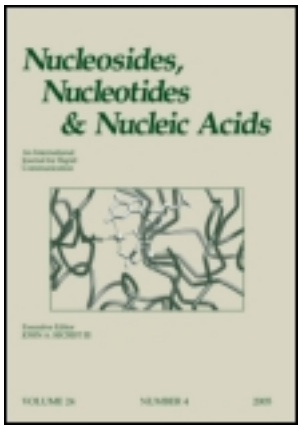

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SYNTHESIS AND STRUCTURE DETERMINATION OF SOME OXADIAZOLE-2-THIONE AND TRIAZOLE-3-THIONE GALACTOSIDES

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SYNTHESIS AND STRUCTURE DETERMINATION OF SOME OXADIAZOLE-2-THIONE AND TRIAZOLE-3-THIONE GALACTOSIDES

Roshan Ahmad,[1,*] Rashid Iqbal,[1] Humaira Akhtar,[1] Zia-ul-Haq,[1] Helmut Duddeck,[2,*] Lech Stefaniak,[3,†] and Jerzy Sitkowski[3]

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ABSTRACT

The syntheses of 5-pyridyl-3(β-D-galactopyranosyl)-1,3,4-oxadiazole-2-thiones **3a**–**3c** and 5-pyridyl-2(β-D-galactopyranosyl)-4-benzyl-1,2,4-triazole-3-thiones **6a**–**6c** are reported. The existence of *N*-galactosides – not *S*-galactosides – was proven by IR and ^{15}N NMR spectroscopy. The structures of the final products and the intermediates were elucidated by IR, ^{1}H, ^{13}C and ^{15}N NMR spectroscopy and mass spectrometry.

During the last thirty years and especially since the discovery of 2′,3′-dideoxycytidine (DDC)[1], 2′,3′-dideoxyinosine (DDI)[2] and azidothymidine (AZT)[3] as anti-HIV agents, a large number of nucleosides have been synthesized. The nucleosides of *N*-substituted azoles constitute a special class both for their biological significance[4] and for the particular synthetic methods involved in their preparation. Amongst the new synthetic nucleosides,

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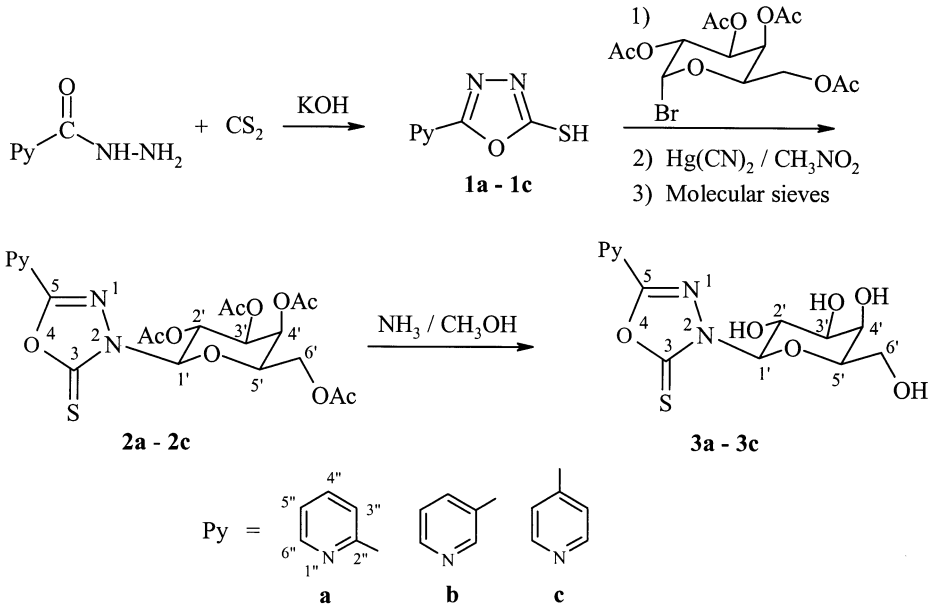
pyrazoles, oxadiazoles, oxatriazoles and triazoles are the significant counterparts of sugars. Ribavirin[5] the first synthetic broad-spectrum non-interferon inducing antiviral agent has been prepared and tested against a variety of both DNA and RNA viruses in tissue culture. Then, the ribonucleoside antibiotics pyrazomycin and formycin[6] have also demonstrated antiviral activity in vitro. Some other triazole nucleosides[7] having haloalkyl groups were reported to be effective against ECA and P388 tumor systems. *N*-Glycosides of oxadiazoles are not very well known but 2-β-D-ribofuranosyl-1,2,4-oxadiazole-3,5-dione[8] showed significant antiviral activity against herpes simplex HSV type 1, HSV type 2 and parainfluenza virus type 3. Glucosides of structurally similar heterocycles have been reported before[9–11].

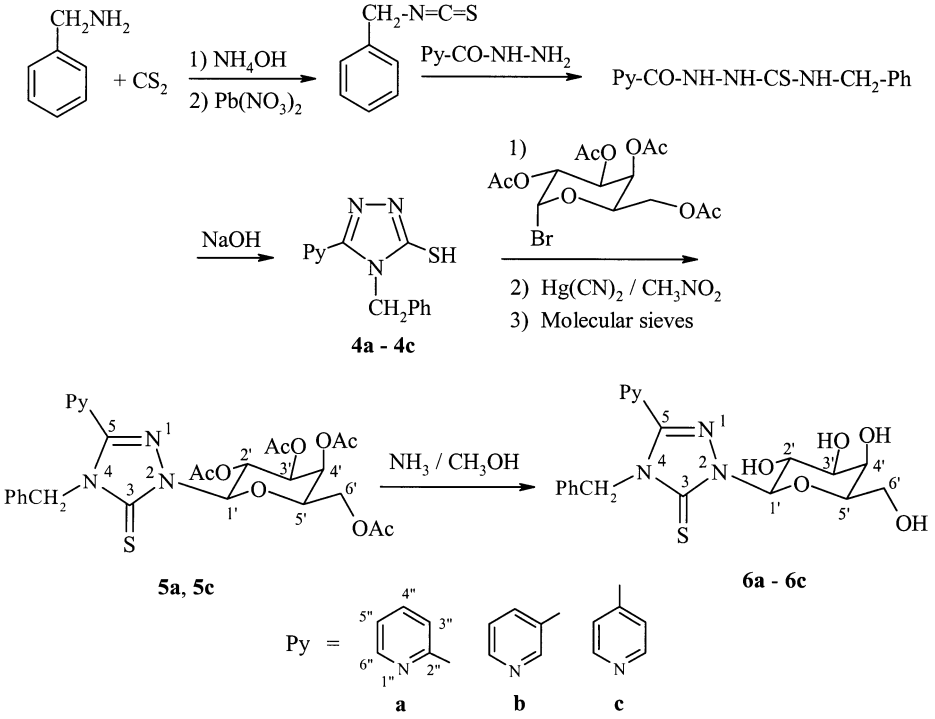
In continuation of our work on the synthesis of novel nucleosides as potential antiviral agents and keeping in mind the biological significance of pyridyl substituted triazoles[12,13] and mercapto-oxadiazoles[14,15], we synthesized new pyridyl-substituted azoles and prepared their nucleosides. We hereby report the synthesis and spectroscopy of 5-pyridyl-3-(β-D-galactopyranosyl)-1,3,4-oxadiazole-2-thiones **3a–3c** and 5-pyridyl-2-(β-D-galactopyranosyl)-4-benzyl-1,2,4-triazole-3-thiones **6a–6c**.

The mercapto-oxadiazoles **1a–1c** were synthesized by the reaction of pyridyl-substituted hydrazides with CS_2/KOH (Scheme 1). The syntheses of some structurally related compounds have been reported earlier using slightly different procedures[16].



Scheme 1. Synthesis of oxadiazole-2-thione galactosides.

The mercaptotriazoles **4a**–**4c** were synthesized as shown in Scheme 2, and the compounds showed the physical data in accordance with the data reported in literature[12].



Scheme 2. Synthesis of triazole-3-thione galactosides.

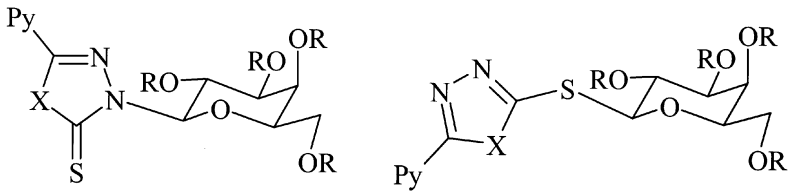
The mercapto-oxadiazoles and triazoles were then coupled with aceto-bromogalactose in the presence of mercuric cyanide/nitromethane to give the corresponding nucleosides **2a**–**2c** and **5a**–**5c**, respectively. The structure of the compounds was established by IR, ^{1}H NMR, ^{13}C NMR, COSY, HETCOR and mass spectrometry. IR spectra showed a peak at 1224 cm^{-1} indicative of C=S. This shows that the glycosides are *N*-glycosides and not *S*-glycosides (Scheme 3).

In the ^{1}H NMR spectra of the compounds **2a**–**2c** and **5a**–**5c** (Table 1) the protons of the acetyl groups appear as singlets in the region $\delta = 1.84-2.25$. H-5′ and H-6′/6′a resonate as multiplets in the range $\delta = 4.13-4.28$. The β configuration of these nucleosides was assigned by NMR measurements; the anomeric proton H-1′ signals appear as doublets with coupling constants of 9–10 Hz in all compounds which clearly indicates the diaxial orientation of H-1′ and H-2′. In case of the compounds **5a**›–**5c**,

Table 1. ^{1}H and ^{15}N Chemical Shifts of the *N*-glycosides **2a**–**2c**, **3a**–**3c**, **5a**, **5c**, and **6a**–**6c**[a,b]

Solvent	**2a** C	**2b** C	**2c** C	**3a** Py	**3b** Py	**3c** Py	**5a** C	**5c** C	**6a** Py	**6b** Py	**6c** Py
H-1′	5.97	5.94	5.93	6.94	6.91	6.48	6.31	6.29	6.93	6.91	6.91
H-2′	5.79	5.75	5.73	5.52	5.53	5.29	5.93	5.84	5.52	5.27	5.54
H-3′	5.29	5.27	5.27	4.43–4.52	4.28–4.53	4.43–4.53	5.29	5.31	4.43–4.51	4.47–4.55	4.47–4.47
H-4′	5.54	5.54	5.54	4.76	4.74	4.74	5.55	5.55	4.78	4.77	4.79
H-5′	4.16–4.24	4.16–4.24	4.16–4.24	4.43–4.52	4.28–4.53	4.43–4.53	4.16–4.26	4.21	4.43–4.51	4.47–4.55	4.47–4.47
H-6′/6′a	4.16–4.24	4.16–4.24	4.16–4.24	4.43–4.52	4.28–4.53	4.43–4.53	4.16–4.26	4.23,4.28	4.43–4.51	4.47–4.55	4.47–4.47
OAc	2.25 (4′)	2.26 (4′)	2.26 (4′)	–	–	–	2.23 (4′)	2.20 (4′)	–	–	–
	2.07 (6′)	2.07 (6′)	2.07 (6′)	–	–	–	2.06 (6′)	2.07 (6′)			
	2.02 (3′)	2.03 (3′)	2.03 (3′)	–	–	–	2.02 (3′)	2.02 (3′)			
	1.98 (2′)	1.99 (2′)	1.98 (2′)	–	–	–	1.84 (2′)	1.92 (2′)			
H-2″	–	9.22	7.84	–	9.21	7.42	–	7.41	–	8.73	7.26
H-3″	8.07	–	8.84	7.71	–	8.80	8.05	8.71	7.54	-/-	8.70
H-4″	7.90	8.27	–	7.63	8.04	–	7.97	–	7.54	7.58	–
H-5″	7.51	7.49	8.84	7.22	7.27	8.80	7.38	8.71	7.20	7.13	8.70
H-6″	8.81	8.82	7.84	8.74	8.72	7.42	8.64	7.41	8.73	8.72	7.26
$C\underline{H_2}Ph$	–	–	–	–	–	–	6.09/5.97	5.41/5.35	6.15	5.60,5.59	5.64,5.63
Ph	–	–	–	–	–	–	~7.2 (5H)	7.31 (*m*, *p*)	7.46 (*o*)	7.20 (*m*, *p*)	7.22–7.25
								7.07 (*o*)	7.11–7.13	7.13 (*o*)	(*m*, *p*)
									(*m*, *p*)		7.17 (*o*)
N-1			–				– 104.8				
N-2			–				– 174.8				
N-3	– 180.7		– 179.8				–				
N-4	– 111.3		– 110.5				– 204.2				
N-1″	– 73.9		– 56.9				– 73.6				

[a] In ppm; relative to TMS; solvents: C = $CDCl_3$, Py = pyridine-d_5.
[b] For $^{1}H,^{1}H$ coupling constants see text.



N-galactoside *S*-galactoside

X = O or N-CH_2Ph; R = H or Ac

Scheme 3. Conceivable isomeric galactosides.

the diastereotopic methylene protons of benzyl group resonate as doublets in the region = 5.35−5.97 and = 5.41−6.09 with geminal coupling constants of 14.3 Hz. The remaining galactose ^{1}H signals appear as doublets with the expected chemical shifts and coupling constants $J(\text{H-}2',3') = 10.0-10.3$ Hz, $J(\text{H-}3',4') = 3.4-3.7$ Hz and $J(\text{H-}4',5') \approx 1$ Hz. The pyridyl ring protons resonate as expected for respective monosubstituted pyridines and reveal the expected coupling splittings[17]. The coupling interactions between different protons were confirmed by COSY experiments.

The ^{13}C NMR spectra of all the isolated nucleosides (Table 2) exhibit signals for the methyl carbon atoms of acetyl groups in the range δ = 20.5−20.8; the carbonyl carbon atoms resonated in the region δ = 169.0−170.4. In each case the anomeric carbon atom resonated at δ = 83.2−83.7 indicating its linkage with the N-atom of the heterocyclic moiety. The C-2 atom **2a**−**2c** and **3a**−**3c** as well as **5a**, **5c**, **6a**−**6c** of the heterocyclic moieties resonate in the region = 170.6−178.9 indicating its linkage with sulfur atom. All proton-carbon connectivities were proven by HETCOR.

In the mass spectra of all the compounds, molecular ion peaks appeared with low intensities (3−14%). Base peaks were formed by the successive loss of CH_3COOH and CH_3CO from the molecular ion. Other prominent peaks were present due to removal of either sugar moiety or heterocyclic moiety from the molecular ion.

The deacetylation of compounds **2a**−**2c** and **5a**−**5c** was carried out successfully in methanolic ammonia to get the corresponding deblocked nucleosides **3a**−**3c** and **6a**−**6c**. IR spectra of all the deacetylated products showed free OH stretching vibrations in the region 3250−3500 cm^{-1} and lacked any signal due to carbonyl stretching vibrations indicating complete deacetylation of the compounds.

In ^{1}H NMR spectra of all the compounds (Table 1), doublets were observed due to anomeric protons which resonated in the region δ = 6.48−6.94 with coupling constants of 9−10 Hz giving a clear indication

Table 2. ^{13}C Chemical Shifts of the *N*-glycosides **2a**–**2c**, **3a**–**3c**, **5a**, **5c**, and **6a**–**6c**[a]

Solvent	**2a** C	**2b** C	**2c** C	**3a** Py	**3b** Py	**3c** Py	**5a** C	**5c** C	**6a** Py	**6b** Py	**6c** Py
C-2	178.0	177.6	177.7	171.6	171.7	178.9					
C-3							171.6	171.3	172.6	172.2	170.6
C-5	158.2	157.5	157.5	–[b]	153.2	157.2	145.9	149.5	148.0	148.9	148.5
C-1′	83.7	83.7	83.6	86.4	86.4	88.0	83.2	83.4	87.6	87.7	86.2
C-2′	67.0	66.9	66.9	69.9	69.7	70.2	67.2	67.7	70.0	70.0	68.2
C-3′	66.8	66.7	66.7	75.6	76.2	76.0	67.0	66.9	76.0	76.0	73.9
C-4′	71.2	71.2	71.1	70.1	70.4	70.3	71.5	70.4	70.3	70.2	68.4
C-5′	73.8	73.8	73.8	80.3	79.9	80.0	73.6	73.7	80.1	80.0	78.5
C-6′	61.2	61.2	61.2	62.1	62.3	62.1	61.2	61.2	62.2	60.6	60.6
O$\underline{C}$OCH$_3$	170.4 (4′)	170.4	170.4	–	–	–	170.4 (4′)	170.4 (4′)	–	–	–
	170.3 (6′)	170.2	170.2	–	–	–	170.3 (6′)	170.3 (6′)	–	–	–
	169.9 (3′)	169.9	169.9	–	–	–	169.9 (3′)	169.9 (3′)	–	–	–
	169.2 (2′)	169.2	169.2	–	–	–	169.0 (2′)	169.1 (2′)	–	–	–
OCO$\underline{C}$H$_3$	20.8 (2′)	20.7	20.7	–	–	–	20.8 (2′)	20.7 (2′)	–	–	–
	20.7 (4′)	20.7	20.7	–	–	–	20.7 (4′)	20.7 (4′)	–	–	–
	20.6 (6′)	20.6	20.6	–	–	–	20.6 (6′)	20.7 (6′)	–	–	–
	20.5 (3′)	20.5	20.5	–	–	–	20.5 (3′)	20.6 (3′)	–	–	–
C-2″	141.7	153.3	151.0	145.4	150.4	151.1	145.9	150.4	146.2	152.1	150.6
C-3″	123.1	118.7	120.0	121.3	122.6	119.8	124.2	122.8	123.4	123.7	122.7
C-4″	137.3	134.1	129.2	137.1	133.6	129.6	137.2	133.3	137.1	136.1	133.4
C-5″	126.6	123.8	120.0	125.2	123.8	119.8	125.3	122.8	125.2	122.7	122.7
C-6″	150.7	147.9	151.0	150.0	147.6	151.1	148.9	150.4	149.0	149.???	150.6
$\underline{C}$H$_2$Ph	–	–	–	–	–	–	48.9	48.8	49.2	49.2	48.0
Ph	–	–	–	–	–	–	135.9 (C)	134.4 (C)	135.3 (C)	135.4 (C)	135.3 (C)
	–	–	–	–	–	–	127.7 (*o*)	126.6 (*o*)	128.2 (*o*)	126.9 (*o*)	126.9 (*o*)
	–	–	–	–	–	–	128.3 (*m*)	129.1 (*m*)	128.6 (*m*)	128.9 (*m*)	128.9 (*m*)
	–	–	–	–	–	–	127.6 (*p*)	128.4 (*p*)	127.7 (*p*)	128.0 (*p*)	128.0 (*p*)

[a] In ppm; relative to TMS; solvents: C = $CDCl_3$, Py = pyridine-d_5.
[b] Not detected.

of diaxial orientation of H-1′ and H-2′, hence confirming the β configuration in these compounds. No signal for methyl protons of acetyl groups was observed confirming complete deacetylation of acetylated nucleosides. H-2′ in all deblocked products resonate at somewhat lower frequencies, in the region $\delta = 5.27-5.54$, while all other protons exhibited the same pattern as in acetylated nucleosides with only slight difference in the chemical shifts. Analogously, in the ^{13}C NMR spectra of these compounds, signals due to methyl carbon atoms and carbonyl carbon atoms were not observed. All other carbon atoms resonate in the same region as for the respective protected nucleosides (Table 2). In the FAB mass spectra, $[M+1]^+$ peaks were observed with reasonable intensities, corresponding to the molecular weight of deacetylated products. Other prominent peaks appeared due to loss of sugar moiety from the molecular ion.

The formation of *N*-galactosides was further confirmed by ^{15}N-NMR spectroscopy. ^{15}N-chemical shift values of **2a**, **2c** and **5a** are given in Table 1. In compounds **2a** and **2c** the N-4 signals are observed at $= -111.3$ and -110.5 while in **5a** the analogous atom N-1 resonates at $= -104.8$ which are typical values for nitrogen atoms in such chemical environment. In all three cases N-3 in **2a**/**2b** and analogously N-2 in **5a** resonate at low frequencies, namely at ≈ -175 to -180, and a difference of about 70 ppm is observed in the chemical shifts of N-3 *vs*. N-4 in **2a**/**2c** and N-2 *vs*. N-1 in **5a**. This clearly indicates that the sugars moieties are attached to nitrogen (Scheme 3) which exists in an sp^3-rather than in an sp^2-hybridization state (aromatic). The signals of the N-1″ atoms in the pyridyl groups resonate at expected -values (Table 1); their assignment has been proven unequivocally by H, ^{15}N HMBC spectroscopy.

It should be noted that alkylation of five-membered heterocyclic thiols resulted in mixtures of *S*- and *N*-alkyl products with the *N*-alkylated isomers being thermodynamically more stable[18]. In contrast, our synthetic procedure afforded the *N*-galactosides exclusively.

EXPERIMENTAL

Melting points were determined on Gallenkamp digital melting point apparatus and are uncorrected. ^1H and ^{13}C NMR spectra were recorded at 400 MHz and 100.6 MHz, respectively, on a Bruker AM-400 spectrometer using $CHCl_3$ (= 7.24) and pyridine-d_4 (= 8.67; highest-frequency signal) and the central peaks of $CDCl_3$ (= 77.0) and pyridine-d_5 (= 123.4; center line of the highest-frequency signal), respectively, as the internal standards. ^{15}N NMR spectra were recorded at 50.7 MHz on a Bruker AMX-500 spectrometer using CH_3NO_2 (= 0) as external standard. COSY and HETCOR spectra were recorded to confirm coupling interactions between ^1H atoms and ^{13}C atoms. Analytical thin layer chromatography was performed on

aluminium sheets coated with 0.2 mm layer of silica gel 60 F_{254} (Merck). The compounds were detected with UV light of 254 nm and by using spray reagent. EI-MS spectra were recorded on a Finnigan MAT-312 and positive FAB-MS on a Fisons Autospec spectrometer.

General Procedure for the Synthesis of 5-pyridyl-2-mercapto-1,3,4-oxadiazoles (1a–1c)

The method used for the preparation of 5-pyridyl-2-mercapto-1,3,4-oxadiazoles starting from isomeric pyridine carboxylic acid hydrazides, was the same as reported[13] for the preparation of 2-(3,4-disubstituted-1,2,4-triazole-5-yl-mercaptomethyl)-5-mercapto-1,3,4-oxadiazoles from the corresponding hydrazides.

The respective pyridine carboxylic acid hydrazide (0.04 moles) was dissolved in absolute ethanol in a round bottom flask; 0.05 moles of carbon disulfide were added to this solution. This was followed by the addition of 0.04 moles of potassium hydroxide dissolved in 20 mL of water. The reaction mixture was thoroughly stirred and subjected to reflux. The progress of the reaction was monitored by TLC in each case. The reaction mixture turned yellow during the reaction, and hydrogen sulfide evolution took place. After reaction completion, excess ethanol was distilled off. Then, the reaction mixture was diluted with water and acidified with 4N HCl to pH 2–3 in case of compounds **1a** and **1c** and to pH 5 for **1b**. This resulted in deposition of a crystalline solid in each case. The solid separated was filtered and recrystallized from water-ethanol mixture.

5-(2-Pyridyl)-2-mercapto-1,3,4-oxadiazole (1a)

Yield 83%. – M.p. 223–224°C. – IR ($\tilde{\nu}$, cm^{-1}, KBr): 1520, 1570, 2550–2600. – EI-MS m/z (%): 179 (M^+), 119, 106 and 78. – $C_7H_5N_3SO$ (179): calcd., C 46.93, H 2.79, N 23.46, S 17.88; found, C 46.56, H 2.79, N 23.26, S 18.25.

5-(3-Pyridyl)-2-mercapto-1,3,4-oxadiazole (1b)

Yield 85%. – M.p. 232–233°C. – IR ($\tilde{\nu}$, cm^{-1}, KBr): 1530, 1630, 2540–2590. – EI-MS m/z (%): 179 (M^+), 119, 106 and 78. – $C_7H_5N_3SO$ (179): calcd., C 46.93, H 2.79, N 23.46, S 17.88; found, C 46.79, H 2.79, N 23.57, S 17.76.

5-(4-Pyridyl)-2-mercapto-1,3,4-oxadiazole (1c)

Yield 95%. – M.p. 269–270°C. – IR ($\tilde{\nu}$), cm^{-1}, KBr): 1540, 1620, 2500–2550. – EI-MS m/z (%): 179 (M^+), 119, 106 and 78. – $C_7H_5N_3SO$

(179): calcd., C 46.93, H 2.79, N 23.46, S 17.88; found, C 46.90, H 2.87, N 23.73, S 17.77.

General Procedure for the Preparation of Nucleosides

To a mixture of 2 mmoles of acetobromogalactose (2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl bromide), 2 mmoles of mercuric cyanide and 2 g of anhydrous calcium sulfate (or molecular sieve) in 80–100 ml of dry nitromethane was added 1 mmole of the appropriate heterocyclic compound. The mixture was refluxed for 5–6 hours. Then, it was filtered while still hot in order to remove an insoluble residue which was washed with more hot nitromethane, and the filtrate was evaporated to dryness *in vacuo*. The product obtained was treated with dichloromethane and filtered to separate a solid (a complex formed by mercuric halide and the corresponding heterocycle). The dichloromethane extract was washed with 30% aqueous potassium iodide, water and then dried over anhydrous sodium sulfate. The solution was filtered, and the solvent was evaporated to dryness. The crude solid obtained was recrystallized from absolute ethanol.

N-(2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranosyl)-5-(2-pyridyl)-1,3,4-oxadiazole-2-thione (2a)

Yield 64%. – M.p. 183°C. – IR ($\tilde{\nu}$, cm^{-1}, KBr): 3464, 1752, 1652, 1588, 1468, 1420, 1368, 1316, 1224, 1124, 1028, 920, 792. – For NMR data see Tables 1 and 2 – EI-MS *m/z* (%): 509 (M^+, 4), 331 ($galAc_4$, 91), 180 (34), 169 (100), 127 (38), 109 (71), 97 (13), 78 (23).

N-(2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranosyl)-5-(3-pyridyl)-1,3,4-oxadiazole-2-thione (2b)

Yield 58%. – M.p. 142°C. – IR ($\tilde{\nu}$, cm^{-1}, KBr): 3464, 2972, 1752, 1624, 1588, 1560, 1472, 1424, 1368, 1320, 1224, 1124, 1076, 1016, 920. – For NMR data see Tables 1 and 2 – EI-MS *m/z* (%): 509 (M^+, 4), 331 ($galAc_4$, 85), 169 (100), 127 (40), 109 (78), 81 (19).

N-(2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranosyl)-5-(4-pyridyl)-1,3,4-oxadiazole-2-thione (2c)

Yield 75%. – M.p. 201°C. – ($\tilde{\nu}$, cm^{-1}, KBr): 3464, 2972, 1752, 1636, 1592, 1552, 1496, 1412, 1368, 1320, 1224, 1124, 1060, 952. – For NMR data see Tables 1 and 2 – EI-MS *m/z* (%): 509 (M^+, 3), 331 ($galAc_4$, 89), 169 (100), 127 (42), 109 (88), 81 (18).

N-(2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranosyl)-5-(2-pyridyl)-4-benzyl-1,2,4-triazole-2-thione (5a)

Yield 57%. – M.p. 177°C. – IR ($\tilde{\nu}$, cm^{-1}, KBr): 3464, 3444, 3060, 1752, 1652, 1588, 1496, 1456, 1424, 1368, 1224, 1172, 1124, 1088, 1060, 952. – For NMR data see Tables 1 and 2 – EI-MS m/z (%): 598 (M^+, 13.3), 330 ($galAc_4$-H, 19), 269 (72), 268 (33), 169 (52), 128 (25), 109 (38), 91 (100).

N-(2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranosyl)-5-(3-pyridyl)-4-benzyl-1,2,4-triazole-2 thione (5b)

This compound could not be separated and was directly subjected to deacetylation to get the corresponding deblocked nucleoside.

N-(2,3,4,6-Tetra-*O*-Acetyl-β-D-galactopyranosyl)-5-(4-pyridyl)-4-benzyl-1,2,4-triazole-2-thione (5c)

Yield 60%. – M.p. 163–4°C. – IR ($\tilde{\nu}$, cm^{-1}, KBr): 3444, 3060, 1752, 1652, 1588, 1456, 1408, 1368, 1224, 1060, 952. – For NMR data see Tables 1 and 2 – FAB-MS m/z (%): 599 ($M + H^+$, 67), 331 ($galAc_4$, 50), 269 (100), 179 (38), 169 (72), 139 (23), 127 (50).

Deprotection of Acetylated Nucleosides

Deprotection of the galactosides was accomplished by the following general procedure: the protected galactosides (1 mmole) were dissolved in dry methanol and a fairly rapid stream of dry ammonia was passed into the solution for 2–3 hours with stirring until TLC (dry methanol) indicated completion of the reaction. The solution was kept for 20 hours at 0–4°C. Removal of the solvent *in vacuo* yielded a sirup which was dissolved in dry ethanol and then recrystallised by adding a few drops of ethyl acetate.

N-(β-D-Galactopyranosyl)-5-(2-pyridyl)-1,3,4-oxadiazole-2-thione (3a)

Yield 33%. – M.p. 170–3°C (decomp). – IR ($\tilde{\nu}$, cm^{-1}, KBr): 3340 (br), 2924, 1656, 1612, 1524, 1004, 832. – For NMR data see Tables 1 and 2 – FAB-MS m/z (%) 341 (M^+, 21), 179 (M^+-gal+H, 34). Analysis $C_{18}H_{15}N_3O_6S$ (341.34) Calculated: C, 45.74; H, 4.42 and N, 12.31. Found: C, 45.64; H, 4.50 and N, 12.29.

N-(β-D-Galactopyranosyl)-5-(3-pyridyl)-1,3,4-oxadiazole-2-thione (3b)

Yield 30%. – M.p. 161–3°C (decomp). – IR ($\tilde{\nu}$, cm^{-1}, KBr): 3376 (br), 2928, 1676, 1596, 1524, 1220, 980, 936. – For NMR data see Tables 1 and 2

– FAB-MS m/z (%) 342 ($M^+ + H$, 26), 197 (28), 179 (M^+-gal+H, 33). Analysis $C_{18}H_{15}N_3O_6S$ (341.34) Calculated: C, 45.74; H, 4.42 and N, 12.31. Found: C, 45.70; H, 4.49 and N, 12.32.

N-(β-D-Galactopyranosyl)-5-(4-pyridyl)-1,3,4-oxadiazole-2-thione (3c)

Yield 49%. – M.p. 149-52°C (decomp). – IR ($\tilde{\nu}$, cm^{-1}, KBr): 3388 (br), 2924, 1688, 1688, 1620, 1552, 1216, 1020, 884. – For NMR data see Tables 1 and 2 – FAB-MS m/z (%) 342 ($M^+ + H$, 60), 180 (M^+-gal + 2H, 80). Analysis $C_{18}H_{15}N_3O_6S$ (341.34) Calculated: C, 45.74; H, 4.42 and N, 12.31. Found: C, 45.80; H, 4.40 and N, 12.40.

N-(β-D-Galactopyranosyl)-5-(2-pyridyl)-4-benzyl-1,2,4-triazole-2-thione (6a)

Yield 53%. – M.p. 190–3°C (decomp). – IR ($\tilde{\nu}$, cm^{-1}, KBr): 3404 (br), 3004, 2924, 1656, 1632, 1552, 1244, 1024, 880. – For NMR data see Tables 1 and 2 – FAB-MS m/z (%) 431 ($M^+ + H$, 21), 269 (M^+-gal+2H, 100). Analysis $C_{20}H_{22}N_4O_5S$ (430.46) Calculated: C, 55.81; H, 5.14 and N, 13.02. Found: C, 55.79; H, 5.05 and N, 13.00.

N-(β-D-Galactopyranosyl)-5-(3-Pyridyl)-4-Benzyl-1,2,4-Triazole-2-thione (6b)

Yield 40%. – M.p. 142–3°C (decomp). – ($\tilde{\nu}$, cm^{-1}, KBr): 3372 (br), 3064, 2920, 1604, 1576, 1542, 1264, 1028, 880, 832. – For NMR data see Tables 1 and 2 – FAB-MS m/z (%) 431 ($M^+ + H$, 19), 269 (M^+-gal+2H, 77). Analysis $C_{20}H_{22}N_4O_5S$ (430.46) Calculated: C, 55.81; H, 5.14 and N, 13.02. Found: C, 55.84; H, 5.18 and N, 13.05.

N-(β-D-Galactopyranosyl)-5-(4-pyridyl)-4-benzyl-1,2,4-triazole-2-thione (6c)

Yield 35%. – M.p. 170–2°C (decomp). – IR ($\tilde{\nu}$, cm^{-1}, KBr): 3351 (br), 3042, 2924, 1612, 1567, 1538, 1220, 998, 881. – For NMR data see Tables 1 and 2 – FAB-MS m/z (%) 431 ($M^+ + H$, 67), 269 (M^+-gal+2H, 100), 154 (47). Analysis $C_{20}H_{22}N_4O_5S$ (430.46) Calculated: C, 55.81; H, 5.14 and N, 13.02. Found: C, 55.86; H, 5.15 and N, 12.92.

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