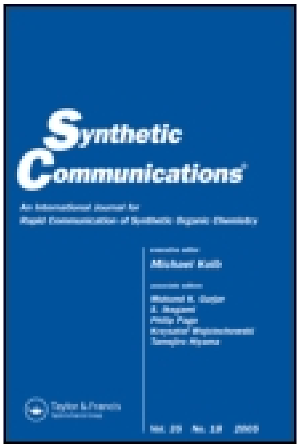

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Conversion of Alkynes into α,α-Dichloro Ketones and α,α-Dichlorodimethyl Ketals Using Trichloroisocyanuric Acid

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ABSTRACT

Trichloroisocyanuric acid reacts with alkynes in the presence of water in acetone or acetonitrile to form α,α-dichloro ketones and in methanol to form α,α-dichlorodimethyl ketals.

Key Words: Alkynes; Oxidation; Addition; Ketones; α,α-Dichloroketones, ketals, α,α-Dichlorodimethylketals; Synthesis; Preparation.

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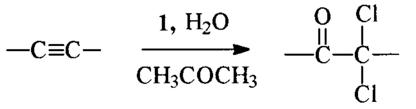
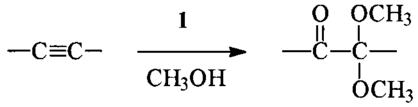
Alkynes can be converted into α,α-dichloro ketones by the action potassium monoperoxysulfate with 1 M HCl in DMF.[1] *N*-chlorosuccinimide in methanol converts alkynes into α,α-dichlorodimethyl ketals which can be hydrolyzed in acid to the corresponding α,α-dichloroketones.[2]

We wish to report that trichoroisocyanuric acid (**1**) [1,3,5-trichloro-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione; TCICA][3] reacts with alkynes in the presence of water to form α,α-dichloro ketones and in methanol to form α,α-dichlorodimethyl ketals as the major products (Eqs. (1) and (2)). Although the product mixtures were quite complex, the desired compound was the major component and could be isolated in reasonable yield and purity. The results are summarized in the Table 1.



$$-C\equiv C- \xrightarrow[CH_3COCH_3]{\mathbf{1},\ H_2O} -\overset{\overset{O}{\|}}{C}-\underset{Cl}{\overset{Cl}{C}}- \qquad (1)$$



$$-C\equiv C- \xrightarrow[CH_3OH]{\mathbf{1}} -\overset{\overset{O}{\|}}{C}-\underset{OCH_3}{\overset{OCH_3}{C}}- \qquad (2)$$

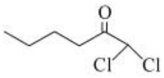
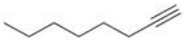
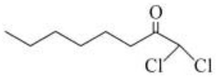
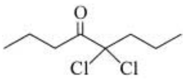
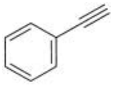
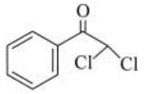
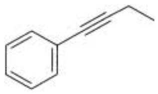
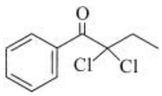
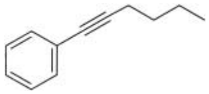
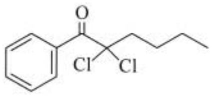
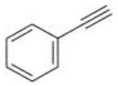
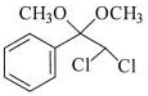
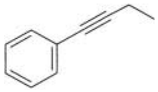
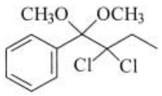
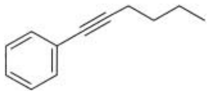
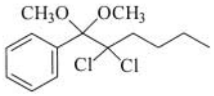
Because the reactions are exothermic and a higher temperature promotes the formation of byproducts, the reaction mixtures were kept below 40°C by means of a room temperature water bath and the slow addition of solid **1**. Acetone and acetonitrile are suitable solvents for the preparation of the ketones, but acetone generally gave higher yields. The product from 1-octyne with **1** in methanol appeared to decompose during distillation and gave an impure product.

It has been proposed that addition of chlorine gives a vinyl cation which then reacts with water to give the enol or with methanol to give the enol ether.[2] These intermediates would be expected chlorinate rapidly a second time leading to the major isolated products. Terminal, phenyl, and symmetrical alkynes gave one major product. Unsymmetrical dialkyl alkynes are expected to give two major products.[2]

EXPERIMENTAL

All reagents were used as received. Reagent grade acetone, anhydrous methanol, 1-hexyne, 1-phenyl-1-butyne, 1-phenyl-1-hexyne, and phenylacetylene were obtained from Aldrich. **1** was obtained from Chem Lab Products (99%, 89% available chlorine). 1-Octyne and 4-octyne were obtained from Farchan. All liquid products were distilled

Table 1.

Entry	Alkyne	Product	Yield (%)	GC purity (%)
1			61	92
2			64	93
3			62	91
4			79	95
5			59	99
6			73	96
7			52	99
8			62	96
9			80	99

through a concentric tube column except for 2,2-dichloro-1,1-dimethoxy-1-phenylbutane, which was purified by simple vacuum distillation.

^{1}H NMR spectra were recorded in $CDCl_3$ using a Brucker AC 200. FT-IR spectra were recorded using Perkin Elmer 1650. GC analyses were obtained using modified Varian 3700 with a 30 m DB-5 capillary column or a Hewlet-Packard 5890 Series II with either a 5 m HP-1 capillary column or a 6 ft 1/8 in 10% Carbowax 20 M packed column.

2,2-Dichloro-1-phenyl-1-hexanone (Entry 6)

1-Phenyl-1-hexyne (15.02 g, 0.0949 mol, 0.1898 π bond eq), water (20.39 g, 1.132 mol), acetone (92 mL), and a magnetic stir bar were added to a 200 mL three-neck round-bottomed flask fitted with a thermometer reaching into the liquid, a condenser, and a solid addition funnel. The flask was placed in a room temperature water bath. In the solid addition funnel was placed **1** (19.22 g, 0.0827 mol, 0.2481 eq). A gentle stream of N_2 was passed through the addition funnel and out the condenser to prevent caking in the tip of the funnel. The **1** was added at 1 min intervals over a period of 35 min, and the temperature of the reaction did not exceed 36°C. After the addition, 15 mL of acetone was used to wash the last traces of **1** into the flask, and stirring was continued for 42 min more. Saturated $NaHSO_3$ solution was added to destroy remaining **1**,[4] and the mixture was filtered to remove the cyanuric acid precipitate. The solution was concentrated on a rotary evaporator, and the residue extracted with ether (2×75 mL). The combined ether layers were washed with 1 N NaOH (50 mL) and saturated NaCl (40 mL), and dried over $MgSO_4$. After filtration and concentration, the residue was distilled through a concentric tube column to give 17.01 g (73%, 96% pure by GC, b.p. 130.0–132.2°C (1.0 torr)) of 2,2-dichloro-1-phenyl-1-hexanone: IR (film) 1701, 1608, 1456, 1259, 1248, 831, 695 cm^{-1}; ^{1}H NMR δ 8.29 (m, 2H, ArH), 7.50 (m, 3H, ArH), 2.50 (m, 2H, CH_2CCl_2), 1.70 (m, 2H, $\mathbf{CH_2}CH_2CCl_2$), 1.44 (sextet, $J = 7.4$, 2H, $\mathbf{CH_2}CH_3$), 0.97 (t, $J = 7.4$, 3H, CH_3); HRMS calcd. for $C_{12}H_{15}OCl_2$ (M + H) 245.04999, found 245.04990.

2,2-Dichloro-1,1-dimethoxy-1-phenylethane (Entry 7)

Phenylacetyl-ene (9.30 g, 0.09105 mol, 0.1821 π bond eq), methanol (100.0 mL, 2.469 mol), and a magnetic stir bar were added to a 200 mL three-neck round-bottomed flask fitted with a thermometer reaching into the liquid, a condenser, and a solid addition funnel. The flask was placed in a room temperature water bath. In the solid addition funnel was placed **1** (10.60 g, 0.04561 mol, 0.1368 eq). A gentle stream of N_2 was passed through the addition funnel and out the condenser to prevent caking in the tip of the funnel. The **1** was added over a period of 15 min, and the temperature of the reaction did not exceed 39°C. Stirring was continued for 2 h more. Saturated $NaHSO_3$ solution was added to destroy remaining **1**,[4] and the mixture was filtered to remove the cyanuric acid precipitate. The solvent was removed on a rotary evaporator and 30 mL of ether was added. More cyanuric acid precipitated and the sample was filtered again. After adding 20 mL more ether, the solution was washed with saturated NaCl (2×20 mL), and dried over $MgSO_4$. After filtration and solvent removal under vacuum, the solid residue was recrystallized from ethanol:water (85:15) to give 11.07 g (52%, 99% pure by GC, m.p. 66.1–66.3°C)[5] of 2,2-dichloro-1,1-dimethoxy-1-phenylethane: IR (mull) 1462, 1451, 1305, 1104, 1075, 1044, 1031, 992, 806, 777, 769, 709, 661 cm^{-1}; ^{1}H NMR δ 7.60 (m, 2H, ArH), 7.33 (m, 3H, ArH), 5.96 (s, 1H, $CHCl_2$), 3.31 (s, 6H, OCH_3); HRMS calcd. for $C_{10}H_{12}O_2Cl$ (M − Cl) 199.05258, found 199.05260.

1,1-Dichloro-2-hexanone (Entry 1)

Mole ratio alkyne:**1**:H_2O 1.20:1:14.34, yield 61% (92% pure by GC), b.p. 131.1–132.0°C (171 torr): IR (film) 1733, 1218, 1149, 793, 736 cm^{-1}; ^{1}H NMR δ 5.82 (s, 1H, $CHCl_2$), 2.84 (t, $J = 7.5$, 2H, CH_2CO), 1.66 (quintet, $J = 7.5$, 2H, $\mathbf{CH_2}CH_2CO$), 1.38 (sextet, $J = 7.5$, 2H, $\mathbf{CH_2}CH_3$), 0.94 (t, $J = 7.5$, 3H, CH_3); HRMS calcd. for $C_6H_{11}OCl_2$ (M + H) 169.01869, found 169.01870.

1,1-Dichloro-2-octanone (Entry 2)

Mole ratio alkyne:**1**:H_2O 1.25:1: 13.74, yield 64% (93% pure by GC), b.p. 133.8–136.7°C (54 torr): IR (film) 1735, 1217, 1142, 791, 735 cm^{-1}; ^{1}H NMR δ 5.82 (s, 1H, $CHCl_2$), 2.82 (t, $J = 7.3$, 2H, CH_2CO), 1.68 (m, 2H, $\mathbf{CH_2}CH_2CO$), 1.33 (m, 6H, $\mathbf{CH_2CH_2CH_2}CH_3$), 0.90 (t, $J = 6.4$, 3H, CH_3); HRMS calcd. for $C_8H_{15}OCl_2$ (M + H) 197.04999, found 197.05000.

5,5-Dichloro-4-octanone (Entry 3)

Mole ratio alkyne:**1**:H_2O 1.31:1: 13.90, yield 62% (91% pure by GC), b.p. 115.0–118.1°C (54 torr): IR (film) 1733, 1155, 1122, 1112, 1010, 894, 760, 670 cm^{-1}; ^{1}H NMR δ 2.93 (t, $J = 7.0$, 2H, CH_2CO), 2.33 (m, 2H, CH_2CCl_2), 1.53, (m, 4H, $\mathbf{CH_2}CH_2CO$ and $\mathbf{CH_2}CH_2CCl_2$), 0.90–1.11 (m, 6H, CH_3 and CH_3); HRMS calcd. for $C_8H_{15}OCl_2$ (M + H) 197.04999, found 197.04997.

α,α-Dichloroacetophenone (Entry 4)

Mole ratio alkyne:**1**:H_2O 1.15: 1:13.70, yield 79% (95% pure by GC), b.p. 96.5–117.7°C (1.5–2.5 torr): IR and ^{1}H NMR spectra were identical to those of an authentic sample.

2,2-Chloro-1-phenyl-1-butanone (Entry 5)

Mole ratio alkyne:**1**:H_2O 1.32:1:15.63, yield 59% (99% pure by GC), b.p. 111.2–112.0°C (2.3 torr): IR (film) 1724, 1252, 1241, 1186, 1106, 1020, 920, 837, 826, 812, 724, 689, 662 cm^{-1}; ^{1}H NMR δ 8.29 (m, 2H, ArH), 7.52 (m, 3H, ArH), 2.53 (q, $J = 7.0$, 2H, CH_2), 1.24 (t, $J = 7.0$, 3H, CH_3); HRMS calcd. for $C_{10}H_{11}OCl_2$ (M + H) 217.01869, found 217.01860.

2,2-Dichloro-1,1-dimethoxy-1-phenylbutane (Entry 8)

Mole ratio alkyne:**1**:CH_3OH 1.33:1:35.55, yield 62% (96% pure by GC), b.p. 100.0–102.0°C (0.25 torr): IR (film) 1450, 1235, 1192, 1181, 1124, 1085, 1064, 918, 837, 831, 803, 755, 709, 680, 668 cm^{-1}; ^1H NMR δ 7.60 (m, 2H, ArH), 7.33 (m, 3H, ArH), 3.50 (s, 6, OCH_3), 1.98 (q, $J = 7.0$, CH_2), 1.14 (t, $J = 7.0$, CH_3); HRMS calcd. for $C_{12}H_{16}O_2Cl$ (M − Cl) 227.08388, found 227.08390.

2,2-Dichloro-1,1-dimethoxy-1-phenylhexane (Entry 9)

Mole ratio alkyne:**1**:CH_3OH 1.25:1:32.40, yield 80% (99% pure by GC), m.p. 44.3–45.1°C (recrystallized from 95% ethanol): IR (mull) 1230, 1190, 1180, 1127, 1111, 1063, 1035, 1020, 943, 820, 800, 760, 741, 718, 709, 678, 652 cm^{-1}; ^1H NMR δ 7.64 (m, 2H, ArH), 7.36 (m, 3H, ArH), 3.52 (s, 6H, OCH_3), 1.87 (m, 2H, CH_2CCl_2), 1.70 (m, 2H, $\mathbf{CH_2}CH_2CCl_2$), 1.28 (sextet, $J = 7.4$, 2H, $\mathbf{CH_2}CH_3$), 0.89 (t, $J = 7.4$, 3H, CH_3); HRMS calcd. for $C_{13}H_{17}OCl_2$ (M–OCH_3) 259.06564, found 259.06560.

ACKNOWLEDGMENT

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4. Wet iodide-starch test paper was used to test for the presence of oxidizing power.
5. Reported m.p. 66–67.5°C, Ref.[2]

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