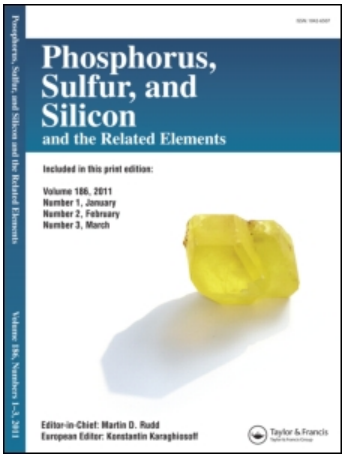

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REACTION OF (2-BENZOTHIAZOLYL)-SULFENAMIDES WITH P-CONTAINING REAGENTS

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REACTION OF (2-BENZOTHIAZOLYL)-SULFENAMIDES WITH P-CONTAINING REAGENTS

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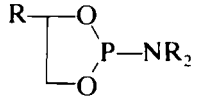
The title reaction was investigated to find that only substitution reaction on amino group occurred when (2-benzothiazolyl)sulfenamides **1** reacted with $P(NR_2)_3$, whereas the treatment of **1** with $(RO)P(NR_2)_2$ gave derivatives of phosphorodiamidothioic acid together with 2-alkylthiobenzothiazole and its isomer in addition to substitution products, and no substitution products obtained when N-substituted analogues of **1** were treated similarly.

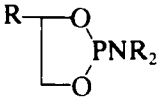
Key words: Nucleophilic attack; (2-benzothiazolyl)sulfenamide; polarization of S—N bond; electronegativity; phosphonium ion.

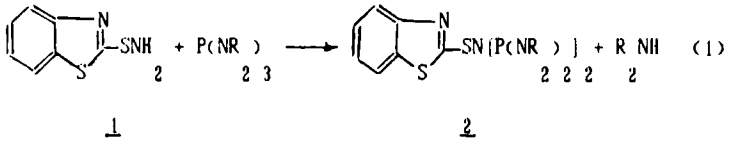
INTRODUCTION

Considerable attention has focused on the versatile use of sulfenamides as reagents for making hetero-hetero atom bonds such as S—N, S—S, and S—P bonds[1–3] due to their strong polar S—N bond which is very easy to be attacked by nucleophiles. However, few convenient methods have so far been found for the synthesis of S-ester of phosphorodiamidothioic acid[4,5] S. Torii and his coworkers[6] have investigated the reaction of phenylsulfenamides with dialkyl phosphites to yield phosphorothiolates and the treatment of (2-benzothiazolyl)sulfenamides **1** with dialkyl and trialkyl phosphites to give phosphoramidates in excellent yields, which was an efficient method to synthesize phosphoramidates. But no other investigation on the reaction of **1** with phosphorus-containing reagents has been reported. As part of our interest in this aspect, we have studied some reactions of **1** to seek a new route to derivatives of phosphorodiamidothioic acid. We wish to report here the reaction of **1** and its derivatives with some tri- and tetra-coordinate phosphorus reagents such as tris(dialkylamino)phosphines, bis(dialkylamino)phosphites, phenylphosphorothioic dichloride $PhP(S)Cl_2$, and 2-dialkylamino-4-alkyl-1,3,2-dioxaphospholane



RESULTS AND DISCUSSION

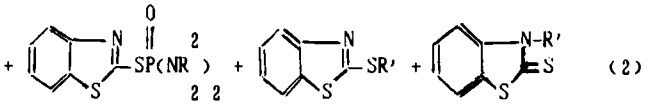
As indicated by T.L.C. and ^{31}P NMR, no reactions took place when **1** was mixed with $PhP(S)Cl_2$ in the presence of pyridine or triethylamine at room temperature or refluxed with  in acetonitrile or xylene solvent, which seems to show the weak nucleophilicity of the amino group of **1**. However, the reaction of **1** with tris(dialkylamino)phosphines(2.2 equiv.) with stirring under a nitrogen atmosphere and reduced pressure of 60–65 torr at 65–70°C afforded 68–72% yields of *N,N*-bis[bis(dialkylamino)phosphino](2-benzothiazolyl)sulfenamides **2**. Dramatical change on the products was encountered in the reaction of **1** with bis(dialkylamino)phosphites(2.6 equiv.) under similar conditions, leading not only to the substitution reaction products **3** (19–20%), but also to products **4** (65–70%), **5** and **6** (trace) through cleavage of S—N bonds (Table I).



(1)

1 **2**

3



(2)

4 **5** **6**

2a-d, R=Me, Et, n-Pr, n-Bu.

3a-c; $R'=R^2=Me$; $R'=R^2=Et$; $R'=Et$, $R^2=n\text{-}Pr$.

5a-b; R'=Me, Et.

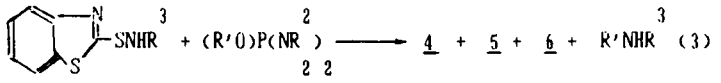
6a-b; R'=Me, Et.

In addition, when N-alkyl-(2-benzothiazoly)sulfenamides reacted with bis(dialkylamino)phosphites only compounds **4** (62–70%), **5** (21–35%) and **6** (trace) were obtained. The reaction conditions and results are listed in Table II.

TABLE I

Reaction of **1** with $(R_2N)_2PX$ (X = R_2N, R'O)

Compound	Temp. °C	N_2 Press. torr	Time h	Yield %	Microanalysis Found/calcd. C%	H%	P%	Formula
2a	65	80	2	68.4	43.11 43.06	6.73 6.70	14.89 14.83	$C_{15}H_{28}N_6P_2S_2$
2b	65	90	1.5	68.6	52.11 52.08	8.29 8.30	11.67 11.69	$C_{23}H_{44}N_6P_2S_2$
2c	70	50	2.5	69.1	57.85 57.94	9.32 9.35	9.59 9.66	$C_{31}H_{60}N_6P_2S_2$
2d	70	50	2.5	72.4	62.08 62.07	10.14 10.08	8.29 8.22	$C_{39}H_{76}N_6P_2S_2$
3a	110	60	2	19.1	39.71 39.80	5.55 5.61	15.70 15.75	$C_{13}H_{22}N_4O_2P_2S_2$
3b	115	60	2	20.0	47.93 47.90	7.22 7.14	13.08 13.03	$C_{19}H_{34}N_4O_2P_2S_2$
3c	115	60	2	19.6	45.62 45.54	6.73 6.70	13.93 13.84	$C_{17}H_{30}N_4O_2P_2S_2$



$$\text{SNHR}^3 + (R'O)P(NR^2_2)_2 \longrightarrow \underline{4} + \underline{5} + \underline{6} + R'NHR^3 \quad (3)$$

$R' = Me, Et;\ R^2 = Me, Et, n\text{-}Pr;\ R^3 = PhCH_2, MeCH, c\text{-}C_6H_{11}$

It is obvious that compounds **2** and **3** result from the nucleophilic attack of amino group of **1** on phosphorus atom of $(R_2N_2)PX$ (X = RO, R_2N), but the yields were low in reaction (2). No reactions even occurred in the case of

TABLE II

Reactions of **7** with $(R'O)P(NR^2_2)_2$

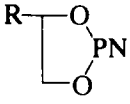
R'	R^2	R^3	Temp. °C	N_2 Press. torr	Time h	Yield(%) **4**	**5**
Me	Me		110	20	3	62.1	28.3
Et	Et	$PhCH_2$	135	30	2	64.9	35.5
Et	n-Pr		135	20	3	60.4	24.5
Me	Me		100	10	4	59.4	21.5
Et	Et	i-Pr	130	20	3	66.0	30.0
Et	n-Pr		135	20	3	67.6	21.6
Me	Me		100	10	4	70.2	20.4
Et	Et	c-	120	20	4	65.0	22.0
Et	n-Pr	C_6H_{11}	130	20	3	63.0	21.4

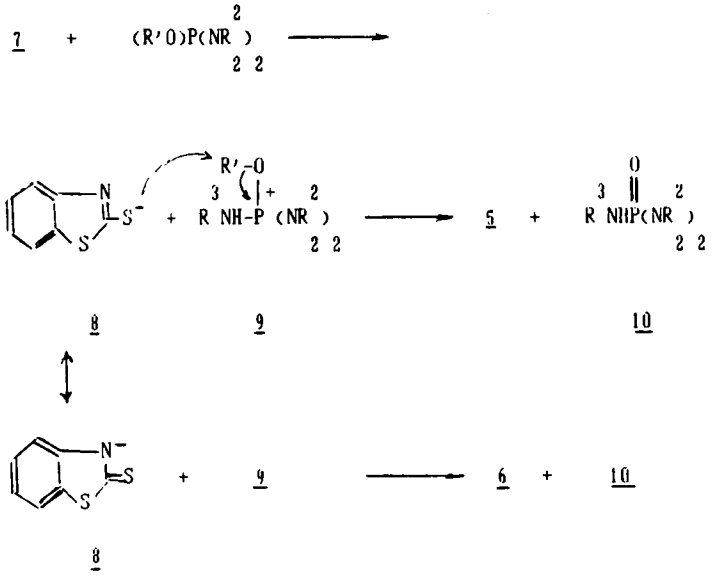
TABLE III

^{13}C, ^{31}P NMR and IR spectral data for compounds **2** and **3**

Compound	^{13}C NMR: δ [ppm][a]			IR: ν, cm^{-1}			^{31}P NMR
	α-C(NR_2)	α-C(OR)	C-2	P—N		P—O	δ [ppm]
2a	37.6(10.2)		157.2(26.5)	1169,	1031		77.5
2b	39.4(10.2)		156.4(26.3)	1176,	1038		77.0
2c	48.8(10.5)		156.0(25.6)	1168,	1036		73.2
2d	44.5(9.8)		159.8(25.3)	1164,	1033		78.4
3a	39.3(9.2)	49.8(7.1)	160.5(24.7)	1164,	1033	1018	77.5
3b	42.1(8.5)	59.6(7.2)	159.4(24.8)	1174,	1054	1019	76.9
3c	49.5(9.8)	60.4(7.5)	160.8(25.6)	1175,	1054	1019	75.6

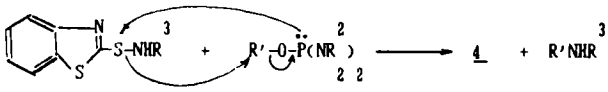
[a] ^{13}C NMR spectral data are only given for α-C of alkoxyl or dialkylamino group connecting with phosphorus atom and C-2 of the benzothiazolyl ring. The coupling constant of the carbon as split by the phosphorus atom is given in hertz in parentheses.

$PhP(S)Cl_2$ and  which might be explained by the powerful electron-withdrawing effect of the 2-benzothiazolyl moiety to weaken the nucleophilic reactivity of the amino group. More surprisingly, the effect would give rise to inversion of the polarization of S—N bond to some extent by donating electron from the nitrogen to the sulfur atom through (d–p)π bond.[7] Therefore, nucleophilic attack of $(R'O)P(NR_2)_2$ onto nitrogen atom of **1** or **7** afforded phosphonium ion **9** followed by another nucleophilic attack of thiolate ion **8** at α-position of alkyl group (R′) of **9** to give **5** or **6** together with phosphoramide **10**. In fact, we have indeed isolated compounds **5** and **6** as trace products. The ^{31}P NMR analysis for the reacting mixture gave three signals in reaction (2) ($R' = R^2 = Me$), the signals at 77.5 ppm and −24.7 ppm are the resonances of



compounds **3a** and **4a** respectively, it seems that the third signal at −16.5 ppm which is in a range from −25 ppm to +5 ppm typical for phosphoramide derivatives comes from the resonance of **10** (R^2 = Me, R^3 = H). Moreover, the fact that the analogues of **2** or **3** were not obtained in reaction (3) shows the influence of steric effect of the group attached to nitrogen on the reactivity of amino group is apparent.

However, the main products were **4** in reactions (2) and (3), which means that the nucleophilic attack of $(R'O)P(NR^2_2)_2$ occurred chiefly on the electron-deficient sulfur atom of S—N bond, permitting the displacement of the amino group with the nucleophile. In this case, the main factor to influence the reaction seems to be the bond polarization derived from differences in electronegativity between sulfur and nitrogen.[1-3]



CONCLUSION

Our investigation showed that owing to the occurrence of nucleophilic attack predominantly on the sulfur atom N-substituted (2-benzothiazolyl)sulfenamides would be a promising precursor for the preparation of S-(2-benzothiazolyl) ester of phosphorodiamidothioic acid. It is possible to find the best reaction conditions to minimize the side reactions and increase the yields of **4**.

EXPERIMENTAL

^{1}H and ^{13}C NMR spectra were taken in $CDCl_3$ on Varian XL-300 spectrometer with chemical shifts reported in ppm downfield from internal tetramethylsilane. ^{31}P NMR spectra were recorded in $CDCl_3$ (vs. 85% H_3PO_4 as external standard) on Varian XL-300 spectrometer. The mass spectra were run at 70 ev on JMS M-80A, GC-MS mass spectrometer (JEOL Ltd., Tokyo, Japan). Elemental analyses were performed by the Institute of Organic Synthesis, Huazhong Normal University and the Institute of Hydrobiology, Academia Sinica, Wuhan, China.

Reaction of (2-Benzothiaozolyl)sulfenamide **1** with Tris(diakylamino)phosphine. The general procedure for the preparation of **2**, as exemplified by the preparation of *N,N*-bis[bis(di-ethylamino)-phosphino](2-benzothiazolyl)sulfenamide **2b**, is as follows. To a 50 ml round-bottom flask with tris(diethylamino)phosphine(1.49 g, 6.05 mmol), **1** (0.50 g, 2.75 mmol) was added. The mixture was heated at 65°C under a nitrogen atmosphere of 90 torr for 1.5 h, and then cooled to the ambient temperature, the residual crude product was purified by rotary T.L.C. apparatus on silica gel using diethyl ether/petroleum ether (1:2) as eluent to afford **2b** as a colourless sticky liquid (1.0 g, 68.6%). For **2a**, ^{1}H NMR: 2.0 (d, 24 H, $^3J_{HP}$ = 8.4 Hz, $8CH_3$), 7.3–8.1 (m, 4H); MS: m/e (rel. intensity) 418 (M, 42.5), 375 ($C_{13}H_{23}N_5P_2S_2^+$, 89.6), 330 ($C_{11}H_{16}N_4P_2S_2$, 69.2), 314 ($C_{14}H_{28}N_4P_2^+$, 77.6). For **2b**, ^{1}H NMR: 1.2 (t, 24H, $8CH_3$), 3.1–3.4 (m, 16H, $^3J_{HP}$ = 8.5 Hz, $8CH_2$), 7.4–8.2 (m, 4H); MS: m/e 530 (M^+, 17.9), 459 ($C_{19}H_{35}N_5P_2S_2$, 94.5), 426 ($C_{22}H_{44}N_4P_2^+$, 76.5), 386 ($C_{15}H_{24}N_4P_2S_2^+$, 71.6), 221 ($C_8H_{20}N_3PS^+$, 86.5). For **2c**, ^{1}H NMR: 0.7–1.2 (m, 24H, $8CH_3$), 1.4–1.8 (m, 16H, $8CH_2$), 2.9–3.3 (m, 16H, $^3J_{HP}$ = 8.7, Hz, $8CH_2$), 7.2–8.1 (m, 4H). For **2d**, ^{1}H NMR: 0.7–1.0 (m, 24H, $8CH_3$), 1.1–1.4 (m, 16H, $8CH_2$), 1.4–1.7 (m, 16H, $8CH_2$), 2.8–3.3 (m, 16H, $^3J_{HP}$ = 8.9 Hz, $8CH_2$). 7.4–8.1 (m, 4H).

Reaction of (2-Benzothiazolyl)sulfenamide **1** with Bis(dialkylamino) Phosphite. General Procedure. To a 50 ml round-bottom flask containing ethyl bis(diethylamino)phosphite(1.57 g, 7.15 mmol) was added 0.50 g (2.75 mmol) of **1** under a gentle stream of nitrogen. The mixture

was heated at 115°C with stirring under a nitrogen atmosphere of 60 torr for 2 h, and then cooled to the room temperature and recovered to normal pressure. The obtained sticky mixture was dissolved in 5.0 ml of dichloromethane and was purified by rotary T.L.C. apparatus on silica gel using diethyl ether/petroleum ether (1:2) as eluent firstly to afford **3b** as a colourless sticky liquid (0.25 g, 20.0%), and then using diethyl ether/petroleum ether (7:3) as eluent to afford **4b** (0.64 g, 65.2%). The products could be further purified by work-up as described above again. Other products of the reaction were collected and purified by preparative T.L.C. silica gel employing diethyl ether/petroleum ether (1:4) as eluent. **5b** and **6b** were obtained as trace products respectively. For **3a,** ^{1}H NMR: 1.9 (d, 12H, $^3J_{HP}$ = 8.2 Hz, $4CH_3$), 3.3 (d, 6H, $^3J_{HP}$ = 13.2, Hz, $2CH_3$), 7.1–8.2 (m, 4H); MS: m/e (rel. intensity) 392 (M^+, 34.6), 288 ($C_{12}H_{22}N_2O_2P_2^+$, 56.8), 286 ($C_9H_{10}N_3P_2S_2^+$, 42.3), 181 ($C_8H_7NS_2^+$, 100). For **3b,** ^{1}H NMR: 1.0–1.5 (m, 18H, $6CH_3$), 2.9–3.2 (m, 8H, $^3J_{HP}$ = 8.5 Hz, $4CH_2$), 3.5–3.7 (m, 4H, $^3J_{HP}$ = 12.0 Hz, $2CH_2$), 7.1–8.0 (m, 4H); MS: m/e 476 (M^+, 8.3), 372 ($C_{18}H_{34}N_2O_2P_2^+$, 40.3), 314 $C_{11}H_{14}N_3P_2S_2$, 35.7), 229 $C_{10}H_{15}O_2P_2$, 37.9), 195 ($C_9H_9NS_2^+$, 100). For **3c,** ^{1}H NMR: 0.8–1.1 (m, 18H, $6CH_3$), 1.3–1.7 (m, 8H, $4CH_2$), 2.9–3.4 (m, 8H, $^3J_{HP}$ = 8.5 Hz, $4CH_2$), 3.7–4.3 (m, 4H, $^3J_{HP}$ = 8.9 Hz, $2CH_2$), 7.1–8.2 (m, 4H). The syntheses for compounds **4**[5], **5**[8] and **6**[9] have been reported. ^{1}H NMR: **4a,** 2.0 (d, 12H, $^3J_{HP}$ = 11.6 Hz, $4CH_3$), 7.1–8.0 (m, 4H). **4b,** 1.2–1.6 (m, 12H, $4CH_3$), 2.8–3.1 (m, 8H, $^3J_{HP}$ = 11.8 Hz, $4CH_2$), 7.1–8.1 (m, 4H). **4c,** 0.8–1.1 (m, 12H, $4CH_3$), 1.4–1.8 (m, 8H, $4CH_2$), 2.9–3.3 (m, 8H, $^3J_{HP}$ = 12.0 Hz, $4CH_2$), 7.2–8.1 (m, 4H). ^{31}P NMR: **4a,** −24.7 ppm; **4b,** −25.1 ppm; **4c,** −24.9 ppm. Anal. Calcd for **4b,** $C_{15}H_{24}N_3OPS_2$: C, 54.42; H, 6.72; P, 8.68. Found: C, 54.45; H, 6.76; P, 8.72. The IR, ^{1}H, ^{13}C NMR and mass spectra of compounds **5** and **6** are consistent with the proposed structures. mp: **5a,** 50–52°C; **5b,** 25–26°C;[8] **6a,** 88–90°C; **6b,** 73–74°C.[9]

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REFERENCES

1. D. N. Harpp and T. G. Back *J. Org. Chem.*, **36,** 3828 (1971).
2. D. A. Armitage, M. J. Clark and A. M. White, *J. Chem. Soc., C,* 3141 (1971).
3. K. A. Petrov, N. K. Bliznyuk and V. A. Savostenok, *Zh. Obshch. Khim.*, **31,** 1361 (1961).
4. E. E. Nifant'ev, I. V. Shilov, *ibid.*, **43** (12), 2658 (1973).
5. E. E. Nifan'ev, S. Y. Sizov, *et al.*, U.S.S.R. Patent 451,704 (1974).
6. S. Torii, N. Sayo and H. Tanaka, *Chem. Lett.*, 695 (1980).
7. F. A. Davis, Int. *J. Sulfur Chem.*, **8,** 71 (1973).
8. Rassow, Döhle, Reim, *Chem. Zentr.*, **II,** 394 (1916).
9. A. I. Kiprianov and Z. N. Patzenko., *Zhur. Obshchei Khim.*, **19,** 1523 (1949).