TETRAZOLE DERIVATIVES

XIX.* SYNTHESIS AND PROPERTIES OF 1-(2-METHYL-5-TETRAZOLYL)-3,5-DIPHENYLFORMAZAN AND A VERDAZYL RADICAL

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Benzaldehyde 2-methyl-5-tetrazolylhydrazone was synthesized and converted to a formazan, which undergoes methylation at the exocyclic nitrogen atom on reaction with dimethyl sulfate. The reaction product undergoes cyclization to the 1-(2-methyl-5-tetrazolyl)-3,5-diphenyl-leucoverdazyl radical when it is heated. Tautomerism due to location of the proton at the $N_{(2)}$ or $N_{(4)}$ atom of the tetrazine ring is characteristic for the verdazyl radical, according to the PMR spectral data. A verdazyl radical was obtained by oxidation of the leucoverdazyl radical.

1-(2-Methyl-5-tetrazolyl)-3,5-diphenylformazan (I) and verdazyl radical II are strong inhibitors of radical polymerization reactions [2, 3]. The radical can be used for the quantitative determination of the rates and rate constants of initiation of radical polymerization processes [3]. The preparation and properties of these compounds are discussed in the present communication.

We obtained triazene IV by diazotization of 2-methyl-5-aminotetrazole (III) by our modification of the method in [4]. As compared with diaryltriazenes [5], which usually are yellow (λ_{max} 320-360 nm), triazene IV is colorless (λ_{max} 295 nm). It is distinguished by its high stability when it is heated and by its ease of reduction with stannous chloride in hydrochloric acid.† Hydrazine V, which is converted without isolation from the reaction mixture to hydrazone VI, is formed in almost quantitative yield as a result of the reaction. The same compound can be obtained by methylation of benzaldehyde 5-tetrazolylhydrazone (VII) with dimethyl sulfate in a slightly alkaline medium, as a result of which a mixture of isomers VIII and VI in a ratio of 3 : 1 is formed. As compared with 1-methyl-substituted VIII, hydrazone VI is only slightly soluble in aqueous alkali; this is evidently due to the decrease in the acid properties on passing to the 2-methyl isomer. This is in agreement with the acidity ratio in the 1- and 2-methyl-5-acylamidotetrazole series, in which the 2-methyl-substituted compounds are two orders of magnitude less acidic [7]. The synthesis of formazan I by azo coupling of hydrazone VI with benzenediazonium chloride must therefore be carried out in an alkaline aqueous alcohol or dimethylformamide (DMF) medium, in contrast to tetrazolyl- or 1-methyl-tetrazolyl-formazans, which are readily obtained in aqueous alkali [8].

Formazan I gives methyl-substituted IX when it is treated with dimethyl sulfate in DMF in the presence of sodium hydroxide. It should be noted that in the case of formazans containing a heteroring attached to the $N_{(1)}$ atom that is capable of displaying amine-imine tautomerism, methylation in alkaline media is realized either at the ring nitrogen atom (benzazolylformazans [9]) or, as in the case of N-(1-methyl-5-tetrazolyl)-substituted formazan, a mixture of products involving methylation in the ring or at the exocyclic nitrogen atoms [8] is formed. The structure of methylation product IX follows from its ability to undergo cyclization to leucoverdazyl radical X when it is heated (by refluxing in heptane). The methylation of formazan I precisely at the exocyclic nitrogen atom is in agreement with the inability of 2-methyl-5-aminotetrazole and its derivatives to exist in the imine form [10]. Leucoverdazyl radical X can be obtained by reaction of formazan I

*See [1] for communication XVIII.

†Some dihetaryltriazenes (for example, benzimidazolyl compounds [6]) are not reduced by tin salts in hydrochloric acid even on prolonged heating.

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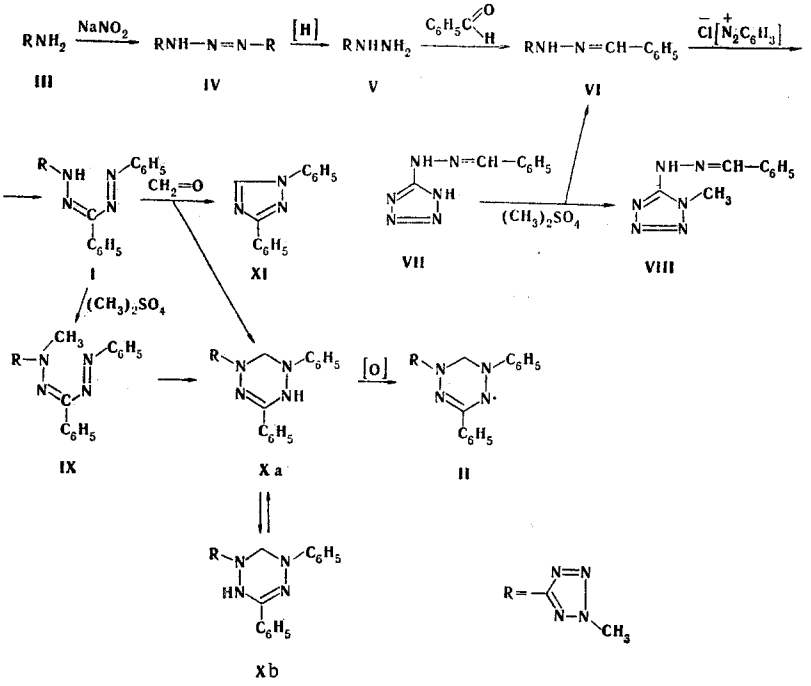
with formaldehyde or paraformaldehyde in an alkaline aqueous alcohol medium. 1,3-Diphenyl-1,2,4-triazole (XI) is similtaneously obtained. We note that the formation of similar triazole



derivatives as side products was observed in the synthesis of triarylverdazyl radicals by reaction of the corresponding formazans with formaldehyde [11].

Doubling of the signals of the methyl and methylene groups at 4.14, 4.19 and 5.12 and 5.19 ppm, respectively, is observed in the PMR spectrum of leucoverdazyl radical X in DMSO. This makes it possible to assume the existence of two prototropic tautomeric forms (Xa and Xb) for leucoverdazyl radical X.

Intermediate pictures of the transition from the conditions of slow exchange between tautomers Xa and Xb to conditions of rapid exchange accompanied by merging of the corresponding lines of the CH_2 and CH_3 groups of both tautomeric forms can be observed upon successive acidification of a solution of a sample in DMSO with acetic acid. The ratio of the intensities of the signals of the methylene protons and the methyl protons of each of the tautomers shows that approximately equal percentages of them (48 and 52%) are present. One of the tautomers predominates in solution in deuterochloroform. The ratio of the intensities of the singlets of the methylene protons at 5.02 and 5.11 ppm and the methyl protons at 4.04 and 4.07 ppm corresponds to the percentages of the tautomeric forms (62 and 38%). Taking into account the data on the structure of 1-(p-nitrophenyl)-3,5-diphenylleucoverdazyl radical [12], for which it has been established that the hydrogen atom is attached to the $N_{(4)}$ atom, it may be assumed that the equilibrium is shifted to favor the Xa form in deuterochloroform.

Two bands at 3351 and 3320 cm^{-1} of approximately identical intensity, which can be assigned to the absorption of the NH group of the leucoverdazyl radical in the Xa and Xb form, are observed in the IR spectrum of X in the crystalline state. On passing to solution in carbon tetrachloride or chloroform the absorption of the NH group is displayed in the form of a single band at 3361 and 3369 cm^{-1}, respectively. The absence of splitting of the NH band as compared with the observed doubling of the signal of this group in the PMR spectrum is due to the close absorption of the NH bond of both forms in the IR spectra of the solutions.

When leuco base X is oxidized with lead dioxide, it is converted to verdazyl radical II. The ESR spectrum of the latter in benzene (g_0 2.0034 ± 0.0002) displays the nine-component structure characteristic for verdazyl radicals. Polycrystalline samples of radical II display less exchange contraction of the ESR line than the 1-(1-methyl-5-tetrazolyl)-3,5-diphenylverdazyl radical [8] (the width of the singlet is 3.4 and 2.7 Oe, respectively).

EXPERIMENTAL

The electronic spectra of the compounds were recorded with SF-4A and SF-10 spectrophotometers. The IR spectra of KBr pellets (2 mg of the substance in 800 mg of KBr) and solutions of the compounds in carbon

tetrachloride and chloroform (saturated solutions at cuvette widths of 5 and 2 cm, respectively) were recorded with a UR-20 spectrometer. The PMR spectra were recorded with a Perkin–Elmer R12B spectrometer. The ESR spectra were recorded with an ÉPR-3 spectrometer. The individuality of the compounds was monitored by thin-layer chromatography (TLC) on Silufol UV-254; the R_f values were presented for a chloroform–acetone system (20:1).

1,3-Bis(2-methyl-5-tetrazolyl)triazene (IV). A solution of 3.45 g (0.05 mole) of sodium nitrite in 30 ml of water was added dropwise with vigorous stirring at 2-5°C to a solution of 9.9 g (0.1 mole) of 2-methyl-5-aminotetrazole in 30 ml of acetic acid, after which the mixture was maintained at room temperature for 24 h, cooled to 0-2°C, and filtered to remove the colorless precipitate. The yield of the triazene was 8.5 g (81%). Successive recrystallization from ethanol and water gave a product with mp 208°C [4] and R_f 0.54 [chloroform–acetone (1:1)]. UV spectrum in ethanol, λ_{max} (log ε): 245 (3.96) and 296 nm (4.38). IR spectrum: 3310, 3150, 3010 (ν_{NH}); 2930, 2870 (ν_{as} and ν_s CH_3), 1600, 1475 (ring ν [13, 14]); 1350 (δ_s CH_3); 1215 cm^{-1} (very strong broad band, vibrations of the –N=N–N= grouping of the triazene ring [15] and the heteroring [13]).

Benzaldehyde 2-Methyl-5-tetrazolylhydrazone (VI). A) An 8.15-g (0.039 mole) of triazene II was added with stirring to a solution of 22.6 g (0.1 mole) of $SnCl_2 \cdot 2H_2O$ in 250 ml of concentrated hydrochloric acid, and the mixture was maintained at 28-30°C for 1.5 h. It was then filtered, 5 ml (0.052 mole) of benzaldehyde was added to the filtrate, and the mixture was stirred for 1 h. It was then filtered to give 7.5 g (95%) of product with mp 133-135°C (as large colorless multifaceted prisms from ethanol) and R_f 0.17. UV spectrum, λ_{max} (log ε): in ethanol 307 (4.37); in 1 M NaOH 360 (4.36); in 0.1 M NaOH 305 (3.97) and 356 nm (3.92) partial ionization of the NH group. IR spectrum: 3250, 3100, 3056 (ν_{NH}); 2940, 2890 (CH_3); 1620 (exocyclic C=N group [16]); 1590 cm^{-1} (heteroring ν). Found: N 41.2%. $C_9H_{10}N_9$. Calculated: N 41.6%.

B) An 11.4-ml (0.12 mole) sample of dimethyl sulfate was added at 18°C to a solution of 18.8 g (0.1 mole) sample of benzaldehyde 5-tetrazolylhydrazone (VII) in 300 ml of 5% Na_2CO_3 solution, and the mixture was stirred at this temperature for 1 h. The resulting precipitate was removed by filtration, and the product was recrystallized from ethanol (12 ml of ethanol per gram) to give 9.1-10.9 g of benzaldehyde 1-methyl-5-tetrazolylhydrazone (VIII) with mp 206°C (209 [17] and 206°C [16]). The filtrate was concentrated to half its original volume to precipitate an additional 2.4-2.7 g of hydrazone VIII (for an overall yield of 57-67%); further concentration of the residue yielded 3.3-3.6 g (16-18%) of hydrazone VI. Recrystallization from ethanol (5 ml per gram) gave a product with mp 133-134°C. No melting-point depression was observed for a mixture of this product with a genuine sample.

1-(2-Methyl-5-tetrazolyl)-3,5-diphenylformazan (I). A solution of a benzenediazonium salt, obtained from 1 ml (11 mmole) of aniline, 2.4 ml (28 mmole) of concentrated hydrochloride acid, 30 ml of water, and 0.76 g (11 mmole) of $NaNO_2$ in 8 ml of water, was added at 0-2°C to a solution of 2.02 g (10 mmole) of hydrazone VI in 75 ml of DMF and 50 ml of a 10% NaOH solution, and the mixture was maintained at room temperature for 1.5 h. It was then treated with 110 ml of water, acidified to pH 2 with concentrated hydrochloric acid, and worked up to give 2.72 g (89%) of dark-claret-colored needles of formazan I with mp 132°C (from ethanol) R_f 0.48. UV spectrum, λ_{max} (log ε): in ethanol 280 (4.28), 427 (4.07); in dioxane 275 (4.29), 430 (4.11); in 0.1 M NaOH 257 (4.05), 462 nm (4.76). IR spectrum: 1570 cm^{-1} (very strong, C=N). Found: N 36.6%. $C_{15}H_{14}N_8$. Calculated: N 36.6%. Complexes with transition metals [λ_{max} in ethanol, ligand-metal composition determined by the isomolar series method, and instability constants determined by the method in [18] in 72% ethanol in the presence of a neutral (pH 7.0) ammonium acetate buffer]: Cu^{2+} 584 nm, 2:3, $0.69 \cdot 10^{-7}$; Ni^{2+} 566, 2:1, $13.0 \cdot 10^{-7}$; Co^{2+} 514, 2:1, $2.36 \cdot 10^{-7}$.

1-Methyl-1-(2-methyl-5-tetrazolyl)-3,5-diphenylformazan (IX). A 6-g (0.15 mole) sample of NaOH was added to a solution of 1.6 g (5.2 mmole) of formazan I in 60 ml of DMF, and the mixture was stirred for 30 min, after which a solution of 15 ml (0.16 mole) of dimethyl sulfate in 15 ml of DMF was added at 0-2°C. After 30 min at 0-2°C, 60 ml of water was added dropwise in the course of 1 h, and the light-orange precipitate was removed by filtration to give 1.5 g (90%) of formazan IX with mp 124-125°C (from acetone) and R_f 0.44. UV spectrum (in ethanol), λ_{max} (log ε): 244 (4.26), 275 (4.28), and 365 nm (4.69). IR spectrum: 1550 cm^{-1} (vs, C=N). Found: N 35.0%. $C_{16}H_{16}N_8$. Calculated: N 35.0%.

4-(2-Methyl-5-tetrazolyl)-2,6-diphenyl-1,2,3,4-tetrahydro-sym-tetrazine (X). A) A solution of 1.5 g (4.7 mmole) of IX in 20 ml of heptane was refluxed for 1 h, after which it was cooled and filtered to give 1.1 g (73%) of leucoverdazyl radical X with mp 160-161°C (colorless elongated prisms from ethanol) and R_f 0.29. UV spectrum (in ethanol), λ_{max} (log ε): 245 (4.30) and 305 nm (4.15). IR spectrum 3351, 3320 (NH); 1570 cm^{-1} (vs, C=N). PMR spectrum, δ: in DMSO 4.14 s, 4.19 s (CH_3 in tautomers a and b); 5.12 s, 5.19 s (CH_2); 7.22-

7.99 m (C_6H_5); 9.05 s, 9.12 s (NH) with a ratio of the intensities of the doubled signals of 1:1.07 (the more intense band is underlined); in $CDCl_3$ 4.04 s, 4.07 s (CH_3); 5.02 s, 511 s (CH_2), 6.49 s, 6.56 s (NH), and 7.17-7.85 m (C_6H_5) ppm with a ratio of the intensities of the doubled signals of 1:1.65. Found: N 34.7%. $C_{16}H_{16}N_8$. Calculated N 35.0%.

B) A 12-ml (15 mmole) sample of 37% formalin was added to a solution of 1 g (3.27 mmole) of formazan I in 160 ml of 5% NaOH solution and 40 ml of ethanol, and the mixture was maintained at room temperature without access to air for 9 days (until it became completely colorless). The precipitate was separated (0.58 g) and treated with 4 ml of hot carbon tetrachloride. The solid was removed by filtration and recrystallized from ethanol to give 0.18 g (17%) of leucoverdazyl radical X, which was identical to the compound obtained by method A with respect to the results of chromatography and the melting points and IR spectra. The filtrate (CCl_4) was concentrated, and the residue was washed with a small amount of alcohol and recrystallized from heptane to give 0.1 g of 1,3-diphenyl-1,2,4-triazole (XI) with mp 80-81°C (82.5-83°C [19]). Found: N 18.6%. $C_{14}H_{11}N_3$. Calculated: N 19.0%. Concentration of the reaction solution to a volume of 60 ml gave an additional 0.05 g of XI.

1-(2-Methyl-5-tetrazolyl)-3,5-diphenylverdazyl (II). A 5.5-g (23 mmole) sample of PbO_2 was added to a solution of 1.1 g (3.4 mmole) of leucoverdazyl radical X in 60 ml of acetone, and the mixture was shaken for 15 min and filtered. Concentration of the filtrate gave a precipitate, which was recrystallized from acetone to give 0.4 g (40%) of a product with mp 134-135°C (dark-green prisms) and R_f 0.46. UV spectrum (in benzene), λ_{max} (log ε): 320 (3.90), 381 (3.89), and 670 nm (3.52). IR spectrum: 1570 cm^{-1} (vs, C=N). Found: N 35.2%. $C_{16}H_{15}N_8$. Calculated: N 35.1%.

LITERATURE CITED

1. V. P. Shchipanov, A. I. Zabolot-skaya, and M. S. Zakharov, Izv. Vuzov, Ser. Khim. i Khim. Tekhnol., 20, 1520 (1977).
2. V. P. Shchipanov, L. G. Surovtsev, S. A. Nagovskaya, and V. V. Kiselev, USSR Author's Certificate No. 572460; Byul. Izobr., No. 34, 54 (1977).
3. L. G. Surovtsev, V. P. Shchipanov, V. V. Kiselev, and N. I. Doronina, USSR Author's Certificate No. 591469; Byul. Izobr., No. 5, 76 (1978).
4. K. Hattori, E. Lieber, and J. Horwitz, J. Am. Chem. Soc., 78, 411 (1956).
5. V. Ya. Pochinok, Triazenes [in Russian], Izd. Kievsk. Univ., Kiev (1968), p. 132.
6. S. N. Kolodyazhnaya, A. M. Simonov, and L. N. Podladchikova, Khim. Geterotsikl. Soedin., No. 6, 829 (1975).
7. V. P. Shchipanov, Zh. Org. Khim., 2, 356 (1966).
8. V. P. Shchipanov, S. A. Nagovskaya, and L. S. Podenko, Khim. Geterotsikl. Soedin., No. 2, 266 (1977).
9. G. N. Lipunova and N. P. Bednyagina, Khim. Geterotsikl. Soedin., No. 5, 882 (1969).
10. V. P. Shchipanov, Zh. Org. Khim., 2, 376 (1966).
11. R. Kuhn and H. Trischman, Monatsh., 95, 457 (1964).
12. F. A. Neugebauer and M. Jenne, Tetrahedron Lett., No. 10, 791 (1969).
13. V. P. Shchipanov, S. L. Portnova, V. A. Krasnova, Yu. N. Sheinker, and I. Ya. Postovskii, Zh. Org. Khim., 1, 2236 (1965).
14. M. M. Sokolova, V. V. Mel'nikov, V. A. Ostrovskii, G. I. Koldobskii, A. A. Mel'nikov, and B. V. Gidaspov, Zh. Org. Khim., 11, 1744 (1975).
15. I. Ya. Postovskii and I. N. Goncharova, Zh. Obshch. Khim., 33, 2334 (1963).
16. V. P. Shchipanov, A. I. Zabolot-skaya, and R. A. Badryzlova, Khim. Geterotsikl. Soedin., No. 6, 850 (1975).
17. F. L. Scott, R. N. Butler, and D. A. Cronin, Angew. Chem., 77, 963 (1965).
18. A. K. Babko, Physicochemical Analysis of Complexes in Solutions [in Russian], Izd. Akad. Nauk Ukr. SSR, Kiev (1955), p. 118.
19. M. R. Atkinson and J. B. Polya, J. Am. Chem. Soc., 75, 1471 (1953).