

Efficient Syntheses of Multisubstituted Methylenecyclopropanes via Novel Ultrasonicated Reactions of 1,1-Dihaloolefins and Metals[†]

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Ultrasonicated reactions of 1,1-dihaloolefins with lithium, magnesium or sodium in the presence of alkenes rapidly afford multisubstituted methylenecyclopropanes.

Dedicated to Professor Lars Skattebøl on the occasion of his 65th birthday.

Additions of alkylidenecarbenes to carbon–carbon double bonds provide a convenient synthesis of substituted methylenecyclopropanes.¹ It has been shown that reactions of 1,1-dibromoolefins² or 1,1-dichloroolefins³ with alkyllithium generate alkylidenecarbenes or the corresponding carbenoids. In contrast, no carbenes were generated when 1,1-dibromoolefins were reacted with a Zn–Cu couple.⁴ However, when 1,1-dibromo-2-methylpropene (**1**) was treated with magnesium in the presence of **2**, carbene adduct **3** was obtained in 18 % yield.⁵

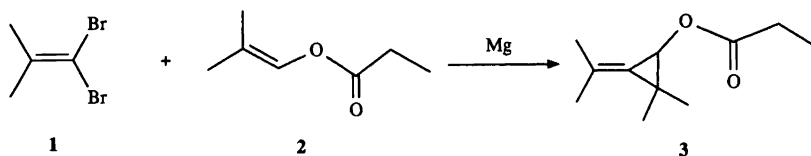
Other olefins, such as cyclohexene, ethyl vinyl ether, cyclohex-1-enyl acetate, and even isopropenyl acetate, an equivalent of **2**, failed to afford the corresponding adducts of alkylidenecarbenes in the reactions of **1** with metals.⁴ Xu *et al.*⁵ reported on reactions of 1,1-dichloroolefins with high surface sodium and found that instead of the expected substituted methylenecyclopropanes, conjugated dienes were obtained as main products.

Organosonochemistry has been intensively studied over the past few years.⁶ In a series of papers the generation of cyclopropylidenes⁷ from ultrasonicated reactions of 1,1-dibromocyclopropanes with lithium and magnesium, respectively, has been reported.⁸ It was found that, in general, good yields could be obtained in short reaction times.

Herein, we report on the generation of alkylidenecarbenes, or the corresponding carbenoids, from reactions of 1,1-dihaloolefins with metals under ultrasonication.

When a mixture of dibromomethylenecyclohexane (**8**), lithium, and cyclohexene in THF was ultrasonicated for 25 min at room temperature in the water bath of an ultrasonic cleaner (120 W, 35 kHz), gas chromatographic analysis showed the total disappearance of **8**. The carbene addition product **9**⁹ was isolated in 85 % yield. In addition, **10** and **11** were also found in small amounts. Similarly, the reaction of dibromomethylenecyclopentane (**4**) with lithium in the presence of cyclohexene gave the corresponding carbene adduct **5**¹⁰ in good yield (see Table 1) along with small amounts of **6** and **7**.

It has been reported that reactions of dibromomethylenecyclobutane (**12**) with phenyllithium in the presence of alkenes only afford [2+2] cycloaddition products of the alkenes with cyclopentyne (**14**)¹¹ which is formed from the rearrangement of the carbene **13** or the corresponding carbenoid.^{2c} A similar rearrangement to **16** was also found in the reaction of bromomethylenecyclohexane with potassium *t*-butoxide.¹⁰ In stark contrast, the main products obtained in the reactions of both **4** and **8** under our conditions proved to be the adducts of cycloalkylidenes although the



Scheme 1.

[†] Carbene Rearrangements 40. For part 39 see: Weber, J., Xu, L. and Brinker, U. H. *Angew Chem.* Submitted for publication.

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In addition to the reaction of both 1,1-dibromo- and 1,1-dichloroolefins **4**, **8**, **12** and **19**, we studied the reaction of bromo(chloro)methylenecyclohexane (**22**) with metals. When treated with sodium, **22** afforded a product composition similar to that observed with **19**. However, with lithium under ultrasonication, **22** yielded chloromethylenecyclohexane (**23**) as the main product. This indicates that the generation of alkylidenecarbenes or the corresponding carbenoids depends upon the different leaving groups present. As expected, in α -elimination reactions chloride is less easily removed than bromide. Thus, the formation of the diene **24** in the reaction of **19** with sodium sand might result from a Wurtz coupling of **23**.

Experimental

^1H and ^{13}C NMR spectra were recorded in ppm on a Bruker AM-360 spectrometer. IR spectra were taken with a Perkin-Elmer 1420 spectrometer. Mass spectra were recorded with a Hewlett Packard HP5890(Ser.II)/HP5971A GC-mass spectrometer. Preparative GC was performed on a $6' \times 0.25''$ aluminium column, 20% OV-17/Chromsorb W (non-acid washed, 80–100 mesh) or a $8' \times 0.25''$ nickel column, 15% OV-17/GasChrom Q (80–100 mesh). All ultrasonicated reactions were carried out in the water bath of a Bandelin SONOREX RK106 ultrasonic cleaner (35 kHz, 120 W).

The dibromomethylenecycloalkanes **4**, **8** and **12** were synthesized according to the literature.¹³ Dichloromethylenecyclohexane **19** was obtained by the method of Ref. 14. Bromo(chloro)methylenecyclohexane **22** was obtained from the Horner–Emmons reaction of cyclohexanone with diethyl bromo(chloro)methylphosphonate. The latter was prepared according to the procedure for the synthesis of diethyl dibromomethylphosphonate in Ref. 13(a), however, the ratio of diethyl chloromethylphosphonate to carbon tetrabromide was changed to 3:1. Under these conditions, diethyl bromo(chloro)methylphosphonate could be obtained in a yield of 71%.

General procedure. 1,1-Dihaloolefin (0.012 mol) and 0.035 mol of lithium shot (6–8 mesh) or magnesium (70–80 mesh), 5 ml of cyclohexene and 15 ml of THF (freshly distilled from LiAlH_4) were placed in a two-necked 50 ml flask with a reflux condenser. The apparatus was immersed into the water bath of an ultrasonic cleaner (35 kHz, 120 W) and placed ca. 0.5 cm above the horn. The reaction mixture was ultrasonicated for 25 min under argon, while the level of the water bath was maintained at the same level of the reaction mixture. After filtration of the metals, the filtrate was washed with water and extracted with pentane. The combined organic layers were dried over anhydrous MgSO_4 . After removal of the solvent, an oil-like product was obtained. The separation was performed by preparative GC.

7-Cyclopentylidenebicyclo[4.1.0]heptane (**5**):¹⁰ ^1H NMR (CDCl_3): δ 1.15–1.23 (m, 4 H, H_2C_3 and H_2C_4), 1.48–1.54

(m, 2 H, HC_1 and HC_6), 1.64–1.76 (m, 8 H, H_2C_2 , H_2C_5 , H_2C_{10} and H_2C_{11}), 2.25–2.35 (m, 4 H, H_2C_9 and H_2C_{12}). ^{13}C NMR (CDCl_3): δ 12.9 (d, $J_{\text{C-H}} = 160$ Hz, C1 and C6), 21.5 (t, $J_{\text{C-H}} = 127$ Hz, C3 and C4), 22.2 (t, $J_{\text{C-H}} = 126$ Hz, C2 and C5), 26.7 (t, $J_{\text{C-H}} = 130$ Hz, C10 and C11), 31.2 (t, $J_{\text{C-H}} = 130$ Hz, C9 and C12), 120.5 (s, C7), 131.0 (s, C8). IR (CDCl_3): $\nu(\text{max})$ 2960 (vs), 2855 (vs), 2680 (w), 2655 (w), 1760 (w), 1605 (m), 1450 (s), 1435 (s), 1365 (w), 1350 (w), 1330 (m), 1305 (w), 1250 (w), 1225 (w), 1210 (w), 1187 (w), 1170 (w), 1152 (w), 1135 (w), 1087 (w), 1062 (w), 842 (m) cm^{-1} . MS m/z (%): 162 (M^{+} , 18), 147 (13), 133 (25), 119 (29), 105 (40), 93 (64), 91 (100), 79 (98), 67 (40), 41 (32); high performance mass spectrum; exact mass (M^{+}): calc. for $\text{C}_{12}\text{H}_{18}$ 162.1408, found 162.1424.

7-Cyclopentylidene-2-oxabicyclo[4.1.0]heptane (**20**). ^1H NMR (CDCl_3): δ 1.37–1.45 (m, 2 H, H_2C_4), 1.62–1.75 (m, 5 H, H-C_6 , H_2C_{10} , and H_2C_{11}), 1.77–1.85 (m, 1 H, *endo* H-C_5), 1.85–1.94 (m, 1 H, *exo* H-C_5), 2.25–2.53 (m, 4 H, H_2C_9 and H_2C_{12}), 3.35 (ddd, 1 H, $J_{\text{gem}} = 10.9$ Hz, $J_{3\text{endo-4}} = 5.4$ and 6.3 Hz, *endo* H-C_3), 3.56 (br dt, 1 H, $J_{\text{gem}} = 10.9$ Hz, $J_{3\text{exo-4}} = 4.1$ Hz, *exo* H-C_3), 3.87 (br d, 1 H, $J_{1,6} = 7.2$ Hz, H-C_1). ^{13}C NMR (CDCl_3): δ 14.3 (d, $J_{\text{C-H}} = 161$ Hz, C6), 19.3 (t, $J_{\text{C-H}} = 130$ Hz, C5), 22.3 (t, $J_{\text{C-H}} = 129$ Hz, C4), 26.45 (t, $J_{\text{C-H}} = 130$ Hz, C11/C10), 26.5 (t, $J_{\text{C-H}} = 130$ Hz, C10/C11), 31.4 (t, $J_{\text{C-H}} = 130$ Hz, C12/C9), 31.9 (t, $J_{\text{C-H}} = 130$ Hz, C9/C12), 50.1 (d, $J_{\text{C-H}} = 187$ Hz, C1), 63.6 (t, $J_{\text{C-H}} = 141$ Hz, C3), 116.2 (s, C7), 136.9 (s, C8). IR (CDCl_3): $\nu(\text{max})$ 2950 (vs), 2850 (vs), 1600 (w), 1420 (m), 1315 (m), 1180 (m), 1130 (m) and 1050 (m) cm^{-1} . MS: m/z : 164 (M^{+} , 13), 136 ($[\text{M}-\text{C}_2\text{H}_4]^{+}$, 55), 135 (30), 121 (24), 117 (20), 108 (66), 107 (76), 108 (65), 93 (64), 91 (67), 79 (100), 77 (52), 67 (45), 65 (28), 55 (23), 53 (21), 41 (45), 39 (46). High performance mass spectrum: found M^{+} 164.1211. Calc. for $\text{C}_{11}\text{H}_{16}\text{O}$: M , 164.1201.

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