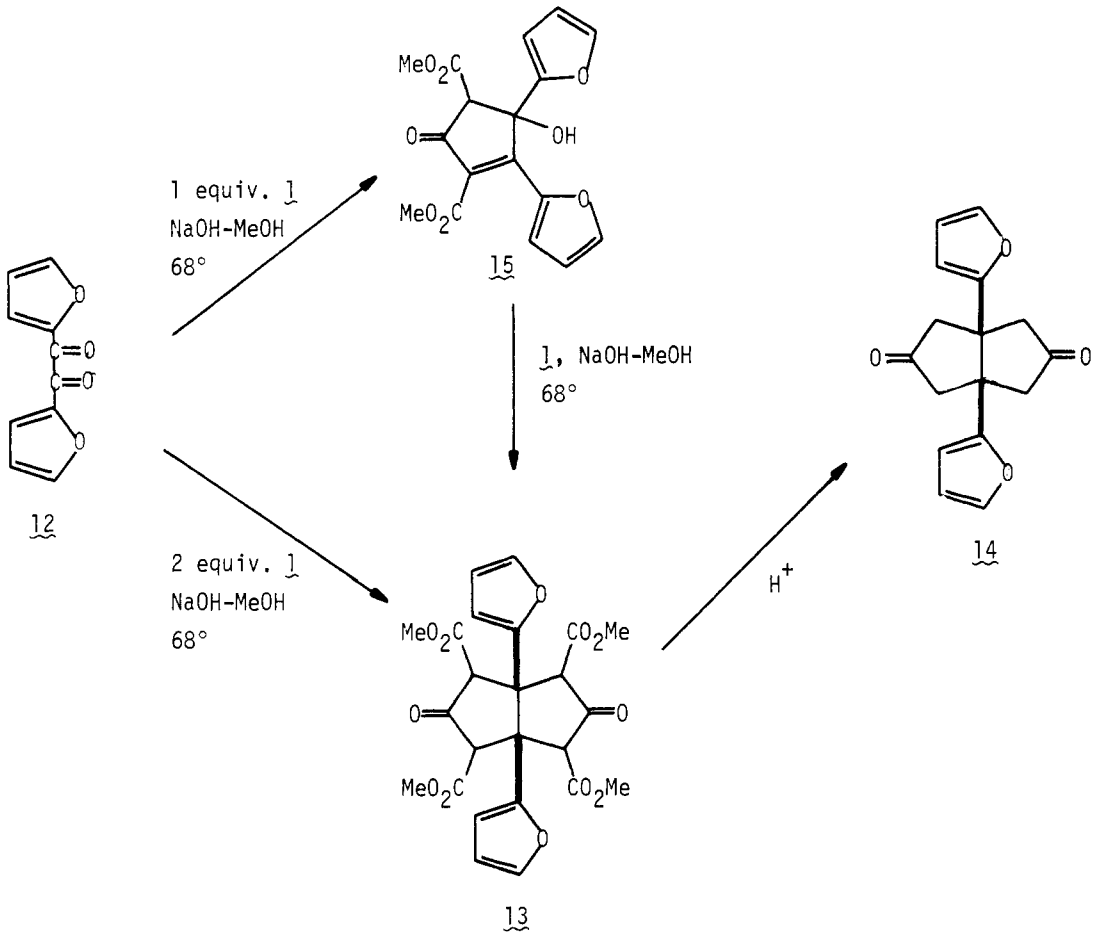
Scheme III




was heated rapidly (20 min) to 87 °C and held between 87 and 90 °C for 7 h, after which the solution was allowed to stir at room temperature overnight. The solution was then cooled, filtered, and diluted with $CHCl_3$ (500 mL). Ice was added and the pH was adjusted to ~8 with solid $Na_2CO_3$. Water (100 mL) was added to the mixture and the phases were separated. The aqueous layer was then extracted with $CHCl_3$ (3 × 100 mL), and the combined organic fractions were dried ($Na_2SO_4$) after which the solvent was removed under reduced pressure to yield **14** (0.92 g, 85%). An analytically pure sample was obtained by recrystallization of **14** from EtOAc/hexane: mp 175–176 °C; IR (KBr) 3464 (w), 3128 (m), 2978 (w), 1742 (s), 1509 (s); $^1H$ NMR ($CDCl_3$) $\delta$ 2.50 (4 H, d, $J$ = 18 Hz) 3.20, (4 H, d, $J$ = 18 Hz), 5.90 (1 H, d), 6.20 (2 H, m), 7.30 (2 H, m); $^{13}C$ NMR ($CDCl_3$) $\delta$ 47.63, 51.80, 105.62, 109.90, 141.94, 154.94, 213.48.

Anal. Calcd for $C_{16}H_{14}O_4$: C, 71.10; H, 5.20: Found: C, 70.70; H, 5.20.

**Conversion of 1:1 Adduct 15 into the 1:2 Adduct 13.** Dimethyl 3-ketoglutarate (**1**, 0.015 g, 0.087 mmol) was added to dry methanol (3 mL) containing sodium hydroxide (4 mg, 0.087 mmol). The solution was heated to 60 °C (oil bath) and the 1:1 adduct **15** (30 mg, 0.087 mmol) was added. The mixture was held at this temperature with stirring for 8 h. The reaction mixture was next cooled in an ice bath and acidified (1% aqueous HCl). At this point the colored solution became clear and a white solid precipitated (26 mg). The compound **13** proved to be identical with the 1:2 adduct **13** previously prepared from furil as evidenced by comparison of the TLC, mixed melting point, and CI mass spectral data of the two materials.

**Treatment of 15 with Strong Alkali.** To a solution of methanol (15 mL) and sodium hydroxide (0.02 g, 0.6 mmol) held at 60 °C (oil bath) was added the 1:1 adduct **15** (100 mg, 0.3 mmol). The mixture was stirred at 60 °C and was periodically monitored by TLC. The mixture was held at this temperature for 48 h and then worked up as previously described. TLC indicated the presence of 1:1 adduct **15** along with baseline material. Examination of the crude product by TLC, NMR, and CI mass spectrometry indicated that none of the glutarate **1**, furil (**12**), or the 1:2 adduct **13** were present.

**Acknowledgment.** We thank the National Science Foundation (CHE-7910302) and the Petroleum Research Foundation, administered by the American Chemical Society, for generous financial support. We also thank Ms. Judith Siegrist for excellent technical assistance.

**Registry No.** **1**, 1830-54-2; **12**, 492-94-4; **13**, 88131-23-1; **14**, 88131-24-2; **15**, 16344-55-1.

---

## Noncoupling Synthesis of Tetrathiafulvalenes

R. R. Schumaker, V. Y. Lee, and E. M. Engler*

*IBM Research Laboratory, San Jose, California 95193*

*Received October 24, 1983*

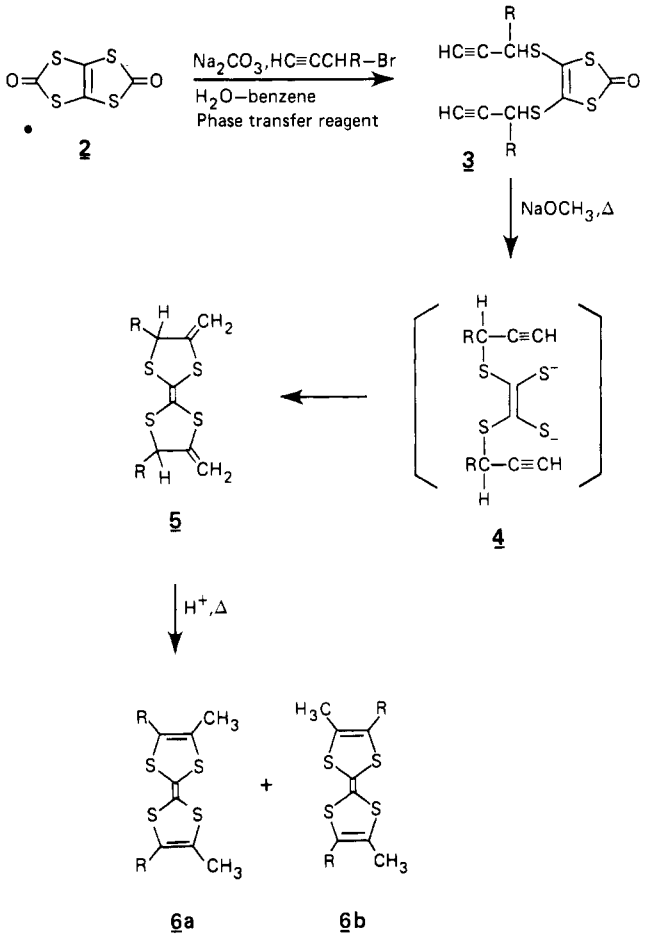
Interest in the chemistry and physics of tetrathiafulvalene derivatives (**1**, X = S, TTF; X = Se, TSeF) continues strong[1] with the discovery of a wealth of novel organic solid-state phenomena, including superconductivity,[2,3] unusual magnetic orderings, and phase transitions.

(1) For a recent summary of work in this area, see: *Mol. Cryst. Liq. Cryst.*, **79**, 1–362 (1982).

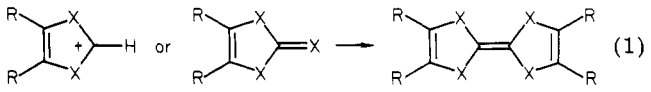
(2) J. Jérome, A. Mazand, M. Ribault, and K. Bechgaard, *J. Phys. Lett (Orsay, Fr.)* **41**, L-95 (1980); M. Ribault, J. P. Pouget, D. Jérome, and K. Bechgaard, *ibid.*, **41**, L-607 (1980); S. S. P. Parkin, M. Ribault, D. Jérome, and K. Bechgaard, *J. Phys. C.* **14**, L-445 (1981); K. Bechgaard, K. Carneiro, F. B. Rasmussen, M. Olsen, G. Rindorf, C. S. Jacobsen, J. H. Pedersen, and J. C. Scott, *J. Am. Chem. Soc.*, **103**, 2440 (1981).

0022-3263/84/1949-0564$01.50/0 

Scheme I




In general, the major procedure for preparing these donors involves coupling of molecular half-units as illustrated in eq 1.[4,5]



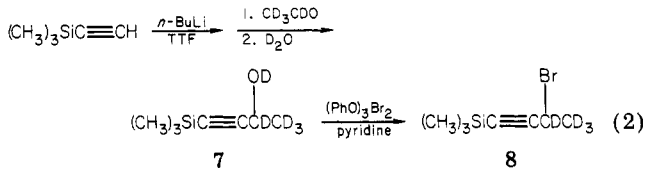
X = S, Se

In the course of exploring the chemistry of thiapen[6] as a means for synthesizing novel solid-state materials, we discovered a new and versatile procedure for constructing the tetrathiafulvalene skeleton that does not require coupling of molecular half-units. The synthesis outlined in Scheme I uses thiapendione (**2**)[6] as the starting point. Selective reaction of one of the carbonyl centers of **2** was affected by using a phase-transfer reagent (Aliquot 336, Fluka) in a water–benzene mixture to which sodium carbonate was added. Addition of propargyl halide derivatives traps the intermediate 2-oxo-1,3-dithiole-4,5-dithiolate as the dipropargyl derivative **3**.[7]

Reaction of **3** with 2 equiv of $NaOCH_3$ in refluxing methanol is expected to provide dithiolate intermediate **4**. Previous work[8] has demonstrated that related propargyl thiocarbonates could be cyclized to 1,3-dithioles. In fact, under the reaction conditions for **3**, intermediate **4** spontaneously undergoes a double internal cyclization to give the dihydrotetrathiafulvalene derivative **5**. On the basis of the cis relationship of the sulfide groups in **4**, cyclization is expected to proceed stereospecifically to give the cis isomer **5**. However, only oils of **5** (R = H, $CH_3$) have been isolated, making X-ray structure determination unfeasible.

The isomerization of **5** to **6** occurs readily on refluxing in benzene with *p*-toluenesulfonic acid to give a mixture of cis and trans isomers (**6a** and **6b**). X-ray analysis of single crystals of **6** for R = H shows the presence of the trans isomer, most likely the result of cis/trans isomerization (via protonation of the central double bond) under the acid reaction conditions necessary for conversion of **5** to **6**. Consequently, this potentially interesting aspect of stereospecific cyclization remains unresolved.

A useful extension of this new synthesis lies in the preparation of deuterated tetramethyltetrathiafulvalene.[9] This deuterated donor is particularly important for neutron-scattering studies of the low-temperature magnetic orderings that have been observed recently in tetramethyltetrathiafulvalene bromide ($TMTTF_2Br$).[10] The deuterated propargyl precursor is prepared from readily available starting materials in high yield as outlined in eq 2. (Trimethylsilyl)acetylene was employed for both protection and ease of handling, the trimethylsilyl group being conveniently replaced by deuterium in the course of the conversion of **3** to **5** by employing 4 equiv of $NaOCH_3$ in $CH_3OD$. In this manner, perdeuteriotetramethyltetrathiafulvalene with a deuterium content of ~97% as determined by mass spectrum and NMR analysis could be prepared in overall yield of 35% (based on thiapendione).



Extenstion of this chemistry to the syntheses of tetraselenafulvalenes is in principle possible with use of the 2-selenoxo-1,3-diselenole-4,5-diselenolate intermediate.[11] However, our initial attempts in this area have so far been unsuccessful.

## Experimental Section

**Materials.** Tetrahydrofuran (THF) was obtained anhydrous by distillation over potassium benzophenone ketyl under nitrogen. Phase-transfer reagent Aliquot 336 was purchased from Fluka and (trimethylsilyl)acetylene from Petrach Systems. *n*-Butyllithium (1.6 M), propargyl bromide (80%), methyl dichloroacetate,

(3) S. S. P. Parkin, E. M. Engler, R. R. Schumaker, R. Lagier, V. Y. Lee, J. C. Scott, and R. L. Greene, *Phys. Rev. Lett.* **50**, 270 (1983).
(4) M. Narita and C. U. Pittman, Jr., *Synthesis*, 489 (1976).
(5) A specialized variation of this theme involves the reaction of *o*-benzenedithiols with tetrachloroethylene (J. S. Bajwa, K. D. Berlin, and H. A. Pohl, *J. Org. Chem.*, **41**, 145 (1976). Recently, this procedure was extended to provide the first tellurium tetraheterofulvalene: F. Wudl and E. Aharon-Shalom, *J. Am. Chem. Soc.*, **104**, 1154 (1982).
(6) (a) R. R. Schumaker and E. M. Engler, *J. Am. Chem. Soc.*, **99**, 5521 (1977); (b) E. M. Engler, V. V. Patel, and R. R. Schumaker, *J. Chem. Soc., Chem. Commun.*, 516 (1979); (c) N. *Martinez*-Rivera, E. M. Engler, and R. R. Schumaker, *ibid.*, 184 (1979); (d) R. R. Schumaker and E. M. Engler, *J. Am. Chem. Soc.*, **102**, 6651 (1980).
(7) An alternate procedure for preparing **3** involves the electrochemical or alkali-metal reduction of $CS_2$ to give 2-thioxo-1,3-dithiole-4,5-dithiolate (S. Wawzonek and S. Heilmann, *J. Org. Chem.*, **39**, 511 (1974)), which can then be reacted with propargyl halides.
(8) K. A. Jensen and L. Henriksen, *Acta Chem. Scand.*, **22**, 1107 (1968); N. F. Haley, *Tetrahedron Lett.*, 5161 (1978).
(9) The synthesis of perdeuteriotetramethyltetraselenafulvalene has recentley been reported: F. Wudl, E. Aharon-Shalom, and S. H. Bertz, *J. Org. Chem.*, **46**, 4612 (1981).
(10) S. S. P. Parkin, J. C. Scott, J. B. Torrance, and E. M. Engler, *Phys. Rev. B*, **26**, 6319 (1982); F. Creuget, T. Takahashi, and D. Jerome, *J. Phys. (Orsay, Fr.)*, in press.
(11) V. Y. Lee, E. M. Engler, R. R. Schumaker, and S. S. P. Parkin, *J. Chem. Soc., Chem. Commun.*, 236 (1983).

acetaldehyde-$d_4$ (99+%), methanol-$d_4$ (99.5+%), DCl (20% in $D_2O$ (99+%)), and $D_2O$ (99.8%) were purchased from Aldrich. Commercially available sodium isopropylxanthate from ICN was recrystallized from acetone/ethyl acetate before use.

**Thiapendione (2).** A preliminary account of the synthesis of thiapendione has been given in a communication.[6a] Below is a more detailed description of its preparation.

Methyl 2,2-bis-(*O*-isopropyldithioxanthyl)acetate was readily prepared by addition of methyl dichloracetate to a suspension of 2 mol equiv of sodium isopropylxanthate in acetone at room temperature. After an initial filtration and removal of the solvent, the residual oil was extracted into hexane and filtered and the solvent removed to provide the bisxanthate as a light yellow oil suitable for further reaction.

In a 4-L beaker containing a large magnetic stir bar and thermometer is placed 1500 mL of concentrated sulfuric acid. The acid is cooled to 0 °C and 50 mL of ether is cautiously added with stirring. Methyl 2,2-bis-(*O*-isopropyldithioxanthyl)acetate (100 g) is then added dropwise to the stirred solution at such a rate that the temperature is maintained between 0 and 5 °C. After the addition, the cooling bath is removed and the temperature allowed to rise to 18 °C at which point the frothy mixture is poured onto 4 L of crushed ice, precipitating crude thiapendione as a tacky white solid. Decantation and filtration through a large coarse sintered glass funnel yield the dione, which is washed well with water and then triturated with two 100-mL portions of ice-cold ether. After drying, thiapendione is recrystallized from a minimal amount of chloroform and/or dimethoxyethane, affording 35–40 g of long white needles, mp 179–181 °C in 57-65% yield. It should be noted that thiapendione has been observed to sensitize and produce skin rashes on some individuals.

**4,5-Bis(propargylthio)-1,3-dithiol-2-one (3, R = H).** A solution of thiapendione (**2**; 5.0 g, 24 mmol), propargyl bromide (4.8 g, 50 mmol), and Aliquot 336 (23.5 g, 48 mmol) in benzene (300 mL) was degassed for 10 min by bubbling nitrogen through the stirred solution. Anhydrous sodium carbonate (10.6 g, 100 mmol) in 100 mL of water was added to the reaction mixture with vigorous stirring under nitrogen for 2 h at 40–45 °C. After the reaction mixture was cooled, the benzene layer was separated, washed with water, and dried over $Na_2SO_4$ and the solvent removed. The crude oil was chromatographed on silica gel (20/80 chloroform/hexane), yielding a clear light yellow oil: 5.0 g (82%); IR (KBr) 2925, 1940, 1672, 1265, 1235, 865 $cm^{-1}$; NMR ($CDCl_3$) $\delta$ 2.32 (1 H), 3.59 (2 H); MS, *m/e* 258.

**Dimethylenetetrahydrotetrathiafulvalene (5, R = H).** To a solution of sodium methoxide, generated by dissolving sodium (1.7 g, 76 mmol) into 80 mL of methanol, was added 5.0 g (19 mmol) of 4,5-bis(propargylthio)-1,3-dithiol-2-one (**3**). The reaction turned orange and then slowly to yellow when heated to reflux for 2 h. After cooling, the reaction was worked up by extraction with ether and water, the organic layer dried, and the solvent evaporated, leaving a yellow oil. The oil was chromatographed on silica gel (20/80 chloroform/hexane) to afford pure product as a yellow oil: 1.4 g (32%); IR (KBr) 2900, 1612, 1220, 1180, 860 $cm^{-1}$; NMR $\delta$ 4.00 (2 H), 5.17 (1 H), 5.27 (1 H); MS, *m/e* 220.

**Dimethyltetrathiafulvalene (6, R = H).** Dimethylenedihydrotetrathiafulvalene (**5**; 2.0 g, 9 mmol) was refluxed in benzene with *p*-toluenesulfonic acid (6.8 g, 36 mmol) for 2 h. On cooling the isomerized product crystallized out as bright orange solid. Recrystallization from acetonitrile yielded orange needles. All spectroscopic analysis of the product agreed with that of an authentic sample.[12]

**1-(Trimethylsilyl)butyn-3-ol-$d_5$ (7).** *n*-Butyllithium (1.6 M, 65 mL, 0.1 mol) was added dropwise to a solution of (trimethysilyl)acetylene (10 g, 0.1 mol) in THF (200 mL) with stirring under nitrogen at −40 °C. After stirring for 1 h, the solution was cooled to −50 °C and acetaldehyde-$d_4$ (5 g, 0.1 mol) was added in one portion. The reaction mixture was warmed to room temperature and then poured into a solution of DCl in $D_2O$. The organic layer was extracted with ether and dried over $Na_2SO_4$. The solvent was removed under reduced pressure, and the deuterated alcohol was distilled as a clear liquid: 9.55 g (62%); bp 65 °C (15 mm); MS, *m/e* 147.

**1-(Trimethylsilyl)-3-bromobutyne-$d_4$ (8).** A solution of **7** (9.5 g, 65 mmol) in dry pyridine (6.4 mL) was added dropwise to an ether suspension of excess dibromotriphenoxyphosphorane[13] at 0 °C. The reaction was stirred at room temperature for 2 h, and then the solids were filtered and washed with ether. The filtrate was extracted with $D_2O$, the ether layer was separated and dried over $Na_2SO_4$, and the solvent removed under reduced pressure. The residual oil was distilled to afford pure bromide: 10.7 g (78%); bp 70 °C (26 mm); MS, *m/e* 209.

**Tetramethyltetrathiafulvalene-$d_{12}$ (TMTTF-$d_{12}$).** The same experimental details described above for **6** was employed for the tetramethyl derivative. 1-(Trimethylsilyl)-3-bromobutyne-$d_4$ (**8**; 50 mmol) was reacted with thiapendione (**2**; 25 mmol) under phase-transfer reaction conditions in $D_2O$ to provide 4,5-bis[1-(trimethylsilyl)butyn-3-yl]-1,3-dithiol-2-one-$d_8$ (**9**) which was isolated after chromatography (silica gel, 20/80 chloroform/hexane) as a clear light-yellow oil in 84% yield; MS, *m/e* 438. Treatment of **9** with 4 equiv of sodium methoxide in refluxing methanol-$d_4$ gave after workup perdeuterated **5** (R = $CD_3$) as a yellow oil in 55% yield; MS, *m/e* 272. Isomerization to TMTTF-$d_{12}$ was affected by treatment with excess *p*-toluenesulfonic acid-*d* in refluxing benzene (2 h) from which the bright orange product precipitated. Recrystallization from acetonitrile gave orange needles; mp 241–243 °C; MS, *m/e* 272. NMR and mass spectral analysis indicated a deuterium content of ~97%.

**Acknowledgment.** We thank J. Mayerle for help in X-ray analysis. This work was supported in part by the Office of Naval Research.

**Registry No.** **3** (R = H), 88180-75-0; **5** (R = H), 88180-76-1; **5** (R = $CD_3$), 88180-79-4; **6a** (R = H), 54397-96-5; **6b** (R = H), 54397-97-6; **7**, 88180-77-2; **8**, 88180-78-3; **9**, 88200-32-2; TMTTF-$d_{12}$, 88200-33-3; $CD_3CDO$, 1632-89-9; $(CH_3)_3SiC{\equiv}CH$, 1066-54-2; methyl 2,2-bis(*O*-isopropyldithioxanthyl)acetate, 64407-81-4; methyl dichloroacetate, 116-54-1; sodium isopropylxanthate, 140-93-2; thiapendione, 64394-45-2; propargyl bromide, 106-96-7.

(12) H. Prinzbach, H. Berger, and A. Lüttringhaus, *Angew. Chem.*, **4**, 435 (1965).

(13) D. K. Black, S. R. Landor, A. N. Patel, and P. F. Whiter, *J. Chem. Soc. C*, 2260 (1967).

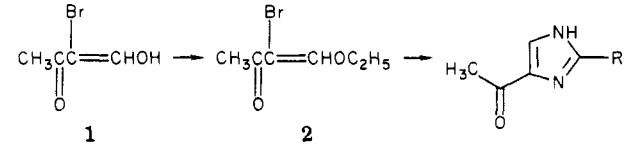
## An Improved Preparation and Use of 2-Bromoacetoacetaldehyde in a New Synthesis of 2-Substituted-4-acetylimidazoles

Christopher A. Lipinski,* Thaddeus E. Blizniak, and Rebecca H. Craig

*Central Research, Pfizer Inc., Groton, Connecticut 06340*

*Received May 23, 1983*

2-Bromoacetoacetaldehyde (3-bromo-4-hydroxy-3-buten-2-one, **1**) is potentially very useful as a reactive and distinctively trifunctionalized intermediate that can be regarded as a vinylogous acetic acid. In contrast to 3-bromoacetylacetone, 2-bromoacetoacetates, and the related and synthetically versatile halomalonaldehydes,[1] the utility of this reagent has not been fully realized because of the lack of a reliable synthesis. We now report a reliable




**1** **2**

synthesis in over 50% yield that is capable of scaleup and

(1) Reichardt, C.; Halbritter, K. *Angew. Chem., Int. Ed. Engl.* **1975**, *14*, 86–94.

0022-3263/84/1949-0566$01.50/0 