The Reaction of Ph_3P^+SR with Thiols: A Simple, Efficient Synthesis of Unsymmetrical Disulphides

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Reaction of $Ph_3P^+SRClO_4^-$, prepared electrochemically from RSSR and Ph_3P, with thiols in n-hexane at room temperature gave unsymmetrical disulphides in excellent yields with recovery of Ph_3P.

Various methods for synthesizing unsymmetrical disulphides have been developed,[1,2] and the difficulties in the synthesis are well documented. Among the conceivable stoicheiometries for the disulphide formation, equation (1) is one of the

$$R^1SSR^1 + 2R^2SH \longrightarrow 2R^1SSR^2 + 2H^+ \qquad (1)$$

most attractive routes. We have formally effected equation (1) by the reaction of electrochemically prepared alkylthio- and arylthio-triphenylphosphonium ions[3]† (**1**) with thiols [equations (2) and (3)]. Although the formation of phosphonium

$$R^1SSR^1 + 2Ph_3P \xrightarrow{-2e} \underset{(\mathbf{1})}{2Ph_3P^+SR^1} \qquad (2)$$

$$(\mathbf{1}) + R^2SH \longrightarrow R^1SSR^2 + Ph_3P + H^+ \qquad (3)$$

ions of type (**1**) has been postulated in the reaction of disulphides with triphenylphosphine, their subsequent reaction with thiolate ions has been shown to give sulphides and triphenylphosphine sulphide.[1,4]

A typical preparation of an unsymmetrical disulphide is as follows. A mixture of $Ph_3P^+SMeClO_4^-$ (29 mmol), c-$C_6H_{11}SH$ (29 mmol), and Et_3N (30 mmol) in n-hexane (75 ml) was stirred for 7 h at room temperature. The crystals (Et_3NHClO_4) deposited were filtered off, and the filtrate was washed with water and dried ($MgSO_4$). The resulting solution, after being concentrated *in vacuo* to *ca.* 20 ml, was cooled to −20 °C. The Ph_3P deposited was filtered off, and c-$C_6H_{11}SSMe$ was obtained by vacuum distillation (70%). Results of other smaller scale preparations are summarized in Table 1. Formation of R^1SR^2 was not detected at all, and the yields of other possible products, R^1SSR^1 and R^2SSR^2, were <1%.

Table 1. Reaction of $Ph_3P^+SR^1ClO_4^-$ with R^2SH.[a]

R^1	R^2	Reaction time/h	Yield of R^1SSR^2/%[b]
Me	$PhCH_2$	2	90
Me	Furfuryl	2	87
Me	p-MeC_6H_4	0.5	95
Me	Bu^n	4	100
Me	Bu^t	7	77
Me	c-C_6H_{11}	6	76
$PhCH_2$	Bu^n	3	92
Ph	Bu^n	3	90

[a] In n-hexane (5 ml) containing Et_3N (1.0 mmol) at room temperature: (**1**), 1.0 mmol; R^2SH, 1.0 mmol; c-C_6H_{11} = cyclohexyl. [b] Determined by g.l.c. on the reaction mixture without removing Ph_3P. The disulphides were characterized by elemental analysis, ^1H n.m.r., and mass spectrometry.

At present, it is not clear why the reaction of (**1**) with thiols proceeds as observed. However, when the reaction of (**1**, R^1 = Me) with $PhCH_2SH$ (see Table 1) was carried out in tetrahydrofuran (THF), THF–H_2O (1 : 1, v/v), and methanol, the yield of $PhCH_2SSMe$ decreased to 86, 74, and 38%,

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† The preparation of (**1**) reported in ref. 3 involves a difficult controlled-potential electrolysis in a two-compartment cell with $NaClO_4$ as supporting electrolyte. However, constant current electrolysis in an open beaker with $HClO_4$ instead of $NaClO_4$ has proved much easier and effective, and a large amount of (**1**) (>20 g) can be readily prepared in a single run.

respectively; in methanol, considerable amounts of $(PhCH_2S)_2$ and $(MeS)_2$ were formed. These findings suggest that the instability of the ion pair, $[Ph_3PSR^1]^+R^2S^-$, might be the driving force of the reaction. Such an ion pair has been suggested as the intermediate in the reaction of Ph_3P and a disulphide.[1]

The present method is versatile and has advantages over the other methods reported; the phosphonium ions (**1**) are easy to prepare and stable, the route to the unsymmetrical disulphides requires only simple and mild conditions, and, particularly, Ph_3P is recovered and can be used repeatedly to prepare (**1**).

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