# The Reaction of *O,O'*-Diethyl α-Lithiomethylphosphonate with Organic Dihalides

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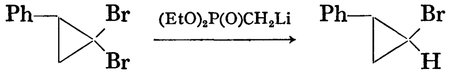
The reactions of the α-lithio derivative of diethyl methylphosphonate with various organic halides are described. The half-reduction of *gem*-dihalocyclopropanes has been achieved with this reagent. The same reagent gives bibenzyl and tetraphenylethane from benzyl bromide and benzhydryl chloride respectively. The deprotonation-metallation process is observed in the reactions of cinnamyl chloride and of *trans*-β-bromostyrene, in which 3-chloro-1,6-diphenyl-1,5-hexadiene and 1,4-diphenyl-3-buten-1-yne are produced respectively.

The half-reduction of olefin-dihalocarbene adducts by organometallic reagents[1)] is a useful method for obtaining monohalocyclopropanes, but it has been limited in scope due to competing reactions arising from the intermediary α-halocyclopropylmetal compounds. We have found that the α-lithio derivative of diethyl methylphosphonate appears to be an excellent reagent for the half-reduction of dihalocyclopropanes under mild conditions. This reagent showed promise of largely circumventing the side reactions encountered with other organometallic reagents.

*O,O'*-Diethyl α-lithiomethylphosphonate (I), prepared simply from *O,O'*-diethyl methylphosphonate and *n*-butyllithium at −78°C,[2)] reacted with 1,1-dibromo-2-phenylcyclopropane (IIa) to give the expected 1-bromo-2-phenylcyclopropane (IIIa) as a predominant product

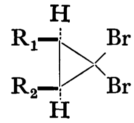
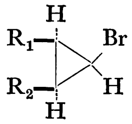


IIa IIIa

(68%). In contrast, the reaction of methylsulfinylcarbanion[3)] with the dibromide, IIa, resulted in a polymeric mixture in which the desired bromide, IIIa, was absent. The anion, I, produced 9-bromo-*cis*-bicyclo[6.1.0]nonane (IIIb) from 9,9-dibromo-*cis*-bicyclo[6.1.0]nonane (IIb) in a 66% yield, while with *n*-butyllithium the latter afforded 1,2-cyclononadiene (IV) as the major product.[4)]

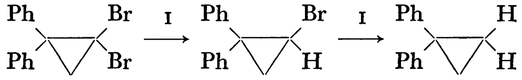
A variety of *gem*-dihalocyclopropanes have been successfully reduced to the respective monobromides using the phosphonate reagent, as is indicated in Table 1. Most noteworthy is the preferential formation of thermodynamically more stable *trans*- or *exo*-monobromocyclopropanes, which might originate from the *endo-exo* isomerization of the initially-formed halocyclopropyllithium.[5)]

Table 1. Reaction of *gem*-dibromocyclopropanes with I in THF

| Substrate<br><br>Code, $R_1$, $R_2$ | Code | Product[a)]<br><br>Yield[b)] (%) | *exo* (*trans*) | | *endo* (*cis*) |
|---|---|---|---|---|---|
| IIa, Ph, H | IIIa | 68 | 79 | : | 21 |
| IIb, $-(CH_2)_6-$ | IIIb | 66 | 80 | : | 20 |
| IIc, $-(CH_2)_4-$ | IIIc | 82 | 90 | : | 10 |
| IId, $-(CH_2)_{10}-$ | IIId | 65[c)] | 83 | : | 17 |
| IIe, $-CH_2-CH$<br>‖<br>$-CH_2-CH$ | IIIe | 75 | 84 | : | 16 |
| IIf, *n*-Hexyl, H | IIIf | 68 | 79 | : | 21 |

a) Products were identified by IR, NMR, and MS spectra with authentic samples.[1a]
b) Analyzed by glc.
c) Allene was also obtained in 9% yield and was identified by comparison with an authentic sample.

The preparation of the totally reduced cyclopropane derivative was also attained with this reagent. When *ca.* three equivalents of the anion, I, were allowed to react with 1,1-dibromo-2,2-diphenylcyclopropane (V), a mixture of 1-bromo-2,2-diphenylcyclopropane (VI), and 1,1-diphenylcyclopropane (VII) was obtained. The cyclopropane, VII, was obtained as the sole product (62%) when a large excess of the anion, I, was used for this reaction (>6 equiv).



V VI VII

The similarity of the anion, I, to methylsulfinylcarbanion prompted us to examine the reaction of I with other organic halides. Corey and Chaykovski have reported[6)] that the treatment of benzyl chloride and benzhydryl chloride with methylsulfinylcarbanion furnished stilbene and tetraphenylethylene respectively.

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[1)] a) T. Shirafuji, K. Oshima, Y. Yamamoto, and H. Nozaki, This Bulletin, **44**, 3161 (1971); b) D. Seyferth, H. Yamazaki, and D. L. Alleston, *J. Org. Chem.*, **28**, 703 (1963); c) D. Seyferth and B. Prokai, *ibid.*, **31**, 1702 (1966); d) T. Ando, H. Yamanaka, F. Namigata, and W. Funasaka, *J. Amer. Chem. Soc.*, **89**, 5719 (1967); e) J. Vilieras and H. Normant, *C. R. Acad. Sci. Paris*, **264**, 593 (1967).

[2)] E. J. Corey and G. T. Kwiatokowski, *J. Amer. Chem. Soc.*, **88**, 5654 (1966).

[3)] Methylsulfinylcarbanion is known to be a good reagent for the half-reduction of *gem*-dihalocyclopropanes, see C. L. Osborn, T. C. Shields, B. A. Shoulders, and P. D. Gardner, *Chem. Ind.* (London), **1965**, 766.

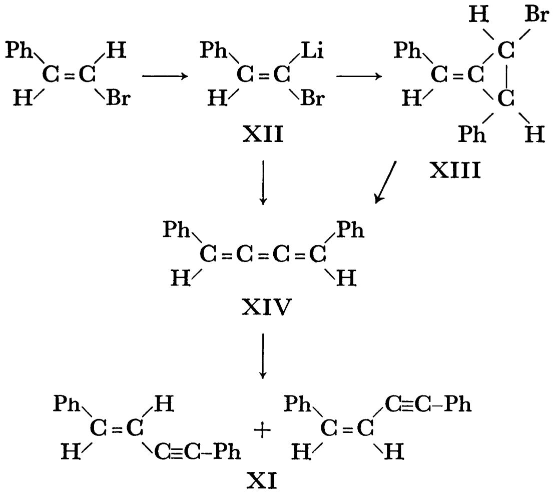
[4)] W. R. Moore and H. R. Ward, *J. Org. Chem.*, **27**, 4179 (1962).

[5)] G. Köbrich and W. Goyert, *Tetrahedron*, **24**, 4327 (1968); For kinetically controlled semireduction with chromous sulfate, see H. Nozaki, T. Aratani, and R. Noyori, *ibid.*, **23**, 3645 (1967).

[6)] E. J. Corey and M. Chaykovski, *J. Amer. Chem. Soc.*, **87**, 1345 (1965).

In contrast to these results, the anion, I, gave bibenzyl (VIII) and tetraphenylethane (IX) from benzyl bromide and benzhydryl chloride respectively. We suppose that this novel condensation reaction involves an unstable arylated carbanion, which affords the final product upon reaction with another halide.

Although the above-mentioned reactions are to be ascribed to the dehalogenation-metallation process, the deprotonation-metallation process has also been observed in some cases. Cinnamyl chloride gave 3-chloro-1,6-diphenylhexadiene-1,5 (X), whereas *trans-β*-bromostyrene afforded 1,4-diphenyl-3-buten-1-yne (XI). The latter reaction might involve an intermediary vinylcarbenoid, XII, which reacts with *β*-bromostyrene to form the methylenecyclopropane, XIII, followed by isomerization to XI through the cumulene derivative, XIV. An alternative pathway might be the direct dimerization of the vinylcarbenoid, XII, to form the cumulene, XIV.[7] The possibility of the formation of phenylacetylene as an intermediate was excluded by the following experiment. When the solution of I was successively treated with phenylacetylene at −78°C and then with *β*-bromostyrene, no trace of XI could be detected among the products.



## Experimental

All the bps are uncorrected. The microanalyses were performed at the Elemental Analyses Center of Kyoto University and by Mrs. Kiyoko Fujimoto. The NMR spectra were taken with a JEOL C-60H spectrometer and the chemical shifts are reported in δ values relative to the TMS internal standard. The mass spectra were obtained on a Hitachi RMU 6D spectrometer. The glc analyses or separations were performed using a 1 m column of SE-30 (30%) on Chromosorb W and He as the carrier gases.

*General Procedure of the Reactions of Organic Halides with* O,O′-*Diethyl α-Lithiomethylphosphonate (I).* In a nitrogen atmosphere, diethyl methylphosphonate was dissolved in freshly-distilled (over LAH) THF so as to give *ca.* a 0.5M solution. The solution was cooled to −78°C on a methanol–dry ice bath, and *n*-butyllithium (1.2 equiv) was added to this solution with stirring. After 15 min, a solution (*ca.* 1M) of organic halide was slowly added at −78°C. The ratio of the bromide to I was taken to be 1: 1.5 unless otherwise stated. The mixture was allowed to stand overnight at room temperature, treated with ice-cold water, and extracted with ether three times. The combined ethereal extracts was concentrated *in vacuo*. The products were separated and identified as usual. The following descriptions refer to cases which are not sufficiently covered by Table 1.

*Reaction of 13,13-Dibromo-*cis*-bicyclo[10.1.0]tridecane (IId)*· The dibromide, IId (600 mg, 1.75 mmol), was treated with the anion, I (3.00 mmol), in dry THF (15 ml) at −78°C. A glc analysis of the crude reaction mixture showed the presence of *exo*-IIId (54%), *endo*-IIId (11%), and 1,2-cyclotridecadiene (9%). The bromide, IIId, was separated by preparative glc.

13-Bromo-*cis*-bicyclo[10.1.0]tridecane (IIId): bp 100°C (bath temp.)/0.05 mmHg; IR (neat) 1469, 1447, 1250, 1238, 1225 cm$^{-1}$; MS *m/e* (relative abundance) 260 (9), 258 (9), 175 (21), 79 (100). The NMR analysis did not reveal the methine proton absorption.

Found: C, 60.5; H, 8.9%. Calcd for $C_{13}H_{23}Br$: C, 60.2; H, 8.9%.

*Reaction of 13,13-Dibromo-*trans*-bicyclo[10.1.0]tridecane (IIg)*· The halide, IIg (600 mg, 1.75 mmol), was treated with the anion, I (3.00 mmol), in dry THF (15 ml) at −78°C. The reaction mixture showed the presence of 13-bromo-*trans*-bicyclo[10.1.0]tridecane (IIIg, 72%) and 1,2-cyclotridecadiene (8%) upon glc assay. The bromide, IIIg, was separated by preparative glc.

IIIg: bp 100°C (bath temp.)/0.05 mmHg; IR (neat) 1465, 1443, 1270, 1248, 1237, 1222 cm$^{-1}$; NMR ($CCl_4$) δ 0.85 (b, 2), 1.42 (b, 2), 2.72 (q, 1, $J_{cis}=7.2$ Hz, $J_{trans}=3.5$ Hz) ppm; MS *m/e* (relative abundance) 260 (12), 258 (12), 179 (10), 135 (18), 109 (31), 95 (100).

Found: C, 60.2; H, 9.1%. Calcd for $C_{13}H_{23}Br$: C, 60.2; H, 8.9%.

*Reaction of 7,7-Dibromobicyclo[4.1.0]heptene-3 (IIe).* A solution of IIe (850 mg, 3.37 mmol) in THF (2 ml) was added to a solution of I (6.00 mmol) in dry THF (7 ml) at −78°C. The reaction mixture was then worked up as usual. The glc analysis of the resulting oil showed the presence of *exo*-IIIe (63%) and *endo*-IIIe (12%); each component was separated by preparative glc.

*exo*-7-Bromobicyclo[4.1.0]heptene-3 (*exo*-IIIe): bp 60°C/18 mmHg; IR (neat) 3050, 1655, 1220 cm$^{-1}$; NMR ($CCl_4$) δ 5.47 (b, 2), 2.74 (t, 1, $J_{trans}=3.1$ Hz), 2.37 (b, 4), 1.45 (b, 2) ppm; MS *m/e* (relative abundance) 174 (12), 172 (12), 131 (11), 117 (11), 93 (100).

Found: C, 48.9; H, 5.5%. Calcd for $C_7H_9Br$: C, 49.2; H, 5.2%.

*endo*-IIIe: bp 65°C/18 mmHg; IR (neat) 3050, 1668, 1252 cm$^{-1}$; NMR ($CCl_4$) δ 3.29 (t, 1, $J_{cis}=7.4$ Hz) ppm.

*Reaction of 1,1-Dibromo-2,2-diphenylcyclopropane (V).* The dibromide, V (700 mg, 2.00 mmol), was treated with the anion, I (3.00 mmol), in THF. The glc analysis of the crude reaction mixture showed the presence of 1-bromo-2,2-diphenylcyclopropane (VI, 73%), which was separated by preparative glc.

VI: bp 140°C (bath temp.)/0.05 mmHg; IR (neat) 1252 cm$^{-1}$; NMR ($CCl_4$) δ 7.15 (d, 1), 3.56 (t, 1, $J=6.5$ Hz), 1.73 (d, 2) ppm; MS *m/e* (relative abundance) 274 (3), 272 (3), 194 (41), 193 (100), 115 (100).

When V (350 mg, 1.00 mmol) was treated with I (3.00 mmol), 1,1-diphenylcyclopropane (VII, 40% by glc assay) was obtained in addition to VI (28% by glc assay). When V (60 mg, 0.17 mmol) was treated with I (1.00 mmol), the cyclopropane, VII (62% by glc assay), was obtained as the

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[7] a) G. Köbrich and W. Drischel, *Tetrahedron*, **22**, 2621 (1966); b) G. Köbrich, H. Heinemann, and W. Zündorf, *ibid.*, **23**, 565 (1967).

sole product.

*Reaction of Benzyl Bromide.* Benzyl bromide (340 mg, 2.00 mmol) was treated with the anion, I (3.00 mmol), in THF (15 ml) at −78°C. The preparative tlc separation of the crude reaction mixture then gave VIII (127 mg, 70%) as the sole product; it was identical in all respects with an authentic sample.

*Reaction of Benzhydryl Chloride.* Benzhydryl chloride (200 mg, 1.00 mmol) was treated with the anion, I (1.50 mmol), in THF (7 ml) at −78°C. After the concentration of the dried extracts *in vacuo*, a white solid was obtained. Recrystallization from benzene–hexane (1:1) gave pure IX (125 mg, 75%) as colorless crystals; the IX was identical in all respects with an authentic sample.

*Reaction of Cinnamyl Chloride.* Cinnamyl chloride (500 mg, 3.30 mmol) was added to a solution of the anion, I (5.00 mmol), in THF (20 ml) at −78°C. The subsequent glc analysis of the reaction mixture showed the presence of 3-chloro-1,6-diphenyl-1,5-diene (X, 71%), which was then separated by preparative glc.

X: bp 160°C (bath temp.)/0.08 mmHg; IR (neat) 1625, 1594, 959, 740, 692 cm$^{-1}$; NMR ($CCl_4$) $\delta$ 7.13 (b, 10), 6.0 (m, 5), 2.55 (t, 2) ppm; MS *m/e* (relative abundance) 270 (0.51), 268 (0.96), 232 (2.4), 151 (17), 117 (100), 115 (61).

Found: C, 80.3; H, 6.6%. Calcd for $C_{18}H_{17}Cl$: C, 80.4; H, 6.4%.

*Reaction of* trans-*β-Bromostyrene.* *trans*-β-Bromostyrene (600 mg, 3.30 mmol) was added to a solution of I (4.90 mmol) in THF at −78°C. The usual work up, followed by glc separation, afforded *cis*-XI (79 mg, 39%) and *trans*-XI (15 mg, 8%).

1,4-Diphenyl-*cis*-3-buten-1-yne (*cis*-XI): bp 80°C/0.05 mmHg; IR (neat) 2200, 780 cm$^{-1}$; NMR ($CCl_4$) $\delta$ 7.73 (m, 2), 7.21 (m, 8), 6.56 and 5.76 (AB q, 1 each, $J_{AB}=15$ Hz); MS *m/e* (relative abundance) 204 (100), 203 (88), 202 (82), 103 (14), 101 (29).

1,4-Diphenyl-*trans*-3-buten-1-yne (*trans*-XI): mp 94—95°C (lit, 95.5—96°C[8]); IR (KBr) 945 cm$^{-1}$; NMR ($CCl_4$) $\delta$ 7.23 (m, 5), 6.96 and 6.26 (AB q, 1 each, $J_{AB}=12$ Hz) ppm; MS *m/e* (relative abundance) 204 (100), 203 (85), 202 (77), 103 (13), 101 (27).

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8) a) H. K. Black, D. H. S. Horn, and B. C. L. Weedon, *J. Chem. Soc.*, **1954**, 1704; b) J. H. Pinckard, B. Wille, and L. Zechmeister, *J. Amer. Chem. Soc.*, **70**, 1938 (1948).