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A Novel Synthesis of 2-Trialkylphosphonio-1,3-dithiole-4-carboxylates

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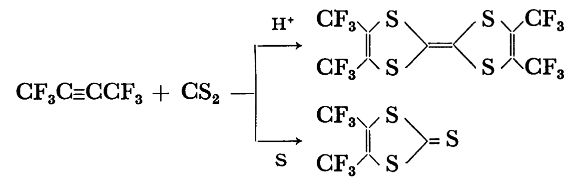
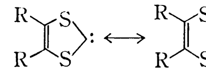
Acetylene carboxylic acids reacted with trialkylphosphine–carbon disulfide ylides to produce fair to good yields of 2-trialkylphosphonio-1,3-dithiole-4-carboxylates (**4**) at temperatures as low as −20 to −30 °C. The formation of these zwitterionic products, by a prototropic shift in the ylide **3**, differs from the known reaction of acetylenes, such as ethyl propiolate, with carbon disulfide and tributylphosphine to give tetrathiafuvalene derivatives. The structure of these zwitterionic products was confirmed by alkaline hydrolysis, reaction with benzaldehyde, and their IR and NMR spectra. Alkaline hydrolysis of **4** gave the corresponding carboxyl-substituted 1,3-dithioles (**7**). Treatment of 2-tributylphosphonio-1,3-dithiole-4-carboxylate (**4e**) with benzaldehyde in the presence of triethylamine resulted in the formation of 2-benzylidene-1,3-dithiole-4-carboxylic acid (**8**). The methine proton of the 1,3-dithiole ring of **4** in DMSO-d_6, appeared at δ 5.41—6.24 as a singlet peak. These methine protons were readily exchanged by deuterium in the presence of methanol-d_4, and disappeared from NMR spectra.

Electron deficient acetylenes and ring-strained acetylenes are known to react with carbon disulfide to give a variety of complex structures including tetrathiafulvalenes.[2–8] For example, perfluoro-2-butyne and carbon disulfide give perfluorotetramethyltetrathiafulvalene, quantitatively, in the presence of acid.[2] In the presence of sulfur, this reaction gave 4,5-bis(trifluoromethyl)-1,3-dithiole-2-thione.[3] In these reactions (shown in Eq. 1), 1,3-dithiolium carbenes, **1** were postulated as intermediates. The chemical properties of **1** have been discussed in the literatures.[8,9] Trialkylphosphine–carbon disulfide ylides, **2**, known for 90 years, also react with electron deficient acetylenes to give tetrathiafulvalenes in poor yields.[4] When aromatic aldehydes were also present, excellent yields of 2-benzylidene-1,3-dithioles were obtained.[5] In these reactions, ylide **3** was presumed to be an intermediate. The unusually high reactivity of ylides, **3**, with aldehydes was attributed to the "antiaromatic" 1,3-dithiol ring. Since the negative charge at the 2-position is not readily accomodated by delocalization over the five-membered ring, the 2-carbon is a relatively strong nucleophile.



(1)



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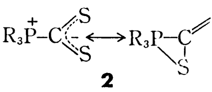

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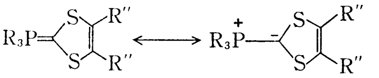
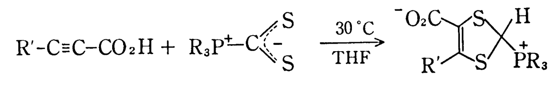


3a–b

Results and Discussion

We now report that propiolic acid and acetylene dicarboxylic acid rapidly reacted with trialkylphosphine–carbon disulfide ylides, **2**, to give the zwitterionic 2-trialkylphosphonio-1,3-dithiole-4-carboxylates, **4** (see Eq. 2). These reactions proceeded at temperatures as low as −20 to −30 °C to give adducts **4a**—**e** which precipitated from THF. Acetylene dicarboxylic acid reacted more rapidly than propionic acid, as judged by the disappearance of the deep maroon color of the solution, and the former also gave better yields than the latter as shown in Table 1.

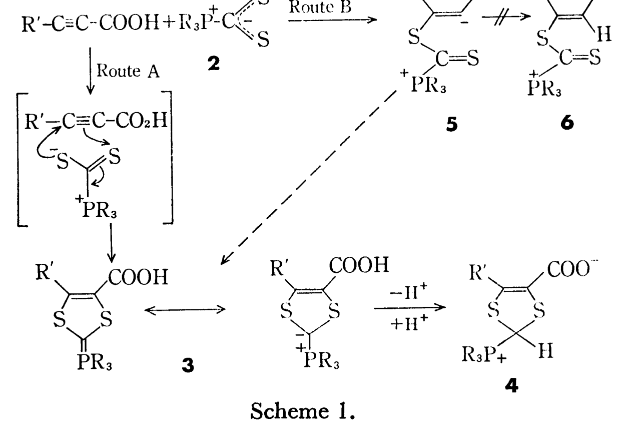


(2)

4a: R′ = COOH, R = Me
4b: R′ = COOH, R = Et
4c: R′ = COOH, R = *n*-Bu
4d: R′ = H, R = Et
4e: R′ = H, R = *n*-Bu

The formation of **4**, instead of the acyclic compound **6** (Scheme 1) is surprising. The absence of **6** suggests the reaction proceeded *via* a concerted one-step addition similar to route A rather than by route B. Stepwise addition of **2** (route B) would initially generate acyclic zwitterion **5** with a vinyl carbanion center. It seems likely that **5** would undergo rapid C-protonation in the acidic media if it had been formed. However, rapid ring closure (**5** to **3**) cannot be definitively ruled out. A route similar to B was previously favored for the reaction of acetylenes with carbon disulfide.[2] In that work,[2] intermediates of the type **3** were implicated.

The formation of 2-trialkylphosphonio-1,3-dithiole-4-carboxylates **4**, contrasts sharply with the analogous reaction of ethyl propiolate with ylides of the type **2**.



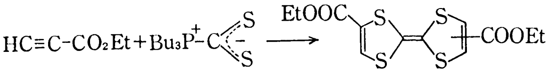
Scheme 1.

TABLE 1. RESULTS OF REACTION OF ACETYLENES WITH PHOSPHINE–CARBON DISULFIDE YLIDES AND AQUEOUS NaOH HYDROLYSIS PRODUCTS FROM 2-TRIALKYL-PHOSPHONIO-1,3-DITHIOLE-4-CARBOXYLATES, **4**

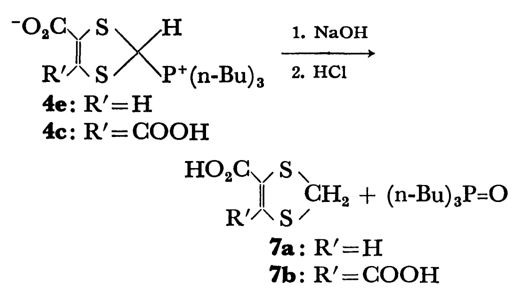
Compound	Yield, %	Recrystallizing solvent	Mp, °C	Formula	C	H	S (Calcd)	P, %
4a	100	water	156 (dec.)	$C_8H_{11}O_4PS_2$	35.41 (36.09	4.41 4.16	23.74 24.08	11.23 11.63)
4b	98	methanol	146 (dec.)	$C_{11}H_{17}O_4PS_2$	43.03 (42.85	5.58 5.56	20.70 20.79	10.15 10.05)
4c	87	acetone	122 (dec.)	$C_{17}H_{29}O_4PS_2$	51.61 (52.02	7.40 7.45	16.01 16.34	7.70 7.89)
4d	41	a)	136 (dec.)	$C_{10}H_{17}O_2PS_2$	45.30 (45.43	6.38 6.48	23.98 24.26	11.90 11.72)
4e	53	a)	116—118 (dec.)	$C_{16}H_{29}O_2PS_2$	55.30 (55.14	8.28 8.39	18.08 18.40	8.93 8.89)
7a	90	toluene	148—150 (dec.)	$C_4H_4O_2S_2$	33.09 (32.52	2.84 2.72	43.17 43.27)	
7b H_2O	95	toluene	158—160 (dec.)	$C_5H_6O_5S_2$	28.67 (28.57	2.83 2.88	30.21 30.50)	

a) Product was purified by washing with acetone.

For example where R=*n*-Bu, 2,6(7)-bis(ethoxycarbonyl) tetrathiafulvalene was formed in yields of 14 to 18% (Eq. 3).



The structures of compounds **4a**—**e** were confirmed by their solubility, analyses, spectra, and hydrolysis reaction products. They were insoluble in benzene, ether, and THF, but soluble in water. Their analyses agreed with the assigned structures (see Table 1). The IR spectra of **4a**—**e** exhibited ν_{CO} bands at 1600, 1550 and 1350—1340 cm^{-1} ($-COO^-$), (see Table 2). Each compound exhibited a sharp melting (or decomposition) point (Table 1) and an NMR spectra (Table3) in accord with the assigned structure. Finally, the zwitterion structure of **4** was unequivocally confirmed by alkaline (NaOH) hydrolysis of **4e** and **4c**, followed by acidification, to give substituted 1,3-dithioles **7a** and **7b**, respectively (Eq. 4).



4e: R′=H
4c: R′=COOH

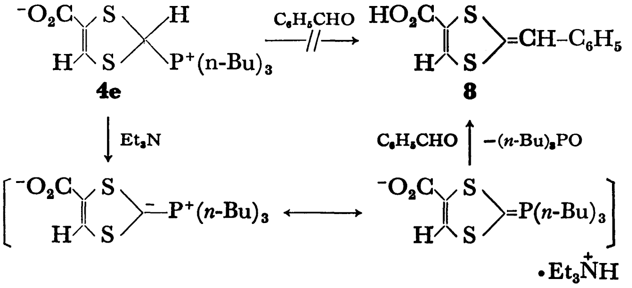
(4)

7a: R′=H
7b: R′=COOH

1,3-Dithiole-4,5-dicarboxylic acid, **7b**, contained a water of crystallization and was obtained as yellow needles which dehydrated at —80 °C to give orange crystals of **7b**. At 160—170 °C, **7b**, smoothly decarboxylated to monoacid **7a** (equation 5). This decarboxylation resembles that of 2-thioxo-1,3-dithiole-4,5-dicarboxylic acid.[11]

$$\mathbf{7b}\cdot H_2O \xrightarrow{80^\circ C} \mathbf{7b} + H_2O \xrightarrow{160-170^\circ C} \mathbf{7a} + CO_2 \quad (5)$$

Compounds **4c** and **4e** did not react with benzaldehyde (See Scheme 2). However, when triethylamine was added to **4c** or **4e**, ylides **3c** and **3e**, respectively, were formed. These ylides, as expected, rapidly reacted with benzaldehyde. For example, **4e** gave 2-benzylidene-1,3-dithiole-4-carboxylic acid, **8**, as shown in Scheme 2. This reaction further confirms the zwitterionic structure assigned to **4**.



Scheme 2.

The NMR spectra of zwitterion structures **4a**—**e** are summarized in Table 3. In DMSO-d_6, the methine proton of the 1,3-dithiole ring of **4a**—**e** appeared as a singlet at δ 5.41—6.24. In the case of **4e**, the methine proton

TABLE 2. IR SPECTRA OF 2-TRIALKYLPHOSPHONIO-1,3-DITHIOLE-4-CARBOXYLATES AND 1,3-DITHIOLE-4(5)-CARBOXYLIC ACIDS, **7**

Compound	IR Bands (cm^{-1}) (KBr)
4a	2980, 2900, 2860, 1680, 1635, 1550 1430, 1340, 1295, 1100, 1070
4b	2975, 2940, 2920, 1680, 1590, 1545 1440, 1340, 1100, 1070, 1050
4c	2960—2870, 1680, 1570, 1540, 1455 1340, 1095, 1075
4d	2940, 2910, 1595, 1555, 1465, 1450 1350, 1045, 1020
4e	2940—2870, 1595, 1460, 1345, 1230 1095, 1020, 1000
7a	1660, 1550, 1435, 1325, 1295, 1240 1040
7b	1660, 1520, 1450, 1270, 1085
7b H_2O	3600, 3400, 1630, 1570—1470, 1370 1225, 1160, 1085

Table 3. NMR spectra of the 2-trialkylphosphonio-1,3-dithiole-4-carboxylates, 4

Compound	Solvent	NMR Signals, δ[a)]
4a	DMSO-d_6	1.96 (d, 9H, $J_{\mathrm{CH_3}\text{-}^{31}\mathrm{P}}=14.4$ Hz) 5.41 (s, 1H)
4a	DMSO-d+methanol-d_4	1.98 (d, $J_{\mathrm{CH_3}\text{-}^{31}\mathrm{P}}=14.4$ Hz) disappearance of the methine H
4b	DMSO-d_6	1.24 (d, t, 9H, $J=7.2$ Hz, $J_{\mathrm{CH_3}\text{-}^{31}\mathrm{P}}=17.5$ Hz) 2.48 (d, q, 6H. $J=7.2$ Hz, $J_{\mathrm{CH_2}\text{-}^{31}\mathrm{P}}=14.4$ Hz) 5.83 (s, 1H)
4c	DMSO-d_6	0.93 (t, 9H, methyl H), 1.3—1.8 (m, 12H, β- and γ-methylene H), 2.1—2.7 (m, 6H, α-methylene H), 5.79 (s, 1H, methine H)
4d	Methanol-d_4	1.34 (d, t, 9H, $J=7.2$ Hz, $J_{\mathrm{CH_3}\text{-}^{31}\mathrm{P}}=17.5$ Hz) 2.49 (d, q, 6H, $J=7.2$ Hz, $J_{\mathrm{CH_2}\text{-}^{31}\mathrm{P}}=14.4$ Hz) 6.74 (s, 1H, vinyl H)
4e	DMSO-d_6	0.93 (t, 9H), 1.3—1.8 (m, 12H), 2.1—2.7 (m, 6H), 6.24 (d, 1H, $J_{\mathrm{CH_2}\text{-}^{31}\mathrm{P}}=2$ Hz, methine H), 6.37 (s, 1H, vinyl H)
4e	DMSO-d_6+methaol	1.0 (t, 9H), 1.3—1.8 (m, 12H), 2.1—2.7 (m, 6H) 6.72 (s, 1H, vinyl H), disappearance of the methine H

a) Measured in ppm downfield from TMS as an internal standard.

was coupled with ^{31}P ($J=2$ Hz). Each methine proton, as expected, was readily exchanged by deuterium in the presence of methanol-d_4, and disappeared from NMR spectra. The methyl protons of **4a** and the methylene protons of **4b** and **4d**, at the α-position of alkyl group attached to phosphorous, were coupled with ^{31}P ($J=14.4$ Hz). The methyl protons of **4b** and **4d** at the β-position of alkyl group attached to phosphorus were also coupled with ^{31}P. ($J=17.5$ Hz). These coupling constants are in reasonable accord with literature precedents.

The reaction of acetylene carboxylic acids with ylides of type **2** to give **4** adds to our growing knowledge of acetylene reactions in tetrathiafulvalene (TTF) syntheses.[8)] A more detailed knowledge of the mechanism (Scheme 1) is still needed to provide the synthetic chemist insight in developing improved routes to substituted TTF derivatives, compounds of intense current interest.[8)]

Experimental

Proton magnetic resonance spectra were recorded on a Hitachi Perkin-Elmer R-20 B with tetramethylsilane as an internal reference. Infrared spectra were obtained with a Beckman IR-33. THF was dried over calcium hydride and distilled prior to use. Melting points are uncorrected. The elemental analyses of sulfur and phosphorus were performed by Schwarzkopf Microanalytical Laboratory, 56—19 37th Avenue, Woodside, New York 11377.

Reaction of Acetylene Carboxylic Acids With Trialkylphosphine–Carbon Disulfide Ylides (2). Trialkylphosphine (0.05 mol) in 50 ml of tetrahydrofuran was added dropwise to a solution of 10 ml of carbon disulfide in 50 ml of tetrahydrofuran at −20—−30°C under nitrogen. In the case of trimethylphosphine and triethylphosphine, the ylides, **2**, precipitated. To the deep maroon solution of **2** a solution of acetylene carboxylic acid (0.05 mol) in 50 ml of tetrahydrofuran was added dropwise. The temperature was maintained between −20 and −30 °C during addition. The system was warmed to room temperature and stirred further for 1 h. The zwitterionic products, **4**, were formed as precipitates. The precipitate was filtered and washed with acetone and/or methanol. The crude products, 2-trialkylphosphonio-1,3-dithiole-4-carboxylates, **4a**—**f**, could be recrystallized from solvents shown in Table 1. Table 1 also gives physical characteristics of the compounds prepared. IR absorption bands of **4** and **7** are summarized in Table 2.

2,6(7)-Bis(ethoxycarbonyl)tetrathiafulvalene. The procedure is the same as preparation of **4**. After addition of ethyl propiolate at −20—−30 °C, instead of acetylene carboxylic acids, the system was warmed to room temperature and stirred further 3 h. Volatiles were removed under reduced pressure and excess ether was added to the residue which was refrigerated. A precipitate formed and was filtered to give 18% of the title compound. Recrystallization from glyme gave a red-orange crystalline product: mp 176—178 °C (lit,[2)] 169—172 °C); NMR (CDCl$_3$) δ 1.35 (t, 3H, methyl H, $J=7$ Hz), 4.31 (q, 2H, methylene H), and 7.40 (s, 1H, vinyl H).

Hydrolysis of 2-Tributylphosphonio-1,3-dithiole-4-carboxylates (4c and 4e). Zwitterionic salt **4c** (4.00 g: 0.01 mol) was suspended in 40 ml of 1 M sodium hydroxide solution and stirred for 30 min. Crystals dissolved gradually, and an oily material was separated. The oily material was extracted with ether. Removal of ether gave tributylphosphine oxide. The aqueous layer was acidified with 3 M hydrochloric acid, while cooled with ice, to give 1.44 g (69%) of yellow needles of 1,3-dithiole-4,5-dicarboxylic acid hydrate, **7b** H_2O. This crude material was purified by reprecipitation from water solution by acidification with 3 M hydrochloric acid. The filtrate was concentrated under vacuum and the residue was washed with acetone. From the washings another 0.50 g (26%) 1,3-dithiole-4,5-dicarboxylic acid, **7b**, was obtained as orange crystals.

The 1,3-dithiole, **4e**, was also hydrolyzed in the same manner to give 1,3-dithiole-4-carboxylic acid, **7a**, in 90% yield.

Physical properties, elemental analyses, and IR data of 1,3-dithiole carboxylic acids were shown in Tables 1 and 2. The NMR spectrum of **7a** in acetone-d_6 consisted of singlets at δ 7.28 (1H) and 4.68 (2H), assigned to olefinic and methylene hydrogens, respectively. In DMSO-d_6, the NMR spectra of **7a** and **7b** H_2O had a singlet at δ 4.49 and δ 4.02 (methylene hydrogens), respectively. The IR spectra of **7a**, **b** were similar to their corresponding 1,3-dithiole-2-thiones except for the absence of the 1070 cm^{-1} ($\nu_{C=S}$).

Pyrolysis of 1,3-Dithiole-4,5-dicarboxylic Acid Hydrate, (7b H_2O). 1,3-Dithiole-4,5-dicarboxylic acid, **7b** H_2O (1.05 g; 5 mmol) was heated for 15 min in an oil bath at 160—170 °C. An effervescing action was observed and fusing occurred to give a brown liquid. Cooling and grinding gave 0.72 g (97%) of 1,3-dithiole-4-carboxylic acid **7a**. Crystallization of **7a** from toluene gave pale pink-orange crystals, mp 148—150 °C.

2-Benzylidene-1,3-dithiole-4-carboxylic Acid, 8. To a solution of 1.01 g (10 mmol) of triethylamine in 20 ml of *N*,*N*-dimethylformamide, 1.75 g (5 mmol) of **4e** was suspended at room temperature. Benzaldehyde, 1.06 g (10 mmol) was then added. After *ca.* 20 min, it became homogeneous. The reaction mixture was stirred for 2 h. It was poured into 150 ml of 1 M hydrochloric acid to give orange crystals. Filtration and washing with small amounts of benzene gave 0.58 g (49%) of **8**: mp 150—152 °C (dec.). Recrystallization from toluene gave pure material: mp 152—154 °C (dec.); IR (KBr): 3100—2500, 1685, 1660, 1580, 1560, 1540, 1490, 1440, 1425, 1345, 1320, 1285, 1210, 1160, 1050 cm^{-1}; NMR (DMSO-d_6): δ 6.76 (s. broad, 1H, vinyl proton in 1,3-dithiole ring), 7.33 (m, 5H, phenyl protons), 7.64 (m, 1H, J 1 Hz).

Found: C, 55.64; H, 3.30; S, 26.81%. Calcd for $C_{11}H_8O_2S_2$: C, 55.91; H, 3.41; S, 27.13%.

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References

1) Preliminary communication: C. U. Pittman, Jr. and M. Narita, *J. Chem. Soc., Chem. Commun.*, **1975**, 960.

2) H. D. Hartzler, *J. Am. Chem. Soc.*, **95**, 4379 (1973).

3) C. G. Krespan and D. E. England, *J. Org. Chem.*, **33**, 1850 (1968).

4) L. R. Melby, H. D. Hartzler, and W. A. Sheppard, *J. Org. Chem.*, **39**, 2456 (1974).

5) H. D. Hartzler, *J. Am. Chem. Soc.*, **93**, 4961 (1971).

6) J. Nakayama, *J. Chem. Soc., Chem. Commun.*, **1974**, 166.

7) A. Krebs and H. Kimling, *Angew. Chem., Int. Ed. Engl.*, **10**, 509 (1971).

8) M. Narita and C. U. Pittman, Jr., *Synthesis*, **1975**, in press.

9) A. W. Hofmann, *Ann. Chem. Suppl.*, **1**, 26, 59 (1961); A. Hantzsch and H. Hibbert, *Chem. Ber.*, **40**, 1508 (1907).

10) H. Prinzbach and E. Futterer in "Advances in Heterocyclic Chemistry," Vol. 7, ed. A. R. Katritzky and H. J. Boulton, Academic Press, New York (1966), p. 103.

11) E. Klingsberg, *J. Am. Chem. Soc.*, **86**, 5290 (1964).