85. 8-Aza-7-deaza-2′,3′-dideoxyguanosine: Deoxygenation of its 2′-Deoxy-β-D-ribofuranoside

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The synthesis of 6-amino-1-(2′,3′-dideoxy-β-D-*glycero*-pentofuranosyl)-1*H*-pyrazolo[3,4-*d*]pyrimidin-4(5*H*)-one (= 8-aza-7-deaza-2′,3′-dideoxyguanosine; **1**) from its 2′-deoxyribofuranoside **5a** by a five-step deoxygenation route is described. The precursor of **5a**, **3a**, was prepared by solid-liquid phase-transfer glycosylation which gave higher yields (57%) than the liquid-liquid method. Ammonolysis of **3b** furnished the diamino nucleoside **3c**. Compound **1** was less acid sensitive at the *N*-glycosydic bond than 2′,3′-dideoxyguanosine (**2**).

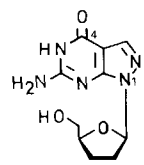
Introduction. – Recent studies on purine and pyrimidine 2′,3′-dideoxyribofuranosides demonstrate that these nucleosides inhibit the *in-vitro* replication cytopathic effect of HIV retroviruses, the etiologic agent of acquired immunodeficiency syndrome (AIDS). As 2′,3′-dideoxynucleoside triphosphates are inhibitors of viral as well as of cellular DNA polymerases, the drug can induce cytotoxicity within the host cell. On the other hand, the dideoxynucleosides can be deactivated by cellular metabolizing enzymes [1–3]. As a consequence, interest appeared in structurally modified compounds which do not show the drawbacks of the already known 2′,3′-dideoxynucleosides.

The present work describes the synthesis of the 2′,3′-dideoxynucleoside **1**, isosteric to 2′,3′-dideoxyguanosine (ddG; **2**), by deoxygenation of the thiocarbonate **7b**. Recently, the starting material **5a** has been synthesized in our laboratory *via* liquid-liquid phase-transfer glycosylation [4] but is now better accessible by applying solid-liquid techniques.

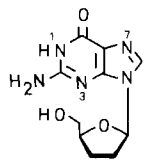
Results and Discussion. – We have found that solid-liquid phase-transfer glycosylation of pyrrolo[2,3-*d*]pyrimidines with an acyl-protected glycosyl halide is superior to the liquid-liquid method [5]. Therefore, we have applied these conditions for glycosylation of 6-amino-4-methoxy-1*H*-pyrazolo[3,4-*d*]pyrimidine [4] with 2-deoxy-3,5-di-*O*-(*p*-toluoyl)-α-D-*erythro*-pentofuranosyl chloride [6] in MeCN with an excess of powdered KOH and in the presence of the cryptand TDA-1. This reaction yielded crystalline **3a** in 57% yield apart from 10% of the N(2) regioisomer **4**. No α-D-nucleosides were formed. Glycosylation under liquid-liquid conditions (30% KOH/THF) in the absence of a catalyst gave 47% of **3a** and 13% of **4** and required chromatographic workup [4].

The protecting groups of **3a** were removed with NaOMe in MeOH affording crystalline **3b** in 84% yield ([4]: 69%). The MeO group of compound **3b** was displaced with NaOH at r.t. [4] to give **5a**; ammonolysis of **3b** furnished the 4,6-diaminonucleoside **3c**.

As described recently, 7-deazaguanine 2′,3′-dideoxyribofuranosides employed the 4,4′-dimethoxytrityl group for 5′-OH protection and either the same group or an amidine



1



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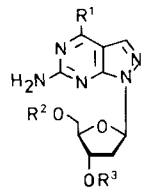
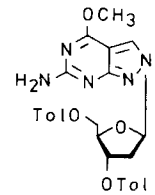


3a $R^1 = OCH_3$, $R^2 = R^3 = Tol$
b $R^1 = OCH_3$, $R^2 = R^3 = H$
c $R^1 = NH_2$, $R^2 = R^3 = H$



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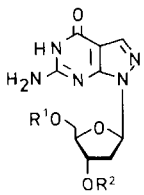
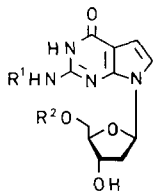
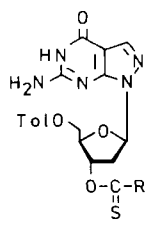


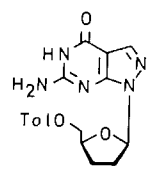
5a $R^1 = R^2 = H$
b $R^1 = Tol$, $R^2 = H$
c $R^1 = R^2 = Tol$



6a $R^1 = R^2 = H$
b $R^1 = H$, $R^2 = Tol$
c $R^1 = R^2 = Tol$



7a R =
b $R = OCH_3$



8

residue to protect the 2-NH_2 group of the nucleobase [7]. As we have synthesized an adequate protected derivative of compound **5a** for solid-phase oligonucleotide synthesis [8], we have tried to introduce the phenoxythiocarbonyl residue at the 3'-OH position. However, decomposition occurred due to the lability of the amino protecting group and/or the sensitivity of the *N*-glycosydic bond. Therefore, we have protected the 5'-OH group of **5a** with the *p*-toluoyl residue as we wished to use mild alkaline conditions for the final deprotection procedure.

Toluoylation of **5a** was accomplished with 1 equiv. of toluoyl chloride at −10° in pyridine yielding crystalline **5b** (73%). As by-product (9%), 3',5'-di-*O*-toluoylated **5c** was isolated by chromatographic separation. In the case of 7-deaza-2'-deoxyguanosine (**6a**) [9], toluoylation with 1 equiv. of *p*-toluoyl chloride gave 54% of 5'-*O*-toluoylated **6b** and 22% of a di-toluoylated compound with the protecting groups at the 5'-OH and 2-NH_2 function (**6c**). However, in the case of **6a**, 4,4'-dimethoxytritylation yielded only

Table 1. *^{13}C-NMR Chemical Shifts of* **1** *and Related Pyrazolo[3,4-d]pyrimidine Nucleosides in (D_6)DMSO*

	C(3)	C(3a)	C(4)	C(6)	C(7a)	C(1')	C(2')	C(3')	C(4')	C(5')	C=O	C=S	CH_3	OCH_3
1	135.1	99.7	157.9	155.0	155.3	83.8	30.3	27.3	81.6	64.3	–	–	–	–
3c	133.3	95.5	162.7[a])	156.9[a])	158.3[a])	83.3	38.0	71.3	87.4	62.7	–	–	–	–
5a	134.9	99.7	157.4	154.6	155.2	83.1	37.9	71.0	87.3	62.4	–	–	–	–
5b	135.5	99.9	157.8	155.1	155.6	83.0	38.1	70.8	83.7	64.6	165.7	–	21.2	–
5c	135.8	100.0	157.8	155.2	155.9	81.3	35.2	75.2	83.5	64.3	165.4, 165.6	–	21.25, 21.28	–
7b	135.9	100.0	157.8	155.3	156.0	83.3	34.5	80.8	83.4	64.0	165.5	195.1	21.3	60.1
8	135.3	99.7	157.9	155.0	155.4	83.9	30.4	27.0	78.2	66.3	165.7	–	21.3	–

[a]) Tentative assignment.

Table 2. *^{13}C-NMR Chemical Shifts of* **6a** *and Related Pyrrolo[2,3-d]pyrimidine Nucleosides in (D_6)DMSO*

	C(2)	C(4)	C(4a)	C(5)	C(6)	C(7a)	C(1')	C(2')	C(3')	C(4')	C(5')	C=O	CH_3
6a	152.5	158.5	100.1	102.1	116.7	150.5	82.2	39.5	70.8	86.9	61.9	–	–
6b	152.8	158.7	100.2	102.7	116.5	150.8	82.2	39.1	70.8	83.5	64.7	165.7	21.3
6c	147.1	156.9	104.6	103.3	119.7	147.8	82.7	39.1	70.9	83.7	64.6	168.8, 165.7	21.2, 21.3

one product; thus the latter procedure was preferred during 3'-deoxygenation of **6a** [7]. The regioisomers were assigned on the basis of ^{13}C-NMR spectra.

Regarding **5a** [4] *(Table 1)*, 5'-*O*-toluoylation (→**5b**) shifts C(5') downfield and C(4') upfield, whereas 3',5'-di-*O*-toluoylated **5c** shows additionally a downfield shift of C(3') and an upfield shift of C(1') and C(2'). ^{13}C-NMR signals of the nucleobase are almost unaffected. If one toluoyl residue is attached to the amino function (see **6c**), ^{13}C-NMR signals of the sugar moiety are similar to **6b**, but the signals of the nucleobase are altered *(Table 2)*.

Compound **5b** was reacted with an excess of *N,N'*-(thiocarbonyl)diimidazole in DMF to give the imidazolide **7a**, which upon reaction with MeOH afforded the methyl thiocarbonate **7b** in 82% yield. Deoxygenation of the latter with tributylstannane [10] [11] in toluene containing 2,2'-azobis(2-methylpropiononitrile) (AIBN) gave **8**. *Zemplen* deprotection furnished crystalline 8-aza-7-deaza-2',3'-dideoxyguanosine **1**.

It has been already observed on the ^{1}H-NMR spectra of 2',3'-dideoxynucleosides that H–C(3') is located upfield from H–C(2') [7] [12]. This assignment was also confirmed for **1** by the 2D-NMR-^{1}H,^{1}H-COSY spectrum. Regarding this, the 2D-^{1}H,^{13}C-correlation spectrum provided the assignment of the ^{13}C-NMR shifts shown in *Table 1*.

The stability of the *N*-glycosydic bond of 2',3'-dideoxynucleosides is related to the pharmacokinetics, as this bond can be cleaved by phosphorylases [13] under loss of the activity. Therefore, we have determined the stability of this linkage against acid-catalysed hydrolysis. Experiments were carried out at 25° in 0.01N HCl at 30 μM nucleoside concentration. From the time-dependent UV-absorbance plots, the half-lifes of nucleobase release were determined. Compared to 2',3'-dideoxyguanosine (**2**; $\tau_{1/2}$ = 37 min [7]), compound **1** showed enhanced hydrolytic stability ($\tau_{1/2}$ = 135 min). This is similar to findings observed on other pyrazolo[3,4-*d*]pyrimidine 2',3'-dideoxyribonucleosides [14]. Antiviral evaluation of **1** is in progress.

Experimental Part

General. TLC: silica gel *SIL G-25 UV_{254}* plates (*Macherey-Nagel*, FRG). Column chromatography: silica gel (70–230 mesh; *Merck*, FRG). Solvent systems: *A* = CH_2Cl_2/MeOH 9:1, *B* = CH_2Cl_2/MeOH 95:5. M.p.: *Linström* apparatus (*Wagner & Munz*, FRG); not corrected. UV spectra: *U-3200* spectrophotometer (*Hitachi*, Japan). NMR spectra: *AC-250* spectrometer equipped with an *Aspect 3000* data system and an array processor (*Bruker*, FRG); operational frequencies 250.133 (^{1}H) and 62.898 MHz (^{13}C); δ values in ppm rel. to tetramethylsilane as internal standard (^{1}H and ^{13}C), δ's positive when downfield from the appropriate standard; digital resolutions 0.275 Hz/pt (^{1}H) and 0.526 Hz/pt (^{13}C). Homonuclear correlation spectroscopy (^{1}H,^{1}H-COSY): pulse sequence D_1–90°–D_0–90°–FID with a relaxation period D_1 of 1 s and an initial delay D_0 of 3 μs; 2048 data points and 512 data points in the t_2 and t_1 directions. 2D-^{1}H,^{13}C-correlation spectrum: 2048 data points and 1024 data points in the t_2 and t_1 dimensions; pulse sequence D_0–90°–D_0–D_0–D_3–90°–BB(^{1}H) and D_1–180°–90°–D_4–FID (^{13}C); the delays were set to D_0 = 3 μs, D_1 = 2.5 μs, D_3 = 0.00345 s, and D_4 = 0.5 D_3; typical 90°-pulse width, 10.8 s. After sine-bell multiplication of the domain data and *Fourier* transformation, the contour plots with a digital resolution of 2.9 Hz/pt were obtained. Elemental analysis were performed by *Mikroanalytisches Labor Beller* (Göttingen, FRG).

*6-Amino-1-[2'-deoxy-3',5'-di-*O*-(p-toluoyl)-β-*D*-*erythro*-pentofuranosyl]-4-methoxy-1*H*-pyrazolo[3,4-d]pyrimidine* (**3a**). Powdered KOH (200 mg, 3.6 mmol) was stirred for 5 min in anh. MeCN (20 ml). Solid 2-amino-4-methoxy-1*H*-pyrazolo[3,4-*d*]pyrimidine (100 mg, 0.6 mmol) [4] was added and stirring was continued for another 10 min. Then the mixture was treated with tris[2-(2-methoxyethoxy)ethyl]amine (TDA-1; 20 µl, 0.06 mmol). After 10 min, solid 2-deoxy-3,5-di-*O*-(*p*-toluoyl)-α-D-*erythro*-pentofuranosyl chloride [6] (240 mg, 0.6 mmol) was added to the stirred suspension and stirring continued for 30 min at r.t. Insoluble material was filtered off, and the filtrate was evaporated yielding a yellowish foam. Crystallization from MeOH afforded colorless needles (176 mg, 57%). M.p. 157° ([4]: 157°).

*6-Amino-2-[2'-deoxy-3',5'-di-*O*-(p-toluoyl)-β-*D*-erythro-pentofuranosyl]-4-methoxy-1*H*-pyrazolo[3,4-d]pyrimidine* (**4**). The mother liquor remaining after crystallization of **3a** was evaporated and the residue chromatographed on silica gel *60* (column 2.5 × 15 cm, *A*). From the fast migrating zone, **4** (30 mg, 10%) was isolated as colorless foam. UV (MeOH): 240, 283, 295 ([4]: 240, 283, 295).

*6-Amino-1-(2'-deoxy-β-*D*-erythro-pentofuranosyl)-4-methoxy-1*H*-pyrazolo[3,4-d]pyrimidine* (**3b**) was prepared as described earlier from **3a** (3.0 g, 5.8 mmol) [4], except that the neutralized mixture was evaporated to dryness. Then, H_2O (200 ml) and CH_2Cl_2 (50 ml) were added. After stirring for 2 h, the org. layer was decanted and the aq. phase again extracted with CH_2Cl_2 (50 ml). From the reduced aq. phase (15 ml), crystallization occurred over night. Colorless needles (1.37 g, 84%). M.p. 149–151° ([4]: 149–151°).

*4,6-Diamino-1-(2'-deoxy-β-*D*-erythro-pentofuranosyl)-1*H*-pyrazolo[3,4-d]pyrimidine* (**3c**). A soln. of **3b** (150 mg, 0.53 mmol) in aq. 25% NH_3 soln. (10 ml) was heated at 50° for 72 h. The solvent was evaporated, and colorless needles (96 mg, 68%) were obtained, after crystallization from H_2O. M.p. 148°. TLC (silica gel, *A*): R_f 0.1. UV (MeOH): 223 (32200), 258 (8800), 275 (9000). ^{1}H-NMR ((D_6)DMSO): 2.13, 2.69 (*2m*, 2H–C(2')); 3.40, 3.47 (*2m*, CH_2(5')); 3.76 (*m*, H–C(4')); 4.37 (*m*, H–C(3')); 4.84 (*t*, *J* = 5.7, OH–C(5')); 5.17 (*d*, *J* = 3.7, OH–C(3')); 6.10 (*s*, NH_2); 6.34 (*t*, *J* = 6.4, H–C(1')); 7.14 (*s*, NH_2); 7.85 (*s*, H–C(3)). Anal. calc. for $C_{10}H_{14}N_6O_3$ (266.3): C 45.11, H 5.30, N 31.56; found: C 44.98, H 5.20, N 31.40.

*6-Amino-1-[2'-deoxy-5'-*O*-(p-toluoyl)-β-*D*-erythro-pentofuranosyl]-1*H*-pyrazolo[3,4-d]pyrimidin-4(5*H*)-one* (**5b**). A soln. of *p*-toluoyl chloride (134 µl, 1 mmol) in 1,2-dichloroethane (2 ml) was added dropwise to a stirred soln. of **5a** [4] (266 mg, 1 mmol) in dry pyridine (5 ml) at −10°. Stirring was continued for 3 h at r.t. The solvent was evaporated and the residue chromatographed on silica gel *60* (column 2.5 × 20 cm, *A*). From the slower migrating main zone, colorless needles (281 mg, 73%) were isolated after crystallization (MeOH). TLC (silica gel, *A*): R_f 0.3. M.p. 236°. UV (MeOH): 245 (25100). ^{1}H-NMR ((D_6)DMSO): 2.31, 2.74 (*2m*, 2H–C(2')); 2.38 (*s*, CH_3); 4.04, 4.23, 4.38 (*3m*, H–C(4'), CH_2(5')); 4.60 (*m*, H–C(3')); 5.44 (*d*, *J* = 4.6, OH–C(3')); 6.34 (*t'*, *J* = 6.4, H–C(1')); 6.70 (*s*, NH_2); 7.33, 7.87 (*2d*, *J* = 8.5, 4 arom. H); 7.85 (*s*, H–C(3)); 10.61 (*s*, NH). Anal. calc. for $C_{18}H_{19}N_5O_5$ (385.4): C 56.10, H 4.97, N 18.17; found: C 56.06, H 4.93, N 18.08.

*6-Amino-1-[2'-deoxy-3',5'-di-*O*-(p-toluoyl)-β-*D*-erythro-pentofuranosyl]-1*H*-pyrazolo[3,4-d]pyrimidin-4(5*H*)-one* (**5c**). From the faster migrating zone, **5c** (45 mg, 9%) was isolated after crystallization from *i*-PrOH. M.p. 210°. TLC (silica gel, *A*): R_f 0.5. UV (MeOH): 243 (41200). ^{1}H-NMR ((D_6)DMSO): 2.37, 2.40 (*2s*, $2CH_3$); 2.67, 3.12 (*2m*, 2H–C(2')); 4.42 (*m*, H–C(4'), CH_2(5')); 5.78 (*m*, H–C(3')); 6.48 (*t'*, *J* = 6.3, H–C(1')); 6.76 (*s*, NH_2); 7.31, 7.35, 7.88, 7.90 (*4d*, *J* = 8.2, 8 arom. H); 7.89 (*s*, H–C(3)); 10.66 (*s*, NH). Anal. calc. for $C_{26}H_{25}N_5O_6$ (503.52): C 62.02, H 5.00, N 13.91; found: C 62.02, H 5.07, N 13.95.

*6-Amino-1-[2'-deoxy-3'-*O*-(methoxythiocarbonyl)-5'-*O*-(p-toluoyl)-β-*D*-erythro-pentofuranosyl]-1*H*-pyrazolo[3,4-d]pyrimidin-4(5*H*)-one* (**7b**). A soln. of **5b** (600 mg, 1.6 mmol) and *N,N'*-(thiocarbonyl)diimidazole (851 mg, 4.8 mmol) in dry DMF (5 ml) was heated at 80° under Ar for 3 h and was then evaporated. The residue in anh. MeOH (50 ml) was heated at 60° for 2 h. After evaporation, the residue was chromatographed at silica gel (column 2.5 × 20 cm, *B*). The main zone was concentrated to 1 ml, and **7b** (583 mg, 82%) was isolated, after precipitation with hexane, as amorphous powder. TLC (silica gel, *A*): R_f 0.5. UV (MeOH): 243 (24800). ^{1}H-NMR ((D_6)DMSO): 2.38 (*s*, CH_3); 2.64, 3.19 (*2m*, 2H–C(2')); 4.03 (*s*, CH_3O); 4.02 (*m*, H–C(4'), CH_2(5')); 5.99 (*m*, H–C(3')); 6.41 (*t'*, *J* = 6.5, H–C(1')); 6.75 (*s*, NH_2); 7.33, 7.90 (*2d*, *J* = 8.1, 4 arom. H)); 7.89 (*s*, H–C(3)); 10.66 (*s*, NH). Anal. calc. for $C_{20}H_{21}N_5O_6S$ (459.5): C 52.28, H 4.61, N 15.24, S 6.98; found: C 52.31, H 4.76, N 15.32, S 6.84.

*6-Amino-1-[2',3'-dideoxy-5'-*O*-(p-toluoyl)-β-*D*-glycero-pentofuranosyl]-1*H*-pyrazolo[3,4-d]pyrimidin-4(5*H*)-one* (**8**). A soln. of **7b** (360 mg, 0.78 mmol), 2,2'-azobis(2-methylpropiononitrile) (20 mg, 0.12 mmol), and tributylstannane (2.4 ml, 8.9 mmol) in anh. toluene (15 ml) was heated at 100° in a stoppered flask under Ar for 2 h. The solvent was evaporated and the residue chromatographed on silica gel (column 2.5 × 20 cm, *B*). The eluate of the main zone was concentrated (1 ml) and then poured into hexane (100 ml). Filtration yielded a colorless powder (267 mg, 93%). TLC (silica gel, *A*): R_f 0.4. UV (McOH): 245 (23900). ^{1}H-NMR ((D_6)DMSO): 2.15 (*m*, 2H–C(3')); 2.41 (*m*, 2H–C(2')); 2.37 (*s*, CH_3); 4.23 (*m*, H–C(4')); 4.35 (*m*, CH_2(5')); 6.23 (*m*, H–C(1')); 6.70 (*s*,

NH_2); 7.32, 7.84 (2*d*, *J* = 8.1, 4 arom. H); 7.82 (*s*, H–C(3)); 10.61 (*s*, NH). Anal. calc. for $C_{18}H_{19}N_5O_4$ (369.4): C 58.53, H 5.18, N 18.96; found: C 58.45, H 5.22, N 18.81.

*6-Amino-1-(2',3'-dideoxy-β-*D-glycero-*pentofuranosyl)-1*H-*pyrazolo[3,4-*d*]pyrimidin-4(5*H*)-one* (**1**). A soln. of **8** (263 mg, 0.7 mmol) in 0.01 M $NaOCH_3$ in MeOH (10 ml) was stirred at r.t. for 48 h. The solvent was evaporated and the residue purified by silica-gel chromatography (column 2.5 × 20 cm, *A*). Evaporation of the solvent and crystallization of the residue from H_2O furnished colorless needles (110 mg, 62%). M.p. 221°. TLC (silica gel, *B*): R_f 0.2. UV (MeOH): 253 (15500). ^{1}H-NMR ((D_6)DMSO): 2.05 (*m*, 2H–C(3')); 2.33 (*m*, 2H–C(2')); 3.41 (*m*, CH_2(5')); 4.04 (*m*, H–C(4')); 4.70 (*t*, *J* = 4.70, OH–C(5')); 6.19 (*dd*, *J* = 3.5, 6.9, H–C(1')); 6.69 (*s*, NH_2); 7.81 (*s*, H–C(3)); 10.60 (*s*, NH). Anal. calc. for $C_{10}H_{13}N_5O_3$ (251.3): C 47.81, H 5.22, N 27.88; found: C 48.01, H 5.30, N 27.83.

*2-Amino-7-[2'-deoxy-5'-*O-(p-*toluoyl)-β-*D-erythro-*pentofuranosyl]-7*H-*pyrrolo[2,3-*d*]pyrimidin-4(3*H*)-one* (**6b**) was synthesized as described for **5b**, except that **6a** (266 mg, 1 mmol) was dissolved in dry pyridine/DMF 1:1 (5 ml). From the slower migrating main zone of the column chromatography, colorless crystals (209 mg, 54%) were isolated, after crystallization from MeOH. M.p. 270°. TLC (silica gel, *A*): R_f 0.3. UV (MeOH): 218 (25000), 245 (20500), 261 (sh, 14700), 277 (sh, 8500). ^{1}H-NMR ((D_6)DMSO): 2.23, 2.40 (2*m*, 2H–C(2')); 2.38 (*s*, CH_3); 4.05 (*m*, H–C(3')); 4.36 (*m*, H–C(4'), CH_2(5')); 5.45 (*d*, *J* = 4.0, OH–C(3')); 6.25 (*d*, *J* = 3.7, H–C(6)); 6.26 (*s*, NH_2); 6.35 (*t*, *J* = 6.3, H–C(1')); 6.84 (*d*, *J* = 3.7, H–C(5)); 7.34, 7.86 (2*d*, *J* = 8.0, 4 arom. H); 10.37 (*s*, NH). Anal. calc. for $C_{19}H_{20}N_4O_5$ (384.4): C 59.37, H 5.24, N 14.58; found: C 59.40, H 5.25, N 14.54.

*7-[2'-Deoxy-5'-*O-(p-*toluoyl)-β-*D-erythro-*pentofuranosyl]-2-(*p-*toluoylamino)-7*H-*pyrrolo[2,3-*d*]pyrimidin-4(3*H*)-one* (**6c**). From the faster migrating zone, colorless needles (108 mg, 22%) were isolated by crystallization from MeOH. M.p. 268°. TLC (silica gel, *A*): R_f 0.6. UV (MeOH): 241 (32100), 312 (15000). ^{1}H-NMR ((D_6)DMSO): 2.25, 2.57 (2*m*, 2H–C(2')); 2.38, 2.40 (2*s*, $2CH_3$); 4.10 (*m*, H–C(3')); 4.42 (*m*, H–C(4'), CH_2(5')); 5.51 (*d*, *J* = 3.6, OH–C(3')); 6.51 (*d*, *J* = 3.6, H–C(6)); 6.54 (*t*, *J* = 6.9, H–C(1')); 7.21 (*d*, *J* = 3.6, H–C(5)); 7.33 (*d*, *J* = 7.3, 4 arom. H); 7.86, 7.96 (2*d*, *J* = 8.1, 4 arom. H); 11.64, 12.12 (2*s*, 2NH). Anal. calc. for $C_{27}H_{26}N_4O_6$ (502.5): C 64.53, H 5.22, N 11.15; found: C 64.51, H 5.22, N 11.20.

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