Asian Journal of Chemistry Vol. 20, No. 5 (2008), 3579-3584

Synthesis and Characterization of α-(Arylaminothiocarbonyloxy)hydrocarbylphosphonates

JIANPING LI*, JUNGE ZHU and RUIJIE LIU
College of Chemical and Environmental Science, The Key Laboratory of Environmental Pollution Control Technology of Henan Province, Henan Normal University Xinxiang, 453007, P.R. China
E-mail: jplig@163.com

In this study, twelve new α-(arylamino thiocarbonyloxy)-hydrocarbylphosphonates were synthesized in excellent yields by addition reaction of α-hydroxyhydrocarbylphosphonates with aryl isothiocyanates in the presence of sodium methoxide. Their structures have been confirmed by IR, ^{1}H NMR and elemental analysis.

Key Words: Synthesis, Phosphonates, Arylisothiocyanates, α-Hydroxyhydrocarbylphosphonates.

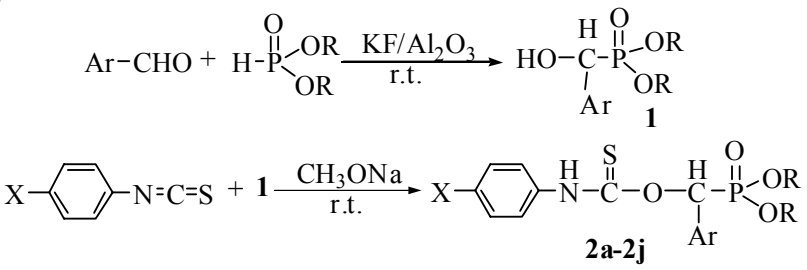
INTRODUCTION

Phosphonates constitute an important class of organophosphorus compounds and are useful in many applications from organic synthesis to agriculture applications as pesticides and plant growth regulating reagents, besides, α-hydroxy phosphonates can be converted into other α-substution phosphonate[1,2]. In the last decade, the research on phosphonates mainly focused on six structure types[3,4] of which α-oxohydrocarbyl phosphonate was a typical one[5,6]. Furthermore, α-hydroxy alkyl phosphonates have become increasingly important for their biological activity[7-9]. They are also convenient intermediates in the synthesis of other substituted phosphonates[10,11]. Based on the research of the predecessors[12-15], we designed and synthesized a new series of α-(arylaminothiocarbonyloxy) hydrocarbylphosphonates. The structures were confirmed by IR, ^{1}H NMR and elemental analysis.

EXPERIMENTAL

Melting points were uncorrected. IR spectra were recorded on a FTS-40 spectrophotometer in KBr. ^{1}H NMR were measured on a Bruker DPX-400 spectrometer using TMS as internal standard and $CDCl_3$ as solvent. Elemental analyses were performed on PE-2400 CHN elemental analyzer.

General procedure for 2a-2j (**Scheme-I**):



Scheme-I

As shown in **Scheme-I**, the 1,2-dichloroethane solution of 4-chlorophenylisothiocyanate (0.438 g, 2.5 mmol) was slowly added to a solution of diethyl α-(hydroxyl)-α-(phenyl)methylphosphonate (0.61 g, 2.5 mmol) and sodium methoxide (0.02 g, 0.37 mmol) in 1,2-dichloroethane (10 mL). The mixture was kept for 0.5 h at room temperature with stirring and the reaction degree was monitored by TLC, then was dried with anhydrous sodium sulfate, the solvent was distilled under reduced pressure and the crude product was easily obtained. The purity of the crude product was detected by TLC and separated on silica gel. Diethyl α-(4-chlorophenylaminothiocarbonyloxy)-α-(phenyl)methylphosphonate **2a** was obtained and the yield was 90 % (Table-1).

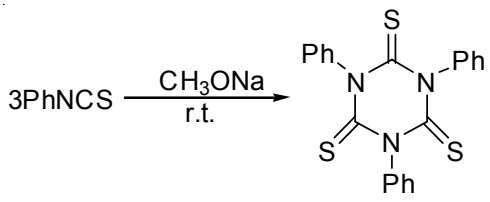
TABLE-1
REACTION TIME, YIELD AND m.p. OF COMPOUNDS **2a-2j**

Products	R	Ar	X	Reaction time (h)	Yield (%)	m.p. (ºC)
2a	Et	C_6H_5	Cl	0.5	90	127-129
2b	Me	C_6H_5	Cl	3.0	78	120-121
2c	*i*-Pr	C_6H_5	Cl	0.5	88	124-126
2d	Et	4-ClC_6H_4	Cl	2.0	83	134-136
2e	Me	4-ClC_6H_4	EtO	3.5	75	131-133
2f	Et	C_6H_5	EtO	0.5	85	91-93
2g	Me	C_6H_5	EtO	1.0	80	140-141
2h	*i*-Pr	4-ClC_6H_4	EtO	1.5	85	117-119
2i	Et	4-ClC_6H_4	Br	2.5	85	127-130
2j	Me	4-ClC_6H_4	Br	1.5	75	126-127

RESULTS AND DISCUSSION

α-Hydroxyhydrocarbylphosphonate **1** was prepared by the reaction of equimolar amounts of aldehyde and phosphate[16-18]. Neutral alumina and potassium fluoride (no dehydration is necessary) were used to facilitate

the reaction[19]. The reaction proceeded on the surface of the catalyst (the mixture of alumina and potassium fluoride) at room temperature. This method had a fast reaction rate, was easy to manipulate and gave high yields with no noticeable side reactions. In the preparation of **2**, the catalyst appeared to play a major role. In absence of sodium methoxide, there is almost no reaction. against yields of 75-90 % in the presence of the catalyst. Aryl isothiocyanate is easily obtained through proper preparation methods[20,21] and has important use in synthesis[22]. Furthermore, due to the thermal instability of arylisothiocyanate, a trimerization reaction occurred if the reaction was heated. This polymerization reactions was extraordinary rapid and the trimer was isolated as a light yellow resinoid[12]. As shown in **Scheme-II**.



Scheme-II

To avoid the trimerization reaction, the sodium methoxide and α-hydroxy-hydrocarbylphosphonate were mixed in the solvent (1,2-dichloro-ethane) at room temperature. Arylisothiocyanate was then slowly added to the mixture for reducing the side reaction.

All compounds **2a-2j** exhibit characteristic IR absorptions for N-H, P=O and C=S groups. In the ^{1}H NMR spectra, the protons on the benzene ring appear at 7.20 to 7.60 ppm. Because the hydrogen on the α-carbon (**2a-2j**, the α-carbon is chiral and is pointed out with an asterisk) is coupled to phosphorus atom, it shows up as a doublet and the coupling constant and chemical shift are respectively 6.85 ppm and 13.0 Hz. In the elemental analysis, all the results are consistent with the theoretical values.

Diethyl-α-(4-chlorophenylaminothiocarbonyloxy)-α-(phenyl)-methylphosphonate (2a): White crystal, IR (KBr, ν_{max}, cm^{-1}): 3169 (N-H), 1597, 1540, 1243 (P=O), 1136 (C=S), 1052 (C-O-C), 743 (P-O). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 9.70 (s, 1H, NH), 7.45 (m, 5H, -C_6H_5), 7.30 (m, 4H, -C_6H_4), 6.93 (d, 1H, $^2J_{PCH}$ = 13.6 Hz, PCH), 4.00 (q, 4H, ^3J = 7.6Hz, 2 × OCH_2), 1.20 (t, 6H, ^3J = 7.6 Hz, 2 × CH_3). Anal calcd. for $C_{18}H_{21}NO_4PSCl$: C, 52.24; H, 5.11; N, 3.38. Found: C, 52.01; H, 4.88; N, 3.14.

Dimethyl-α-(4-chlorophenylaminothiocarbonyloxy)-α-(phenyl)-methylphosphonate (2b): Faint yellow crystal, IR (KBr, ν_{max}, cm^{-1}): 3168 (N-H), 1596, 1541, 1251 (P=O), 1134 (C=S), 1042 (C-O-C), 769 (P-O). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 9.65 (s, 1H, NH), 7.40 (m, 5H, -C_6H_5), 7.31

(m, 4H, -C_6H_4), 6.93 (d, 1H, $^2J_{PCH}$ = 13.6 Hz, PCH), 3.50 (s, 6H, 2 × OCH_3). Anal calcd. for $C_{16}H_{17}NO_4PSCl$: C, 49.81; H, 4.44; N, 3.63. Found: C, 50.14; H, 4.21; N, 3.53.

Diisopropyl-α-(4-chlorophenylaminothiocarbonyloxy)-α-(phenyl)-methylphosphonate (2c): White crystal, IR (KBr, ν_{max}, cm^{-1}): 3169 (N-H), 1598, 1542, 1243 (P=O), 1136 (C=S), 1052 (C-O-C), 743 (P-O). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 9.15 (s, 1H, NH), 7.55 (m, 5H, -C_6H_5), 7.30 (m, 4H, -C_6H_4), 6.92 (d, 1H, $^2J_{PCH}$ = 14.0 Hz, PCH), 4.57 (m, 2H, ^3J = 5.6 Hz, 2 × OCH), 1.25 (d, 12H, ^3J = 5.6 Hz, 4 × CH_3). Anal calcd. for $C_{20}H_{25}NO_4PSCl$: C, 54.33; H, 5.70; N, 3.17. Found: C, 54.24; H, 5.93; N, 2.89.

Diethyl-α-(4-chlorophenyl)-α-(4-chlorophenylaminothiocarbonyloxy)methylphosphonate (2d): White crystal, IR (KBr, ν_{max}, cm^{-1}): 3172 (N-H), 1598, 1544, 1232 (P=O), 1135 (C=S), 1041 (C-O-C), 767 (P-O). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.70 (s, 1H, NH), 7.41 (m, 4H, -C_6H_4), 7.33 (m, 4H, -C_6H_4), 6.84 (d, 1H, $^2J_{PCH}$ = 14.0 Hz, PCH), 4.04 (q, 4H, ^3J = 6.8 Hz, 2 × OCH_2), 1.27 (t, 6H, ^3J = 6.8 Hz, 2 × CH_3). Anal calcd. for $C_{18}H_{20}NO_4PSCl_2$: C, 48.22; H, 4.50; N, 3.12. Found: C, 48.40; H, 4.76; N, 2.86.

Dimethyl-α-(4-chlorophenyl)-α-(4-ethoxyphenylaminothiocarbonyloxy)methylphosphonate (2e): Faint yellow crystal. IR (KBr, ν_{max}, cm^{-1}): 3172 (N-H), 1585, 1541, 1247 (P=O), 1135 (C=S), 1055 (C-O-C), 773 (P-O). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.37 (s, 1H, NH), 7.34 (m, 4H, -C_6H_4), 7.27 (m, 4H, -C_6H_4), 6.96 (d, 1H, $^2J_{PCH}$ = 12.4 Hz, PCH), 4.00 (q, 2H, ^3J = 5.6 Hz, OCH_2), 1.40 (t, 3H, ^3J = 5.6 Hz, CH_3), 3.70 (s, 6H, 2 × OCH_3). Anal calcd. for $C_{18}H_{21}NO_5PSCl$: C, 50.28; H, 4.92; N, 3.26. Found: C, 50.01; H, 4.64; N, 3.44.

Diethyl-α-(4-ethoxyphenylaminothiocarbonyloxy)-α-(phenyl)-methylphosphonate (2f): Faint yellow crystal, IR (KBr, ν_{max}, cm^{-1}): 3156 (N-H), 1591, 1537, 1263 (P=O), 1138 (C=S), 1044 (C-O-C), 738 (P-O). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.75 (s, 1H, NH), 7.30 (m, 5H, -C_6H_5), 7.50 (m, 4H, -C_6H_4), 6.88 (d, 1H, $^2J_{PCH}$ = 9.2 Hz, PCH), 4.00 (q, 4H, ^3J = 6.8 Hz, 3 × OCH_2), 1.30 (t, 9H, ^3J = 6.8Hz, 3 × CH_3). Anal. calcd. for $C_{20}H_{26}NO_5PS$: C, 56.73; H, 6.19; N, 3.31. Found: C, 56.45, H, 5.92; N, 3.11.

Dimethyl-α-(4-ethoxyphenylaminothiocarbonyloxy)-α-(phenyl)-methylphosphonate (2g): Faint yellow crystal, IR (KBr, ν_{max}, cm^{-1}): 3175 (N-H), 1610, 1538, 1246 (P=O), 1124 (C=S), 1053 (C-O-C), 740 (P-O). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 9.25 (s, 1H, NH), 7.35 (m, 5H, -C_6H_5), 6.96 (d, 1H, $^2J_{PCH}$ = 12.4 Hz, PCH), 6.85 (m, 4H, -C_6H_4), 4.40 (q, 2H, ^3J = 6.0 Hz, OCH_2), 3.65 (s, 6H, OCH_3), 1.27 (t, 2H, ^3J = 6.0 Hz, CH_3); Anal. calcd. for $C_{18}H_{22}NO_5PS$: C, 54.68; H, 5.60; N, 3.54. Found: C, 54.39; H, 5.34; N, 3.71.

Diisopropyl-α-(4-chlorophenyl)-α-(4-ethoxyphenylaminothiocarbonyloxy)methylphosphonate (2h): White crystal. IR (KBr, ν_{max}, cm^{-1}): 3182 (N-H), 1602, 1543, 1230 (P=O), 1126 (C=S), 1013 (C-O-C), 766 (P-O). ^1H NMR (400 MHz, $CDCl_3$) δ: 8.75 (s, 1H, NH), 7.50 (m, 4H, $-C_6H_4$), 7.36 (m, 4H, $-C_6H_4$), 6.70 (d, 1H, $^2J_{PCH}$ = 13.6 Hz, PCH), 4.57 (m, 2H, ^3J = 6.4 Hz, 2 × CH), 4.00 (q, 2H, ^3J = 6.8 Hz, OCH_2), 1.27 (t, 3H, ^3J = 6.8 Hz, CH_3), 1.15 (d, 12H, ^3J = 6.4 Hz, 4 × CH_3). Anal calcd. for $C_{22}H_{29}NO_5PSCl$: C, 54.38; H, 6.01; N, 2.88. Found: C, 54.50; H, 5.73; N, 2.59.

Diethyl-α-(4-bromophenylaminothiocarbonyloxy)-α-(4-chlorophenyl)methylphosphonate (2i): White crystal, IR (KBr, ν_{max}, cm^{-1}): 3168 (N-H), 1597, 1542, 1232 (P=O), 1135 (C=S), 1017 (C-O-C), 767 (P-O); ^1H NMR (400 MHz, $CDCl_3$) δ: 9.10 (s, 1H, NH), 7.45 (m, 4H, $-C_6H_4$, ^3J = 7.6 Hz), 7.30 (m, 4H, $-C_6H_4$, ^3J = 8.0 Hz), 6.87 (d, 1H, $^2J_{PCH}$ = 14.0 Hz, PCH), 4.05 (q, 4H, ^3J = 4.0Hz, 2 × OCH_2), 1.25 (t, 6H, ^3J = 4.0 Hz, 2 × CH_3); Anal Calcd. for $C_{18}H_{20}NO_4PSBrCl$: C, 43.87; H, 4.10; N, 2.84; Found: C, 43.64; H, 4.25; N, 2.99.

Dimethyl-α-(4-bromophenylaminothiocarbonyloxy)-α-(4-chlorophenyl)methylphosphonate (2j): Faint yellow crystal; IR (KBr, ν_{max}, cm^{-1}): 3180 (N-H), 1595, 1545, 1251 (P=O), 1130 (C=S), 1043 (C-O-C), 763 (P-O); ^1H NMR (400MHz, $CDCl_3$) δ: 8.60 (s, 1H, NH), 7.43 (m, 4H, $-C_6H_4$, ^3J = 8.8 Hz), 7.32 (m, 4H, $-C_6H_4$, ^3J = 7.6 Hz), 6.96 (d, 1H, $^2J_{PCH}$ = 12.4 Hz, PCH), 3.70 (s, 6H, 2 × OCH_3); Anal Calcd. for $C_{16}H_{16}NO_4PSBrCl$: C, 41.35; H, 3.47; N, 3.01; Found: C, 41.16; H, 3.38; N, 3.21.

Conclusion

In conclusion, we have synthesized a new series of α-(arylaminothiocarbonyloxy)hydrocarbylphosphonates. The operation is simple and the yield is quite high (75-90 %).

ACKNOWLEDGEMENT

The authors are grateful for the financial from the Natural Science Foundation of Technology Commission of Henan Province (No. 0611021700).

REFERENCES

1. K.P. Kumar, C. Muthiah, S. Kumaraswamy and K.C.K. Swamy, *Tetrahedron Lett.*, **42**, 3219 (2001).
2. C. Muthiah, K.P. Kumar, C.A. Mani and K.C.K. Swamy, *J. Org. Chem.*, **65**, 3733 (2000).
3. G.F. Zheng and L.T. Li, *Pest Trans.*, **18**, 1 (1996).
4. K.C.K. Swamy, S. Kumaraswamy, K.S. Kumar and C. Muthiah, *Tetrahedron Lett.*, **46**, 3347 (2005).
5. X.F. Liu and Y. Wang, *Chin. J. Appl. Chem.*, **22**, 40 (2005).
6. S. Failla, P. Finocchiaro and G.A. Consiglio, *Heteroatom Chem.*, **14**, 493 (2000).
7. H.W. He and Z.J. Liu, *Chin. J Org. Chem.*, **21**, 878 (2001).

8. K. Kozlowski, P. Rath and C.D. Spilling, *Tetrahedron*, **51**, 6385 (1995).
9. D.V. Petal, K.R. Gauvin and D.E. Ryono, *Tetrahedron Lett.*, **31**, 5587 (1990).
10. F. Hammerschmidt and H. Vollenkle, *Leibigs. Ann. Chem.*, **12**, 577 (1989).
11. L. Maier, *Phosphorus, Sulfur, Silicon Rel. Elem.*, **76**, 119 (1993).
12. H.W. He, S.Q. Wang and Z.J. Liu, *Chin. J Appl. Chem.*, **15**, 89 (1998).
13. A.F. Prokofeva, L.P. Gryaznova and N.N. Melnikov, *Zh. Obshchei Khimii*, **53**, 1517 (1983).
14. V.V. Alekseev and N.P. Pokryshchenko, *Zh. Obshchei Khimii*, **38**, 1770 (1968).
15. E. Andrzej and H. Wosik, *Tetrahedron: Asymmetry*, **15**, 2075 (2004).
16. F.T. Boullet and A. Foucaud, *Synthesis*, 916 (1982).
17. T. Boullet and A. Foucaud, *Synthesis*, 165 (1982).
18. T. Boullet and M. Lequitte, *Tetrahedron Lett.*, **27**, 3515 (1986).
19. X.F. Liu, H.W. He and Q.C. Zhou, *Chin. J. Pesticide Sci.*, **3**, 73 (2001).
20. E. Joe and W.P. Reeves, *J. Org. Chem.*, **29**, 3098 (1964).
21. R.P. Yves, S. Herve, V. Philippe, L. Eric, D. Sonia and M. Charles, *Tetrahedron Lett.*, **42**, 8479 (2001).
22. R.P. Yves, S. Herve, V. Philippe, J. Ludovic, V. Alain and M. Charles, *Chem. Eur. J.*, **8**, 2910 (2002).

(*Received*: 23 July 2007; *Accepted*: 4 February 2008) AJC-6290