Tellurium-Assisted Cyclopropanation and Alkylidenation of α,β-Unsaturated Carbonyl Compounds with Dibromomalonic Esters[1)]

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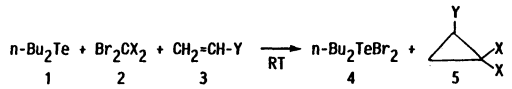
Synopsis. Dibutyl telluride assists cyclopropanation of α,β-unsaturated ketone, ester, and nitrile with dibromomalonic esters without solvent at room temperature. In addition, it effects alkylidenation of aldehydes including α,β-unsaturated aldehyde with the same reagent.

The dehalogenation of *vic*-dibromide with diphenyl telluride giving the corresponding olefin and diphenyltellurium dibromide is the first reported transformation of an organic molecule using organotellurium compound.[2)] The halophilic nature of the divalent telluride is due to high stability of the resulting tetravalent tellurane. A recent paper has described the cyclopropanation of electron-deficient olefins with dibromomalonic ester with the aid of trialkylstibine, giving polysubstituted cyclopropanes with electron-withdrawing groups,[3)] which are very useful in organic syntheses.[4)] This has prompted us to study the utility of organotellurium species in a similar reaction as one of our interests on organotellurium chemistry. We like to report here tellurium-assisted cyclopropanation of α,β-unsaturated carbonyl compounds as well as alkylidenation of common aldehydes including α,β-unsaturated aldehydes with dibromomalonic esters. The latter provides a novel example of tellurium-based condensation, while a Wittig reaction using telluronium ylides has been already known.[5)]

Dibutyl telluride (**1**), like organostibine, induced cyclopropanation of α,β-unsaturated ester, ketone, or nitrile **3** with dibromomalonic ester **2** (Scheme 1).



2	X
a	CO_2Me
b	CO_2Et
c	CN

3	Y
a	CO_2Me
b	CO_2Et
c	CO_2-n-Bu
d	COMe
e	CN

5	X	Y
a	CO_2Me	CO_2Me
b	CO_2Et	CO_2Me
c	CO_2Me	CO_2Et
d	CO_2Et	CO_2Et
e	CO_2Me	CO_2-n-Bu
f	CO_2Et	CO_2-n-Bu
g	CO_2Me	COMe
h	CO_2Et	COMe
i	CN	COMe
j	CO_2Me	CN
k	CO_2Et	CN

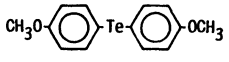
Scheme 1.

The termolecular reaction exothermically took place without solvent at room temperature to give the corresponding cyclopropane derivative **5** in moderate to high yields after 1—24 h. The main by-product was dibutyltellurium dibromide (**4**).[6)] A variety of trisubstituted cyclopropanes **5a—k** were thus obtained by appropriate combinations of reactants summarized in Table 1. When benzene or ethanol was used as a solvent, the reaction took longer time. On the other hand, a similar reaction using dibromomalononitrile (**2c**) instead of dibromomalonic ester vigorously occurred, leading to decomposition in most cases. Only from the reaction of **1**, **2c**, and vinyl methyl ketone (**3d**) in ethanol at 0 °C for 3 h, 1-acetyl-2,2-dicyanocyclopropane (**5i**) could be isolated in 85% yield. Bis(*p*-methoxyphenyl) telluride (**6**) instead of dibutyl telluride hardly promoted the reaction even at 150 °C.

Table 1. Tellurium-Assisted Cyclopropanation and Alkylidenation[a)]

Reactants	Time/h	Product	Yield/%[b)]
2a+3a	12	**5a**	52
2b+3a	12	**5b**	94
2a+3b	18	**5c**	32
2b+3b	16	**5d**	73
2a+3c	12	**5e**	39
2b+3c	24	**5f**	47
2a+3d	1	**5g**	78
2b+3d	1	**5h**	86
2c+3d	3	**5i**	85[c)]
2a+3e	12	**5j**	41
2b+3e	12	**5k**	57
2a+7a	0.5	**9a**	87
2b+7a	0.5	**9b**	79
2a+7b	1	**9c**	59
2b+7b	1	**9d**	68
2a+7c	1	**9e**	82
2b+7c	3	**9f**	47
2a+7d	1	**9g**	47
2b+7d	1	**9h**	63
2a+7e	5	**9i**	66
2b+7e	2	**9j**	53
2a+7f	2	**9k**	71
2b+7f	6	**9l**	48

a) Reaction conditions: no solvent at RT unless otherwise stated. b) Yield of isolated product. c) Reaction conditions: ethanol solvent at 0 °C.



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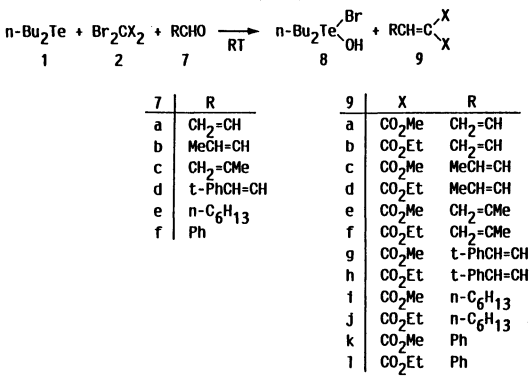
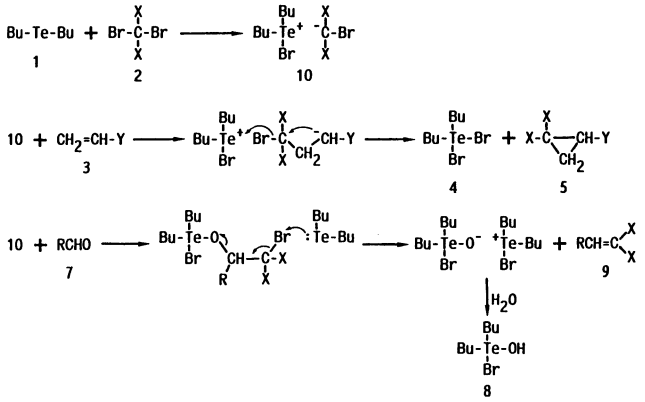
Although organostibine can also induce a similar cyclopropanation of α,β-unsaturated aldehydes, **1** behaves differently. It thus allowed acrylaldehyde (**7a**), crotonaldehyde (**7b**), methacrylaldehyde (**7c**), or *trans*-cinnamaldehyde (**7d**) to react at the aldehyde function with dibromomalonic ester **3**, giving a conjugated olefin **9** (Scheme 2). The optimal reaction required two equiv of **1**, as different from the above cyclopropanation using one equiv of **1**. The formation of **4** as a product from **1** was little detected. On the other hand, dibutylbromotellurium hydroxide (**8**)



Scheme 2.

was obtained in an excellent yield after aqueous treatment of the reaction mixture. This alkylidenation is also applicable for common aldehydes such as heptanal (**7e**) and benzaldehyde (**7f**), affording simple condensed products **9** and accordingly useful as a substitute for Knoevenagel condensation of aldehyde and active methylene.[7]

Although the mechanisms are not established, these reactions are likely to proceed through pathways as shown in Scheme 3. The chemoselectivity of cyclo-



Scheme 3.

propanation and alkylidenation of α,β-unsaturated carbonyl compound **3** depends on reactivity of the initial complex **10**. Aldehydes **7** suffer ready 1,2-addition leading to alkylidenation. In contrast, ketones, esters, and nitriles are inert, and accordingly their conjugated olefins can effect Michael type addition leading to cyclopropanation.

Experimental

Melting points are uncorrected. All reactions were carried out under an argon atmosphere. Dibutyl telluride (**1**),[8] dimethyl dibromomalonate (**2a**),[9] diethyl dibromomalonate (**2b**),[9] and dibromomalononitrile (**2c**)[10] were prepared according to the reported methods. Other chemicals are commercially available. IR spectroscopy was run on a Hitachi 260-30 spectrophotometer. NMR spectra were recorded on a JEOL PMX-60 spectrometer (60 MHz) using carbon tetrachloride as a solvent. Mass spectra were measured with a Shimazu QP-1000 spectrometer.

Typical Procedure for Cyclopropanation: 1-Acetyl-2,2-bis(ethoxycarbonyl)cyclopropane (5h). Diethyl dibromomalonate (**2b**; 954 mg, 3 mmol) and methyl vinyl ketone (**3d**; 267 mg, 3.1 mmol) were placed in a 20 mL round-bottomed flask with a septum cap, which was purged with an argon gas. Dibutyl telluride (**1**; 726 mg, 3 mmol, 1 equiv) was added by a syringe and the mixture was stirred at room temperature under an inert gas. The exothermic reaction was complete within 1h. It was then chromatographed on an alumina column (70—230 mesh) with ethyl acetate as eluent to give first dibutyltellurium dibromide (**4**)[6] as a colorless oil, yield 1.012 g (84%); ^{1}H NMR (CCl_4) δ=0.88—1.21 (m, 6H, $2CH_3$), 1.21—2.60 (m, 8H, $4CH_2$), and 3.41—3.80 (m, 4H, $2TeCH_2$).

Further elution gave 1-acetyl-2,2-bis(ethoxycarbonyl)-cyclopropane (**5h**) as a colorless oil, which was further purified by bulb-to-bulb distillation; bp 88—90 °C/11 Pa (lit,[11] bp 92 °C/11 Pa); yield 587 mg (86%).

5a: colorless oil, bp 137—140 °C/15 Pa; IR (neat) 3020, 1755, 1750, 1735, and 885 cm^{-1}; ^{1}H NMR δ=1.55 (dd, 1H, J=5.5 and 8 Hz), 1.83 (dd, 1H, J=4.5 and 7 Hz), 2.46 (dd, 1H, J=7 and 8 Hz), 3.68 (s, 6H), and 3.74 (s, 3H); MS m/z (rel intensity) 216 (M^+, 0.3) and 157 (M^+-CO_2Me, 100). Anal. ($C_9H_{12}O_6$) C, H.

5b: colorless oil, bp 115—116 °C/5 Pa (lit,[12] bp 84—85 °C/1 Pa).

5c: colorless oil, bp 105—107 °C/11 Pa; IR (neat) 3000, 1760, 1750, 1730, and 865 cm^{-1}; ^{1}H NMR δ=1.25 (t, 3H, J=7 Hz), 1.56 (dd, 1H, J=4.5 and 8 Hz), 1.84 (dd, 1H, J=4.5 and 7 Hz), 2.45 (dd, 1H, J=7 and 8 Hz), 3.66 (s, 3H), 3.74 (s, 3H), and 4.10 (q, 2H, J=7 Hz); MS m/z 230 (M^+, 2.1) and 185 (M^+-OEt, 100). Anal. ($C_{10}H_{14}O_6$) C, H.

5d: colorless oil, bp 99—102 °C/8 Pa (lit,[13] bp 76—80 °C/7 Pa).

5e: colorless oil, bp 103—105 °C/11 Pa; IR (neat) 2960, 1760, 1755, 1730, and 885 cm^{-1}; ^{1}H NMR δ=0.8—1.7 (m, 7H), 1.56 (dd, 1H, J=4.5 and 8.5 Hz), 1.85 (dd, 1H, J=4.5 and 7 Hz), 2.49 (dd, 1H, J=4.5 and 8.5 Hz), 3.67 (s, 3H), 3.74 (s, 3H), and 4.07 (bt, 2H, J=6 Hz); MS m/z (rel intensity) 258 (M^+, 13) and 185 (M^+-OBu, 100). Anal. ($C_{12}H_{18}O_6$) C, H.

5f: colorless oil, bp 129—132 °C/11 Pa; IR (neat) 2990, 1755, 1750, 1745, and 860 cm^{-1}; ^{1}H NMR δ=0.8—1.7 (m, 7H), 1.30 (t, 3H, J=7 Hz), 1.33 (t, 3H, J=7 Hz), 1.51 (dd, 1H, J=4.5 and 8.5 Hz), 1.82 (dd, 1H, J=4.5 and 7 Hz), 2.47 (dd, 1H, J=7 and 8.5 Hz), 4.11 (q, 2H, J=7 Hz), 4.19 (q, 2H, J=7 Hz), and 4.31 (t, 2H, J=6 Hz), MS m/z (rel intensity) 286 (M^+, 0.04) and 185 (M^+-CO_2Bu, 100). Anal. ($C_{14}H_{22}O_6$) C, H.

5g: colorless oil, bp 117—120 °C/11 Pa; IR (neat) 3000, 1730, 1708, and 880 cm^{-1}; ^{1}H NMR δ=1.49 (dd, 1H, J=4.5 and 8.5 Hz), 1.88 (dd, 1H, J=4.5 and 7 Hz), 2.33 (s, 3H), 2.77 (dd, 1H, J=7 and 8.5 Hz), 3.62 (s, 3H), and 3.73 (s, 3H); MS m/z (rel intensity) 200 (M^+, 2.3) and 185 (M^+-Me, 100). Anal. ($C_9H_{12}O_5$) C, H.

5i: colorless oil, bp 129—132 °C/11 Pa; IR (neat) 3120, 2255, 1715, and 840 cm^{-1}; ^{1}H NMR δ=2.0—2.4 (m, 2H), 2.40 (s, 3H), and 3.10 (dd, 1H, J=7 and 8.5 Hz); MS m/z (rel intensity) 134 (M^+, 1.4) and 43 (COMe, 100). Anal. ($C_7H_6N_2O$) C, H, N.

5j: colorless oil, bp 121—123 °C/1470 Pa (lit,[14] bp 123—125 °C/1730 Pa).

5k: colorless oil, bp 99—103 °C/15 Pa (lit,[12] bp 98—100 °C/13 Pa).

Typical Procedure for Alkylidenation: Diethyl 2-Propenylidenemalonate (9b). A mixture of diethyl dibromomalonate (**2b**; 477 mg, 1.5 mmol) and acrylaldehyde (87 mg, 1.5 mmol) was treated with dibutyl telluride (**1**; 726 mg, 3 mmol, 2 equiv) as described for the preparation of **5h**. After 30 min, the mixture was taken up with chloroform (30 mL) and washed with water, dried over anhydrous magnesium sulfate, and concentrated in vacuo. The

residue was diluted with hexane (20 mL). The insoluble material was filtered off and the filtrate was chromatographed on silica-gel column (88—125 mesh) with chloroform to give first dibutyltellurium dibromide (**4**) as a colorless oil, yield 30 mg (5%), and then diethyl 2-propenylidenemalonate (**9b**) as a colorless oil, yield 258 mg (87%), which was purified by bulb-to-bulb distillation; bp 63—65 °C/16 Pa; IR (neat) 2990, 1745, 1720, 1590, and 865 cm^{-1}; ^1H NMR δ=1.27 (t, 3H, J=7 Hz), 1.30 (t, 3H, J=7 Hz), 4.18 (q, 2H, J=7 Hz), 4.20 (q, 2H, J=7 Hz), 5.49 (dd, 1H, J=2 and 9.5 Hz), 5.61 (ddd, 1H, J=9.5, 11, and 17 Hz), and 7.14 (d, 1H, J=11 Hz); MS m/z (rel intensity) 198 (M^+, 31) and 153 (M^+—OEt, 100). HRMS Found: m/z 198.0934. Calcd for $C_{10}H_{14}O_4$: M, 198.0892.

Recrystallization of the insoluble material from benzene-hexane gave white scales of dibutylbromotellurium hydroxide (**8**); yield 811 mg (80%); mp 141—142 °C; IR (KBr) 3450 (O-H) and 2970 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.84—1.20 (m, 6H, $2CH_3$), 1.20—2.33 (m, 8H, $4CH_2$), 1.69 (br s, 1H, OH), and 2.70—3.85 (m, 4H, $2TeCH_2$). Anal. ($C_8H_{19}BrOTe$) C, H.

9a: colorless oil, bp 85—87 °C/15 Pa; IR (neat) 3050, 1735, 1720, 1590, and 840 cm^{-1}; ^1H NMR δ=3.74 (s, 3H), 3.77 (s, 3H), 5.54 (dd, 1H, J=2 and 9.5 Hz), 5.67 (dd, 1H, J=2 and 17 Hz), 6.68 (ddd, J=9.5, 11, and 17 Hz), and 7.16 (d, 1H, J=11 Hz); MS m/z (rel intensity) 170 (M^+, 52) and 139 (M^+—OMe, 100). HRMS Found: m/z 170.0577. Calcd for $C_8H_{10}O_4$: M, 170.0579.

9c: colorless oil, bp 120—123 °C/147 Pa (lit,[15] bp 130—135 °C/200 Pa).

9d: colorless oil, bp 145—148 °C/2000 Pa (lit,[16] bp 143 °C/2000 Pa).

9e: colorless oil, bp 101—103 °C/10 Pa; IR (neat) 2965, 1745, 1735, 1655, and 845 cm^{-1}; ^1H NMR δ=1.89 (br s, 3H), 3.78 (s, 6H), 5.2—5.5 (m, 2H), and 7.19 (s, 1H); MS m/z (rel intensity) 184 (M^+, 100) and 153 (M^+—OMe, 52). HRMS Found: m/z 184.0746. Calcd for $C_9H_{12}O_4$: M, 184.0736.

9f: colorless oil, bp 93—95 °C/4 Pa (lit,[17] bp 85—87 °C/1.3 Pa).

9g: colorless crystals, mp 60—62 °C; IR (KBr disk) 2965, 1745, 1735, 1620, and 865 cm^{-1}; ^1H NMR δ=3.73 (s, 3H), 3.79 (s, 3H), and 6.7—7.6 (m, 8H); MS m/z (rel intensity) 246 (M^+, 42) and 215 (M^+—OMe, 100). Anal. ($C_{14}H_{14}O_4$) C, H.

9h: colorless crystals, mp 35—36 °C (lit,[18] mp 34—35 °C).

9i: colorless oil, bp 125—128 °C/40 Pa; IR (neat) 2970, 1740, 1730, 1645, and 840 cm^{-1}; ^1H NMR δ=0.7—2.5 (m, 13H), 3.70 (s, 3H), 3.75 (s, 3H), and 6.88 (t, 1H, J=8 Hz); MS m/z (rel intensity) 228 (M^+, 5.7) and 197 (M^+—OMe, 100). Anal. ($C_{12}H_{20}O_4$) C, H.

9j: colorless oil, bp 138—141 °C/67 Pa (lit,[19] bp 143—145/67 Pa).

9k: colorless oil, bp 131—134 °C/20 Pa (lit,[20] bp 143—146 °C/27 Pa).

9l: colorless oil, bp 163—165 °C/1470 Pa (lit,[21] bp 179.5 °C/1870 Pa).

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