Desulphurisation of Aliphatic Trisulphides, a Mechanistic Dichotomy[1]

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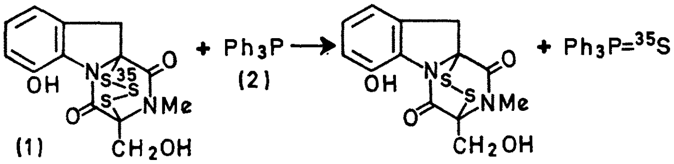
Summary The central sulphur atom of aliphatic trisulphides is removed with triphenylphosphine, whereas with tris(diethylamino)phosphine only the sulphur bonded to carbon is extruded.

A RECENT publication[2] has shown by ^{35}S radioactive tracer work that the central sulphur atom of thiodehydrogliotoxin (**1**) is removed by triphenylphosphine (**2**). Since this molecule may constitute a special case,† we felt it could be misleading to use it as a model to generalize on the mechanism of the reaction.[2] A substrate which could mechanistically accommodate removal of both sulphur atom types was required. Accordingly, ^{35}S-labelled benzyl trisulphide (**3**) was prepared and desulphurised with triphenylphosphine (**2**). In this case, as in the gliotoxin derivative (**1**),



$$PhCH_2\text{–}S\text{–}^{35}S\text{–}S\text{–}CH_2Ph$$
(**3**)

predominantly the central sulphur atom (90%) is extruded by the phosphine (Table).

In contrast with these results, we find a complete reversal of reaction pathway with the same trisulphide (**3**) and tris(diethylamino)phosphine (**4**).[3] This phosphine removes mainly the *terminal sulphur atom* (96%). Interestingly, tri-n-butylphosphine exhibited intermediate behaviour in that it removed significant amounts of both sulphur atom types (terminal, 25%; central, 75%). Thus the mode of desulphurisation is highly dependent on the type of phosphine used.

TABLE

$R^1_3P + R^2\text{–}S\text{–}^{35}S\text{–}S\text{–}R^2 \rightarrow R^2\text{–}S\text{–}S\text{–}R^2 + R^1_3P{=}S$

		Activity (mCi mole^{-1})[a]		
R^1	R^2	$R^2S^{35}SSR^2$	R^2SSR^2	$R^1_3P{=}S$
Ph	$PhCH_2$	0·138	0·014	0·122
Et_2N	$PhCH_2$	0·138	0·137	0·006
Bu^n	$PhCH_2$	0·098	0·024	0·071

[a] The relative error for each activity measurement is considered to be not greater than 2%.

$$\begin{tikzcd}
 & PhCH_2\text{–}S\text{–}S\text{–}CH_2Ph + Ph_3P{=}^{35}S \\
2PhCH_2SH + Cl^{35}SCl \arrow[r] & PhCH_2\text{–}S\text{–}^{35}S\text{–}S\text{–}CH_2Ph \arrow[u, "Ph_3P\ (2)"'] \arrow[d, "(Et_2N)_3P\ (4)"'] \\
 & PhCH_2\text{–}S\text{–}^{35}S\text{–}CH_2Ph + (Et_2N)_3P{=}S
\end{tikzcd}$$

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† It is difficult to imagine terminal sulphur being extruded since this would appear to necessitate front side displacement of phosphine sulphide by mercaptide.

A number of reaction pathways similar to those suggested for the desulphurisation of organic disulphides[3a] may be advanced to explain these reactions. The pathways can involve as possible intermediates phosphonium salts (such as **5** and **6**) as well as a quinquecovalent species (**7**). At present it is not certain if any or all of these are implicated but the above results indicate that this reaction is more complex than previously thought.[2,4]

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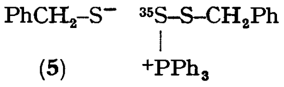
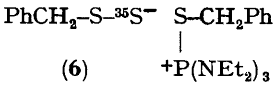


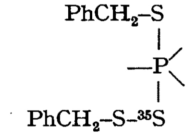
$$\mathrm{PhCH_2{-}S^-}\qquad \begin{array}{l}\mathrm{{}^{35}S{-}S{-}CH_2Ph}\\ |\\ \mathrm{{}^{+}PPh_3}\end{array}$$

(**5**)



$$\mathrm{PhCH_2{-}S{-}{}^{35}S^-}\qquad \begin{array}{l}\mathrm{S{-}CH_2Ph}\\ |\\ \mathrm{{}^{+}P(NEt_2)_3}\end{array}$$

(**6**)



(**7**)

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[1] Previous paper: *J. Org. Chem.*, in the press.

[2] S. Safe and A. Taylor, *Chem. Comm.*, 1969, 1466.

[3] This phosphine has been used to desulphurise a variety of other related molecules; (a) D. N. Harpp, J. G. Gleason, and J. P. Snyder, *J. Amer. Chem. Soc.*, 1968, **90**, 4181; (b) D. N. Harpp and J. G. Gleason, *Tetrahedron Letters*, 1969, 1447.

C. Moore and B. Trego, *Tetrahedron*, 1963, **19**, 1251.