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Facile Addition of Dichloroketene to Acetylenes Mediated by Zinc and Ultrasound

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FACILE ADDITION OF DICHLOROKETENE TO ACETYLENES MEDIATED BY ZINC AND ULTRASOUND

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Abstract: The addition of dichloroketene, generated from trichloroacetyl chloride, zinc dust and ultrasound, to terminal and internal acetylenes is reported. This procedure is a more convenient alternative to Zn-Cu couple.

Derivatives of cyclobutene-1,2-diones, squaric acid and semi-squaric acid are attracting considerable interest for their synthetic potential,[1] biological activity,[2] and photochemical behavior.[3] Moore[4a] and Liebeskind[4b] have reported a versatile method for the preparation of substituted cyclobutene-1,2-dione via the addition of organolithiums to commercially available squaric esters. Another common method of synthesis involves thermal [2+2] cycloaddition of perhaloethylene or dichloroketene to acetylenes followed by hydrolysis, however these methods often require long reaction times and/or high temperatures.[5]

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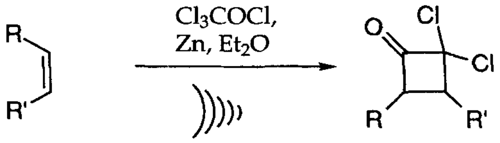
We are currently investigating the photochemistry of simple cyclobutene-1,2-diones and required a convenient method for their preparation. Danheiser[6a] has recently reported that dichloroketene generated from trichloroacetyl chloride and zinc-copper couple reacts smoothly with acetylenes to give 4,4-dichlorocyclobutenones in high yield. There are many variables which must be considered when preparing and using zinc-copper couple such as mesh size and supplier of zinc dust,[6b] time of exposure of zinc to copper sulfate[6a] and the need for a zinc chloride sequestering agent such as dimethoxyethane[6a] or phosphorous oxychloride.[6b] We found this method to be inconvenient due the time consuming preparation of the zinc-copper couple and the long reaction times required for the generation and addition of dichloroketene to acetylenes. In addition, in our hands the activity of the zinc-copper couple degraded rapidly over time.

Ultrasound has been used to mediate a variety of chemical reaction involving active metal surfaces.[7] Mehta and Rao reported that the [2+2] cycloaddition of dichloroketene to a variety of olefins to give 2,2-dichlorocyclobutanones could be promoted if the ketene was generated from trichloroacetyl chloride, zinc dust and ultrasound.[8] To our surprise, this procedure has not been widely applied to acetylenes, in fact we found only one such example in the literature, that being with bis(trimethylsilyl)acetylene.[3a] We report herein the extension of this procedure to terminal and internal acetylenes to yield 2,3-substituted 4,4-dichlorocyclobutenones which are subsequently hydrolyzed to the corresponding cyclobutene-1,2-diones.[5]



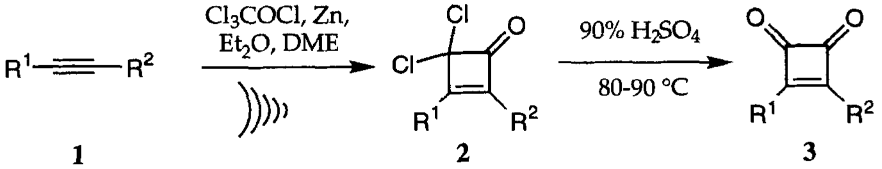


Table 1:

	R_1	R_2	% yield (2a-f)	% yield (3a-f)
a.	Ph	Ph	87	70
b.	Ph	H	69 (82:18)	89
c.	Et	Et	76	91
d.	C_5H_{11}	H	77 (57:43)	83
e.	Ph	Me	81 (>95:5)	90
f.	Ph	Et	88	84

The results of our study are summarized above in Table 1. Internal as well as terminal acetylenes react smoothly with dichloroketene generated from trichloroacetyl chloride, zinc dust and ultrasound in ether to give the corresponding 4,4-dichlorocyclobutenone in respectable yields; generally, the reactions were complete within two hours. Addition of dimethoxyethane improved the yields modestly. The products were analyzed by GC-MS and the mass spectra for all 4,4-dichlorocyclobutenones gave the characteristic isotopic ion distribution for dichlorides. Terminal acetylenes (entries **b** and **d**) gave an inseparable mixture of regioisomers which were resolved by GC. Unsymmetrical internal acetylene **1e** gave greater than a 95:5 ratio of isomers while **1f** appeared to give a single cycloadduct. The mass spectra of these pairs of isomers were nearly identical. Hydrolysis of the geminal dichloride in 90% sulfuric acid at 80-90 °C provided the

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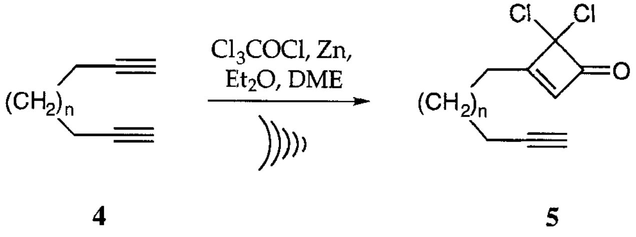

Table 2:

	n	% yield (5a,b)
a.	2	72 (64:34)
b.	1	83 (84:16)

corresponding dione in high yield.[6] Reaction of diynes **4a** and **4b** with dichloroketene under the same conditions as above, provided only the mono-cycloadducts (**5**) in 72% and 83% yield respectively.

The present procedure represents a convenient two-step sequence for the preparation of simple cyclobutene-1,2-diones from the corresponding acetylenes. The sequence is characterized by short reaction times, convenient reaction conditions and good overall yield and should be a valuable method for the preparation of simple substituted cyclobutene-1,2-diones

Experimental Procedures: Ether and dimethoxyethane was freshly distilled from a sodium/benzophenone ketyl. Melting points are uncorrected. NMR data was recorded at 300 MHz in $CDCl_3$; shifts are given in ppm downfield from TMS (δ=0). GC-MS were recorded on a Hewlett-Packard 5890 series II GC with a 5971 series mass selective detector (electron impact ionization) using the following GC parameters: injector temperature: 250 °C; oven temperature: 70 °C for 2 minutes then increased 20 °C per minute until a final temperature of 240 °C is reached; detector temperature: 300 °C; a solvent delay of 2.5 minutes for ether was used.

4,4-Dichloro-2,3-diphenyl-3-cyclobutenones **(2a):** An oven-dried 250 mL round bottom flask was centered in an ultrasonic cleaning bath (Branson model 2200) and charged with 2.32 g of diphenylacetylene (0.013 mols) and 1.83 g of zinc dust (0.026 mols, Aldrich, 325 mesh) in 50 mL of dry diethyl ether under an argon atmosphere. The flask was fitted with a dropping funnel which contained 10 mL of diethyl ether, 12 mL of DME, and 2.18 ml of trichloroacetyl chloride (0.0195 mols). This solution was added dropwise over 45 minutes while the flask was sonicated; the temperature was maintained at 10-15 °C by adding ice to the bath. The reaction mixture was sonicated for 2 hours including addition time. The mixture was quenched with diethyl ether, filtered through celite, then washed three times with 20 mL of water and twice with 20 mL of saturated sodium bicarbonate solution. The organic layer was dried over sodium sulfate, filtered and evaporated. The product was purified by flash chromatography on silica gel to give 3.02g of **2a** (87% yield). Recrystallization with ether/hexanes gave clear needles, mp= 117-120.5 °C (lit.[4b] mp = 121 °C); ^{1}H NMR δ 8.1-8.05 (m, 2H), 7.83-7.78 (m, 2H), 7.64-7.44 (m, 6H); IR (KBr) 1772 cm^{-1} (C=O); MS 225 (100%), 288 (M, 38%), 290 (M+2, 25%), 292 (M+4, 5%); GC retention time 10.8 min.

2b: ether/hexane gave white crystals, mp= 74.3-75.1 °C (lit.[5a] mp = 79.5-80.5 °C); ^{1}H NMR δ 7.93 (d, J= 4.0 Hz, 2H), 7.65-7.56 (m, 3H), 6.62 (s, 1H); IR (KBr) 1775 cm^{-1} (C=O); MS m/z 149 (100%), 212 (M, 49%), 214 (M+2, 32%), 214 (M+4, 5%); GC retention time 7.33 (18%), 7.51 (82%) min.

2c: an amber oil; ^{1}H NMR δ 2.72 (q, J= 7.5 Hz, 2H), 2.25 (q, J= 7.5 Hz, 2H), 1.38 (t, J= 7.5 Hz, 3H), 1.14 (t, J= 7.5 Hz, 3H); IR (thin film) 1788 cm^{-1} (C=O);

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MS m/z 77 (100%), 192 (M, 91%), 194 (M+2, 60%), 194 (M+4, 10%); GC retention time 4.9 min.

Anal. Calcd for $C_8H_{10}Cl_2O$: C, 49.77; H, 5.22. Found : C, 49.86; H, 5.15.

2d: an amber oil; ^{1}H NMR δ 6.20 (t, J= 1.6 Hz, 1H), 2.68 (dt, J= 1.6, 7.5 Hz, 2H), 1.76-1.10 (m, 2H), 1.41-1.35 (m, 4H), 0.91 (t, J= 7.1, 3H); IR (thin film) 1801 cm^{-1} (C=O); MS m/z 150 (100%), 206 (M, 59%), 208 (M+2, 38%), 210 (M+4, 6%); GC retention time 5.3 (43%), 6.03 (57%) min.

2e: yellow plates from ether/hexanes, mp= 130-131.5 °C; ^{1}H NMR δ 7.95-7.92 (m, 2H), 7.61-7.57 (m, 3H), 2.18 (s, 3H); IR (KBr) 1779 cm^{-1} (C=O); MS m/z 163 (100%), 226 (M, 52%), 228 (M+2, 33%), 230 (M+4, 6%); GC retention time 7.52 (4.5%), 7.84 (95.5%) min .

2f: yellow plates from ether/hexanes, mp= 119-123 °C (lit.[5a] mp = 119-121 °C); ^{1}H NMR δ 7.94-7.90 (m, 2H), 7.60-7.57 (m, 3H), 2.61 (q, J= 7.7 Hz, 2H), 1.31 (t, J= 7.7 Hz, 3H); IR 1776 (KBr) cm^{-1} (C=O); MS m/z 240 (M, 100%), 242 (M+2, 55%), 244 (M+4, 7%); GC retention time 8.1 min.

3,4-diphenyl-3-cyclobutene-1,2-dione **(3a):** 860 mg of **2a** was placed in a round bottom flask and immersed in a 80-90 °C water bath. 10 mL of 90% sulfuric acid was added and the mixture stirred for 1 hour. The reaction mixture was poured over ice and extracted three times with 20 ml of ether. The ether layer was washed twice with 20 mL of water and three times with 20 mL of saturated sodium bicarbonate solution. The organic layer was dried over sodium sulfate, filtered and evaporated. The product was purified by flash chromatography on silica gel to give 0.489g of **3a** (70% yield). Recrystallization from chloroform/hexanes gave yellow crystals, mp= 95-96 °C (lit.[5a] mp = 97-97.2 °C);

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^{1}H NMR δ 8.06 (d, J= 7.5 Hz, 2H), 7.63-7.51 (m, 3H); IR (KBr) 1777 cm^{-1} (C=O); MS m/z 178 (100%), 234 (M, 18%); GC retention time 10.7 min.

3b: recrystallization in chloroform/hexanes gave yellow crystals, mp = 148.5-151.5 °C (lit.[5a] mp = 152-153 °C); ^{1}H NMR δ 9.06 (s, 1H), 8.10-8.00 (m, 2H), 7.72-7.60 (m, 3H); IR 1771 cm^{-1} (C=O); MS m/z 102 (100%), 158 (M, 6%); GC retention time 7.35 min.

3c: an amber oil; ^{1}H NMR δ 2.74 (q, J= 7.5 Hz, 2H), 1.29 (t, J= 7.5 Hz, 3H); IR (thin film) 1765 cm^{-1} (C=O); MS m/z 67 (100%), 138 (M, 33%); GC retention time 4.7 min.

Anal. Calcd for $C_8H_{10}O_2$: C, 69.55; H, 7.30. Found : C, 69.57; H, 7.33.

3d:[9] an amber oil; ^{1}H NMR δ 9.27 (t, J= 1.40 Hz, 1H), 2.80 (dt, J= 1.40, 7.7, 2H), 1.75-1.67 (m, 2H), 1.39-1.30 (m, 4H), 0.92 (t, J= 7.30, 3H); IR (thin film) 1798 cm^{-1} (C=O); MS m/z 81 (100%), 152 (M, 20%); GC retention time 5.9 min.

3e: yellow plates from ether/hexanes, mp= 101-103 °C (lit.[4b] mp = 98-100 °C); ^{1}H NMR δ 8.04 (m, 2H), 7.60-7.57 (m, 3H), 2.67 (s, 3H); IR (KBr) 1781 cm^{-1} (C=O); MS m/z 115 (100%), 172 (27%); GC retention time 7.4 min.

3f: yellow plates from ether/hexanes, mp= 57-58 °C (lit.[5a] mp = 62 °C); ^{1}H NMR δ 8.05-8.00 (m, 2H), 7.61-7.57 (m, 3H), 3.09 (q, J= 7.62 Hz, 2H), 1.44 (s, J= 7.66 Hz), 3H); IR (KBr) 1782 cm^{-1} (C=O); MS m/z 115 (100%), 186 (M, 33%); GC retention time 7.8 min.

5a: amber oil; ^{1}H NMR δ 6.27 (t, J=1.6, 1H), 2.75 (d,t, J=1.6, 7.5, 2H), 2.29 (d,t, J=2.6, 6.8,2H), 2.00 (t, J=2.6,1H), 1.93-1.86 (m, 2H), 1.73-1.66 (m, 2H); IR (thin film) 1796 (C=O), 3300 (C≡C), 2100 (≡C-H) cm^{-1}; MS m/z 125 (100%), 216 (M,18%), 218 (M+2, 12%), 220 (M+4, 2%); GC retention time 6.15 (66%), 6.26 (34%) min.

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5b: amber oil; ^{1}H NMR δ 6.27 (t, J = 1.6, 1H), 2.87 (t,d, J = 7.6, 1.5, 2H), 2.37 (t,d, J = 6.8, 2.64, 2H), 2.06 (t, J = 2.7, 1H), 1.94-2.04 (m, 2H); IR (thin film) 1791 cm^{-1} (C=O), 3302 (C$\equiv$C), 2150 ($\equiv$C-H) cm^{-1}; MS m/z 103 (100%), 202 (M, 22%), 204 (M+2, 14%), 206 (M+4, 3%); GC retention time 5.25 (84%), 5.34 (16%) min.

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References and Notes

1. a) Moore, H.W. and Decker, O.H.W., Chem. Rev., 1986, 86, 821. b) Moore, H.W. and Yerxa, B.R., Chemtracts: Org. Chem., 1992, 5, 273. c) Liebeskind, L.S., Tetrahedron, 1989, 45, 3053. d) Negri, J.T., Morwick, T., Doyon, J., Wilson, P.D., Hickey, E.R. and Paquette, L.A., J. Am. Chem. Soc., 1993, 115, 12189. e) Edwards, J.P., Krysan, D.J. and Liebeskind, L.S., J. Am. Chem. Soc., 1993, 115, 9868. f) Gurski, A. and Liebeskind, L.S., J. Am. Chem. Soc., 1993, 115, 6101.
2. a) Cole, R.J., Kirksey, J.W., Cutler, H.G., Doupnik, J.W. and Peckham, J.C., Science, 1973, 179, 1324. b) Springer, J.P., Clardy, J., Cole, R.J., Kirksey, J.W., Hill, R.K., Carlson, R.M. and Isidor, J.L., J. Am. Chem. Soc., 1974, 96, 2267. c) Burka, L.T., Doran, J. and Wilson, B.J., Biochem. Pharmacol., 1982, 31, 79. d) Campbell, E.F., Kinney, W.A., Fengl, R.W.and Liebeskind, L.S., "Abstract of Papers, 208th National Meeting of the American Chemical Society," Washington, DC; American Chemical Society: Washington, DC, August 1994; ORGN 191.

3. a) Zhao, D., Allen, A.D. and Tidwell, T.T., J. Am. Chem. Soc., 1993, 115, 10097. b) Allen, A.D., Lai, W.-Y., Ma, J. and Tidwell, T.T., J. Am. Chem. Soc., 1994, 116, 2625. c) Miller, R.D., Kirchmeyer, S., J. Org. Chem., 1993, 58, 90. d) Boate, D.R., Johnston, L.J., Kwong, P.C., Lee-Ruff, E. and Scaiano, J.C., J. Am. Chem. Soc., 1990, 112, 8858.
4. a) Reed, M.W., Pollart, D.J., Perri, S.T.; Foland, L.D. and Moore, H.W., J. Org. Chem., 1988, 53, 2477. b) Liebeskind, L.S., Fengl, R.W.; Wirtz, K.R. and Shawe, T.T., J. Org. Chem., 1988, 53, 2482. c) also see: Sidduri, A., Budries, N., Laine, R.M.and Knochel, P., Tetrahedron Lett., 1992, 33, 7515.
5. a) Schmidt, A.H. and Ried, W., Synthesis, 1978, 1. b) Toda, F. and Garratt, P., Chem. Rev., 1992, 92, 1685.
6. a) Danheiser, R.L., Savariar, S. and Cha, D.D., Org. Synth., 1989, 68, 32. b) Depres, J.-P. and Greene, A.E., Org. Synth., 1989, 68, 41.
7. a) Abdulla, R.F., Aldrichimica Acta, 1988, 21, 31. b) Einhorn, C., Einhorn, I., Luche, J.-L., Synthesis, 1989, 787.
8. Mehta, G. and Rao, H.S.P., Syn. Commun., 1985, 15, 991.
9. Compound **3d** was shown to be pure by ^{1}H NMR and GC however, repeated attempts to obtain elemental analysis were unsuccessful. Purified **3d** begins to discolor within one hour if left at room temperature.

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