[Chem. Pharm. Bull. 17(5) 974—979 (1969)]

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# Studies on Acetylenic Compounds. XLVIII.[1] The Reactions of Allenic and Acetylenic Sulfides with Methyl Iodide

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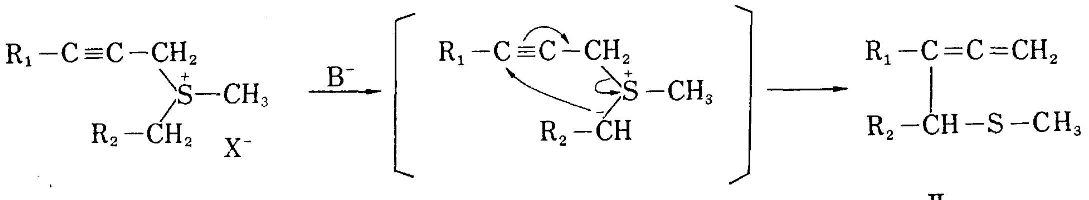
Treatment of allenic sulfides, methyl 2-phenyl-2,3-butadienyl sulfide (IIa) and methyl 1-(2-phenylethynyl)-2-phenyl-2,3-butadienyl sulfide (IIb), with methyl iodide gave sulfur-free compounds of 1,3-diene derivatives, 2-iodo-3-phenyl-1,3-butadiene (III) and 2-iodo-3,6-diphenyl-*cis*-1,3-hexadien-5-yne (IV–a), respectively. This desulfurization with methyl iodide was extended to some acetylenic sulfides (V, VIII and IX) and the tendency of the cleavage of C–$\overset{+}{S}$ bond was determined. Treatment of bis(3-phenyl-2-propynyl)sulfide (IX) with methyl iodide in ether, however, afforded sulfur-involving product, 4-phenyl-1,3-dihydronaphtho[2,3-*c*]thiophene methyl iodide (X).

In the preceding paper,[3] we reported formations of some allenic sulfides by the base-catalyzed rearrangements of acetylenic sulfonium salts as outlined in Eq. 1.

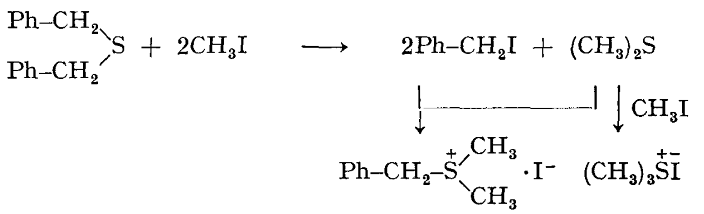


(1)

I II

a: $R_1$=Ph, $R_2$=H, X=Br b: $R_1$=Ph, $R_2$=Ph-C≡C–, X=$CH_3SO_4$

Commonly, it is known that the sulfides which are activated by having allyl- or benzyl group react with methyl iodide to afford sulfur-free compounds.[4] In many of such cases, the sulfur is lost as trimethylsulfonium iodide. For example, Schöller[5] have reported the reaction of dibenzyl sulfide with methyl iodide to give trimethylsulfonium iodide and dimethyl benzylsulfonium iodide (Eq. 2).



(2)

This paper deals with the reactions of some allenic sulfides, which were obtained by the base-catalyzed rearrangements of acetylenic sulfonium salts, and of acetylenic sulfides with methyl iodide.

Methyl 2-phenyl-2,3-butadienyl sulfide (IIa), a base-induced rearrangement product of dimethyl 3-phenyl-2-propynylsulfonium bromide (Ia), reacted with methyl iodide in anhydrous

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[1] Part XLVII: A. Terada and Y. Kishida, *Chem. Pharm. Bull.* (Tokyo), **17**, 966 (1969).

[2] Location: *Hiromachi, Shinagawa-ku, Tokyo.*

[3] A. Terada and Y. Kishida, *Chem. Pharm. Bull.* (Tokyo), **17**, 966 (1969).

[4] D.S. Tarbell, *Chem. Rev.*, **49**, 1 (1951).

[5] C. Schöller, *Chem. Ber.*, **7**, 1274 (1874).

benzene under mild conditions to afford two products. The first reaction product, precipitated from the reaction mixture, melted at 206—209° and had a molecular formula, $C_3H_9SI$, which was identical in all respects with an authentic sample of trimethylsulfonium iodide prepared from dimethyl sulfide and methyl iodide. The second product (III), obtained in 52.6% yield, boiled at 60—65° (0.0001 mmHg) and had an empirical formula, $C_{10}H_9I$. The ultraviolet spectrum showed an absorption maximum at 234 m$\mu$ ($\varepsilon$=13100) and the infrared (IR) spectrum revealed the characteristic terminal methylene band at 905 cm$^{-1}$. The nuclear magnetic resonance (NMR) spectrum in deuteriochloroform exhibited an aromatic multiplet centered at 7.38 ppm (5H) and two sets of AB type pattern at 5.40 and 5.59 ppm (2H, $J$=1.0 cps), and at 6.22 and 6.09 ppm (2H, $J$=1.1 cps) for two characteristic terminal methylene protons. From these results, the structure of III was concluded to be 2-iodo-3-phenyl-1,3-butadiene. This assignment was further supported by the mass spectrum which showed an intense molecular ion at *m/e* 256 with the other intense peaks at *m/e* 129 (base peak, M–I), *m/e* 128 (M–HI) and *m/e* 105 (M–$C_2H_2I$).

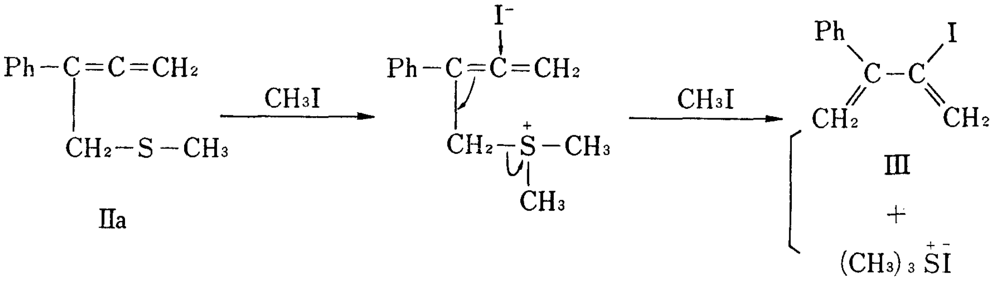
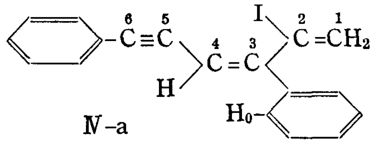


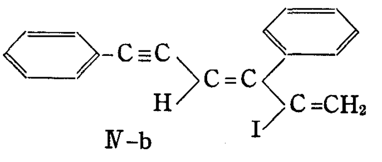
Chart 1

In order to prepare a stable crystalline derivative, we attempted the Diels–Alder reaction of III with dienophiles such as tetracyanoethylene or dimethyl acetylenedicarboxylate. The reactions were carried out in ethyl acetate at room temperature, because of the unstable nature of this butadiene derivative to heat, but unfortunately failed in giving the expected Diels–Alder products. The plausible mechanism for the formation of III from IIa would be expressed by a $S_N2'$ reaction as indicated in Chart 1. Preferential splitting of 2-phenyl-2,3-butadienyl cation would be thought in an intermediate stage rather than the methyl group, since it is well known, especially from the elegant work of Ingold,[6] that the group with the greatest cationic stability is the one leaving from the sulfonium ion.

Similary, treatment of methyl 1-(2-phenylethynyl)-2-phenyl-2, 3-butadienyl sulfide (IIb), prepared by the base-catalyzed rearrangement of methyl bis (3-phenyl-2-propynyl) sulfonium methyl sulfate (Ib), with methyl iodide gave trimethyl sulfonium iodide and a crystalline compound (IV) of mp 130°, $C_{18}H_{13}I$, in 30% yield. The infrared spectrum of IV showed a typical terminal methylene band at 917 cm$^{-1}$ and an absorption at 2195 cm$^{-1}$ for triple bond, and the ultraviolet spectrum showed absorption maxima at 222.5 ($\varepsilon$=19770), 247 ($\varepsilon$=12930) (shoulder) and 327 m$\mu$ ($\varepsilon$=30850). The NMR spectrum exhibited the signals at 6.17 ppm (1H, singlet) ascribable to vinyl proton, a AB type pattern at 6.32 and 6.47 ppm (2H, $J$=1.0 cps) due to nonequivalent protons of the terminal methylene group and a multiplet centered at 7.45 ppm assignable to two phenyl protons (10 H). These data suggested that the compound, IV, would be either IV-a or IV-b described below.



IV-a



IV-b

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[6] J.L. Gleave, E.D. Hughes and C.K. Ingold, *J. Chem. Soc.*, **1935**, 240.

It looks very difficult to differentiate the two structures for the compound by chemical means. The problem, however, could be efficiently solved by investigating intramolecular "Nuclear Overhauser Effects" (NOE). If IV has *cis* configuration (IV-a), the $C_4$ proton signal intensity at 6.17 ppm should be strongly enhanced when the $H_0$ at $C_3$-phenyl group at 7.45 ppm is irradiated, but if IV has *trans* configuration (IV-b) the intensity of $C_4$ proton signal should be unaffected even if the $H_0$ is irradiated.

This was indeed observed, 31% increase of the $C_4$ proton intensity telling the compound, IV, to be the *cis*; 2-iodo-3,6-diphenyl-*cis*-1,3-hexadien-5-yne (IV-a).

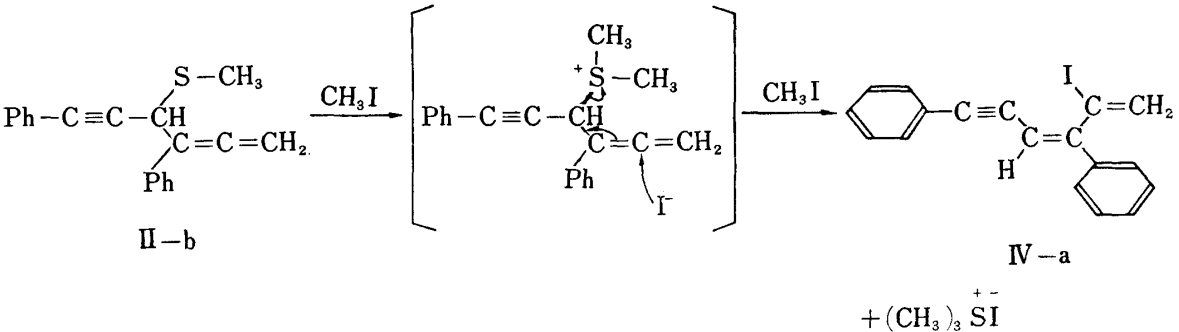


Chart 2

The reaction forming IV-a from II-b would proceed with just the same behavior as the conversion of II-a to III, in conformity with the Ingold theory.

Since it has been very difficult to obtain such 1,3-diene derivatives as III or IV-a this method would be useful for the preparation.

From these results and others,[4] it became clear that the active sulfides react easily with methyl iodide to give sulfur-free compounds under mild conditions. This desulfurization with methyl iodide was further extended to some acetylenic sulfides.

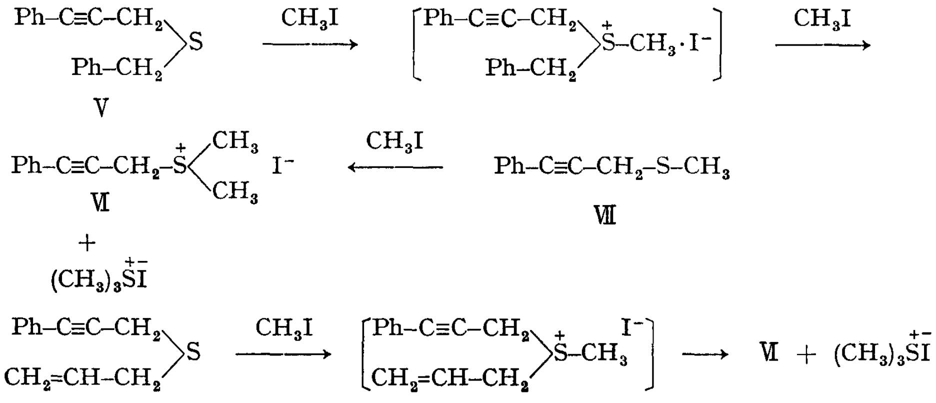


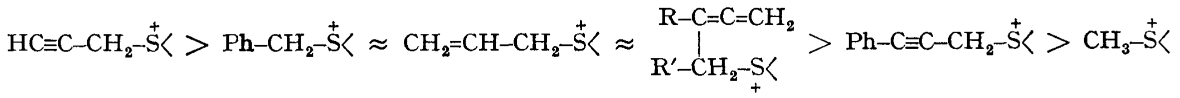
Chart 3

Treatment of benzyl 3-phenyl-2-propynyl sulfide (V) with methyl iodide afforded dimethyl 3-phenyl-2-propynylsulfonium iodide (VI) together with trimethylsulfonium iodide. The former substance had a molecular formula, $C_{11}H_{13}SI$, and melted at 118—119°. The infrared spectrum of VI showed the characteristic acetylenic absorption band at 2205 $cm^{-1}$. The NMR spectrum exhibited signals at 2.99 ppm (6H, singlet) due to dimethyl groups, 4.58 ppm (2H, singlet) assignable to the methylene protons and an aromatic multiplet centered at 7.50 ppm (5H). The structure assignment based on these data was finally confirmed by an unequivocal synthesis from methyl 3-phenyl-2-propynyl sulfide (VII) and methyl iodide. Considering the reaction mechanisms, benzyl iodide and 3-phenyl-2-propynyl iodide should be formed, but they were not detectable even on the thin-layer chromatography.

While, (2-propenyl)(3-phenyl-2-propynyl) sulfide (VIII) reacted with methyl iodide to give dimethyl 3-phenyl-2-propynyl sulfonium iodide (VI) and trimethylsulfonium iodide.

Again allyl iodide and 3-phenyl-2-propynyl iodide should be formed, considering the reaction mechanism stoichiometrically, however, either of the compounds could not be detected even on the thin-layer chromatography. It is clear that benzyl and allyl groups would split away predominantly from the parent sulfonium salts rather than 3-phenyl-2-propynyl- or methyl groups in accordance with the cationic stability.

From these results together with the findings in the preceding paper,[3] the ease of the cleavage of C-$\overset{+}{S}$ bond in this reaction can be illustrated by the following order:



$$HC{\equiv}C{-}CH_2{-}\overset{+}{S}\langle \; > \; Ph{-}CH_2{-}\overset{+}{S}\langle \; \approx \; CH_2{=}CH{-}CH_2{-}\overset{+}{S}\langle \; \approx \; \begin{array}{c} R{-}C{=}C{=}CH_2 \\ | \\ R'{-}CH_2{-}\underset{+}{S}\langle \end{array} \; > \; Ph{-}C{\equiv}C{-}CH_2{-}\overset{+}{S}\langle \; > \; CH_3{-}\overset{+}{S}\langle$$

In the cases of the rearrangements of (acetylenic) ammonium salts[7] and von Brown's reaction,[8] the order of the fission of C-$\overset{+}{N}$ (or C-N) bond are as follows:
rearrangements of ammonium salts,

$$HC{=}C{-}CH_2{-}\overset{+}{N}\langle \; > \; Ph{-}CH_2{-}\overset{+}{N}\langle \; \approx \; H_2C{=}CH{-}CH_2{-}\overset{+}{N}\langle \; > \; Ph{-}C{\equiv}C{-}CH_2{-}\overset{+}{N}\langle \; > \; CH_3{-}\overset{+}{N}\langle$$

von Brown's reaction,

$$Ph{-}CH_2{-}N\langle \; \approx \; H_2C{=}CH{-}CH_2{-}N\langle \; > \; HC{\equiv}C{-}CH_2{-}N\langle \; > \; CH_3{-}N\langle$$

Therefore, the tendency of the cleavage of C-$\overset{+}{S}$ is almost similar with that of C-$\overset{+}{N}$ or C-N bond with the exception of the propargyl group in von Brown's reaction.

On the other hand, refluxing of bis (3-phenyl-2-propynyl) sulfide (IX) with two equivalents of methyl iodide in anhydrous ether afforded crystalline substance (X) of mp 146°, $C_{19}H_{17}SI$, in 7.2% yield. This compound, X, no longer showed the infrared absorption maximum at 2200 cm$^{-1}$ region for triple bond. The ultraviolet (UV) spectrum revealed maxima at 232 ($\varepsilon$=6290), 287 ($\varepsilon$=8500) and 296 m$\mu$ ($\varepsilon$=7800) (shoulder) which are characteristic of a naphthalene derivative. The NMR spectrum exhibited a singlet at 2.78 ppm (3H) due to methyl protons, two kinds of AB type pattern at 4.24 and 4.98 (2H, $J$=16.5 cps), and at 4.88 and 5.23 ppm (2H, $J$=16.5 cps) due to nonequivalent protons of two geminal methylene groups, and an aromatic multiplet centered at 7.50 ppm (10H). From these data and the reported fact[7] that the reaction of bis(3-phenyl-2-propynyl) sulfide with base gave 4-phenyl-1,3-dihydronaphtho[2,3-*c*] thiophene (XI), the product, X, was assigned to be 4-phenyl-1,3-dihydronaphtho[2,3-*c*] thiophene methyl iodide. This assignment was further confirmed by comparison with an authentic sample prepared from the dihydrothiophene[7] (XI) and methyl iodide.

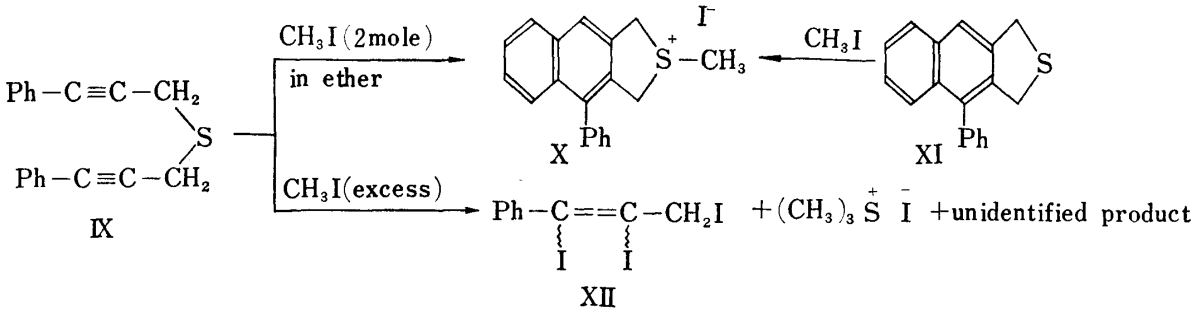


Chart 4

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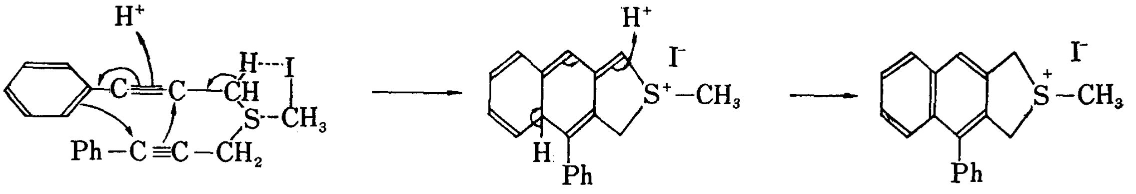
[7] I. Iwai and T. Hiraoka, *Chem. Pharm. Bull.* (Tokyo), **11**, 1556 (1963).
[8] H.A. Hageman, "Organic Reaction," Vol. VII, New York, p. 231.

In this reaction, no C–S bond cleavage product was detected, differing from the cases mentioned before. A mechanistic assumption for the formation of X from IX would be explained as shown in Chart 5.



X

Chart 5

However, treatment of IX with excess methyl iodide without solvent at room temperature gave triiodo compound (XII) of mp 123° in 12% yield together with trimethylsulfonium iodide and unidentified product. The elemental analysis of the triiodo compound agreed with the empirical formula corresponding to $C_9H_7I_3$. The infrared spectrum showed no absorption maximum at 2200 $cm^{-1}$ region for triple bond. The NMR spectrum showed a singlet at 4.70 ppm (2H) due to the methylene protons and a multiplet at 7.35 ppm (5H) ascribable to the phenyl hydrogens. From these results, the structure of the triiodo compound, XII, was assigned to be 1,2,3-triiodo-1-phenyl-1-propene. The formation of XII from IX would be explained to proceed presumably *via* phenyl propargyl iodide. Namely, the methyl group of methyl iodide replaced phenyl propargyl group to produce first, dimethyl sulfide or resultant trimethylsulfonium iodide and phenylpropargyl iodide. The origin of the vicinal iodines of XII, although they might come from phenyl propargyl iodide, is not clear at present. The unidentified product was not further investigated.

## Experimental[10]

**2-Iodo-3-phenyl-1,3-butadiene (III)**——A solution of methyl 2-phenyl-2,3-butadienyl sulfide (1.3 g) and methyl iodide (5.0 g) in 1 ml of benzene was allowed to stand for 48 hr at room temperature. The resulting crystalline substance was collected by filtration and washed with benzene. Recrystallization from EtOH afforded colorless prisms of trimethylsulfonium iodide (1.2 g), mp 206—209°, which was identical in all respects with an authentic sample. The filtrate was concentrated under reduced pressure to give an oil. This oil was distilled *in vacuo* to give 2-iodo-3-phenyl-1,3-butadiene of bp 60—65° (0.0001 mmHg) (bath temp.) (0.994 g). *Anal.* Calcd. for $C_{10}H_9I$: C, 46.87; H, 3.52; I, 49.60. Found: C, 46.76; H, 3.44; I, 50.02.

**2-Iodo-3,6-diphenyl-*cis*-1,3-hexadien-5-yne (IV—a)**——A solution of methyl 1-(2-phenylethynyl)-2-phenyl-2,3-butadienyl sulfide (1.0 g) and methyl iodide (6.0 g) in 3 ml of benzene was allowed to stand for 115 hr at room temperature. The resulting crystalline substance was collected by filtration, washed with benzene and recrystallized from EtOH to give trimethylsulfonium iodide of mp 208—210° (0.4 g). The filtrate was concentrated under reduced pressure and the residue was recrystallized from $CCl_4$ to give colorless leaflets of 2-iodo-3,6-diphenyl-*cis*-1,3-hexadien-5-yne (0.385 g), mp 129—130°. *Anal.* Calcd. for $C_{18}H_{13}I$: C, 60.68; H, 3.65; I, 35.68. Found: C, 60.50; H, 3.81; I, 36.16.

**Dimethyl 3-Phenyl-2-propynylsulfonium Iodide (VI) from Methyl 3-Phenyl-2-propynyl Sulfide (VII) and Methyl Iodide**——A mixture of methyl 3-phenyl-2-propynyl sulfide (0.486 g) and methyl iodide (0.70 g) was allowed to stand for 12 hr at room temperature. The resulting crystalline substance was collected by filtration and washed with ether. Recrystallization from EtOH gave colorless leaflets of dimethyl 3-phenyl-2-propynylsulfonium iodide, mp 118—119° (0.5 g). IR: $\nu_{max}^{Nujol}$ $cm^{-1}$: 2205 (–C≡C–). *Anal.* Calcd. for $C_{11}H_{13}SI$: C, 43.42; H, 4.27; S, 10.53. Found: C, 43.40; H, 4.45; S, 10.90.

**Reaction of Benzyl 3-Phenyl-2-propynyl Sulfide (V) with Methyl Iodide**——A mixture of benzyl 3-phenyl-2-propynyl sulfide (2.4 g) and methyl iodide (2.2 g) was allowed to stand for 5 days at room temperature. The resulting crystalline substance was collected by filtration and washed with ether. Fractional recrystalli-

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9) I. Iwai and J. Ide, *Chem. Pharm. Bull.* (Tokyo), **12**, 1094 (1964).

10) All melting and boiling points are uncorrected. The NMR spectra were taken on Varian A-60 and HA-100 spectrometer with tetramethylsilane as an internal standard.

zation from EtOH gave trimethylsulfonium iodide (0.1 g), mp 205—206°, and dimethyl 3-phenyl-2-propynylsulfonium iodide, mp 118—119°, (1.0 g), which was identical in all respects with an authentic sample prepared from methyl 3-phenyl-2-propynyl sulfide and methyl iodide.

**Reaction of (2-Propenyl)(3-phenyl-2-propynyl)sulfide (VIII) with Methyl Iodide**——A mixture of (2-propenyl)(3-phenyl-2-propynyl)sulfide (1.88 g) and methyl iodide (1.42 g) was allowed to stand for 24 hr at room temperature. The resulting crystalline substance was collected by filtration and washed with ether. Fractional recrystallization from EtOH gave trimethylsulfonium iodide, mp 206—209°, and dimethyl 3-phenyl-2-propynylsulfonium iodide (0.1 g), mp 118—119°, which was identical in all respects with an authentic sample prepared from methyl 3-phenyl-2-propynyl sulfide and methyl iodide.

**4-Phenyl-1,3-dihydronaphtho[2,3-c]thiophene Methyl Iodide (X) from Bis(3-phenyl-2-propynyl)sulfide (IX) and Methyl Iodide in Ether**——A solution of bis(3-phenyl-2-propynyl)sulfide (5.24 g) and methyl iodide (5.6 g) in 10 ml of anhyd. ether was allowed to stand for 3 days at room temperature. The resulting crystalline substance was collected by filtration. Fractional recrystallization from EtOH gave trimethylsulfonium iodide (0.057 g), mp 206—210°, and colorless needles of 4-phenyl-1,3-dihydronaphtho[2,3-*c*]thiophene methyl iodide (0.29 g), mp 143—146°. *Anal.* Calcd. for $C_{19}H_{17}SI$: C, 56.43; H, 4.25; S, 7.92; I, 31.43. Found: C, 56.24; H, 4.28; S, 7.90; I, 31.36.

**4-Phenyl-1,3-dihydronaphtho[2,3-*c*]thiophene Methyl Iodide (X) from 4-Phenyl-1,3-dihydronaphtho[2,3-*c*]thiophene (XI) and Methyl Iodide**——A mixture of 4-phenyl-1,3-dihydronaphtho[2,3-*c*]thiophene⁹⁾ (0.65 g) and methyl iodide (5.0 g) was allowed to stand for 2 days at room temperature. Recrystallization from EtOH afforded colorless needles of 4-phenyl-1,3-dihydronaphtho[2,3-*c*]thiophene methyl iodide (0.60 g), mp 142—143°, which was identical in all respects with a product prepared from bis(3-phenyl-2-propynyl)sulfide and methyl iodide.

**Reaction of Bis(3-phenyl-2-propynyl)sulfide (IX) with Excess Methyl Iodide**——A mixture of bis(3-phenyl-2-propynyl)sulfide (5.24 g) and methyl iodide (20.0 g) was allowed to stand for a week at room temperature. The precipitate was removed by filtration and washed with ether. The filtrate was concentrated under diminished pressure and the residue was chromatographed on $Al_2O_3$(Woelm, grade I, 200 g). Elution with hexane–benzene (2:1) afforded 1.2 g of pale yellow solid. Recrystallization from ether gave 1,2,3-triiodo-1-phenyl-1-propene, mp 122—123°. *Anal.* Calcd. for $C_9H_7I_3$: C, 21.77; H, 1.41; I, 76.81. Found: C, 21.77; H, 1.02; I, 77.29.

**Acknowledgement** We are very thankful to Dr. T. Hiraoka for his kind assistance and valuable discussion.