A Simple Route to 2-Alkenethioic *O*-Esters and 2-Alkenedithioic Esters [Thiono- and Dithioesters, 37[1]]

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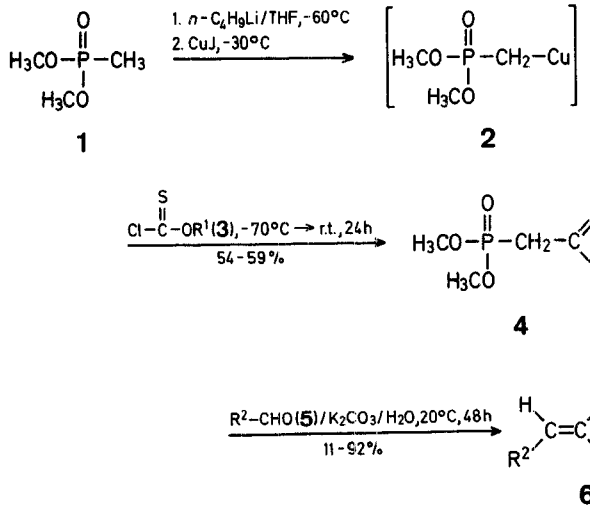
The reaction of the copper(I) derivative of dimethyl methanephosphonic ester with *O*-alkyl carbonochloridothioates affords *O*-alkyl (dimethoxyphosphinyl)-thioacetates. These compounds as well as the corresponding dithioesters react with aldehydes in a Horner-Emmons reaction to give *O*-alkyl 2-alkenethioates or alkyl 2-alkenedithioates, respectively.

We have earlier shown[2] that the copper derivatives **(2)** of methanephosphonic esters **(1)** are easily thioacylated with alkyl carbonochloridodithioates according to Ref.[3] to form dialkoxyphosphinyldithioacetic acid esters (e.g. **7**) in good yield. By an analogous route using *O*-alkyl carbonochloridothioates **(3)**, *O*-alkyl (dialkoxyphosphinyl)-thioacetates **(4)** can be obtained. A related ester, *O*-ethyl (diethoxyphosphinyl)-thioacetate, has recently been prepared by another method starting with diethoxyphosphinylacetonitrile. The nitrile function was first converted into an imidic ester and then with hydrogen sulfide into a thiocarboxylic *O*-ester[4].

It is known that dialkoxyphosphinylacetic esters are useful starting materials for the preparation of 2-alkenoic esters via Horner-Emmons reaction[5]. According to our results, this is also true for *O*-alkyl (dimethoxyphosphinyl)-thioacetates **(4)** which can thus be converted into *O*-alkyl 2-alkenethioates **(6)** with a *trans*-configurated double bond ($^3J_{H,H}$ = 16 Hz). By performing the condensation with an aldehyde in the usual way under anhydrous conditions (e.g. potassium *t*-butoxide/THF or sodium hydride/THF), only poor to fair yields could be obtained (these observations have recently been confirmed by others[4]). However, in a two-phase system containing aqueous potassium carbonate as base the yields are high. These conditions have also been successfully applied to the classical Horner-Emmons reaction[6].

In our standard procedure (Method A), the *O*-alkyl (dimethoxyphosphinyl)-acetate **4** is simply stirred with the liquid aldehyde **5** in aqueous potassium carbonate for 48 hours at room temperature. With solid aldehydes **5**, the reaction rate is slow under these conditions. Solid aldehydes **5** are therefore dissolved in a small quantity of chloroform or the reaction is performed at a temperature just above the melting point of the aldehyde (Method B). In the latter case, the weaker base potassium hydrogen carbonate gives better results.



The difference between the anhydrous and the aqueous version of the Horner-Emmons reaction may be illustrated by two examples. With acetaldehyde and potassium carbonate in dioxan we obtained *O*-methyl 2-butenethioate **(6a)** in 25% yield whereas a 66% yield of **6a** was obtained when the reaction with acetaldehyde was carried out in aqueous potassium carbonate. Analogous results have been reported[4] for the synthesis of a thiocinnamic ester using sodium hydride in tetrahydrofuran (32% yield) or aqueous potassium carbonate (90% yield, this work), respectively.

As we have found[2], (dimethoxyphosphinyl)-dithioacetic esters such as **7** are not suitable as starting materials for the synthesis of 2-alkenedithioic esters by the Horner-Emmons reaction under anhydrous conditions; they can be used as starting materials, however, when aqueous potassium carbonate in a two-phase system is employed. Thus, 4-nitrobenzaldehyde was converted into methyl 4-nitrodithiocinnamate (**8**, R^2 = 4-H_3C—C_6H_4—) in 54% yield. The success in the preparation of the α,β-unsaturated dithioester under these conditions depends mainly on the stability of the end product. If the decomposition of the α,β-unsaturated dithioester (e.g. dimerisation or polymerisation) is relatively rapid, only a poor yield can be expected.

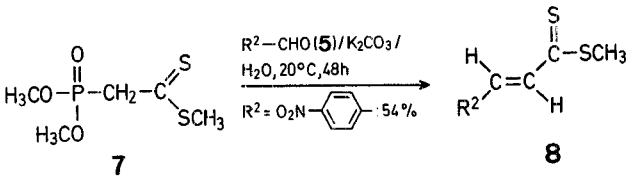


Table 1. 2-Alkenethioic *O*-Esters **(6)** and 2-Alkenedithioic Esters **(8)** prepared

Product No.	R^1	R^2	Method	Yield[a] [%]	m.p. [°C] (solvent) or b.p. [°C]/torr[b]	Molecular Formula[c]
6a	CH_3	CH_3	A	66	b.p. 55°/15	C_5H_8OS (116.2)
6b	C_2H_5	i-C_3H_7	A	81	b.p. 102°/15	$C_8H_{14}OS$ (158.3)
6c	CH_3		A	90	b.p. 130°/0.2	$C_9H_{10}OS$ (166.2)
6d	CH_3		A	38	m.p. 75–77° (hexane)	$C_{10}H_9NO_3S$ (223.3)
6e	C_2H_5		B	61	m.p. 127° (toluene)	$C_{11}H_{11}NO_3S$ (237.3)
6f	C_2H_5		A	73	b.p. 130°/0.2	$C_{12}H_{14}OS$ (206.3)
6g	C_2H_5		A	92	b.p. 195°/11	$C_9H_{10}O_2S$ (182.2)
6h	CH_3		A	11	m.p. 40° (methanol)	$C_{12}H_{10}OS$ (202.3)
8				54	m.p. 131° (methanol)	$C_{10}H_9NO_2S_2$ (239.3)

[a] Yield of pure product isolated by column chromatography.
[b] Temperature of air bath in Kugelrohr distillation.
[c] The microanalyses were in satisfactory agreement with the calculated values: C ± 0.46, H ± 0.34, N ± 0.30, S ± 0.54.

Table 2. N.M.R. Data of Compounds **6** and **8**

Compound	^{1}H-N.M.R. (solvent/TMS_{int})[a]		^{13}C-N.M.R. ($CDCl_3$/TMS_{int})[b]
	Solvent	δ [ppm]	δ [ppm]
6a	CCl_4	1.87 (d, 3H); 4.03 (s, 3H); 6.30 (d, 1H); 6.60–7.03 (m, 1H)	17.9; 58.3; 133.3; 140.9; 211.5
6b	CCl_4	1.11 (d, 6H); 1.40 (t, 3H); 2.07–2.77 (m, 1H); 4.50 (q, 2H); 6.20 (d, 1H); 6.85 (d, 1H)	13.7; 21.2; 30.9; 67.6; 129.7; 151.2; 211.4
6c	CCl_4	4.08 (s, 3H); 6.85 (d, 1H); 7.10–7.53 (m, 5H); 7.57 (d, 1H)	58.4; 128.2; 128.4; 128.8; 130.1; 134.5; 140.5; 210.8
6d	$CDCl_3$	4.20 (s, 3H); 7.00 (d, 1H); 7.67 (d, 1H); 7.6–8.4 (m, 4H)	
6e	$CDCl_3$	1.48 (t, 3H); 4.64 (q, 2H); 7.18 (d, 1H); 7.67 (d, 1H); 7.65, 8.20 (AB system, 4H)	13.6; 68.2; 124.1; 128.6; 132.2; 136.4; 140.9; 148.1; 208.8
6f	CCl_4	1.45 (t, 3H); 2.43 (s, 3H); 4.58 (q, 2H); 6.77 (d, 1H); 7.0–7.6 (m, 4H); 8.20 (d, 1H)	
6g	CCl_4	1.42 (t, 3H); 4.53 (q, 2H); 6.37 (dd; 1H); 6.58 (d, 1H); 6.77 (d, 1H); 7.36 (d, 1H); 7.40 (s, 1H)	13.8; 67.6; 112.6; 115.5; 126.6; 126.9; 144.8; 151.3; 209.7
6h	CCl_4	4.10 (s, 3H); 6.67 (d, 1H); 7.00 (d, 1H); 7.2–8.5 (m, 5H)	
8	CD_2Cl_2	2.75 (s, 3H); 7.43 (d, 1H); 7.80 (d, 1H); 7.75, 8.21 (AB system, 4H)	

[a] Recorded on a Varian T 60 at 60 MHz.
[b] Recorded on a Varian XL 100.

***O*-Methyl (Dimethoxyphosphinyl)-thioacetate (4a); Typical Procedure:**

To a cooled, stirred mixture of a butyllithium solution (1.6 molar in hexane; 60 ml, 96 mmol) and dry tetrahydrofuran (90 ml) under nitrogen is added dropwise a solution of dimethyl methanephosphonate (**1**; 12.0 g, 96 mmol) in tetrahydrofuran (90 ml) at such a rate that the temperature does not rise above −60 °C. Then, copper(I) iodide (20.1 g, 0.1 mol) is added, the mixture gradually allowed to warm to −15° to −30 °C, and kept at this temperature for 4 h with efficient stirring. When the copper(I) iodide has practically dissolved, the dark-green to black-brown solution is again cooled to −70 °C and treated dropwise with a solution of *O*-methyl carbonochloridothioate[7] (**3**, $R^1 = CH_3$; 10.5 g, 96 mmol) in tetrahydrofuran (50 ml), keeping the temperature below −60 °C. The resultant mixture is allowed to come to room temperature overnight. Then, dichloromethane (150 ml) and water (400 ml) are added and the mixture is filtered. The organic layer is separated, dried, and evaporated and the residue is fractionated in a Kugelrohr apparatus to give **4a** as yellow oil; yield: 10.3 g (54%); b.p. 90 °C/0.2 torr.

$C_5H_{11}O_4PS$ (198.2) calc. C 30.30 H 5.59 found 30.09 5.59

^{1}H-N.M.R. ($CDCl_3$/TMS_{int}): δ = 3.46 (d, 2H); 3.74 (d, 6H); 4.10 ppm (s, 3H).

^{13}C-N.M.R. ($CDCl_3$/TMS_{int}): δ = 44.9 (P—CH_2); 52.9 (P—OCH_3); 59.4 (OCH_3); 210.8 ppm (C=S).

***O*-Ethyl (Dimethoxyphosphinyl)-thioacetate (4b):**

Prepared as above from dimethyl methanephosphonate (**1**; 12.0 g, 96 mmol) and *O*-ethyl carbonochloridothioate[7] (**3**, $R^1 = C_2H_5$; 12.0 g, 96 mmol); yield: 12.0 g (59%); yellow oil, b.p. 115 °C/0.2 torr.

$C_6H_{13}O_4PS$ (212.2) calc. C 33.96 H 6.17 found 34.09 6.07

^{1}H-N.M.R. (CCl_4/TMS_{int}): δ = 1.43 (t, 3H); 3.43 (d, 2H); 3.73 (d, 6H); 4.52 ppm (q, 2H).

^{13}C-N.M.R. ($CDCl_3$/TMS_{int}): δ = 13.0 (O—CH_2—CH_3); 45.2 (P—CH_2); 52.8 (OCH_3); 68.7 (O—CH_2—CH_3); 210.0 ppm (C=S).

Methyl (Dimethoxyphosphinyl)-dithioacetate (7):

Prepared as above from dimethyl methanephosphonate (**1**; 12.0 g, 96 mmol) and methyl carbonochloridodithioate[8] (12.2 g, 96 mmol). The crude product **7** is purified by column chromatography on silica gel using ethanol/chloroform (1/2) as eluent; yield: 10.1 g (47%); red-yellow oil, b.p. 102 °C/0.1 torr.

$C_5H_{11}O_3PS_2$ (214.2) calc. C 28.03 H 5.18 found 27.73 5.26

^{1}H-N.M.R. ($CDCl_3$/TMS_{int}): δ = 2.70 (s, 3H); 3.73 (d, 6H); 3.80 ppm (d, 2H).

^{13}C-N.M.R. ($CDCl_3$/TMS_{int}): δ = 20.8 (SCH_3); 49.4 (P—CH_2); 53.2 (P—OCH_3); 223.3 ppm (C=S).

***O*-Alkyl 2-Alkenethioates (6) and Alkyl 2-Alkenedithioates (8); General Procedures:**

Method A: To a solution of potassium carbonate (690 mg, 5 mmol) in water (5 ml) are added the liquid aldehyde **5** (3 mmol) [solid aldehydes are better dissolved in 2–5 ml of chloroform] and *O*-methyl (dimethoxyphosphinyl)-thioacetate (**4**, $R^1 = CH_3$; 400 mg, 2 mmol), *O*-ethyl (dimethoxyphosphinyl)-thioacetate (**4**, $R^1 = C_2H_5$; 425 mg, 2 mmol), or methyl (dimethoxyphosphinyl)-dithioacetate (**7**; 428 mg, 2 mmol) and the mixture is stirred for 48 h at room temperature. Then, chloroform (10 ml) and water (10 ml) are added, the organic layer is separated, dried with calcium sulfate, and evaporated, and the residue is purified by chromatography on silica gel using chloroform as eluent. The product thus obtained is spectroscopically (^{1}H-N.M.R.) pure.

Method B: To a stirred solution of potassium hydrogen carbonate (400 mg, 4 mmol) in water (5 ml) are added *O*-methyl (dimethoxyphosphinyl)-thioacetate (**4**, $R^1 = CH_3$; 400 mg, 2 mmol) or *O*-ethyl (dimethoxyphosphinyl)-thioacetate (**4**, $R^1 = C_2H_5$; 425 mg, 2 mmol) and the solid aldehyde **5** (2.5 mmol) [e.g. 4-nitrobenzaldehyde (380 g)]. The mixture is heated at a temperature just above the melting point of the aldehyde **5** and the progress of the reaction is followed by T.L.C. (reaction conditions for 4-nitrobenzaldehyde: 75 °C, 45 min). Work-up is as in Method A.

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