of all strong reflections in the complete data set. In each case, reflections were integrated from several series of exposures with different crystal orientations selected to cover more than a hemisphere of reciprocal space; each exposure covered 0.3° in $\omega$. Analysis of symmetry-equivalent and repeated data indicated no significant decay in intensities.

All three structures were solved by automatic direct methods and were refined on $F^2$ for all unique data, with weighting $w^{-1} = \sigma(F_o^2) + (aP)^2 + (bP)$, where $P = (F_o^2 + 2F_c^2)/3$. Non-hydrogen atoms were refined anisotropically and hydrogen atoms (except for freely refined N–H) were constrained with a riding model and with isotropic $U$ set to 1.2 (1.5 for methyl groups) times $U_{eq}$(C). An isotropic extinction parameter was refined such that $F_c' = F_c/(1 + 0.001\ xF_c^2\ \lambda^3/\sin 2\theta)^{\frac{1}{4}}$. For DMT-$NHCH_2$Ph the two methoxy groups were found to be disordered over all three *para* positions with occupancy factors 0.960(6), 0.872(7) and 0.168(7), so that there is one predominant orientation of the disubstituted trityl group. The residual $wR2 = \{\Sigma[w(F_o^2 - F_c^2)^2]/\Sigma[w(F_o^2)^2]\}^{\frac{1}{2}}$ for all data, $R1$ is the conventional $R$-factor on $F$-values of reflections having $F_o^2 > 2\sigma(F_o^2)$; the goodness-of-fit is calculated from all $F^2$-values. Programs were standard Stoe and Siemens control and intensity integration software, local programs and SHELXTL.[26] Full lists of atomic coordinates, thermal parameters, and bond lengths and angles have been deposited at the Cambridge Crystallographic Data Centre (CCDC).†

### 4,4′,4″-Trimethoxytrityl tetrafluoroborate 3a

To a stirred solution of 4,4′,4″-trimethoxytrityl alcohol (5.0 g, 14.2 mmol) in acetic anhydride (32.7 g, 30 cm$^3$, 320 mmol) at −5 °C was added 40% aq. tetrafluoroboric acid (5.5 cm$^3$, 82.0 mmol) dropwise over a period of 2 h. Addition of diethyl ether to the resulting scarlet solution caused precipitation of the

† See Instructions for authors, in the January issue. Any request to the CCDC for this material should quote the full literature citation and the reference number 207/137.

**Table 1** Crystallographic data

| Compound | **2c** | **3e** | **3g** |
|---|---|---|---|
| Formula | $C_{28}H_{27}NO_2$ | $C_{26}H_{31}NO_3$ | $C_{30}H_{31}NO_3$ |
| M | 409.5 | 405.5 | 453.6 |
| Crystal system | Monoclinic | Monoclinic | Monoclinic |
| Space group | $P2_1/n$ | $P2_1/c$ | $P2_1/n$ |
| $a$/Å | 10.258(3) | 16.369(2) | 13.7969(13) |
| $b$/Å | 21.672(9) | 9.3392(11) | 12.7808(12) |
| $c$/Å | 11.004(3) | 14.692(2) | 15.0873(15) |
| $\beta$/° | 115.85(3) | 98.481(3) | 114.120(2) |
| $V$/Å$^3$ | 2201.5(13) | 2221.5(4) | 2428.1(4) |
| $Z$ | 4 | 4 | 4 |
| $D_c$/g cm$^{-3}$ | 1.236 | 1.212 | 1.241 |
| $\mu$/mm$^{-1}$ | 0.077 | 0.078 | 0.079 |
| $F$(000) | 872 | 872 | 968 |
| Crystal size/mm | 0.52 × 0.48 × 0.36 | 0.54 × 0.36 × 0.19 | 0.32 × 0.24 × 0.12 |
| $2\theta_{max}$/° | 45 | 51 | 53 |
| Maximum indices $hkl$ | 11, 23, 11 | 18, 10, 17 | 17, 15, 18 |
| Reflections measured | 2966 | 9270 | 12 721 |
| Unique reflections | 2841 | 3643 | 4887 |
| $R_{int}$ | 0.0802 | 0.0405 | 0.0576 |
| Weighting parameters $a$, $b$ | 0.0616, 1.4132 | 0.0309, 1.0724 | 0.0211, 2.0601 |
| Extinction coefficient $x$ | 0 | 0.0119(10) | 0.0044(6) |
| No. of refined parameters | 301 | 279 | 312 |
| $wR2$ (all data) | 0.1800 | 0.1124 | 0.1450 |
| $R1$ ('observed' data) | 0.0470 (1696) | 0.0496 (3214) | 0.0672 (3279) |
| Goodness-of-fit | 1.062 | 1.155 | 1.207 |
| Max., min. el. density/e Å$^{-3}$ | 0.187, −0.248 | 0.171, −0.148 | 0.203, −0.220 |

product, which was filtered off and dried *in vacuo* (0.01 mmHg, 3 h) to give the *title compound* as plum coloured crystals (4.39 g, 85%), m.p. 177–178 °C (Found: C, 62.78; H, 4.95. $C_{22}H_{21}BF_4O_3$ requires C, 62.88; H, 5.04%); $\delta_H$(200 MHz; [$^2H_3$]acetonitrile) 4.08 (9 H, s, 3 × OMe), 7.32 (6 H, d, $J$ 9, 3- and 5-H) and 7.60 (6 H, d, $J$ 9, 2- and 6-H).

### General procedure: 4,4′-Dimethoxytritylamine 2b and 4,4′,4″-trimethoxytritylamine 3b

Liquid ammonia (70 cm$^3$), condensed into a cooled flask at −78 °C (acetone/solid $CO_2$), was poured into a flask containing either 4,4′-dimethoxyltrityl tetrafluoroborate **2a** (7.0 g, 17.9 mmol) or 4,4′,4″-trimethoxytrityl tetrafluoroborate **3a** (1.00 g, 2.75 mmol) and the resulting orange solution was stirred at −78 °C for 1 h. The yellow solution was allowed to warm up to room temperature and was stirred until evaporation of the excess of ammonia was complete. The residue was extracted with diethyl ether (3 × 30 cm$^3$) and the combined extracts were dried ($MgSO_4$) and filtered. Removal of the ether from the filtrate gave a solid, which was purified by chromatography on silica gel [elution with ethyl acetate–light petroleum–triethylamine (49.5 : 49.5 : 1)]. The resulting solid was recrystallised from diethyl ether–light petroleum to give one of the *title compounds* as crystals.

DMT-$NH_2$ **2b** (5.06 g, 89%), m.p. 47–48 °C (Found: C, 78.85; H, 6.52; N, 4.29. $C_{21}H_{21}NO_2$ requires C, 78.97; H, 6.63; N, 4.39%); $\lambda_{max}$(MeOH)/nm 228 (log $\varepsilon$ 4.35), 276 (3.57) and 283 (3.51); $\nu_{max}$(KBr)/cm$^{-1}$ 3367, 3301 ($NH_2$), 2836 (OMe), 1607, 1582, 1509 (Ar), 1246, 1188, 1034 (C–O–C) and 828 (4-OMe); $\delta_H$(200 MHz; $CDCl_3$) 2.32 (2 H, s, $NH_2$), 3.78 (6 H, s, 2 × OMe), 6.82 (4 H, d, $J$ 8.9, 3- and 5-H), 7.05 (4 H, d, $J$ 8.9, 2- and 6-H) and 7.21 (5 H, m, ArH); $\delta_C$(50.3 MHz; $CDCl_3$) 55.3 (2 × OMe), 65.4 (C-$NH_2$), 113 (C-3), 126 (C-4′), 127.9 and 128.1 (C-3′ and -2′), 129.3 (C-2), 141.2 (C-1), 149.3 (C-1′) and 158.2 (C-4); $m/z$ (EI) 319 ($M^+$, 20%), 303 ($M^+ - NH_2$, 63), 242 ($M^+ - Ph$, 100), 212 ($M^+ - C_6H_4OMe$, 6) and 77 ($Ph^+$, 31).

TMT-$NH_2$ **3b** (0.37 g, 45%), m.p. 98–99 °C (lit.,[6] 105–106 °C) (Found: C, 75.40; H, 6.39; N, 3.96. $C_{22}H_{23}NO_3$ requires C, 75.62; H, 6.63; N, 4.01%); $\delta_H$(200 MHz; [$^2H_3$]acetonitrile) 2.37 (2 H, s, $NH_2$), 3.76 (9 H, s, 3 × OMe), 6.84 (6 H, d, $J$ 9, 3- and 5-H), 7.10 (6 H, d, $J$ 9, 2- and 6-H).

### General procedure A: DMT or TMT protection of amines

To a stirred scarlet solution of 4,4′-dimethoxytrityl tetrafluoroborate **2a** or 4,4′,4″-trimethoxytrityl tetrafluoroborate **3a** (1.0 mol equiv.) in dry acetonitrile (5.0 cm$^3$) was added the corresponding amine (2.2 mol equiv.) dropwise over a period of 10 min. The reaction mixture was stirred under nitrogen at 20 °C for 1 h. For those amines that react rapidly with the DMT or TMT cation, the reaction mixture became almost immediately colourless. The resulting solution was concentrated *in vacuo* (0.01 mm Hg) and the oil thus obtained was treated with aq. sodium hydroxide (2.0 M; 20 cm$^3$). The mixture was extracted with diethyl ether (6 × 25 cm$^3$). The extracts were combined, dried ($MgSO_4$) and filtered. The filtrate was concentrated to give a cream oil, that was chromatographed on silica gel [elution with ethyl acetate–light petroleum–triethylamine (29.5 : 69.5 : 1)] to give a solid. This was recrystallised from diethyl ether–light petroleum to yield the protected amine as crystals.

### General procedure B: Alkylation of DMT- or TMT-amines

A bromoalkane (1.0 mol equiv.) and potassium carbonate (2.5 mol equiv.) were added to a stirred solution of 4,4′-dimethoxytritylamine **2b** or 4,4′,4″-trimethoxytritylamine **3b** (1.0 mol equiv.) in dry DMF (1.0 cm$^3$). Stirring was continued under nitrogen at 20 °C for 3 days. The resulting solution was diluted with water (10 cm$^3$) and extracted with diethyl ether (3 × 10 cm$^3$). The ethereal extracts were combined, dried ($MgSO_4$) and filtered. The filtrate was concentrated to give an oil, which was purified by chromatography on silica gel [elution with ethyl acetate–light petroleum–triethylamine (29.5 : 69.5 : 1)] to give a solid. This was recrystallised from diethyl ether–light petroleum to yield the protected amine as crystals.

### *N*-Benzyl-4,4′-dimethoxytritylamine 2c

Procedure A (0.37 g, 88%), procedure B (1.10 g, 75%); mp 98–99 °C (Found: C, 82.36; H, 6.67; N, 3.37. $C_{28}H_{27}NO_2$ requires C, 82.12; H, 6.65; N, 3.42%); $\nu_{max}$(KBr)/cm$^{-1}$ 3319 (NH), 2836 (OMe), 1607, 1582 and 1509 (Ar), 1252, 1181, 1030 (C–O–C) and 826 (4-OMe); $\delta_H$(200 MHz; [$^2H_6$]DMSO) 3.07 (1 H, t, $J$ 8.2, NH), 3.32 (2 H, d, $J$ 7.9, $CH_2$), 3.82 (3H, s, OMe), 6.83 (4 H, d, $J$ 8.9, 3- and 5-H) and 7.41 (14 H, m, ArH); $\delta_C$(50.3 MHz; [$^2H_6$]DMSO) 47.7 ($CH_2NH$), 55.3 (2 × OMe), 69.9 (C–NH),

113.4 (C-3), 126.3 and 126.8 (C-4′ and -4Ar), 127.9, 128.0, 128.5 and 129.9 (C-2, -2′, -3′, -2Ar and -3Ar), 138.6 (C-1), 141.5 (C-1Ar), 147.1 (C-1′) and 157.7 (C-4); *m/z* (CI) 410 ($MH^+$, 43%), 332 ($M^+ - Ph$, 70), 303 ($M^+ - PhCH_2NH$, 100), 106 ($PhCH_2NH^+$, 66), 91 ($PhCH_2^+$, 82) and 77 ($Ph^+$, 14).

**_N_-Benzyl-4,4′,4″-trimethoxytritylamine 3c**

Procedure A (3.89 g, 64%), procedure B (0.12 g, 60%); mp 100–101 °C (Found: C, 78.84; H, 6.44; N, 3.05. $C_{29}H_{29}NO_3$ requires C, 79.24; H, 6.65; N, 3.19%); $\nu_{max}$(KBr)/cm$^{-1}$ 3317 (NH), 2831 (O–Me), 1606, 1578 and 1504 (Ar), 1246, 1176, 1029 (C–O–C) and 828 (4-OMe); $\lambda_{max}$($CH_3CN$)/nm 262 (log $\varepsilon$ 3.95 cm$^3$ mol$^{-1}$ cm$^{-1}$) and 274 (3.44); $\delta_H$(200 MHz; [$^2H_3$]acetonitrile) 2.45 (1 H, br s, NH), 3.25 (2 H, s, $CH_2$), 3.76 (9 H, s, 3 × OMe), 6.88 (6 H, d, *J* 9, 3- and 5-H), 7.38 (5 H, m, Ph) and 7.42 (6 H, d, *J* 9, 2- and 6-H); $\delta_C$(50.3 MHz; [$^2H_3$]acetonitrile) 47.56 ($CH_2NH$), 54.73 (3 × OMe), 69.31 (CNH), 112.8 (C-3Ar), 126.50 (C-4Ph), 127.75 (C-2Ph), 128.16 (C-3Ph), 129.51 (C-2Ar), 138.74 (C-1Ar), 141.21 (C-1Ph) and 157.82 (C-4Ar); *m/z* (+EI) 439 ($M^+$, 17%), 348 ($M^+ - CH_2Ph$, 62), 333 ($M^+ - NHCH_2Ph$), 100), 226 ($M^+ - C_6H_4OMe - NHCH_2Ph$, 65), 134 ($M^+ - 2 \times C_6H_4OMe - CH_2Ph$, 61), 107 ($C_6H_4OMe$, 70), 106 ($NHCH_2$-Ph, 67), 91 ($CH_2Ph$, 78), 77 (Ph, 45).

**4,4′,4-Trimethoxy-_N_-propyltritylamine 3d**

Procedure A (0.74 g, 69%), mp 100–101 °C (Found: C, 76.75; H, 7.53; N, 3.22. $C_{25}H_{29}NO_3$ requires C, 76.72; H, 7.42; N, 3.58%); $\nu_{max}$(KBr)/cm$^{-1}$ 3313 (NH), 2830 (O–Me), 1606, 1582 and 1506 (Ar), 1247, 1176, 1034 (C–O–C) and 826 (4-OMe); $\lambda_{max}$($CH_3CN$)/nm 262 (log $\varepsilon$ 3.41 cm$^3$ mol$^{-1}$ cm$^{-1}$) and 274 (3.58); $\delta_H$(200 MHz; [$^2H_3$]acetonitrile) 0.87 (3 H, t, *J* 7, $CH_3$), 1.50 (2 H, m, $CH_2$), 1.97 (2 H, m, $CH_2N$), 2.40 (1 H, br t, NH), 3.76 (9 H, s, 3 × OMe), 6.87 (6 H, d, *J* 9, 3- and 5-H) and 7.31 (6 H, d, *J* 9, 2- and 6-H); $\delta_C$(50.3 MHz; [$^2H_3$]acetonitrile) 11.25 ($CH_3$), 23.44 ($CH_2$), 45.38 ($CH_2NH$), 54.68 (3 × OMe), 69.02 (CNH), 112.71 (C-3Ar), 129.48 (C-2Ar), 139.08 (C-1Ar) and 157.70 (C-4Ar); *m/z* (+EI) 391 ($M^+$, 40%), 349 ($MH^+ - Pr$, 40), 333 ($MH^+ - NHPr$, 100), 226 ($M^+ - C_6H_4OMe - NHPr$, 23), 134 ($M^+ - 2 \times C_6H_4OMe - Pr$, 59) and 107 ($C_6H_4OMe$, 24).

**_N_-Butyl-4,4′,4″-trimethoxytritylamine 3e**

Procedure A (0.49 g, 44%), procedure B (0.08 g, 28%); m.p. 104–105 °C (Found: C, 76.75; H, 7.65; N, 3.25. $C_{26}H_{31}NO_3$ requires C, 77.03; H, 7.65; N, 3.46%); $\nu_{max}$(KBr)/cm$^{-1}$ 3315 (NH), 2834 (OMe), 1606, 1581 and 1505 (Ar), 1244, 1176, 1035 (C–O–C) and 826 (4-OMe); $\lambda_{max}$($CH_3CN$)/nm 261 (log $\varepsilon$ 3.32 cm$^3$ mol$^{-1}$ cm$^{-1}$) and 275 (3.49); $\delta_H$(200 MHz; [$^2H_3$]acetonitrile) 0.87 (3 H, t, *J* 7, $CH_3$), 1.40 (6 H, m, 3 × $CH_2$), 2.04 (1 H, br t, NH), 3.76 (9 H, s, 3 × OMe), 6.87 (6 H, d, *J* 9, 3- and 5-H) and 7.30 (6 H, d, *J* 9, 2- and 6-H); $\delta_C$(50.3 MHz; [$^2H_3$]acetonitrile) 13.12 ($CH_3$), 20.03 ($CH_2$), 32.33 ($CH_2$), 42.90 ($CH_2NH$), 54.40 (3 × OMe), 68.88 (CNH), 112.50 (C-3Ar), 129.30 (C-2Ar), 138.89 (C-1Ar) and 157.51 (C-4Ar); *m/z* (+EI) 406 ($MH^+$, 40%), 348 ($M^+ - Bu$, 42), 333 ($M^+ - NHBu$, 100), 298 ($M^+ - C_6H_4OMe$, 93), 226 ($M^+ - C_6H_4OMe - NHBu$, 23), 134 ($M^+ - 2 \times C_6H_4OMe - Bu$, 41) and 107 ($C_6H_4OMe$, 18).

**4,4′,4″-Trimethoxy-_N_-(2-methylpropyl)tritylamine 3f**

Procedure A (0.05 g, 44%); oil; $\nu_{max}$(film)/cm$^{-1}$ 3321 (NH), 2834 (O–Me), 1607, 1581 and 1505 (Ar), 1251, 1175, 1037 (C–O–C) and 830 (4-OMe); $\delta_H$(200 MHz; [$^2H_3$]acetonitrile) 0.91 (6 H, d, *J* 6.5, 2 × $CH_3$), 1.69 (3 H, m, $CH_2$), 3.76 (9 H, s, 3 × OMe), 6.83 (6 H, d, *J* 9, 3- and 5-H) and 7.37 (6 H, d, *J* 9, 2- and 6-H); $\delta_C$(50.3 MHz; [$^2H_3$]acetontrile) 20.18 (2 × $CH_3$), 29.07 (CH), 51.20 ($NCH_2$), 54.69 (OMe), 68.95 (C–N), 112.71 (C-3Ar), 129.52 (C-2Ar), 139.08 (C-1Ar) and 157.67 (C-4Ar).

**_N_-Benzyl-4,4′,4″-trimethoxy-_N_-methyltritylamine 3g**

Procedure A (0.98 g, 63%), m.p. 114–115 °C (Found: C, 79.34: H, 6.70; N, 3.03. $C_{30}H_{31}NO_3$ requires C, 79.62; H, 6.88; N, 3.09%); $\nu_{max}$(KBr)/cm$^{-1}$ 2834 (OMe), 1606, 1580 and 1505 (Ar), 1246, 1176, 1035 (C–O–C) and 826 (4-OMe); $\lambda_{max}$($CH_3CN$)/nm 247 (log $\varepsilon$ 3.95 cm$^3$ mol$^{-1}$ cm$^{-1}$) and 2.74 (3.44); $\delta_H$(200 MHz; [$^2H_3$]acetonitrile) 1.90 (3 H, s, $CH_3N$), 3.34 (2 H, s, $NCH_2Ph$), 3.74 (9 H, s, 3 × OMe), 6.83 (6 H, d, *J* 9, 3- and 5-H), 7.44 (5 H, m, Ph) and 7.48 (6 H, d, *J* 9, 2- and 6-H); $\delta_C$(50.3 MHz; [$^2H_3$]acetonitrile) 36.38 ($CH_3$), 54.51 (3 × OMe), 56.05 ($CH_2$), 75.67 (C–N), 112.43 (C-3Ar), 126.32 (C-4Ph), 127.61 (C-2Ph), 128.09 (C-3Ph), 130.07 (C-2Ar), 138.55 (C-1Ar), 139.88 (C-1Ph) and 157.45 (C-4Ar); *m/z* (+EI) 453 ($M^+$, 25%), 362 ($M^+ - CH_2Ph$, 13), 333 ($M^+ - N[Me]CH_2Ph$, 100), 226 ($M^+ - C_6H_4OMe - N[Me]CH_2Ph$, 18), 133 ($M^+ - 2 \times C_6H_4OMe - Me - CH_2Ph$, 9), 120 ($N[Me]CH_2Ph$, 23), 91 ($CH_2Ph$, 75) and 77 (Ph, 17).

**General procedure for attempted synthesis of _N_-(2,2-dimethylethyl)- and _N_,_N_-dialkyl-4,4′,4″-trimethoxytritylamines**

**Procedure A.** To a stirred solution of 4,4′,4″-trimethoxytrityl tetrafluoroborate **3a** (1.0 mol equiv.) in dry acetonitrile (2.0 cm$^3$) was added (2,2-dimethylethylamine or the dialkylamine (2.2 mol equiv.) dropwise over a period of 10 min. The reaction was stirred under nitrogen at 20 °C for 3 days. Work-up gave an oil, which was chromatographed on silica gel [elution with ethyl acetate–light petroleum–triethylamine (29.5 : 69.5 : 1)] to give a yellow oil which crystallised on refrigeration (4 °C; 1 week) to yield 4,4′,4″-trimethoxytrityl alcohol, $\delta_H$(200 MHz; [$^2H_3$]acetonitrile) 2.16 (1 H, s, OH), 3.77 (9 H, s, 3 × OMe), 6.83 (6 H, d, *J* 9, 3- and 5-H) and 7.37 (6 H, d, *J* 9, 2- and 6-H).

**Procedure B.** A bromoalkane (1.0 mol equiv.) and potassium carbonate (2.5 mol eqiv.) were added to a stirred solution of an *N*-alkyl-4,4′,4″-trimethoxytritylamine (1.0 mol equiv.) in dry DMF (2 cm$^3$) and the stirring was continued under nitrogen at 20 °C for 2 days, after which time no reaction appeared to have taken place (TLC). The reaction was refluxed for 1 day at 40 °C, for 2 days at 60 °C and for 2 days at 80 °C. Work-up yielded the starting *N*-alkyl-4,4′,4″-trimethoxytritylamine.

**Attempted synthesis of _N_-(2,2-dimethylethyl)-4,4′,4″-trimethoxytritylamine**

Procedure A (0.65 g, 68%) recovered as TMT-OH.

**Attempted synthesis of _N_,_N_-dibenzyl-4,4′,4″-trimethoxytritylamine**

Procedure A (0.15 g, 62%) recovered as TMT-OH; procedure B (0.96 g, 80%) recovered as *N*-benzyl-4,4′,4″-trimethoxytritylamine.

**Attempted synthesis of _N_,_N_-dibutyl-4,4′,4″-trimethoxytritylamine**

Procedure A (0.07 g, 71%) recovered as TMT-OH; procedure B (0.24 g, 96%) recovered as *N*-butyl-4,4′,4″-trimethoxytritylamine.

**General procedure for deprotection of _N_-butyl-4,4′,4″-trimethoxytritylamine 3e**

To a solution of *N*-butyl-4,4′,4″-trimethoxytritylamine (0.10 g, 0.25 mmol) in THF (0.7 cm$^3$) was added HCl (0.2 M in water; 0.7 cm$^3$ or 0.5 M in water; 0.7 cm$^3$), tetrazole (0.5 M in water; 0.7 cm$^3$), or TFA (0.5 M in water; 0.7 cm$^3$). The reaction mixture was stirred at 20 °C until formation of 4,4′,4″-trimethoxytrityl alcohol was complete (TLC). Work-up [*e.g.*, for HCl: the aqueous solution was extracted with diethyl ether (3 × 20 cm$^3$) and the aqueous layer concentrated] gave butylamine hydrochloride; $\delta_H$(200 MHz; $D_2O$) 0.89 (3 H, t, *J* 7, $CH_3$), 1.38 (2 H, sextet, *J* 7, $CH_2$), 1.61 (2 H, quintet, *J* 7, $CH_2$) and 2.96 (2 H, t, *J* 7, $CH_2$).

**4,4′-Dimethoxytrityl($^{15}$N)amine ($^{15}$N)-2b**

Aq. sodium hydroxide (0.99 g, 24 mmol in 5 cm$^3$) was added *via* a syringe to aq. ($^{15}$N)ammonium chloride (1.00 g, 18 mmol in

5 $cm^3$). The mixture was refluxed (4 h) and the ($^{15}$N)ammonia thus produced was passed through a soda lime drying tube to a flask containing 4,4′-dimethoxytrityl tetrafluoroborate **2a** (846 mg, 2.17 mmol). On reaction with ($^{15}$N)ammonia the DMT salt turned from bright orange/red to a cream coloured solid. Excess of ($^{15}$N)ammonia was trapped in a Dreschel bottle containing 2 M hydrochloric acid and recycled. The crude product was extracted with diethyl ether (3 × 10 $cm^3$). The combined extracts were washed with water and the organic layer was collected and dried ($MgSO_4$). After filtration, the ethereal solution was concentrated to give a solid, which was dried *in vacuo* (0.01 mmHg). The title compound was obtained as a solid (589 mg, 85%); $\delta_H$(200 MHz; $CDCl_3$) 2.21 (2 H, s, $^{15}NH_2$), 3.68 (6 H, s, 2 × OMe), 6.72 (4 H, d, *J* 8.9, 3- and 5-H), 7.05 (4 H, d, *J* 8.9, 2- and 6-H) and 7.09–7.23 (5 H, m, ArH); $\delta_C$(50.3 MHz; $CDCl_3$) 50.4 (OMe), 61.0 (d, *J* 3.0, C-$^{15}NH_2$), 108.3 (C-3), 121.6 (C-4′), 123.0 (C-3′), 123.2 (C-2′), 124.4 (C-2), 136.3 (C-1), 144.3 (C-1′) and 153.3 (C-4); $\delta_N$(30.4 MHz: $CDCl_3$; $MeNO_2$) −328.7; *m*/*z* (CI) 320 ($M^+$, 17%), 303 ($M^+ - {}^{15}NH_2$, 100), 243 ($M^+$ − Ph, 77), 213 ($M^+ - C_6H_4OMe$ 82) and 77 ($Ph^+$, 8).

### *N*-Benzyl-4,4′-dimethoxytrityl($^{15}$N)amine ($^{15}$N)-2c

Benzyl bromide (518 mg, 3.03 mmol) and potassium carbonate (905 mg, 6.55 mmol) were added to a stirred solution of 4,4′-dimethoxytrityl($^{15}$N)amine (799 mg, 2.49 mmol) in dry DMF (5 $cm^3$). The reaction mixture was stirred at 20 °C for 3 days. The solvent was removed *in vacuo* (0.01 mmHg) and the resulting solid was extracted with diethyl ether (5 × 10 $cm^3$). The combined extracts were concentrated and the residue was chromatographed on silica gel [elution with ethyl acetate–light petroleum–triethylamine (29.5 : 69.5 : 1)]. The oil was dried (0.01 mmHg; 2 h) and refrigeration yielded the title compound as a crystalline solid (902 mg, 88%); $\delta_H$(200 MHz; [$^2H_6$]DMSO) 3.09 (1 H, t, *J* 8.2, $^{15}$NH), 3.29 (2 H, d, *J* 8.0, $CH_2$), 3.81 (6 H, s, 2 × OMe), 6.96 (4 H, d, *J* 8.8, 3- and 5-H) and 7.16–7.59 (14 H, m, ArH); $\delta_C$(50.3 MHz; [$^2H_6$]DMSO) 47.7 ($CH_2{}^{15}NH$), 55.3 (2 × OMe), 69.9 ($C^{15}NHCH_2$), 113.4 (C-3), 126.3 and 127.6 (C-4′ and -4Ar), 127.9, 128.0, 128.5 and 129.8 (C-2, -2′, -3′, -2Ar and -3Ar), 138.6 (C-1), 141.4 (C-1Ar), 147.1 (C-1′) and 157.7 (C-4); $\delta_N$(50.7 MHz; [$^2H_6$]DMSO; $MeNO_2$) −313.4.

### Benzyl($^{15}$N)amine

To a solution of *N*-benzyl-4,4′-dimethoxytrityl($^{15}$N)amine (715 mg, 1.74 mmol) in dry diethyl ether (10 $cm^3$) was added 1.91 M hydrochloric acid (10 $cm^3$) and the mixture was stirred for 3 h at 20 °C. The ethereal layer was separated and treated with saturated aq. sodium hydroxide (10 $cm^3$). The benzyl($^{15}NH_2$)amine was extracted with dichloromethane (5 × 10 $cm^3$). The extracts were combined, dried ($MgSO_4$) and filtered, and the filtrate was concentrated to give the title compound as a liquid (171 mg, 91%); $\delta_H$(200 MHz; $CDCl_3$) 1.68 (2 H, br s, $^{15}NH_2$), 3.80 (2 H, s, $CH_2$) and 7.12–7.32 (5 H, m, ArH); $\delta_C$(50.3 MHz; $CDCl_3$), 46.5 (d, *J* 3.2, $CH_2{}^{15}NH_2$), 126.8 (C-4), 127.1 (C-2), 128.6 (C-3) and 143.5 (C-1); $\delta_N$(50.7 MHz; $CDCl_3$; $MeNO_2$) − 354.4; *m*/*z* (EI) 108 ($M^+$, 100%), 91 ($M^+ - {}^{15}NH_2$, 52) and 77 ($Ph^+$, 35).

### 6-*N*$^6$-Benzyl(6-$^{15}$N)adenosine 4b

Benzyl($^{15}$N)amine (100 mg, 0.93 mmol) was added to a solution of 6-chloropurine riboside **5a** (140 mg, 0.46 mmol) in dry DMF (3 $cm^3$) containing triethylamine (140 mg, 1.39 mmol). After being stirred at 20 °C for 3 days, the solution was filtered. The filtrate was concentrated *in vacuo* (0.01 mmHg) and the residual solid was recrystallised from methanol to yield crystals of the *title compound* (141 mg, 89%), m.p. 182–184 °C (Found: C, 57.04; H, 5.26; N, 19.60. $C_{17}H_{19}N_5O_4$ requires C, 57.14; H, 5.36: N, 19.60%); $\delta_H$(200 MHz; [$^2H_6$]DMSO) 3.75 (2 H, m, 5′-$H_2$), 4.07 (1 H, m, 4′-H), 4.23 (1 H, m, 3′-H), 4.72 (1 H, dd, *J* 6.1 and 11.6, 2′-H), 4.82 (2 H, s, C$H_2$Ph), 5.31 (1 H, d, *J* 4.6, 5′-OH), 5.51 (2 H, m, 2′- and 3′-OH), 5.99 (1 H, d, *J* 6.1, 1′-H), 7.42 (5 H, m, ArH), 8.30 (1 H, s, 2-H), 8.48 (1 H, s, 8-H) and 8.59 (1 H, s, NH); $\delta_C$(50.3 MHz; [$^2H_6$]DMSO) 43.2 ($CH_2$), 61.2 (C-5′), 70.4 (C-3′), 73.8 (C-2′), 85.7 (C-4′), 88.0 (C-1′), 119.6 (C-5), 125.5, 126.3 and 127.1 (Ar), 137.4 (C-1Ar), 139.0 (C-8), 144.5 (C-4), 150.6 (C-2) and 151.2 (C-6); $\delta_N$(50.7 MHz; [$^2H_6$]DMSO; $MeNO_2$) − 344.07; *m*/*z* (EI) 357 ($M^+$, 40%), 268 ($M^+$ − PhC, 39), 225 ($M^+ - C_5H_8O_4$, 87), 120 ($C_5H_4N_4^+$, 60), 106 ($PhCH_2NH^+$, 86) and 91 ($PhCH_2^+$, 100).

### 2′,3′,5′-Triacetyl-6-*N*-benzyl(6-$^{15}$N)adenosine 4c

A mixture of 6-*N*-benzyl(6-$^{15}$N)adenosine (50.0 mg, 0.15 mmol), acetic anhydride (0.7 $cm^3$, 0.007 mmol) and dry pyridine (0.9 $cm^3$) was stirred at 20 °C for 2 h. The solution was concentrated *in vacuo* (0.01 mmHg) and the resulting clear oil was extracted with ethanol (4 × 2 $cm^3$). The combined extracts were concentrated on a rotatory evaporator to give an oil which crystallised on storage (62 mg, 90%); $\delta_H$(200 MHz; [$^2H_6$]DMSO) 2.10 (3 H, s, $OCH_3$), 2.13 (3 H, s, $OCH_3$), 2.21 (3 H, s, $OCH_3$), 4.48 (3 H, m, 4′-H and 5′-$H_2$), 4.81 (2 H, s, C$H_2$Ph), 5.73 (1 H, m, 3′-H), 6.14 (1 H, m, 2′-H), 6.30 (1 H, d, *J* 5.4, 1′-H), 7.42 (5 H, m, ArH), 8.33 (1 H, s, 2-H), 8.49 (1 H, s, 8-H) and 8.64 (1 H, s, NH); $\delta_C$(50.3 MHz; [$^2H_6$]DMSO) 20.5, 20.6 and 20.8 (3 × $OCH_3$), 43.2 ($CH_2$), 63.1 (C-5′), 70.6 (C-3′), 73.3 (C-2′), 80.3 (C-4′), 86.3 (C-1′), 120.1 (C-5), 127.4, 127.7 and 128.4 (C-2Ar, -3Ar and -4Ar), 138.3 and 140.4 (C-1Ar and -8), 148.6 (C-4), 153.1 (C-2), 155.5 (C-6), 169.4, 169.7 and 170.4 (3 × C=O); *m*/*z* (EI) 483 ($M^+$, 51%), 225 ($M^+ - C_5H_8O_4$, 100) and 91 ($PhCH_2^+$, 45).

### (6-$^{15}$N)Adenosine 4d

2′,3′,5′-Triacetyl-6-*N*-benzyl(6-$^{15}$N)adenosine (50 mg, 0.11 mmol), sodium periodate (10 mg, 0.45 mmol) and a catalytic amount of ruthenium(IV) oxide were stirred at 20 °C for 2 h in a mixture of $CH_2Cl_2$–$CH_3CN$–water (1 ml; 1 ml; 1.5 ml). The mixture was filtered, the product was extracted with dichloromethane, and the extract was concentrated, and then stirred (12 h) in aq. ammonia. The ammonia was removed to leave a solid, which was chromatographed on silica gel [elution with methanol–dichloromethane (15 : 85 to 30 : 70)] to give the title compound as a solid (14 mg, 49%), m.p. 234–235 °C (Found: C, 45.06; H, 4.83; N, 26.21. $C_{10}H_{13}N_5O_4$ requires C, 44.94; H, 4.91; N, 26.21%); $\delta_H$(200 MHz; [$^2H_7$]DMF) 3.58 (2 H, m, 5′-$H_2$), 3.95 (1 H, m, 4′-H), 4.16 (1 H, m, 3′H), 4.66 (1 H, m, 2′-H), 5.15 (1 H, s, 5′-OH), 5.48 (2 H, m, 2′- and 3′-OH), 5.85 (1 H, d, *J* 6.2, 1′-H), 7.29 (2 H, s, $NH_2$), 8.01 (1 H, s, 2-H) and 8.23 (1 H, s, 8-H); $\delta_C$(50.3 MHz; [$^2H_7$]DMF) 61.2 (C-5′), 70.4 (C-3′), 73.0 (C-2′), 87.7 (C-4′), 88.0 (C-1′), 119.5 (C-5), 139.2 (C-8), 148.1 (C-4), 151.2 (C-2) and 156.3 (C-6); $\delta_N$(50.7 MHz; [$^2H_7$]DMF; $MeNO_2$) −369.3; *m*/*z* (EI) 267 ($M^+$, 35%), 251 ($M^+ - NH_2$, 30), 135 ($M^+ - C_5H_8O_4$, 100), 108 ($C_4H_4N_4^+$, 86), 91 ($PhCH_2^+$, 55), 81 ($C_3H_3N_3^+$, 42) and 66 ($C_3H_2N_2^+$, 44).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