Heteroatom Chemistry
Volume 19, Number 7, 2008

Intramolecular *C*-Thiocarbamoylation of Aroxy(Isothiocyanato)Phosphonium Salts

R. V. Smalii, A. P. Marchenko, Y. N. Koidan, A. A. Chaikovskaya, A. M. Pinchuk, and A. A. Tolmachev

Institute of Organic Chemistry, National Academy of Sciences of Ukraine, Murmanska 5, Kyiv-94, 02094, Ukraine

Received 3 April 2008; revised 25 June 2008

ABSTRACT: *Isothiocyanatophosphonium salts bearing an aroxy group at the phosphorus atom have been obtained for the first time. As found, these compounds undergo an intramolecular heterocyclization to give hitherto unknown benzoxazaphosphininethiones or cyanoiminophosphoranes, according to the nature of the substituents on the aryl ring.* © 2008 Wiley Periodicals, Inc. Heteroatom Chem 19:667–670, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/hc.20491

INTRODUCTION

Reactions of intramolecular *C*-(thio)carbamoylation with various iso(thio)cyanates have been extensively used in heterocyclic synthesis [1–6]. Iso(thio)cyanatophosphonium salts have not yet been studied in this respect in spite of their great structural diversity and high (thio)carbamoylation reactivity toward *C*-nucleophilic substrates. As shown by us previously, amido(isothiocyanato)phosphonium compounds efficiently thiocarbamoylate a number of electron-rich heterocycles and enamines [7]. The present study addresses the design of novel phosphonium salts in which an electrophilic *P*-isothiocyanato group is combined with a *C*-nucleophilic center, thus affording an intramolecular heterocyclization.

Correspondence to: A. A. Chaikovskaya; e-mail: chaikoff2005@ukr.net.

RESULTS AND DISCUSSION

As synthetic precursors of bifunctional isothiocyanatophosphonium salts, unsubstituted phenol and its electron-donor-substituted derivatives were used (Fig. 1), because compounds of this kind have been thoroughly studied in both inter- and intramolecular *C*-carbamoylations [4,5,8,9].

To synthesize hitherto unknown aroxy (isothiocyanato)phosphonium salts, we started from aroxyphosphonium salts **2a–d** obtained by the reaction of *O*-phosphorylated phenols **1a–d** with dichloroethane (Scheme 1).

Aroxy(chloro)phosphonium chlorides **2a–b** containing a diethylamino group on the aromatic ring were treated with trimethylsilyl isothiocyanate to provide the corresponding aroxy (isothiocyanato)phosphonium isothiocyanates **3a,b**, which were characterized by ^{31}P NMR spectra without isolation. They were cyclized in situ in the presence of the equivalent quantity of triethylamine at 20°C. As was expected, the intramolecular cyclization furnished new heterocycles, benzoxazaphosphininethiones **4a** and **4b**, with respective yields of 33% and 25% (Scheme 2). Compounds **4a,b** were obtained as pale yellow high-melting solids stable to atmospheric moisture and oxygen.

As one would expect in going to phenol derivatives **2c,d** bearing less electron-donating

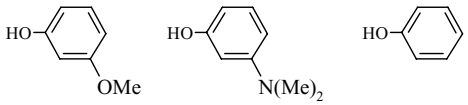


FIGURE 1

three substituents, intermediate aroxy(isothiocyanato)phosphonium salts **5a,b** become much more stable, so that these compounds can be isolated in the pure state, provided they are not heated above 40°C. It was, however, unexpected that the heterocyclization did not occur, if attempted under more severe conditions; instead, carbon disulfide was eliminated and cyanoiminophosphoranes **6a** and **6b** were formed in 74% and 35% yields, respectively (Scheme 3).

Scheme 4 represents a plausible mechanism for the formation of cyanoiminophosphoranes from salts **5a,b**. It is likely that the counterion (in our case, thiocyanate anion) initially attacks the carbon atom of the isothiocyanate group, which is typical of such compounds [10], followed by a rearrangement and elimination of carbon disulfide.

CONCLUSION

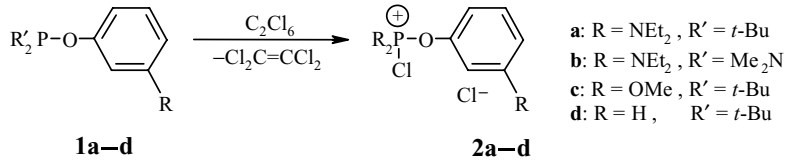
As found, aroxy(isothiocyanato)phosphonium isothiocyanates furnish, in the presence of the equivalent quantity of triethylamine, the corresponding benzoxazaphosphininethiones or cyanoiminophosphoranes. The course of the reaction is governed by the electron-donating properties of the substituents on the aryl ring: a decreased nucleophilicity of the aromatic carbon atoms stabilizes the aroxy(isothiocyanato)phosphonium salt both in the pure state and in solution, hinders the heterocyclization, and favors cyanoiminophosphorane formation.

EXPERIMENTAL

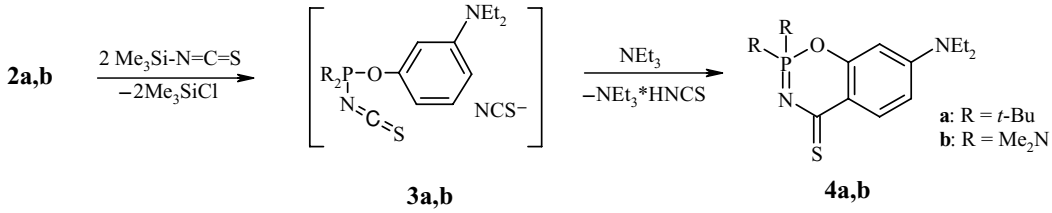
^{1}H (300 MHz, TMS as internal standard) and ^{31}P (282.2 MHz, 85% H_3PO_4 as external standard) NMR spectra were recorded on a Varian VXR-300 spectrometer. IR spectra were obtained on an UR-20 spectrometer for samples in KBr disks. Mass spectra were registered using an Agilent 1100 series LC/MSD system. All reactions were carried out under dry argon using the Schlenk-type glassware. Solvents, including deuterated solvents used for NMR spectroscopy, were dried and distilled prior to use.

Aroxy(chloro)phosphonium Chlorides **2a,b**

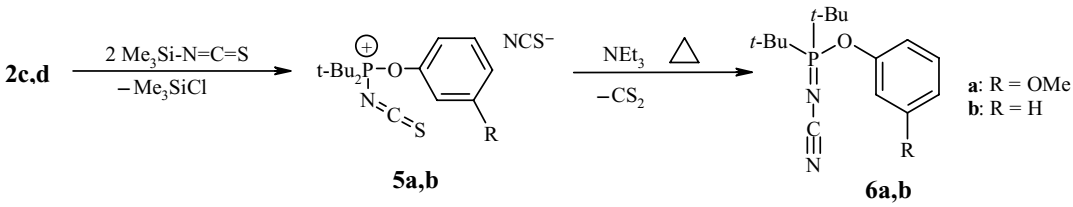
To a stirred solution of aroxyphosphines **1a,b** (0.01 mol) in benzene (20 mL) at 5°C for **1a** or in Et_2O



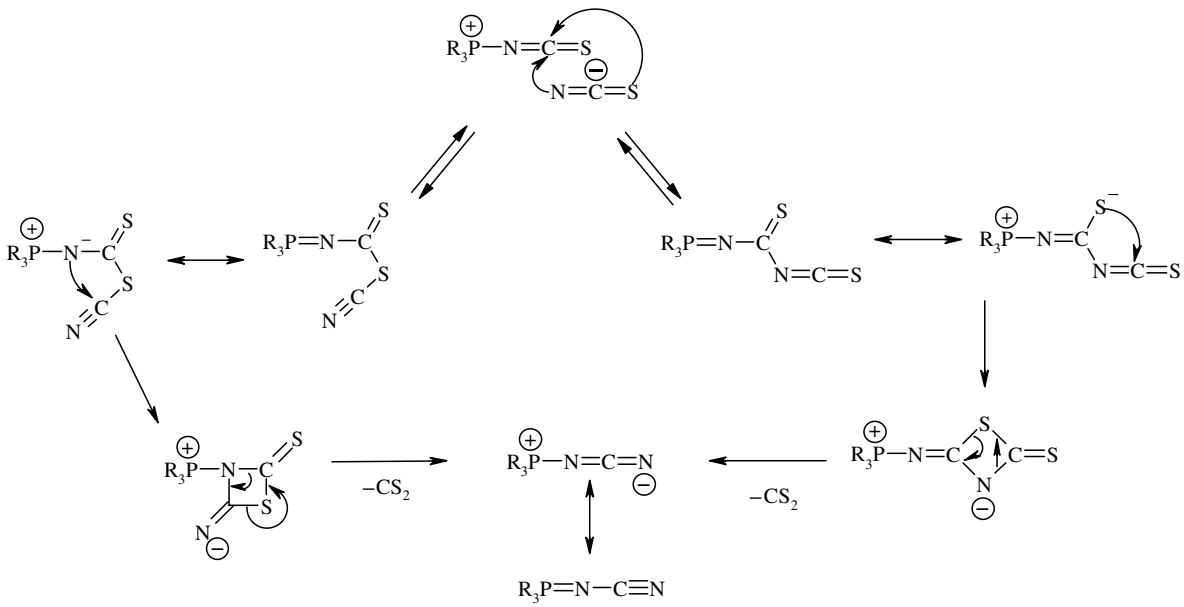
SCHEME 1



SCHEME 2



SCHEME 3



SCHEME 4

(20 mL) at −40°C for **1b**, a solution of C_2Cl_6 (2.37 g, 0.01 mol) in benzene (20 mL) for **1a** or in Et_2O (20 mL) for **1b** was added. The reaction mixture was heated to 20°C and held at this temperature for 2 h. After decanting the solvent, Et_2O (20 mL) was poured over the oily product and it was rubbed until crystallization occurred. The resulting precipitate was filtered off on a dry filter and washed with Et_2O (2 × 10 mL).

Compound **2a**. Yield 3.19 g (84%). ^{31}P NMR (C_6D_6), δ_P(ppm): 126.70. ^{1}H NMR (C_6D_6), δ (ppm): 0.91 (t, $J_{HH} = 6.9$ Hz, 6H, CH_3), 1.18 (d, $J_{HP} = 11.7$ Hz, 18H, *t*-Bu), 2.99 (q, $J_{HH} = 6.9$ Hz, 4H, CH_2), 6.25 (m, 1H, Ar), 6.81 (m, 2H, Ar), 7.14 (m, 1H, Ar).

Compound **2b**. Yield 3.44 g (84%). ^{31}P NMR (C_6D_6), δ_P(ppm): 39.00.

Aroxy(chloro)phosphonium Chlorides **2c,d**

To a stirred solution of aroxyphosphines **1c,d** (0.01 mol) cooled to −40°C, a solution of C_2Cl_6 (2.37 g, 0.01 mol) in Et_2O (10 mL) was added. The reaction mixture was heated to 20°C and held at this temperature for 1 h. The precipitate of the product was filtered off on a dry filter and washed with Et_2O (2 × 10 mL).

Compound **2c**. Yield 2.88 g (85%), mp 85–86°C. ^{31}P NMR (C_6D_6), δ_P (ppm): 127.90.

Compound **2d**. Yield 2.72 g (88%), mp 80–85°C. ^{31}P NMR (C_6D_6), δ_P (ppm): 128.10.

2,2-Dimethyl-4H-1,3,2λ^5-benzoxazaphosphinine-4-thiones **4a,b**

To a solution of aroxy(chloro)phosphonium chlorides **2a,b** (0.01 mol) in CH_2Cl_2 (10 mL), a solution of Me_3SiNCS (3.28 g, 0.025 mol) in CH_2Cl_2 (10 mL) was added at 20°C and the reaction mixture was held at this temperature for 2 h. Resulting aroxy(isothiocyanato)phosphonium isothiocyanates **3a,b** were characterized by ^{31}P NMR spectra without isolation. ^{31}P NMR (CH_2Cl_2), δ_P (ppm) for 4**a**: br 81.18 and for 4**b**: br 19.5, ca. 50% intensity relative to the other signals. After adding triethylamine (2.52 g, 0.025 mol) to the reaction mixture, it was allowed to stand for 1 h and then evaporated. The product was extracted from the residue with benzene, followed by evaporation of benzene and extraction of the product from the residue with Et_2O (5 × 20 mL). The resulting ether solution was held over activated charcoal, filtered, evaporated to 1/4 of its volume, and left overnight. The crystals that deposited from the solution were filtered off and dried until the constant mass was achieved.

7-(Diethylamino)-2,2-di-tert-butyl-2,2-dihydro-4H-1,3,2-benzoxazaphosphinine-4-thione **4a**. Yield 1.21 g (33%), mp 177–178°C. ^{31}P NMR (C_6D_6), δ_P(ppm): 64.30. ^{1}H NMR (C_6D_6), δ (ppm): 0.78 (t, $J_{HH} = 7.2$ Hz, 6H, CH_3), 1.00 (d, $J_{HP} = 15.6$ Hz, 18H, *t*-Bu), 2.80 (q, $J_{HH} = 7.2$ Hz, 4H, CH_2), 6.13 (d, $J = 2.7$ Hz, $J = 2.7$ Hz, 1H, Ar), 6.18 (dd, $J_{HH} = 9.3$ Hz, $J = 2.7$ Hz, 1H, Ar), 9.41 (d, $J_{HH} = 9.3$ Hz,

1H, Ar). *m/z* 366 $[M]^+$. Found: P 8.37; S 8.84. $C_{19}H_{31}N_2OPS$. Calcd.: P 8.45; S 8.75.

7-(Diethylamino)-2,2-bis(dimethylamino)-2,2-dihydro-4H-1,3,2-benzoxazaphosphinine-4-thione **4b**. Yield 0.85 g (25%), mp 158–159°C. ^{31}P NMR (C_6D_6), δ_P (ppm): 19.80. ^{1}H NMR (C_6D_6), δ (ppm): 0.75 (t, $J_{HH} = 6.6$ Hz, 6H, CH_3), 2.21 (d, $J_{HP} = 10.5$ Hz, 12H, Me), 2.78 (q, $J_{HH} = 6.6$ Hz, 4H, CH_2), 6.10 (d, $J_{HH} = 2.7$ Hz, 1H, Ar), 6.24 (dd, $J_{HH} = 9.3$ Hz, $J = 2.7$ Hz, 1H, Ar), 9.39 (d, $J_{HH} = 9.3$ Hz, 1H, Ar). *m/z* 340 $[M]^+$. Found: P 9.19; S 9.38. $C_{15}H_{25}N_4OPS$. Calcd.: P 9.10; S 9.42.

Aroxy(isothiocyanato)phosphonium Isothiocyanates **5a,b**

To a solution of aroxy(chloro)phosphonium chlorides **2c,d** (0.01 mol) in CH_2Cl_2 (10 mL), a solution of Me_3SiNCS (3.28 g, 0.025 mol) in CH_2Cl_2 10 mL was added at 20°C, and the reaction mixture was held at this temperature for 5 min. After evaporating the solvent at a bath temperature not above 30–35°C, the residue was washed several times with Et_2O. Ether was then decanted, and the residue was dried under vacuum.

Compound **5a**. Yield 3.27 g (85%), mp 76–78°C. ^{31}P NMR (C_6D_6), δ_P (ppm): 80.80. ^{1}H NMR (C_6D_6), δ (ppm): 1.93 (s, 9H, *t*-Bu), 1.98 (s, 9H, *t*-Bu), 3.81 (s, 3H, OMe), 6.42 (d, 7.8 Hz, 1H, Ar), 6.52 (d, $J_{HH} = 7.8$ Hz, 1H, Ar), 6.67(d, $J_{HH} = 8.0$ Hz, 1H, Ar), 7.20 (s, 1H, Ar).

Compound **5b**. Yield 3.01 g (85%), mp 85–89°C. ^{31}P NMR (C_6D_6), δ_P (ppm): 80.70 ^{1}H NMR (C_6D_6), δ (ppm): 1.94 (s, 9H, *t*-Bu), 1.98 (s, 9H, *t*-Bu), 6.85 (t, $J_{HH} = 7.8$ Hz, 1H, Ar), 7.07 (t, $J_{HH} = 7.8$ Hz, 2H, Ar), 7.27 (d, $J_{HH} = 7.8$ Hz, 2H, Ar).

Cyanoiminophosphoranes **6a,b**

To a solution of aroxy(isothiocyanato)phosphonium salts **5a,b** in CH_2Cl_2 (20 mL), triethylamine was added (2.00 g, 0.02 mol). The reaction mixture was heated at 100°C in a hermetically sealed flask for 20 min and evaporated until the constant mass was achieved. After extracting the residue with Et_2O (4 × 20 mL), the solution was evaporated and the residue was recrystallized from Et_2O.

3-Methoxyphenyl P,P-di(tert-butyl)-N-cyanophosphinimidoat **6a**. Yield 1.08 g (35%), mp 104–105°C. ^{31}P NMR (C_6D_6), δ_P (ppm): 65.40. ^{1}H NMR (C_6D_6), δ (ppm): 1.18 (d, $J_{HP} = 11.7$ Hz, 18H, *t*-Bu), 3.31 (s, 3H, OMe), 6.53 (d, $J_{HH} = 7.8$ Hz, 1H, Ar), 7.00 (d, $J_{HH} = 7.8$ Hz, 1H, Ar), 7.10 (d, $J_{HH} = 8.1$ Hz, 1H, Ar), 7.32 (s, 1H, Ar). IR (KBr) $\Delta\nu = 2200$ cm^{-1}(C≡N).

Phenyl P,P-di(tert-butyl)-N-cyanophosphinimidoat **6b**. Yield 2.06 g (74%), mp 73–74°C. ^{31}P NMR (C_6D_6), δ_P (ppm): 66.00. ^{1}H NMR (C_6D_6), δ (ppm): 1.05 (d, $J_{HP} = 15.9$ Hz, 18H, *t*-Bu), 6.82 (t, $J_{HH} = 7.5$ Hz, 1H, Ar), 7.01 (t, $J_{HH} = 8.1$ Hz, 2H, Ar), 7.22 (d, $J_{HH} = 8.1$ Hz, 2H, Ar). IR (KBr) $\Delta\nu = 2200$ cm^{-1}(C≡N).

REFERENCES

[1] (a) Samaraj, L. I.; Bondar, W. A.; Derkatsch, G. I. Angew Chem 1967, 79, 897; (b) Angew Chem Int Ed Engl 1967, 6(10), 864.
[2] Vovk, M. V.; Samarai, L. I.; Khim Geterotsikl Soed 1991, 5, 698; Chem Abstr 1991, 115, 279947.
[3] Gorbatenko,V. I.; Fetyukhin, V. N.; Mel'nichenko, N. V.; Samarai, L. I. Zh Obshch Khim 1977, 13(11), 2320; Chem Abstr 1978, 88, 74171.
[4] Vovk, M. V.; Pokholenko, A. A.; Bol'but, A. V. Zh Org Khim 1996, 32(3); Chem Abstr 1996, 125, 300917.
[5] Vovk, M. V.; Bol'but, A. V.; Chernega, A. N. J Fluorine Chem 2002, 116, 97.
[6] Knoelker, H.-J.; Braxmeier, T. Syn Lett 1997, 8, 925.
[7] Smalii, R. V.; Koidan, G. N.; Chaikovskaya, A. A.; Marchenko, A. P.; Pinchuk, A. M.; Tolmachev, A. A. Russ. J Gen Chem 72, 11, 2002, 1688; Chem Abstr 2003, 139, 101006.
[8] Effenberger, F.; Cleiter, R.; Heider, L.; Niess, R. Chem Ber 1968, 101, 502.
[9] Lohaus, G. Chem Ber 1967, 100, 2719.
[10] Marchenko, A. P.; Shaposhnikov, S. I.; Koidan, G. N.; Kharchenko, A. V.; Pinchuk, A. M. Zh Obshch Khim 1988, 58(10), 2230; Chem Abstr 1990, 112, 7578.