

DESILYLATIVE CONDENSATION REACTIONS OF ELECTRONEGATIVELY SUBSTITUTED
1-(TRIMETHYLSILYL)CYCLOPROPANES¹

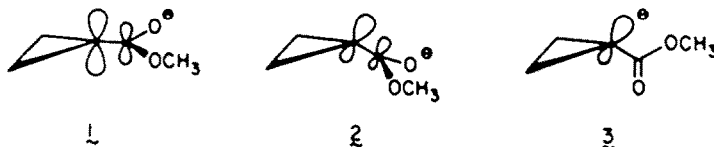
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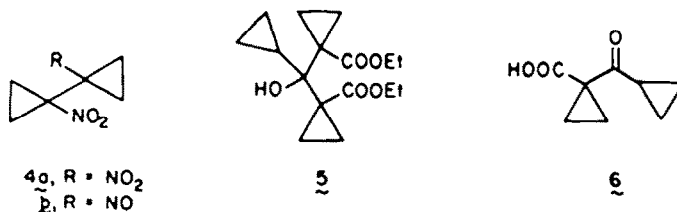
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Abstract: The 1-trimethylsilyl derivatives of methyl cyclopropanecarboxylate, cyanocyclopropane, and acetylcyclopropane are readily converted into tetraalkylammonium salts of the corresponding anions by desilylation. These reactions occur at 0 °C in tetrahydrofuran solution and constitute a preparatively useful method for generating the anions of cyclopropanes containing a conjugative electron-withdrawing group. Benzyltrimethylammonium fluoride has emerged as the promoter of choice in effecting aldol condensations of these reactive intermediates. Extension of this chemistry to more highly delocalized anions such as those derived from 42 and 44 is also detailed.

Protons attached to cyclopropane have long been recognized to be more acidic than their counterparts in larger, less strained rings.^{2,3} The heightened p character of the orbitals external to carbon has properly been held responsible for this phenomenon. This trend is strikingly reversed, however, when the three-membered carbocyclic ring carries a carbonyl, sulfonyl, cyano, or nitro group.^{4,5} The presence of an electron-withdrawing substituent allows for arrival at three principal limiting structures illustrated as 1-3 for the carbo-methoxy derivative.⁶ The accompanying development of a planar carbanion center has dramatic

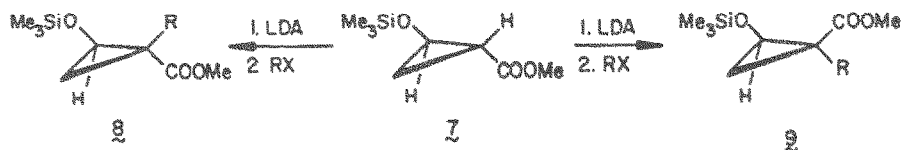


consequences, chief among which are instability and enhanced reactivity. Where the nitro-cyclopropyl anion is concerned,⁷ uncoupling of the electron pair to give a ground-state radical has been postulated.⁸ The chemical end result is formation of 4a and 4b. Attempts to deprotonate ethyl cyclopropanecarboxylate have given rise to trimer 5.⁹ Near 50 °C, the dianion of cyclopropanecarboxylic acid rapidly self-condenses to give 6.¹⁰



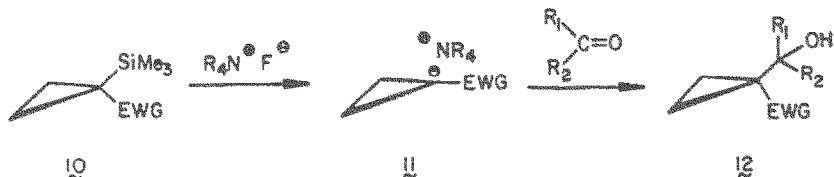
These undesirable side reactions did understandably curtail the use of simple electro-negatively substituted cyclopropanes as synthetic building blocks for some time. More re-cently, however, substantive progress has been made in dealing with their chemical reac-

tivity. For example, it is now recognized that the dianion of cyclopropanecarboxylic acid is capable of condensation with select reactive electrophiles.¹⁰⁻¹² Bulky groups appended to the carbonyl [e.g., *-Stert*Bu,^{13,14} *Otert*Bu,¹⁵ 2,6-di(*tert*-Bu)-4-methylphenoxy¹⁶] retard the proclivity for dimerization and allow various condensation reactions to proceed normally. Reissig's study of 2-silyloxy substituted methyl cyclopropanecarboxylates (7) has shown not only that deprotonation can be conveniently achieved, but that high diastereoselection favoring 8 often operates during subsequent alkylation.^{16,17}

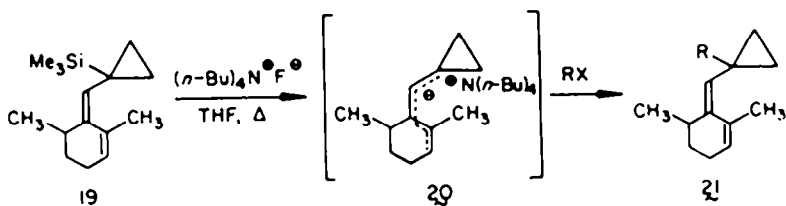
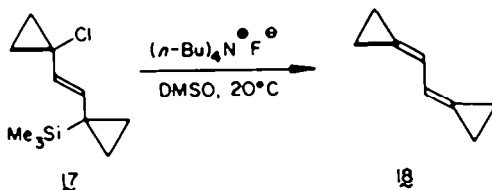
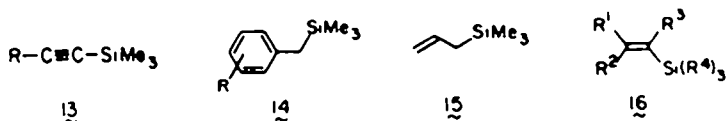


Other electron-withdrawing groups have proven less troublesome, perhaps because of their differing conjugative demand at the α -carbon.¹⁸ Thus, the α -lithio derivatives of cyano,¹⁹ isocyano,²⁰ phenylsulfonyl,²¹ and diethylphosphinoxy cyclopropanes²² have been reported and rather extensively examined.

With the exception of the Hirao study²² and considerably older work on benzoylcyclopropane,^{23,24} the counterion in all of the earlier investigations has been lithium. Although the precise role of the cation is, as always, difficult to delineate precisely, factors such as ion pairing and degree of aggregation are certain to play a role in chemical reactivity. During an investigation of the chemistry of functionalized silylcyclopropanes,^{25,26} we sought to determine if tetraalkylammonium fluoride-induced desilylation of readily available molecules typified by 10 might be a convenient source of carbanions such as 11 where the counterion is now R_4N^+ . Since aldol condensations of cyclopropyl anions had not been examined at the time this work was undertaken,^{27,28} this utilitarian C-C bond-forming process is highlighted here.



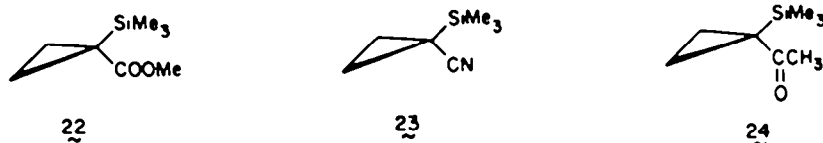
Tetraalkylammonium fluorides are well known to act effectively on silyl substituted compounds such as 13-16 to deliver the corresponding stabilized carbanions and to catalyze certain aldol and alkylation reactions.²⁹ The ability of 2-functionalized cyclopropylsilanes to undergo facile β -elimination in the presence of fluoride ion is recognized to be a general cyclopropane synthesis.³⁰ Furthermore, dicyclopropylideneethane (18) has been arrived at in essentially quantitative yield upon exposure to the conditions illustrated.^{25j} Heating 19 with anhydrous tetra-*n*-butylammonium fluoride in tetrahydrofuran solution generates pentadienyl anion 20, which enters into regioselective electrophile capture at the cyclopropyl carbon atom to give 21 in order to skirt around the development of methylenecyclopropane character.^{25d,i}



As will now be shown, comparable *in situ* removal of an α -Me₃Si group from an electro-negatively substituted three-membered ring is seen to be operationally well suited to preparative cyclopropyl carbanion generation.

Results

First to be examined was methyl ester 22, nitrile 23, and methyl ketone 24. The ester, which had been observed originally as a by-product by Ainsworth and Kuo,¹¹ was prepared in quantity by C-silylation of the dianion of cyclopropanecarboxylic acid and esterification



with diazomethane.³¹ The nitrile was directly accessed by stepwise spiroalkylation of commercially available (trimethylsilyl)acetonitrile with 1,2-dibromoethane in the presence of lithium diisopropylamide.^{25h} Treatment of the carboxylic acid precursor to 22 with excess methyllithium delivered 24 in 80% yield. This route to 24 is more direct than that reported earlier.^{25e}

For the aldol condensations, use was first made of dry tetra-*n*-butylammonium fluoride (TBAF) solutions in cold (0 °C) anhydrous tetrahydrofuran. The aldehyde or ketone was pre-mixed with the fluoride salt and 22 was slowly introduced. Rapid reaction ensued. After 30 min at 0 °C, workup afforded the β -hydroxy esters 25-29 (Table I). These products proved amenable to purification by column or gas chromatography without evidence of retroaldol fragmentation.

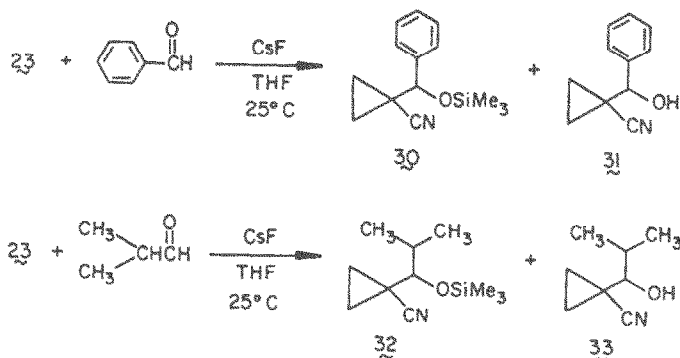
Although the yields involving 22 proved satisfactory in most cases (note consequences of varied equivalents of electrophile), the stringent need for dry TBAF and its recognized tendency for partial degradation³² sometimes proved troublesome. Yields sometimes varied from batch to batch of TBAF, despite careful precautions to duplicate exactly the preparation of

Table I. Desilylation-Aldol Condensations of 22.

fluoride source	carbonyl reagent	mol equiv	product	isolated yield, %
TBAF		5.0		90
TBAF		5.0		51
TBAF		5.0		68
TBAF		1.2		27
		2.2		49
TBAF		1.2		45
		2.0		42

the reagent. When reaction efficiencies dropped, product purification became more tedious and involved, because of the similar R_f values of the impurities.

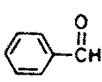
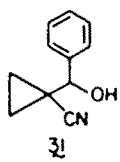
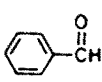
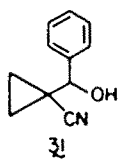
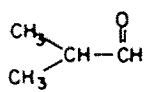
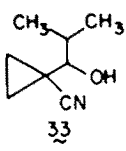
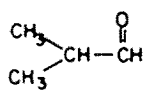
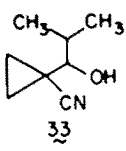
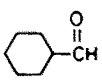
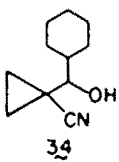
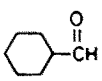
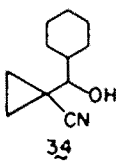

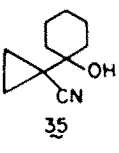

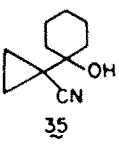
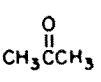
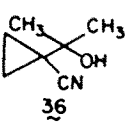
For these reasons, the decision was made to treat 23 with different fluoride sources in the presence of reactive carbonyl partners. The suitability of dry cesium fluoride was therefore tested. In tetrahydrofuran at room temperature, desilylation of 23 was found to occur readily in the presence of this salt. However, straightforward generation of the expected products did not occur. With benzaldehyde as electrophile, the O-silylated alcohol



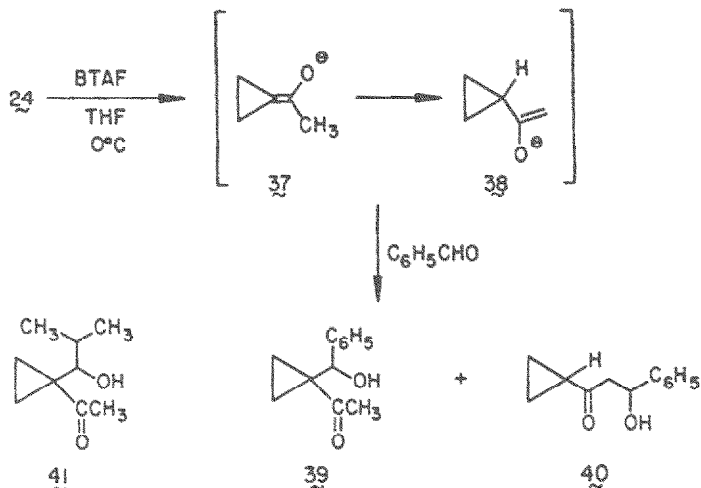
30 was obtained in 59% yield alongside 7% of 31. Similar results were encountered with iso-butylaldehyde, the condensation affording 24% of 32 and 23% of 33. Although the combined yields of these product pairs could pass as acceptable, the generation of mixtures was not. Interestingly, such trimethylsilyl group transfers were witnessed only with cesium fluoride

Although the more stable benzyltrimethylammonium fluoride (BTAF)^{28f} is not as soluble in tetrahydrofuran, its presence served in almost every instance to improve substantially the yield of aldol product (Table II). As before, advantage was taken of the volatility of the lower molecular weight carbonyl co-reagents. They could be introduced in multiple molar equivalents and the excess subsequently removed during solvent evaporation. Self-condensation was not troublesome. In general, the use of TBAF as promoter greatly facilitated product purification, because the reaction mixtures were significantly less contaminated with impurities.

Table II. Desilylation-Aldol Condensations of 23.

fluoride source	carbonyl reagent	mol equiv	product	isolated yield, %
TBAF		2.4		47
BTAF		3.0		83
TBAF		2.2		13
BTAF		2.0		60
TBAF		2.0		21
BTAF		2.0		56
TBAF		1.5		43
BTAF		2.6		43
BTAF		4.3		55

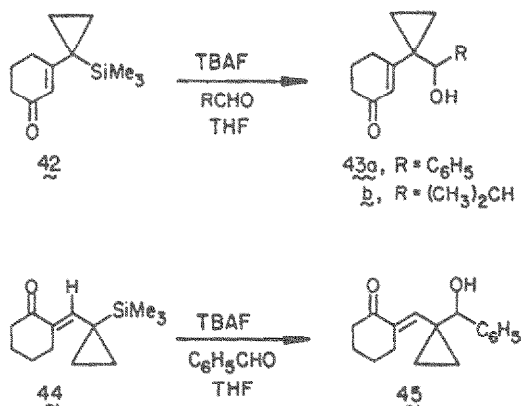
One reason underlying our interest in ketone 24 was the latent tendency of initially formed enolate anion 37 to experience prototropic shift prior to capture of the electrophile. The extent of leakage from 37 to 38 could easily be measured by analysis of the



product distribution. When 24 was reacted with BTAF in the presence of benzaldehyde (2.5 equiv), 39 often proved to be the only product isolated (58-63%). On occasion, varying amounts (up to 19%) of 40 were obtained. Although the underlying cause of this fluctuation in product distribution was never elucidated, we convinced ourselves that proton transfer is not a serious side reaction.

In the single experiment performed in the presence of isobutyraldehyde, 41 was the only aldol product isolated.

The response of 24 prompted examination of the more extended ketonic silylcyclopropanes 42^{25e} and 44.^{25h} In these examples, the enolates produced by desilylation will be



more delocalized than heretofore and consequently less reactive as nucleophilic reagents. Nonetheless, both substrates were successfully engaged in aldol condensations. For example, the conversion of 42 to 43a proceeded in 73% yield. With an increase in steric bulk as found in isobutyraldehyde came a lower yield (27%) of the corresponding aldol 43b. The protonation product, 3-cyclopropylcyclohexenone, was now the major product (70%). Under analogous reaction conditions, 44 was transformed in the presence of benzaldehyde into 45 (45%). Especially noteworthy is the high regioselectivity of these condensations.

In summary, the protocol described above offers an opportunity for developing new synthetic strategies around cyclopropyl carbanions substituted with electronegative groups. The one limitation would appear to be the inertness of the electrophilic partner toward direct reaction with fluoride ion at 0 °C for short periods of time. In no case has an attempt been made to maximize yields. Notwithstanding, TBAF clearly emerges as the promoter of choice for these condensation reactions.

Experimental Section

Desilylative Condensation Reactions of 22. General Procedure. A solution of the ketone or aldehyde (1.2-5.0 mmol) in dry tetrahydrofuran (10 mL) was cooled to 0 °C, whereupon a solution of anhydrous tetra-*n*-butylammonium fluoride (1.2 mmol) in 2-3 mL of the same solvent was added via syringe. To the stirred reaction mixture was added dropwise over about 2 h via a syringe pump a solution of 22 (1.0 mmol) in 2 mL of dry tetrahydrofuran. After being stirred for an additional 30 min, the reaction mixture was poured into a separatory funnel containing 5 mL of water and 25 mL of ether. The organic phase was washed with water and saturated sodium bicarbonate solution before being dried, filtered, and concentrated. The crude products were further purified using conventional techniques.

(a) Methyl 1-(1-Hydroxyethyl)cyclopropanecarboxylate (25). Treatment of 23 in the above manner with 5 equiv of freshly distilled acetaldehyde provided 25 in 90% yield as a colorless liquid following chromatography on silica gel (elution with 15% ethyl acetate in hexane). A sample for analysis was obtained by VPC (6 ft x 0.25 in. 10% SE-30 on Chromosorb G, 80 °C): IR (CHCl₃, cm⁻¹) 3530, 2980, 2960, 2940, 1715, 1440, 1360, 1305, 1238, 1155, 1085, 1025, 955, 905, 855; ¹H NMR (δ, CDCl₃) 3.60 (s, 3 H), 3.55 (q, *J* = 7 Hz, 1 H), 2.95 (br s, 1 H), 1.20 (d, *J* = 6 Hz, 3 H), 1.15-0.70 (2m, 4 H); MS *m/z* 129 (M⁺-CH₃), 127 (M⁺-OH).

Anal. Calcd for C₇H₁₂O₃: C, 58.31; H, 8.41. Found: C, 58.26; H, 8.42.

(b) Methyl 1-(1-Hydroxy-2,2-dimethylpropyl)cyclopropanecarboxylate (26). Treatment of 22 as above with 5 equiv of freshly distilled trimethylacetaldehyde furnished 26 in 51% yield following chromatographic purification on silica gel (elution with 15% ether in hexane). A sample for analysis was obtained by VPC (6 ft x 0.25 in. 10% SE-30 on Chromosorb G, 130 °C): IR (CHCl₃, cm⁻¹) 3580, 3510, 2960, 2905, 2875, 1705, 1478, 1439, 1360, 1330, 1235, 1212, 1191, 1150, 1050, 1010, 978, 765; ¹H NMR (δ, CDCl₃) 3.6 (s, 1 H), 3.55 (s, 3 H), 2.6 (s, 1 H), 1.5-0.7 (m, 4 H), 0.85 (s, 9 H); MS *m/z* 169 (M⁺-OH), 137 (M⁺-OH and CH₃), 129 (M⁺-tBu).

Anal. Calcd for C₁₀H₁₈O₃: C, 64.47; H, 9.76. Found: C, 64.42; H, 9.75.

(c) Methyl 1-(2-Hydroxy-2-propyl)cyclopropanecarboxylate (27). Submission of 22 to the above conditions in the presence of acetone (5 equiv) gave 27 in 68% yield following MPLC on silica gel (elution with 30% ether in hexane). A sample for analysis was obtained by VPC (6 ft x 0.25 in. 10% SE-30 on Chromosorb G, 80 °C): IR (neat, cm⁻¹) 3480, 2955, 2930, 1705, 1435, 1369, 1320, 1197, 1105, 1026, 988, 966, 940, 868, 821, 750; ¹H NMR (δ, CDCl₃) 3.55 (s, 3 H), 3.50 (s, 1 H), 1.25 (s, 6 H), 1.20-1.10 (t, *J* = 2.5 Hz, 2 H), 1.10-0.95 (t, *J* = 2.5 Hz, 2 H); MS *m/z* calcd (M⁺-CH₃) 143.0708, obsd 143.0713.

Anal. Calcd for C₈H₁₄O₃: C, 60.73; H, 8.94. Found: C, 60.64; H, 8.92.

(d) Methyl 1-(Cyclohexylhydroxymethyl)cyclopropanecarboxylate (28). Reaction of 22 as above with cyclohexanecarboxaldehyde (1.2 equiv) gave 28 in 27% yield after chromatographic purification on silica gel (elution with 4% ethyl acetate in hexane). A sample for analysis was obtained by VPC (6 ft x 0.25 in. 10% SE-30 on Chromosorb G, 135 °C): IR (neat, cm⁻¹) 3400, 2900, 1710, 1430, 1320, 1240, 1030, 900, 720; ¹H NMR (δ, CDCl₃) 3.6 (s, 3 H), 2.7-2.4 (m, 2 H), 1.9-0.8 (m, 15 H); MS *m/z* calcd (M⁺-H₂O) 194.1307, obsd 194.1311.

Anal. Calcd for C₁₂H₂₀O₃: C, 67.88; H, 9.51. Found: C, 67.96; H, 9.58.

(e) Methyl 1-(1-Hydroxycyclohexyl)cyclopropanecarboxylate (29). Reaction of 22 according to the above procedure with cyclohexanone (1.2 equiv) gave 29 as a colorless oil after workup and distillation in a Kugelrohr apparatus at 0.05 torr and 110 °C. A sample for analysis was obtained by VPC (6 ft x 0.25 in. 10% SE-30 on Chromosorb G, 135 °C): IR (neat, cm⁻¹) 3450, 2900, 1710, 1420, 1210, 1100, 860, 720; ¹H NMR (δ, CDCl₃) 3.50 (s, 3 H), 2.20 (m, 1 H), 1.80-1.20 (m, 10 H), 1.05-0.85 (m, 4 H); MS *m/z* calcd (M⁺) 198.1256, obsd 198.1294.

Anal. Calcd for C₁₁H₁₈O₃: C, 66.62; H, 9.17. Found: C, 66.82; H, 9.16.

Desilylative Condensation of 23 with Benzaldehyde in the Presence of Cesium Fluoride. A solution of 23 (0.51 g, 3.67 mmol) in 15 mL of anhydrous tetrahydrofuran was added dropwise over 2 h to a magnetically stirred mixture of benzaldehyde (1.00 g, 9.5 mmol) and cesium fluoride (0.92 g, 6.1 mmol) in 10 mL of the same solvent at room temperature. GC analysis indicated ready desilylation at this temperature. The reaction mixture was stirred for 30 min following completion of the addition and poured into 50 mL of saturated salt solution in 50 mL of ether. The reaction flask was rinsed with 50 mL of ether. The layers were separated and the organic phase was washed with 50 mL of saturated sodium bicarbonate solution, dried, and evaporated to leave a white crystalline solid. This material was taken up in 50

mL of 10% aqueous methanol and the solid was collected by suction filtration; the flask was rinsed with an additional amount of aqueous methanol. Additional product crystallized from the filtrate as methanol evaporated from the mixture. The filtration process was repeated four times and the white crystalline 30 was dried in vacuo over phosphorus pentoxide overnight. There was obtained 0.53 g (59%) of 30, mp 97-98 °C; IR (Nujol, cm^{-1}) 2240, 1255, 1085, 1065, 880, 840; ^{13}C NMR (ppm, CDCl_3) 140.6, 129.2, 128.2, 122.1, 74.4, 18.1, 12.2, 11.4, -0.2.

Anal. Calcd for $\text{C}_{14}\text{H}_{19}\text{NO}$: C, 68.52; H, 7.80. Found: C, 68.60; H, 7.82.

The residue which remained after collection of 30 was chromatographed on silica gel as described above and 0.05 g (7%) of 31 was isolated. This compound is characterized below.

Desilylative Condensation Reactions of 23 with BTAF. General Procedure. (a) 1-(1-Hydroxy-2-methylpropyl)cyclopropyl Cyanide (33). A solution of 23 (0.33 g, 2.4 mmol) in 15 mL of anhydrous tetrahydrofuran was slowly added to a magnetically stirred slurry of BTAF (0.65 g, 3.8 mmol) and isobutyraldehyde (0.35 g, 4.9 mmol) in 10 mL of the same solvent at 0 °C. The reaction mixture was stirred for 30 min after completion of the addition and 5 mL of water was added. The reaction mixture was transferred to a separatory funnel and 100 mL of ether was added. The organic layer was washed with 50 mL of saturated salt solution and 50 mL of saturated aqueous sodium bicarbonate solution prior to drying. Evaporation of the solvent gave a clear, colorless liquid which was further purified by chromatography on silica gel (elution with 15% ethyl acetate in petroleum ether). There was isolated 0.20 g (61%) of pure 33; IR (neat, cm^{-1}) 3460, 2240; ^1H NMR (δ , CDCl_3) 2.69 (br d, $J = 7.9$ Hz, 1 H), 2.10 (m, 1 H), 1.81 (br, 1 H), 1.35-1.20 (m, 2 H), 1.08-0.95 (m, 8 H); ^{13}C NMR (ppm, CDCl_3) 121.7, 80.0, 19.3, 18.6, 15.4, 13.3, 11.7.

Anal. Calcd for $\text{C}_8\text{H}_{13}\text{NO}$: C, 69.03; H, 9.41. Found: C, 68.80; H, 9.48.

(b) 1-(1-Hydroxybenzyl)cyclopropyl Cyanide (31). Cyanide 23 (0.33 g, 2.4 mmol) was added to a slurry of BTAF (0.59 g, 3.5 mmol) and benzaldehyde (0.74 g, 7.0 mmol) over 1 h as described above. Pure product was collected by chromatography on silica gel (elution with 15% ethyl acetate in petroleum ether) to give 0.34 g (83%) of 31 as a clear, colorless oil which crystallized upon standing at 0 °C overnight; mp 78.5-79.5 °C (from hexanes); IR (Nujol, cm^{-1}) 3420, 2240, 1085, 1060; ^1H NMR (δ , CDCl_3) 7.45-7.35 (m, 5 H), 4.37 (s, 1 H), 2.78 (br, 1 H), 1.31-1.06 (m, 4 H); ^{13}C NMR (ppm, CDCl_3) 140.0, 128.6, 128.5, 126.2, 121.7, 75.1, 17.4, 12.5, 11.4.

Anal. Calcd for $\text{C}_{11}\text{H}_{11}\text{NO}$: C, 76.28; H, 6.40. Found: C, 76.01; H, 6.47.

(c) 1-(Cyclohexylhydroxymethyl)cyclopropyl Cyanide (34). Cyanide 23 (0.32 g, 2.3 mmol) was added to a slurry of BTAF (0.57 g, 3.4 mmol) and cyclohexanecarboxaldehyde (0.53 g, 4.7 mmol) over 3 h as described above. Pure product was collected by chromatography on silica gel (elution with 20% ethyl acetate in petroleum ether). There was isolated 0.23 g (56%) of 34 as a clear, colorless oil; IR (neat, cm^{-1}) 3460, 2230; ^1H NMR (δ , CDCl_3) 2.66 (d, $J = 8.3$ Hz, 1 H), 2.08-2.03 (br m, 3 H), 1.93-1.65 (m, 4 H), 1.39-1.09 (m, 5 H), 1.06-0.90 (m, 4 H).

Anal. Calcd for $\text{C}_{11}\text{H}_{17}\text{NO}$: C, 73.70; H, 9.56. Found: C, 73.35; H, 9.59.

(d) 1-(1-Hydroxycyclohexyl)cyclopropyl Cyanide (35). Cyanide 23 (0.37 g, 2.7 mmol) was added to a slurry of BTAF (0.51 g, 3.0 mmol) and cyclohexanone (0.38 g, 3.9 mmol) over 3 h as described above. A clear liquid was obtained after removal of volatiles on the rotary evaporator and cyclohexanone under vacuum (0.3 mm). A white solid was obtained (0.19 g, 43%), mp 93-94 °C (from hexanes); IR (CHCl_3 , cm^{-1}) 3610, 3480, 3010, 2950, 2870, 2250, 1455, 1160, 1070, 990; ^1H NMR (δ , CDCl_3) 1.83-1.42 (m, 10 H), 1.13 (br, 1 H), 1.08-1.02 (m, 4 H); ^{13}C NMR (ppm, CDCl_3) 123.0, 69.3, 35.4, 25.2, 21.5, 20.4, 9.4.

Anal. Calcd for $\text{C}_{10}\text{H}_{15}\text{NO}$: C, 72.69; H, 9.15. Found: C, 72.66; H, 9.18.

1-Acetyl-1-trimethylsilylcyclopropane (24). A 1.7 M solution of methyl lithium in ether (78 mL, 133 mmol) was added dropwise over 25 min to a magnetically stirred solution of 1-(trimethylsilyl)cyclopropanecarboxylic acid (7.0 g, 44 mmol) in 250 mL of ether cooled in an ice water bath. Midway through the addition, the cooling bath was removed and the reaction mixture was allowed to come to room temperature, at which point stirring was maintained for an additional 5.5 h. The reaction mixture was transferred to a separatory funnel and added to a solution of 15 g of ammonium chloride in 500 mL of water over 10 min with magnetic stirring. The layers were separated and the organic phase was washed twice with 150 mL portions of saturated aqueous sodium bicarbonate solution prior to drying. Concentration on a rotary evaporator gave a clear yellow liquid which was distilled under reduced pressure to give 5.5 g (80%) of 24, bp 62-63 °C (6.0 mm). The spectral properties of this material were identical to those reported earlier.^{25e}

1-Acetyl-1-(hydroxybenzyl)cyclopropane (39). A 0.39 g (2.5 mmol) sample of 24 was added to a slurry of BTAF (0.84 g, 5.0 mmol) and benzaldehyde (0.66 g, 6.2 mmol) over 2 h as described for 23. After workup, the crude product was chromatographed on silica gel (elution with 50:50 ether-petroleum ether). Major product 39 eluted first: 0.28 g (58%); IR (neat, cm^{-1}) 3450, 1690; ^1H NMR (δ , CDCl_3) 7.35-7.23 (m, 5 H), 5.03 (s, 1 H), 3.5 (br, 1 H), 1.94 (s, 3 H), 1.32-1.20 (m, 1 H), 1.19-1.13 (m, 1 H), 1.09-1.02 (m, 1 H), 0.85-0.78 (m, 1 H); ^{13}C NMR (ppm, CDCl_3) 209.8, 140.9, 128.1, 127.6, 126.9, 74.3, 37.3, 24.9, 13.9, 11.8.

Anal. Calcd for $\text{C}_{12}\text{H}_{14}\text{O}_2$: C, 75.76; H, 7.42. Found: C, 75.56; H, 7.43.

1-Acetyl-1-(1-hydroxy-2-methylpropyl)cyclopropane (41). A 0.30 g (1.92 mmol) sample of 24 in 15 mL of anhydrous tetrahydrofuran was added to a slurry of BTAF (0.55 g, 3.3 mmol) and isobutyraldehyde (0.53 g, 4.4 mmol) in 10 mL of the same solvent at 0 °C over 2 h as described for 23. The usual workup and chromatography (silica gel, elution with 50% ether

in petroleum ether) furnished 80 mg (27%) of 41. The analytical sample was obtained as a colorless oil by preparative VPC (6 ft x 0.25 in. 5% SE-30 on Chromosorb C, 150 °C); IR (neat, cm^{-1}) 3460, 1680; $^1\text{H NMR}$ (δ , CDCl_3) 2.70 (d, $J = 7.5$ Hz, 1 H), 2.08 (m, 1 H), 1.94 (s, 3 H), 1.88 (br, 1 H), 1.27 (t, $J = 7.5$ Hz, 6 H), 1.30-1.13 (m, 2 H), 1.10-0.86 (m, 2 H).

Anal. Calcd for $\text{C}_9\text{H}_{16}\text{O}_2$: C, 69.19; H, 10.32. Found: C, 68.77; H, 10.41.

Condensation of 42 with Benzaldehyde in the Presence of TBAF. A solution of 42 (0.19 g, 0.91 mmol) in 10 mL of anhydrous tetrahydrofuran was added dropwise to a magnetically stirred slurry of BTAF (0.18 g, 1.07 mmol) and benzaldehyde (0.24 g, 2.3 mmol) in 5 mL of the same solvent at 0 °C over 2 h. The reaction mixture was stirred for an additional 30 min and 2 mL of water was added. The reaction mixture was transferred to a separatory funnel, diluted with 100 mL of ether, and washed with 50 mL of brine and 50 mL of saturated sodium bicarbonate solution prior to drying. Solvent evaporation gave a clear yellow oil which was chromatographed on silica gel (elution with 20% ethyl acetate in petroleum ether). There was obtained 0.16 g (73%) of 43a as a clear oil which solidified to a white solid on standing at room temperature overnight; mp 92.5-94.5 °C; $^1\text{H NMR}$ (δ , CDCl_3) 7.33-7.24 (m, 5 H), 5.86 (t, $J = 1.4$ Hz, 1 H), 4.71 (s, 1 H), 2.40-2.25 (m, 3 H), 2.17-2.07 (m, 1 H), 1.89-1.79 (m, 2 H), 1.60 (br, 1 H), 1.03-0.88 (m, 2 H), 0.82-0.72 (m, 2 H); $^{13}\text{C NMR}$ (ppm, CDCl_3) 200.0, 166.2, 141.6, 128.6, 128.3, 128.0, 126.4, 76.9, 37.6, 33.4, 29.2, 23.0, 10.7, 10.0.

Anal. Calcd for $\text{C}_{17}\text{H}_{20}\text{O}_2$: C, 79.65; H, 7.86. Found: C, 79.58; H, 8.03.

Condensation of 42 with Isobutyraldehyde in the Presence of TBAF. A solution of 42 (0.22 g, 1.06 mmol) in 10 mL of anhydrous tetrahydrofuran was added dropwise to a magnetically stirred slurry of BTAF (0.31 g, 1.8 mmol) and isobutyraldehyde (0.25 g, 3.5 mmol) in 10 mL of the same solvent at 0 °C over 2 h. Workup and chromatography in the predescribed manner afforded 60 mg (27%) of 43b as a colorless oil. The major product was desilylated starting material (100 mg). For 43b: $^1\text{H NMR}$ (δ , CDCl_3) 5.98 (s, 1 H), 2.92 (d, $J = 7.8$ Hz, 1 H), 2.73-2.63 (m, 1 H), 2.41-2.31 (m, 3 H), 2.00-1.89 (m, 2 H), 1.75-1.66 (m, 2 H), 0.94 (t, $J = 6.7$ Hz, 6 H), 0.89-0.78 (m, 4 H); MS m/z calcd (M^+) 208.1463, obsd 208.1455.

Condensation of 44 with Benzaldehyde in the Presence of TBAF. A solution of 44 (0.09 g, 0.41 mmol) in 10 mL of dry tetrahydrofuran was added to a cold (0 °C), magnetically stirred slurry of TBAF (0.20 g, 1.2 mmol) and benzaldehyde (0.23 g, 2.2 mmol) in 5 mL of the same solvent. After 30 min, water (2 mL) was introduced, stirring was continued for 10 min, and the usual workup followed. Silica gel chromatography (elution with 20% ethyl acetate in petroleum ether) gave 45 mg (45%) of 45 as a colorless solid, mp 101-102 °C (from ether-hexanes); $^{13}\text{C NMR}$ (ppm, CDCl_3) 202.0, 142.0, 141.7, 135.7, 128.1, 127.7, 126.4, 79.1, 40.6, 28.2, 26.0, 23.6, 23.5, 11.6, 11.1.

Anal. Calcd for $\text{C}_{17}\text{H}_{20}\text{O}_2$: C, 79.65; H, 7.86. Found: C, 79.38; H, 7.93.

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