Compounds II-VI, VIII, and IX were colorless liquids that were stable on heating, while VII was a crystalline substance.

General Method of Nitration. A 1-g sample of the product was added to 7.5 ml of HNO_3 cooled to 5°C, and the mixture was allowed to stand at this temperature for 25 min. The solution was then poured over ice, and the aqueous mixture was allowed to stand overnight. A precipitated crystalline substance was removed by filtration, whereas an oil was extracted with $CHCl_3$, the extract was dried, and the solvent was removed in vacuo.

Absorption bands at 1646-1674 (C=C), 920-990 (CH=), and 710 cm^{-1} (C–Cl) and stretching vibrations of a triazole ring at 1288, 1380, 1470, and 1560 cm^{-1} were the most characteristic bands for the IR spectra of II-IX. The most characteristic bands for nitration products X-XII were found at 1570 and 1380 cm^{-1} (NO_2) and at 1625 and 1285 cm^{-1} (ONO_2).

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DIRECTION OF GLYCOSYLATION OF 5-SUBSTITUTED 4-CHLORO-1,2,3-TRIAZOLES

I. D. Shingarova, A. T. Lebedev, and M. N. Preobrazhenskaya

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The structures of previously obtained nucleosides of 5-substituted 4-chloro-1,2,3-triazoles were refined by means of high-resolution mass spectrometry and ^{13}C NMR spectroscopy. It is shown that fusion of 5-substituted 4-chloro,1,2,3-triazoles with tetra-O-acylribofuranoses in the presence of di(p-nitrophenyl) phosphate leads to the formation of 2-nucleosides of the corresponding triazoles. The signals of the carbon atoms in the ^{13}C NMR spectra of the 4,5-di-substituted triazoles and their nucleosides were assigned.

We have previously obtained nucleosides of 5-substituted 4-chloro-1,2,3-triazoles, to which 1-nucleoside structures were assigned [1]. Continuing our research on the glycosylation of triazoles, we have obtained 2-β-D-ribofuranosyl-4-methylthio-5-methoxycarbonyl-1,2,3-triazole and its derivatives involving the carboxy group by fusion of 4-methylthio-5-methoxycarbonyl-1,2,3-triazole with tetra-O-acetylribofuranose in the presence of catalytic amounts of di(p-nitrophenyl) phosphate 2 . Our attention was drown to the closeness of the characteristics of the PMR spectra of the newly obtained 2-nucleosides of sulfur-containing triazoles and the previously described 1-nucleosides of 5-substituted 4-chloro-1,2,3-triazoles.

All-Union Oncologic Research Center, Academy of Medical Sciences of the USSR, Moscow 115478. M. V. Lomonosov Moscow State University, Moscow 117234.

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TABLE 1. Data from the ^{13}C NMR Spectra of 4,5-Disubstituted Triazoles and Their Nucleosides

Compound	$C_{(4)}$	$C_{(5)}$	CN	$COO(CH_3)$	$C_{(1')}$	$C_{(2')}$	$C_{(3')}$	$C_{(4')}$	$C_{(5')}$	CH_3	CH_2	$(CH_3)CO$
I	139,4	118,4	110.2									
VII	141,0	120,8	109,2		94,3	73,2	69,8	80,5	62,1	20,3; 20,1; 20,1		169,4; 169,1; 168,8
III	137.4	132,6		159,4								
IV	138,3	135,3		159,1	96,9	74,3	70,4	86,5	61,7	52,5		
VI	123,6	135,0		159,0						61,2	14,0	

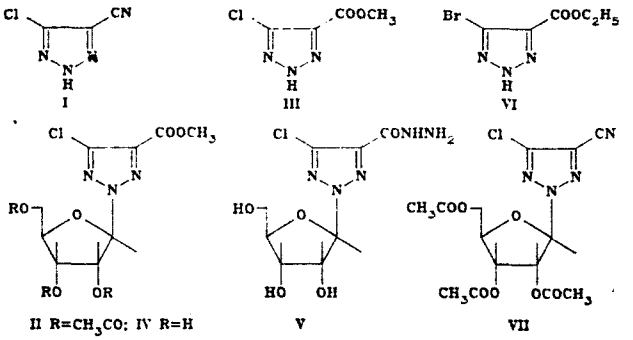
In this connection we addressed ourselves to the problem of the structures of these compounds.

The classification of the nucleosides of 5-substituted 4-chloro-1,2,3-triazoles as 1-nucleosides was previously made on the basis of the observed shifts of the signals of the carbon atoms in the ^{13}C NMR spectra for the hypothetical 1-(2,3,5-tri-O-acetyl-β-D-ribofuranosyl)-4-chloro-5-cyano-1,2,3-triazole as compared with 4-chloro-5-cyano-1,2,3-triazole (I). In the ^{13}C NMR spectrum of the hypothetical 1-nucleoside we observed a 0.96-ppm shift (α shift) of the signal of the $C_{(5)}$ atom to strong field and a 1.62-ppm shift (β shift) of the signal of the $C_{(4)}$ atom to weak field as compared with the spectrum of the unglycosylated heterocycle. Confirmation of the assigned structure was also obtained in an examination of the mass spectrum of 4-chloro-5-cyano-1,2,3-triazole tri-O-acetylriboside. The two fragments with m/z 126 and 128 were assigned to structural units formed in a complex fragmentation process with the ejection of two nitrogen atoms from the molecule and the formation of an aziridine ring; this is characteristic for $N_{(1)}$-substituted triazoles [1, 3].

In the present research we again studied the mass-spectrometric fragmentation of the previously obtained tri-O-acetylribofuranosyl-4-chloro-5-cyano-1,2,3-triazole and determined the elementary compositions of the ions with m/z 126 and 128 by high-resolution mass spectrometry. The ion with m/z 128 was found to be a composite: two thirds of the intensity of its peak are due to the $C_6H_8O_3$ ion (calculated 128.0473; determined 128.0469), which is formed in the fragmentation of the per-O-acetylated nucleoside, and one third is due to the $C_3H^{35}ClN_4$ ion, i.e., the pseudomolecular triazole ion $(B + H)^+$, which was formed in the migration of a hydrogen atom from the glycoside to the heterocyclic fragment with cleavage of the $C_{(1')}$–N bond (calculated 127.9889; determined 127.9884). An isotope ion with m/z 129.9860, viz., $C_3H^{37}ClN_4$, and an intensity of 30% of the $C_3H^{35}ClN_4$ ion, which, as a consequence of its low intensity, could not be observed in the spectrum, corresponds to this ion. The precise mass of the ion with m/z 126 is 126.0376. None of the fragments formed in the fragmentation of the nucleoside can have this mass, regardless of the site of glycosylation. In addition, in a reanalysis of the results of chromatographic-mass-spectrometric experiments we noted that the ion with m/z 126 vanishes completely in the case of scanning of the mass spectrum from the left side of the chromatographic peak, while the intensities of the other fragments decrease by 30-50%. These results make it possible to assert that the ion with m/z 126 is formed in the fragmentation of impurities that have close retention times. Thus fragments formed through the loss of two nitrogen atoms by the molecular or fragment ions of the molecule are completely absent in the mass spectrum of the acetylated nucleoside of 4-chloro-5-cyano-1,2,3-triazole; this makes it possible to assume that glycosylation takes place at the $N_{(2)}$ atom of the triazole. This led us to the conclusion that in [1] the assignment of the chemical shifts of the $C_{(5)}$ atom and the carbon atom in the cyano group in the ^{13}C NMR spectra of tri-O-acetyl-β-D-ribofuranosyl-4-chloro-5-cyano-1,2,3-triazole and its heterocycle was made incorrectly because of the closeness of their values. Thus the model selected for the investigation was unfortunate.

We synthesized 2-(2,3,5-tri-O-acetyl-β-D-ribofuranosyl)-4-chloro-5-methoxycarbonyl-1,2,3-triazole (II) in 76% yield by fusion of 4-chloro-5-methoxycarbonyl-1,2,3-triazole (III) with tetra-O-acetyl-D-ribofuranose in vacuo at 130°C in the presence of di(p-nitrophenyl) phosphate. Deacetylation of nucleoside II gave 2-β-D-ribofuranosyl-4-chloro-5-methoxycarbonyl-1,2,3-triazole (IV). This compound was identical to the compound that we previously obtained by treatment of tri-O-acetyl-β-D-ribofuranosyl-4-chloro-5-cyano-1,2,3-triazole with sodium methoxide in methanol [1]. 2-β-D-Ribofuranosyl-4-chloro-1,2,3-triazole-5-carboxylic acid hydrazide (V) was synthesized by treatment of nucleoside IV or 2-(2,3,5-tri-O-benzoyl-β-D-ribofuranosyl)-

4-chloro-5-methoxycarbonyl-1,2,3-triazole, which we previously obtained [1], with hydrazine hydrate at 20°C.



For the assignment of the chemical shifts of the carbon atoms in 5-substituted 4-chloro-1,2,3-triazoles and their nucleosides we studied the ^{13}C NMR spectra of 4-chloro-5-cyano-, 4-chloro-5-methoxycarbonyl-, and 4-bromo-5-ethoxycarbonyl-1,2,3-triazoles (I, III, VI), as well as 2-(2,3,5-tri-O-acetyl-β-D-ribofuranosyl)-4-chloro-5-cyano-1,2,3-triazole (VII), which we previously obtained [1], and 2-β-D-ribofuranosyl-4-chloro-5-methoxycarbonyl-1,2,3-triazole (IV). We assigned the signals of the carbon atoms in the spectra of these compounds taking into account the chemical shifts of the $C_{(4)}$ and $C_{(5)}$ atoms in the spectra of unsubstituted 1,2,3-triazole, as well as the additive contributions to the chemical shifts of the substituents [4]. The assignment of the carbon atoms of the carbonyl groups in III and VI is not difficult: $\delta_{(CO)}$ 159.4 ppm for III, and $\delta_{(CO)}$ 159.0 ppm for VI (Table 1). A comparison of III and VI shows that the immediate environment of the $C_{(5)}$ atom remains almost unchanged, and the chemical shifts of the $C_{(5)}$ atoms in these compounds consequently should be close; this is in agreement with the data for the ^{13}C NMR spectra of heterocycles III and VI: $\delta_{C_{(5)}}$ 132.6 and 135.0 ppm, respectively. The chemical shift of the $C_{(4)}$ atom is shifted 13.8 ppm to strong field on passing from III to VI; the chemical shifts of the $C_{(4)}$ atoms in them appear at 137.4 and 123.6 ppm, respectively. The intensities of the shifts of the $C_{(4)}$ and $C_{(5)}$ atoms serve as an additional confirmation of the correctness of their assignment. Since the bromine atom has a pronounced quadrupole effect, a substantial increase (by a factor of two) in the intensity of the signal of the $C_{(4)}$ atom bonded to a bromine atom occurs.

On comparing the ^{13}C NMR spectra of heterocycle III and nucleoside II we note a β shift of the $C_{(4)}$ and $C_{(5)}$ signals to weak field. This indicates that the riboside is attached in the $N_{(2)}$ position. Since II was obtained from acetyl-substituted nucleoside VII, it might be concluded that the latter is also a 2-nucleoside.

In heterocycles I and III only the substituents attached to the $C_{(5)}$ atom differ. It might be assumed that, in view of the invariability of the environment of the $C_{(4)}$ atom, its chemical shifts in the spectra of I and III are close, while the positions of the $C_{(5)}$ signal should differ more substantially. This is actually observed in the spectra of triazoles I and III. The $C_{(4)}$ signals in them appear at 139.4 and 137.4 ppm. We assigned the signals of the $C_{(5)}$ atom and the carbon atom in the cyano group taking into account the fact that a β shift should be observed for $N_{(2)}$-nucleoside VII; this is possible when the chemical shift of the $C_{(5)}$ atom in this compound is 120.8 ppm and $\delta_{(CN)}$ = 109.2 ppm, as compared with $\delta_{C_{(5)}}$ = 118.4 ppm and $_{(CN)}$ = 110.2 ppm for I.

The results obtained in this research make it possible to conclude that the glycosylation fo the 5-substituted 4-chloro-1,2,3-triazoles by fusion with tetra-O-acylribofuranoses in vacuo in the presence of di(p-nitrophenyl) phosphate leads to the formation of 2-nucleosides of 1,2,3-triazoles.

EXPERIMENTAL

The PMR spectra were recorded with a Bruker WH-360 spectrometer (360 MHz) with tetramethylsilane (TMS) as the internal standard. The ^{13}C NMR spectra were obtained with a Varian FT-80A spectrometer equipped with a broad-band detection system and operating with noise decoupling of the protons under pulse conditions at an operating frequency of 20 MHz. The spectra were recorded using an ampul with a diameter of 10 mm and internal stabilization with respect to D_2 nuclei. The signal of d_6-DMSO was used for stabilization. The system was equipped with a computer that made it possible to use a memory with a volume of 16 K for accumulation of the

spectrum. The IR spectra of KBr pellets of the compounds were recorded with a Perkin–Elmer 283 spectrometer. The mass spectrum of VII was obtained by means of chromatographic mass spectrometry with a Hewlett–Packard HP-5985 spectrometer. The chromatography conditions were as follows: an initial temperature of 35°C, a subsequent increase in the temperature to 200°C at a rate of 20 deg/min, and a source temperature of 250°C. The high-resolution mass spectrum was obtained with a Varian Mat-212 spectrometer with the use of a system for direct introduction of the samples into the ion source. The temperature of the sample was 70°C, the temperature of the source was 250°C, and the ionizing-electron energy was 70 eV. Perfluorinated kerosene was used as a mass reference. Silufol UV-254 was used for analytical thin-layer chromatography (TLC). Preparative chromatography was carried out on plates (20 × 20 cm) with a loose layer of LSL_{254} silica gel (5-40 μm, Chemapol) at a layer thickness of 1 mm. Column chromatography was carried out on silica gel L (40-100 μm). The following systems were used for chromatography: A [benzene–acetone (50:1], B [chloroform–methanol (4:1)], and C [chloroform–methanol (8:1)].

2-(2,3,5-Tri-O-acetyl-β-D-ribofuranosyl)-4-chloro-5-methoxycarbonyl-1,2,3-triazole (II). A 0.7-g (2.1 mmole) sample of tetra-O-acetyl-D-ribofuranose and 0.03 g of di(p-nitropnenyl) phosphate were added to 0.32 g (2 mmole) of fused heterogycle III, and the mixture was heated for 40 min at 130°C in vacuo. The black melt was dissolved in 3 ml of benzene and applied to a column (3 × 8 cm) packed with silica gel. Successive elution with benzene and system A gave 0.65 g (76%) of a colorless oil. PMR spectrum ($CDCl_3$): 6.18 (1H, d, 1'-H), 5.86 (1H, dd, 2'-H), 5.69 (1H, t, 3'-H), 4.48 (2H, m, 4'-H, 5'-H), 4.19 (1H, dd, 5''-H), 3.97 (3H, s, OCH_3), 2.13 (3H, s, CH_3), 2.12 ppm (6H, s, CH_3).

2-β-D-Ribofuranosyl-4-chloro-t-methoxycarbonyl-1,2,3-triazole (IV). A 0.13-g (0.3 mmole) sample of nucleoside II was placed in 5 ml of anhydrous methanol containing 0.03 g of sodium metal, and the solution was allowed to stand at 20°C for 1 h. The solvent was then removed by distillation, and the residue was chromatographed on plates in system C to give 0.06 g (65%) of a product with R_f 0.52. According to the UV and PMR spectral data, the product was identical to the compound that we obtained in [1].

2-β-D-Ribofuranosyl-4-chloro-1,2,3-triazole-5-carboxylic Acid Hydrazide (V). A) A 0.45-g sample of 2-(2,3,5-tri-O-benzoyl-β-D-ribofuranosyl)-4-chloro-5-methoxycarbonyl-1,2,3-triazole was placed in 20 ml of methanol containing 0.5 ml of hydrazine hydrate, and the mixture was then removed by distillation in vacuo with methanol (three 10-ml portions), and the residue was chromatographed in system B to give 0.09 g (42.8%) of product. IR spectrum: 1680 (C=O), 3391 cm^{-1} (NH). PMR spectrum (CD_3OD): 5.97 (1H, d, 1'-H), 4.60 (1H, dd, 2'-H), 4.43 (1H, t, 3'-H), 4.12 (1H, dd, 4'-H), 3.78 (1H, dd, 5'-H), 3.67 ppm (1H, dd, 5''-H).

B) A 0.38-g (1.3 mmole) sample of ester IV was placed in 20 ml of methanol containing 0.6 ml of hydrazine hydrate, and the mixture was maintained at 20°C for 3 days. It was then worked up as in method A to give 0.31 g (81.6%) of a substance that, according to the IR and PMR spectral data, was identical to the substance obtained by method A.

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