BULLETIN OF THE CHEMICAL SOCIETY OF JAPAN VOL. 43 2632—2633 (1970)

A Convenient Method for the Preparation of Thiolesters

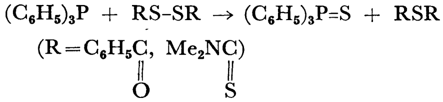
Tadashi ENDO, Shinichi IKENAGA and Teruaki MUKAIYAMA

Laboratory of Organic Chemistry, Tokyo Institute of Technology, Ookayama, Meguro-ku, Tokyo

(Received February 12, 1970)

In connection with a continuing investigation on the new synthetic reactions by the use of a disulfide as an oxidant, it was reported in the preceding paper that bis(diethylthiocarbamoyl) disulfide or benzenesulfenyl chloride reacts with mercuric carboxylates to give carboxylic acid anhydrides in high yields.[1] The present paper describes a convenient method for the preparation of thiolesters from free carboxylic acids by the use of triphenylphosphine and diphenyl disulfide.

It is known that dibenzoyl or bis(dimethylthiocarbamoyl) disulfide reacts with triphenylphosphine in refluxing benzene to give the corresponding sulfide and triphenylphosphine sulfide.[2)]

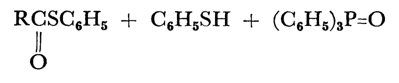


$$(C_6H_5)_3P + RS\text{-}SR \rightarrow (C_6H_5)_3P{=}S + RSR \quad (R{=}C_6H_5\underset{\underset{O}{\|}}{C},\ Me_2N\underset{\underset{S}{\|}}{C})$$

Schönberg reported that 2 equiv. of benzenethiol and triphenylphosphine oxide resulted in low yields by treating diphenyl disulfide with triphenylphosphine in the presence of water in boiling benzene.[3)]

$$(C_6H_5)_3P + (C_6H_5S)_2 + H_2O \rightarrow 2C_6H_5SH + (C_6H_5)_3P{=}O$$

This result suggests that the use of carboxylic acids in place of water as proton donors in the above reaction would lead to the formation of thiolesters, benzenethiol, and triphenylphosphine oxide. As expected, carboxylic acids reacted readily with diphenyl disulfide and triphenylphosphine in boiling acetonitrile to give thiolesters, benzenethiol, and triphenylphosphine oxide in high yields as shown in Table 1.



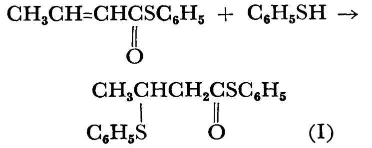
$$RCO_2H + (C_6H_5S)_2 + (C_6H_5)_3P \rightarrow R\underset{\underset{O}{\|}}{C}SC_6H_5 + C_6H_5SH + (C_6H_5)_3P{=}O \quad (1)$$

TABLE 1. REACTIONS OF CARBOXYLIC ACIDS WITH DIPHENYL DISULFIDE AND TRIPHENYLPHOSPHINE

Carboxylic acid	Time hr	Yield, %		
		Thiolester	C_6H_5SH	$(C_6H_5)_3P{=}O$
Acetic	3	90	75	94
Propionic	3	94	80	92
Benzoic	3	89	73	90
Succinic	5	81	73	89
Crotonic	5	77[a)]		90
Chloroacetic	3	81	64	92

a) The yield of the adduct (I)

Except for the case of crotonic acid, analytically pure thiolesters were easily isolated by chromatography over silica gel.[4)] However, in the case of crotonic acid, phenyl *dl*-3-phenylthiothiolbutyrate (I) was obtained in 77% yield. The adduct (I)[5)] resulted from the addition of benzenethiol to phenyl thiolcrotonate initially formed by the reaction (Eq. (1)).



$$CH_3CH{=}CH\underset{\underset{O}{\|}}{C}SC_6H_5 + C_6H_5SH \rightarrow CH_3\underset{\underset{C_6H_5S}{|}}{C}HCH_2\underset{\underset{O}{\|}}{C}SC_6H_5 \quad \text{(I)}$$

The reaction can be explained by considering an initial formation of the first phosphonium salt (II) from diphenyl disulfide and triphenylphosphine. The intermediate (II) is in turn changed into the second phosphonium salt (III) by nucleophilic attack of a carboxylic acid on phosphorus of II with the elimination of benzenethiol. The intermediate (III) is further converted to the third phosphonium salt (IV) by the intramolecular oxidation-reduction reaction. In this process, the phenylthio moiety attached to phosphorus in the intermediate (III) accepts two electrons from phosphorus to be reduced to the benzenethiolate anion of the intermediate (IV). The intermediate (IV) undergoes decomposition to a thiolester and triphenylphosphine oxide.

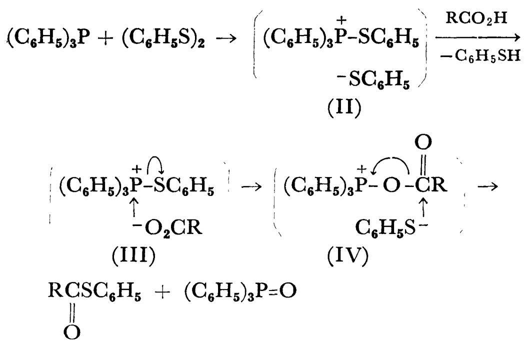
[1)] T. Mukaiyama, T. Endo, S. Ikenaga and K. Osonoi, *J. Org. Chem.*, **33**, 2242 (1968).

[2)] A. Schönberg and M. Z. Barakat, *J. Chem. Soc.*, **1949**, 892.

[3)] A. Schönberg, *Ber.*, **68**, 163 (1935).

[4)] With chloroacetic acid, phenyl chlorothiolacetate and benzenethiol were obtained in 81 and 64% yields, respectively, indicating that phenyl chlorothiolacetate is unreactive with benzenethiol.

[5)] A. A. Schleppnik and F. B. Ziently, *J. Org. Chem.*, **29**, 1910 (1964).



$$(C_6H_5)_3P + (C_6H_5S)_2 \rightarrow \underset{\text{(II)}}{\left(\begin{array}{c}(C_6H_5)_3\overset{+}{P}\text{-}SC_6H_5\\ {}^{-}SC_6H_5\end{array}\right)} \xrightarrow[-C_6H_5SH]{RCO_2H}$$

$$\underset{\text{(III)}}{\left(\begin{array}{c}(C_6H_5)_3\overset{+}{P}\text{-}SC_6H_5\\ \uparrow\\ {}^{-}O_2CR\end{array}\right)} \rightarrow \underset{\text{(IV)}}{\left(\begin{array}{c}(C_6H_5)_3\overset{+}{P}\text{-}O\text{-}\overset{\overset{\displaystyle O}{\|}}{C}R\\ \uparrow\\ C_6H_5S^{-}\end{array}\right)} \rightarrow$$

$$R\underset{\underset{\displaystyle O}{\|}}{C}SC_6H_5 + (C_6H_5)_3P=O$$

When diethyl disulfide was used as an oxidant, no reaction took place and the starting materials were recovered almost quantitatively. This result suggests that the reactivities of the disulfides in this reaction depend on the oxidizing power of the disulfides, which was found to decrease in the order of decreasing stabilities of the corresponding thiolate anions of the disulfides.[6]

Experimental

Materials. Various carboxylic acids, diphenyl disulfide, and triphenylphosphine were all commercial materials and purified by distillation or recrystallization before use. Acetonitrile was purified by the conventional procedure.

Preparation of Phenyl Thiolpropionate. Propionic acid (0.74 g, 0.01 mol), diphenyl disulfide (2.18g, 0.01 mol), and triphenylphosphine (2.62 g, 0.01 mol) were refluxed in 30 m*l* of acetonitrile for 3 hr. After the reaction mixture was concentrated under reduced pressure, the residue was chromatographed on silica gel. Elution first with petroleum ether gave benzenethiol (0.88 g, 80%), bp 50—55°C/10 mmHg, and phenyl thiolpropionate (1.44 g, 94%), bp 112—113°C/10 mmHg. The infrared spectrum of this thiolester showed carbonyl absorption at 1710 cm^{-1}. Elution with ethyl acetate gave triphenylphosphine oxide (2.56 g, 92%), which was recrystallized from methylene chloride - petroleum ether, mp 154—156°C.

Preparation of Phenyl Thiolsuccinate. Succinic acid (0.60 g, 0.005 mol), diphenyl disulfide (2.18 g, 0.01 mol), and triphenylphosphine (2.62 g, 0.01 mol) were refluxed in 30 m*l* of acetonitrile for 5 hr. After the reaction mixture was concentrated *in vacuo*, the residual oil was chromatographed on silica gel to isolate three products. Elution first with petroleum ether gave benzenethiol (0.80 g, 73%), bp 50—53°C/10 mmHg. Elution next with methylene chloride - petroleum ether (1 : 1) gave first phenyl thiolsuccinate (1.23 g, 81%), mp 89—90°C, after recrystallization from isopropanol, then gave triphenylphosphine oxide (2.42 g, 89%).

Reaction of Crotonic Acid with Diphenyl Disulfide and Triphenylphosphine. Crotonic acid (0.86 g, 0.01 mol), diphenyl disulfide (2.18 g, 0.01 mol), and triphenylphosphine (2.62 g, 0.01 mol) were refluxed for 5 hr in 30 m*l* of acetonitrile. After removal of the solvent from the reaction mixture, the resulting oil was chromatographed on silica gel. Elution with petroleum ether gave phenyl *dl*-3-phenylthiothiolbutyrate (I) (2.31 g, 77%), bp 148—150°C/0.07 mmHg, n_D^{22} 1.6114 (lit,[5] bp 172—173°C/0.2 mmHg, n_D^{25} 1.6106). (Found: C, 66.50; H, 5.59; S, 21.94%). Elution next with methylene chloride gave triphenylphosphine oxide (2.54 g, 90%).

---

6) T. Mukaiyama and T. Endo, This Bulletin, **40**, 2388 (1967).