STRUCTURE AND PROPERTIES OF THE PRODUCT OF BROMINATION OF STYRYLTETRAZOLE

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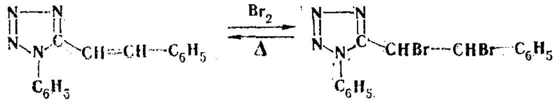
It was shown by means of x-ray diffraction analysis, NMR spectroscopy, and mass spectrometry that, regardless of its phase state, 1-(1'-phenyl-5'-tetrazolyl)-2-phenyl-1,2-dibromoethane (II) exists in the form of the threo conformer (the erythro form is also observed in the gas phase). The thermolysis of II is accompanied by facile splitting out of a molecule of bromine.

Dibromo derivative II was obtained by bromination of 1-phenyl-5-(β-styryl)tetrazole (I) [1] with bromine in chloroform. Treatment of dibromide II with sodium acetate in acetic acid gives a styryltetrazole instead of the expected diacetoxy derivative.

Carrying out the reaction with aniline as the acceptor of the liberated bromine makes it possible to detect tribromoaniline in the reaction mixture. The debromination of II is also readily accomplished with zinc in ethanol or with thiourea in acetone; heating II to 160-170°C without a solvent also leads to elimination of a molecule of bromine.



I

II

In addition to signals of aromatic protons, two doublets of aliphatic protons at 5.45 and 5.86 ppm with a spin–spin coupling constant (SSCC) of 11.6 Hz are present in the PMR spectrum of a solution of II in $CHCl_3$. This high value of the SSCC is characteristic for both the threo-oriented ethane protons and for the magnetically equivalent geminal protons [2]. Two doublet signals with residual $J_{H-^{13}C}$ values with chemical shifts (δ) of 52.46 and 38.16 ppm are recorded at strong field in the ^{13}C NMR spectrum of a solution of dibromide II in $CDCl_3$ recorded under conditions of extraresonance one-frequency suppression of the coupling of the protons with the carbon nuclei. The doublet structure of these signals constitutes evidence for the presence of two methylidyne carbon atoms in the ethane part of the molecule, i.e., it proves the 1-(1'-phenyl-5'-tetrazolyl)-2-phenyl-1,2-dibromomethane structure, which exists in the threo form in solution.

The indicated ambiguity of the structural assignment from the spin–spin coupling constant of the protons and the facile elimination of a molecule of bromine from the dibromide compelled us to make a more detailed study of its structure.

A molecular-ion peak (M^+) was not recorded for II in the mass spectrum [electron-impact mass spectrum (EI-MS)] at an ionizing energy of 70 eV. A decrease in the ionizing-electron energy to 12 eV makes it possible to record M^+ with a characteristic isotope distribution of the intensities of the peaks for molecules that contain two bromine atoms. Fragment ions that convey structural information were not observed in this case. Low intensity of the M^+ ions under electron-impact conditions is a diagnostic sign of 1-phenyl-5-alkyl-substituted tetrazoles [3].

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TABLE 1. Coordinates of the Atoms [$\cdot 10^4$ ($\cdot 10^5$ for Br)] in Dibromide II

Atom	x	y	z	Atom	x	y	z
$Br_{(1)}$	66553(4)	−51648(16)	12406(6)	$C_{(6)}$	9294(4)	−5830(15)	4048(6)
$Br_{(2)}$	76116(3)	6270(14)	36185(6)	$C_{(7)}$	9540(3)	−7751(15)	3529(7)
$N_{(1)}$	8360(3)	−2773(12)	1646(4)	$C_{(8)}$	9387(4)	−7988(16)	2421(7)
$N_{(2)}$	8526(3)	−1871(12)	742(4)	$C_{(9)}$	8997(3)	−6403(15)	1800(6)
$N_{(3)}$	8082(4)	−446(12)	325(5)	$C_{(10)}$	6295(3)	−2307(16)	2951(6)
$N_{(4)}$	7617(3)	−344(11)	920(6)	$C_{(11)}$	5812(4)	−620(16)	2873(7)
$C_{(1)}$	6750(4)	−2190(17)	2161(6)	$C_{(12)}$	5359(4)	−808(17)	3497(6)
$C_{(2)}$	7433(4)	−2211(17)	2587(6)	$C_{(13)}$	5388(4)	−2647(16)	4212(6)
$C_{(3)}$	7797(3)	−1739(15)	1743(6)	$C_{(14)}$	5876(4)	−4362(16)	4287(6)
$C_{(4)}$	8765(3)	−4478(13)	2304(5)	$C_{(15)}$	6342(4)	−4151(15)	3686(6)
$C_{(5)}$	8902(3)	−4161(14)	3396(6)				

Processes involving the elimination of neutral H_2 or Br_2 molecules from the M^+ ions will be energetically favorable in the case of a geminal or erythro orientation of the bromine atoms in dibromide II [4]. Ions of this sort were not recorded in the EI-MS. The successive detachment of Br and HBr atoms from the M^+ ions and the formation of an $[HBr]^+$ ion are practicable for a threo orientation of the bromine atoms. A study of the spectra of the metastable ions (by the DADI technique [3]) gives the following fragmentation scheme:

$$M^{+} \xrightarrow{-Br} [M-Br]^{+} \xrightarrow{-HBr} [(M-Br)-HBr]^{+}\ (\mathbf{F}) \xrightarrow{-N_2} [\mathbf{F}-N_2]^{+}\ (\mathbf{F_1})$$

The subsequent fragmentation of the F and F_1 ions proceeds via the scheme that is typical for 1-phenyl-5-styryltetrazole [5]. An $[HBr]^+$ ion is recorded in the EI-MS. The results suggest that the M^+ ions of II exist in the gas phase in the form of the threo conformer.

In the chemical-ionization method [in the chemical-ionization mass spectrum (CI-MS)] the protonated M^+ ion exists primarily in the ground state [6]. The criteria that determine the orientation of the bromine atoms in the molecule remain the same. In fact, the $[M + H]^+$ protonated molecular ion with the corresponding isotope distribution is recorded in the CI-MS (see the experimental section). The threo conformation is proved by the successive elimination of two molecules of HBr from the $[M + H]^+$ ion, which is followed by splitting out of $N_{(2)}$ [the process includes the $N_{(2)}$ and $N_{(3)}$ atoms [7]]. In addition, peaks of ions due to the processes presented above are observed in the CI-MS, and these processes take place more energetically than the former:

$$[M+H]^{+} \xrightarrow{-Br_2} [(M+H)-Br_2]^{+}\ (\mathbf{F_2}) \xrightarrow{-N_2} [\mathbf{F_2}-N_2]^{+}$$

Thus it may be stated that dibromide II exists in the gas phase in the form of two conformers with threo and erythro orientations of the bromine atoms in the molecules.

Data on the structure of dibromide II in the crystalline state were obtained by x-ray diffraction analysis. A three-dimensional model with designation of the atoms and an indication of the interatomic distances and bond angles is presented in Fig. 1. It is apparent from Fig. 1 that the bromine atoms are located on adjacent carbon atoms of the ethane part of the molecule. The conformation relative to the $C_{(1)}-C_{(2)}$ bond is transoid: the $Br_1C_1C_2Br_2$ and $C_{10}C_1C_2C_3$ torsion angles are close to 180°C. The lengths of the C–Br bonds (2.04 and 2.06 Å) are somewhat greater than the usual standard values (2.02 Å) [8]. The molecule can be conveniently regarded as consisting of three planar fragments, viz., a tetrazole fragment (A) and two phenyl fragments (B and C) attached to the $N_{(1)}$ and $C_{(1)}$ atoms; if A and B are noncoplanar (the A/B dihedral angle is 134°), the angle between the A and C planes is only 15°. The length of the central $C_{(1)}-C_{(2)}$ bond (1.44 Å) is considerably shorter as compared with the usual length of the C–C bonds of sp^3-hybridized atoms (1.54 Å) [8]. The distribution of the bond lengths in the tetrazole ring indicates alternation of the double [N=N 1.27(1) Å, N=C 1.34(1) Å] and single [N–N 1.37(1) and 1.38(1) Å, N–C 1.36(1) Å] bonds, as in other tetrazole derivatives [9, 10].

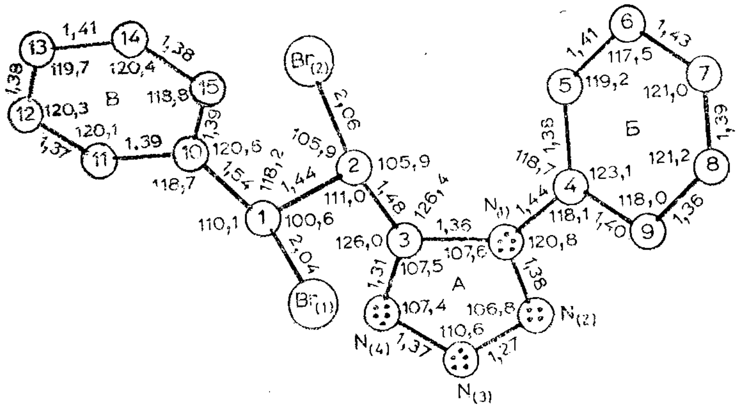

Fig. 1. Bond lengths and bond angles in II.

The results show that 1,2-dibromide II exists in the threo form in solution and in the crystalline state, while both the threo and erythro forms are recorded in the gas phase.

It may be assumed that conversion of the threo conformer to the erythro form precedes the elimination of a molecule of bromine from II upon heating. The steric strain that develops as the bulky bromine atoms approach one another as a result of shortening of the $C_{(1)}-C_{(2)}$ bond and lengthening of the C—Br bonds in the molecule evidently explains the ease of elimination of a molecule of bromine.

EXPERIMENTAL

The ^{13}C NMR spectra of a 10% solution of dibromide II in $CDCl_3$ were recorded with a Brucker WH-90 spectrometer (Federal Republic of Germany) with an operating frequency of 22.62 MHz at 30°C. The chemical shifts were measured with respect to the spectrum recorded under conditions of complete suppression of coupling of the protons with the carbon nuclei with respect to the signal of the absorption of the solvent and are expressed on the δ scale (δ_{CDCl_3} = 77.0 ppm). The PMR spectra of a solution in $CDCl_3$ were recorded with a Perkin–Elmer R-12B spectrometer (60 MHz) with tetramethylsilane as the internal standard.

The electron-impact mass spectra (EI-MS) were obtained with a Varian MAT-311A spectrometer under the standard operating conditions of the apparatus [5]. The high-resolution mass spectra were measured with the same apparatus with $M/\Delta M$ = 15,000 and perfluorinated kerosene as the standard. The peaks of ions with intensities ≥5% of the maximum peak are presented.

Electron-impact mass spectrum of II (sample-vaporization temperature 100°C), m/z (%): 51 (13.5), 55 (14.8), 57 (18.3), 64 (15.2), 76 (6.5), 77 (62.6), 80 (12.0); 82 (12.6) ($[HBr]^+$); 90 (11.7), 91 (38.4) ($[C_6H_5N]^+$) (experimentally determined value 91.0413, calculated value 91.0422); 102 (10.6), 103 ($[C_7H_5N]^+$) (experimentally determined value 103.0415, calculated value 103.0422); 109.5 (5.0) ($[C_{15}H_{11}N_2]^{2+}$); 116 (9.8), 117 (7.5) ($[C_7H_5N_2]^+$) (experimentally determined value 117.0450, calculated value 117.0453); 128 (5.2), 129 (7.3) ($[C_9H_7N]^+$) (experimentally determined value 129.0566, calculated value 129.0578); 193 (14.3) ($[C_{14}H_{11}N]^+$ or $[F_1 - CN]^+$) (experimentally determined value 193.0905, calculated value 193.0891); 218 (6.4), 219 (100.0) ($[C_{15}H_{11}N_2]^+$ or F_1) (experimentally determined value 219.0898, calculated value 219.0922); 247 (40.5) ($[C_{15}H_{11}N_4]^+$ or F^+) (experimentally determined value 247.1003, calculated value 247.0983); 248 (12.7); 327 (10.2); 329 (9.6) ($[M - Br]^+$).

The chemical-ionization mass spectra were obtained with a Finnigan-4021 spectrometer at an ionizing-electron energy of 70 eV; the cathode emission current was 0.3 μA, the sample-vaporization temperature was 150°C, and the gas-reactant (CH_4) pressure was 0.4 torr.

Chemical-ionization mass spectrum of II, m/z (%): 219 (8.5); 220 (3.3); 221 (5.5) ($[F_2 - N_2]^+$); 247 (19.0) ($[(M+H) - 2HBr]^+$); 249 (100.0) (F_2); 250 (15.3); 327 (5.1); 329 (5.2) ($[(M+H) - HBr]^+$); 407 (6.0); 409 (13.0); 411 (6.1) ($[M + H]^+$).

The x-ray diffraction study was conducted with a Synthex P1 diffractometer with Cu K_α emission and an Ni filter. The intensities of 1654 reflections with $F \geqslant 3\sigma$ were measured; a correction for absorption was introduced. The crystals of II were monoclinic and had the following parameters: $a = 21.214(9)$, $b = 5.638(8)$, $c = 12.792(8)$ Å, $\beta = 101.97(5)°$, $V = 1497(1)$ Å^3, $d_{calc} = 1.82$ g-cm^{-3}, $z = 4$, and space group P 21/c. The structure was decoded by the heavy-atom method and was refined by the method of least squares within the anisotropic fully matrix approximation up to $R = 0.053$ ($R_W = 0.078$). The coordinates of the atoms are presented in Table 1. The temperature factors can be obtained from the authors.

1-(1'-Phenyl-5'-tetrazolyl)-2-phenyl-1,2-dibromoethane (II). A solution of 1.6 g (10 mmole) of bromine in 25 ml of chloroform was added with stirring to a solution of 2.48 g (10 mmole) of styryltetrazole I in 40 ml of chloroform, and the mixture was heated on a water bath to 50-60°C and maintained at this temperature for 3 h. The solvent was removed to give 4.08 g (quantitative) of dibromide II in the form of colorless crystals with mp 154°C (ethanol). Found: C 44.0; H 3.0; N 13.8%. $C_{15}C_{12}Br_2N_4$. Calculated: C 44.1; H 3.0; N 13.7%.

Debromination of II in Acetic Acid with Sodium Acetate. A 2.8-g (7 mmole) sample of dibromide II was refluxed for 5 h in 5 ml of acetic acid with 1.15 g (14 mmole) of sodium acetate. The solvent was then removed, 40 ml of water was added to the residue, and the mixture was filtered to give 1.84 g (quantitative) of styryltetrazole I. The IR spectrum of the product (mp 182-183°C) was identical to the spectrum of genuine 1-phenyl-5-(β-styryl)-tetrazole.

Thermolysis of II. A 2.04-g (5 mmole) of dibromide II was heated at 165-170°C for 3 h, after which the residue was crystallized from ethanol to give 1.0 g (80%) of styryltetrazole I.

Debromination of II with Thiourea. A solution of 0.81 g (2 mmole) of dibromide II and 0.15 g (2 mmole) of thiourea in 30 ml of acetone was maintained at room temperature for 7 days with periodic removal of the resulting precipitate by filtration. The filtrate was evaporated to dryness, and the residue was chromatographed on silica gel (elution with chloroform) to give 0.2 g (80%) of styryltetrazole I.

Debromination of II with Zinc. A 2-g (5 mmole) sample of dibromide II was refluxed for 3 h with 1 g of zinc powder in 50 ml of ethanol, after which the mixture was filtered, and the filtrate was evaporated to dryness to give styryltetrazole I in quantitative yield.

According to the results of elementary analysis and the PMR and IR spectroscopic data, the 1-phenyl-5-(β-styryl)tetrazole (I) obtained by debromination was identical to the I obtained by the method in [1]. No melting-point depression was observed for a mixture of the two samples.

LITERATURE CITED

1. V. A. Zyryanov, I. Ya. Postovskii, V. L. Nirenburg, and V. L. Rusinov, Khim. Geterotsikl. Soedin., No. 3, 416 (1978).
2. A. Zhunke, Nuclear Magnetic Resonance in Organic Chemistry [Russian translation], Mir, Moscow (1974), p. 81.
3. N. A. Klyuev, É. N. Istratov, R. A. Khmel'nitskii, V. P. Suboch, V. L. Rusinov, and V. A. Zyryanov, Zh. Org. Khim., 13, 1501 (1977).
4. V. A. Valovoi and A. A. Polyakova, Zh. Org. Khim., 3, 842 (1967).
5. V. A. Zyryanov, N. A. Klyuev, V. L. Rusinov, I. Ya. Postovskii, A. B. Belikov, and L. F. Gusev, Khim. Geterotsikl. Soedin., No. 4, 558 (1980).
6. A. A. Solov'ev, V. I. Kadentsev, and O. S. Chizhov, Usp. Khim., 48, 1180 (1979).
7. N. A. Klyuev, Yu. V. Shurukhin, V. A. Konchits, I. I. Grandberg, V. L. Rusinov, V. A. Zyryanov, and I. Ya. Postovskii, Khim. Geterotsikl. Soedin., No. 2, 265 (1980).
8. International Tables for X-Ray Crystallography, Vol. 3, Kynoch Press, Birmingham, England (1964).
9. D. D. Bray and J. G. White, Acta Crystallogr., 35, 3089 (1979).
10. K. Kamiga, M. Takamoto, I. Wada, and M. Nishikawa, Chem. Pharm. Bull., 29, 609 (1981).