LITERATURE CITED

1. V. A. Azimov, D. M. Krasnokut-skaya, I. N. Palant, and L. N. Yakhontov, Khim. Geterotsikl. Soedin., No. 3, 375 (1979).
2. R. E. Willette, Adv. Heterocycl. Chem., 9, 27 (1968).
3. L. N. Yakhontov, Usp. Khim., 37, 1258 (1968).
4. D. A. Bochvar, A. A. Bagatur'yants, A. B. Turkevich, L. N. Yakhontov, M. Ya. Uritskaya, D. M. Krasnokut-skaya, and M. V. Rubtsov, Izv. Akad. Nauk SSSR, Ser. Khim., 354 (1966).
5. D. A. Bochvar and A. A. Bagatur'yants, Teor. Eksp. Khim., No. 6, 793 (1967).
6. L. N. Yakhontov, V. A. Azimov, and E. I. Lapan, Tetrahedron Lett., 1909 (1969).
7. A. El-Anani, S. Clementi, A. R. Katritzky, and L. N. Yakhontov, J. Chem. Soc., Perkin Trans. II, No. 7, 1072 (1973).
8. V. A. Azimov and L. N. Yakhontov, Khim. Geterotsikl. Soedin., No. 10, 1425 (1977).
9. A. A. Prokopov and L. N. Yakhontov, Khim. Geterotsikl. Soedin., No. 8, 1135 (1977).
10. L. N. Yakhontov, M. Ya. Uritskaya, and M. V. Rubtsov, Zh. Obshch. Khim., 34, 1449 (1964).
11. A. A. Prokopov and L. N. Yakhontov, Khim. Geterotsikl. Soedin., No. 4, 496 (1978).
12. L. N. Yakhontov, M. Ya. Uritskaya, and M. V. Rubtsov, Zh. Org. Khim., 1, 2032 (1965).

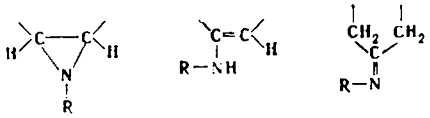
SYNTHESIS AND REACTIONS OF AZIDOPOLYBROMOPYRIDINES

S. D. Moshchitskii, A. A. Zeikan',
A. F. Pavlenko, and V. P. Kukhar'

UDC 547.822.5

Azido derivatives of organic compounds are interesting and highly reactive reagents. Recently the chemistry of aromatic azides, and particularly that of azidotetrafluoro(chloro)-pyridines, has been intensively studied [1-3]. Seeking to synthesize 4-azido-2,3,5,6-tetrabromopyridine (I), we have examined the reaction of pentabromopyridine with sodium azide in DMSO. We found that at 20°C the attack of azide ion is directed exclusively at position 4 and compound (I) is formed quantitatively. We verified the absence of the isomeric product by TLC and established the position of substitution of the bromine atom by independent synthesis of azide (I) by substitution of azido for the methylsulfonyl group in 4-methylsulfonyl-2,3,5,6-tetrabromopyridine. Reaction of pentabromopyridine with excess sodium azide at 20°C forms 2,4,6-triazido-3,5-dibromopyridine (II). Azides (I) and (II) are stable in the dark at room temperature, melt without exploding or decomposing, and decompose at 150-155°C with evolution of nitrogen.

Thermal decomposition of aromatic azides is known to generate nitrenes, which are capable either of conversion to primary amines or of insertion into the C—H bond of hydrocarbons. Consequently we subjected azide (I) to thermolysis in N,N-dimethylaniline at a temperature close to its decomposition point. Analysis by gas—liquid chromatography (GLC) identified the major thermolysis product as 4-amino-2,3,5,6-tetrabromopyridine (III). When heated in excess cyclohexene, azide (I) gave an oily product with the formula $C_{11}H_{10}Br_4N_2$, which could have three possible structures:



A B C

R = 2,3,5,6-tetrabromo-4-pyridyl

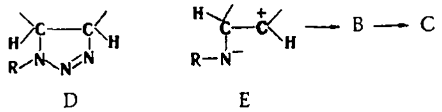
The IR and PMR parameters unequivocally support structure B, i.e., 4-(1-cyclohexenyl)amino-2,3,5,6-tetrabromopyridine (IV). After several hours enamine (IV) crystallized and the IR and PMR spectra of the crystalline product now lacked the band and signal of the NH group, which had been replaced by a band and signals typical of structure C, implying the isomerization of enamine (IV) to 4-cyclohexylideneamino-2,3,5,6-tetrabromopyridine (V). Since the

---

Institute of Organic Chemistry, Academy of Sciences of the Ukrainian SSR, Kiev 252660. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 11, pp. 1492-1495, November, 1979. Original article submitted July 17, 1978; revision submitted January 16, 1979.

0009-3122/79/1511-1197$07.50

reaction of compound (I) with cyclohexene was carried out at a temperature below the decomposition point of azide (I), the reaction apparently involves the initial addition of the azido group to the double bond to form the unstable triazoline intermediate D [3], which eliminates nitrogen and gives betaine E. This is converted to enamine B by proton migration from the α-carbon to nitrogen. In time enamine B is converted to the thermodynamically more stable imine (V). The formation of imine (V) rather than aziridine A, which can be prepared by reaction of phenyl azide with cyclohexene [4], seems to be the consequence not only of the presence of the bulky bromine atoms in positions 3 and 5, which hinder the formation of the three-membered ring, but also of the presence of the electron-accepting tetrabromopyridine residue, which withdraws electron density from the exocyclic nitrogen atom (structure E) and promotes proton abstraction from the neighboring carbon atom rather than inhibiting it as would be the case with phenyl.

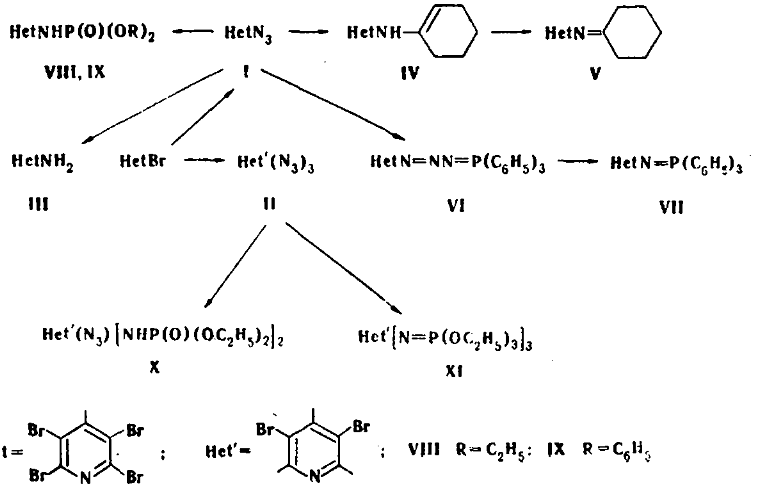


R = 2,3,5,6-tetrabromo-4-pyridyl

Prolonged heating of azide (I) in cyclohexane and toluene does not generate the reactive tetrabromopyridylnitrene intermediate, which supports the suggested ionic mechanism for the reaction of azide (I) with cyclohexene.

Reduction of compound (I) with lithium aluminum hydride is exothermal and forms amine (III).

Azide (I) readily undergoes the Staudinger reaction with triphenylphosphine, triethyl phosphite, and triphenyl phosphite. The reaction with triphenylphosphine proceeds via the relatively stable 4-(triphenylphosphazido)-2,3,5,6-tetrabromopyridine (VI), which at 118°C evolves nitrogen and is converted to the high-melting 4-triphenylphosphazenyl-2,3,5,6-tetrabromopyridine (VII). In the pure form phosphazide (VI) is stable for several days at −5°C, while it becomes colorless after several hours heating in ethereal solution, implying the conversion of phosphazide (VI) to compound (VII). The UV spectrum shows over a period of time the reduction to zero of the intensity of the 258 nm maximum of phosphazide (VI) and the appearance and concomitant intensification of two bands at 230 and 294 nm typical of compound (VII). Azide (I) reacts so rapidly with triethyl and triphenyl phosphite in ether that the phosphazides cannot be detected; since the resulting phosphazenyl compounds are viscous liquids we hydrolyzed them with 5% HCl to the 2,3,5,6-tetrabromo-4-pyridyl amidophosphate esters (VIII) and (IX).



The reaction of azide (II) with triethyl phosphite at room temperature involves two of the azido groups and forms an oily phosphazenyl compound, which we converted to 4-azido-2,6-bis-(diethoxyphosphinylamine)-3,5-dibromopyridine (X) by hydrolysis with 5% HCl. We verified the position of the phosphinyl groups from the PMR spectrum, in which the signals of the ethoxy protons are accompanied by one singlet at 2.52 ppm due to the NH protons. The presence of only one singlet implies that the NH groups are positioned symmetrically, i.e., in

TABLE 1. Properties of the Synthetic Compounds

Compound	mp, °C	IR spectrum, cm^{-1}	Found, %			Formula	Calculated, %			Yield, %
			N	Br	P		N	Br	P	
I	122–123[a]	2125, 2157 (N_3)	12,7	73,2	—	$C_5Br_4N_4$	12,8	73,3	—	98
II	85–86[a]	2125, 2160 (N_3)	38,7	44,6	—	$C_5Br_2N_{10}$	38,9	44,4	—	97
IV		1670 (C=C), 2875 (CH), 3280 (NH)	5,6	65,5	—	$C_{11}H_{10}Br_4N_2$	5,7	65,3	—	99
V	168–170[a]	2880 (CH), 1665 (C=N)	5,7	65,5	—	$C_{11}H_{10}Br_4N_2$	5,7	65,3	—	99
VI	118 (decomp)[b]	—	7,8	46,0	—	$C_{23}H_{15}Br_4N_4P$	8,0	45,8	—	81
VII	205–206[b]	—	4,2	—	4,8	$C_{23}H_{15}Br_4N_2P$	4,2	—	4,6	74
VIII	200–201[c]	1250 (P=O), 2925, 2980 (CH), 3120 (NH)	5,0	—	5,6	$C_9H_{11}Br_4N_2O_3P$	5,1	—	5,7	69
IX	207–208[c]	1265 (P=O), 2860, 2930 (CH), 3080 (NH)	4,4	—	—	$C_{17}H_{11}Br_4N_2O_3P$[d]	4,4	—	—	83
X	177–178[c]	1250 (P=O), 2143 (N_3), 2860, 2930, 2980 (CH), 3120 (NH)	14,6	—	10,9	$C_{13}H_{22}Br_2N_6O_6P_2$	14,5	—	10,7	51
XI	bp (0,1mm) 218–223[c]		7,3	—	12,0	$C_{23}H_{45}Br_2N_4O_9P_3$	7,2	—	12,0	96

---

[a] From ethenol. [b] From ether. [c] From benzene. [d] Found: C 31.7; H 1.7%. Calculated: C 31.8; H 1.7%.

positions 2 and 6. The IR spectrum of compound (X) has an intense band of the remaining azido group at 2140 cm^{-1}. When azide (II) is heated, all three azido groups react with triethyl phosphite to form 2,4,6-tris(triethoxyphosphazenyl)-3,5-dibromopyridine (XI), whose IR spectrum lacks the azido band.

EXPERIMENTAL

Spectra were recorded on: IR: a UR-20 in KBr tablets and CCl_4 solutions; UV: a Specord UV-vis, in ethanol; PMR: a Tesla BS-487B (80 MHz), at room temperature in CCl_4, external standard hexamethyldisiloxane (HMDS). The GLC analyses were carried out on a Tsvet-4 chromatograph with SE-30 siloxane polymer on Chromosorb W. The injector temperature was 350°C. The properties of the synthetic compounds are summarized in Table 1.

4-Azido-2,3,5,6-tetrabromopyridine (I). A. To a solution of pentabromopyridine (2.5 g, 5.2 mmole) in DMSO (60 ml) was added sodium azide (0.34 g, 5.2 mmole). The mixture was stirred at 20°C for 5 h and then poured into water (100 ml). The yield was 2.3 g.

B. The compound was prepared in the same way from 2,3,5,6-tetrabromo-4-pyridyl methyl sulfone. The yield was quantitative.

2,4,6-Triazido-3,5-dibromopyridine (II) was prepared in the same way as (I) using a 1:3 reactant ratio and reaction time 15 h.

4-Amino-2,3,5,6-tetrabromopyridine (III). A. Azide (I) (0.87 g, 2 mmole) was refluxed in anhydrous ether (100 ml) with lithium aluminum hydride (0.07 g, 2 mmole) for 3 h. The mixture was then filtered and the solvent was removed under vacuum. The yield was 0.52 g (64%), mp 236-238°C (decomposition; from ethanol). Literature [5]: mp 237-239°C (decomposition).

B. A mixture of azide (I) (0.43 g, 1 mmole) and dimethylaniline (5 ml) was heated at 165-170°C for 4 h. The reaction mixture was diluted with heptane (150 ml), precipitating amine (III) (0.15 g, 36%), mp 237-239°C.

4-(1-Cyclohexenyl)amino-2,3,5,6-tetrabromopyridine (IV). A mixture of azide (I) (0.44 g, 1 mmole) and cyclohexene (10 ml) was refluxed for 8 h. The excess cyclohexene was stripped off under vaccum; the residue contained the oily product. The yield was 0.48 g. PMR spectrum, δ: 6.1 (t, 1H, C=CH), 4.5 (s, 1H, NH), 2.3 ppm, (m, 8H).

4-Cyclohexylideneamino-2,3,5,6-tetrabromopyridine (V). The oily enamine (IV) was converted to the crystalline amine (V) over a period of 5 h at 20°C. PMR spectrum, δ: 2.6 [t, 4H, $(CH_2)_2C{=}N$], 2.35 ppm (m, 6H).

4-(Triphenylphosphazido)-2,3,5,6-tetrabromopyridine (VI). To a solution of azide (I) (0.22 g, 0.51 mmole) in ether (15 ml) at −10°C was added triphenylphosphine (0.13 g, 0.5 mmole). The mixture was stirred at −10°C for 30 min. The remaining orange precipitate was filtered off. The yield was 0.28 g. UV spectrum, λ_{max} (log ε): 258 nm (4.24).

4-Triphenylphosphazenyl-2,3,5,6-tetrabromopyridine (VII). A mixture of azide (I) (0.44 g, 1 mmole) and triphenylphosphine (0.26 g, 1 mmole) in ether (30 ml) was refluxed for 4 h. The yield was 0.5 g. UV spectrum, λ_{max} (log ε): 230 (3.95), 294 nm (4.49).

Diethyl 2,3,5,6-Tetrabromo-4-pyridyl Amidophosphate (VIII). To a solution of azide (I) (0.6 g, 1.37 mmole) in ether (25 ml) was added triethyl phosphite (0.23 g, 1.38 mmole). The solution instantly became colored and an exothermal reaction started with evolution of nitrogen. After a few minutes the color was discharged. The ether was removed under vacuum and the residual oily product was hydrolyzed with 5% HCl (30 ml). After 6 h the precipitate was filtered off. The yield was 0.52 g.

Diphenyl 2,3,5,6-Tetrabromo-4-pyridyl amidophosphate (IX) was prepared from azide (I) and triphenyl phosphite in the same way as (VIII).

4-Azido-2,6-bis(diethoxyphosphinylamine)-3,5-dibromopyridine (X). To a solution of azide (II) (0.36 g, 1 mmole) in ether (50 ml) was added triethyl phosphite (0.55 g, 3.3 mmole). The mixture was kept at 20°C for 12 h. The product was isolated in the same way as (VIII). The yield was 0.35 g. PMR spectrum, δ: 3.87 (q, CH_2), 2.52 (s, NH), 1.0 ppm (t, CH_3) in $(CD_3)_2CO$.

2,4,6-Tris(triethoxyphosphazenyl)-3,5-dibromopyridine (XI). To a solution of azide (II) (1.1 g, 3 mmole) in ether (50 ml) was added triethyl phosphite (1.6 g, 9.6 mmole). The mixture was refluxed for 6 h. The yield was 2.27 g n_D^{20} 1.5272.

LITERATURE CITED

1. R. E. Banks and G. R. Sparkes, J. Chem. Soc., Perkin Trans. I, 2964 (1972).
2. J. R. A. Bernard, G. E. Chivers, R. J. W. Cremlyn, and K. G. Mootoosamy, Aust. J. Chem., 27, 171 (1974).
3. S. Patai (ed.), The Chemistry of the Azido Group, Interscience, New York (1971), p. 345.
4. K. R. Honery-Logan and R. A. Clark, Tetrahedron Lett., 801 (1968).
5. J. Collins and H. Suschitzky, J. Chem. Soc., C, 1523 (1970).