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In contrast to the reaction with CF_3OF,[2] the amide group survives our reaction conditions as is demonstrated by the reaction of acetanilide. Thus, it is also possible to apply this method on various aniline derivatives. Phenol, on the other hand, reacts too vigorously and produces various oligomers, polymers, and carbonyl-containing compounds. The reaction can be tamed to some extent by introducing an electron-withdrawing group as in the case of methyl salicilate although the yield is only 20%. Yet, when such a deactivated group is present, but the phenolic hydroxyl is protected as in the case of *p*-nitroanisol, the yield is more than doubled (see Table I). Good yields are also obtained in the fluorination of 2-methoxynaphthalene. The yield is even better with the more activated 1,3-dimethoxybenzene. Its reaction with CH_3COOF produces mainly the 1,5-difluoro-2,4-dimethoxybenzene along with the monofluoro derivative in practically quantitative yield.

Acknowledgment. We thank the Israel Commission for basic research and The Israel Academy of Sciences and Humanity for financial support.

Registry No. 1, 78948-09-1; acetanilide, 103-84-4; anisole, 100-66-3; 1,3-dimethoxybenzene, 151-10-0; 2-methoxynaphthalene, 93-04-9; 1-methoxy-4-nitrobenzene, 100-17-4; methyl 2-hydroxybenzoate, 119-36-8; *o*-fluoroacetanilide, 399-31-5; *p*-fluoroacetanilide, 351-83-7; *o*-fluoroanisole, 321-28-8; *p*-fluoroanisole, 459-60-9; 1-fluoro-2,4-dimethoxybenzene, 17715-70-7; 1,5-difluoro-2,4-dimethoxybenzene, 79069-70-8; 1-fluoro-2-methoxynaphthalene, 27602-71-7; 2-fluoro-1-methoxy-4-nitrobenzene, 455-93-6; methyl 3-fluoro-2-hydroxybenzoate, 70163-98-3; methyl 5-fluoro-2-hydroxybenzoate, 391-92-4.

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such interactions are also operative in transition states. In any case, it is clear at this stage, that there is an interaction between the heteroatom and the hypofluorite 1, resulting in a subsequent attack mainly at the ortho position. The reaction of 1 with toluene also supports this idea. Being less activated toward electrophilic substitutions, toluene reacts slowly, and after 2 h the conversion is less than 50%. The part that does react yields a lot of tar, but still a small amount of fluorinated toluenes can be detected. However, since in this case no interactions are likely between the aromatic methyl group and the hypofluorite 1, the ratio of the *o*-fluoro- to *p*-fluorotoluene is about 1:1.

(8) Zefirov, N. S.; Samoshin, V. V.; Sabotin, O. A.; Baranenkov, V. I.; Wolfe, S. *Tetrahedron* **1978**, *34*, 2953.

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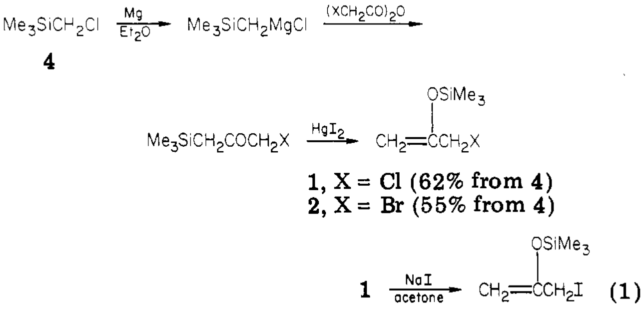
3-Chloro-2-(trimethylsiloxy)-1-propene as an Electrophilic Acetonyl Equivalent. A Novel Regioselective Synthesis of 1,4-Dicarbonyl Compounds[1]

Summary: α-Metalated imines, hydrazones, and activated methylene compounds are acetonylated with 3-chloro-2-(trimethylsiloxy)-1-propene in high yield. Highly regioselective acetonylation at either the tertiary or secondary α-carbon of 2-methylcyclohexanone can be carried out by selecting the reaction condition.

Sir: Acetonylation of ketone enolates is one of the most important routes to the synthesis of 1,4-diketones which can serve as precursors for the synthesis of naturally occurring cyclopentanoids, furans, and pyrroles,[2,3] and therefore numerous efforts have been directed to the development of new acetonylating reagents.[4] For instance, 3-bromo-2-methoxypropene[4j] and in situ generated 3-bromo-2-[(tetrahydropyran-2-yl)oxy]propene[4k] have been proposed as convenient electrophilic reagents for introducing an acetonyl group by a single-step process, but these reagents are rather thermally unstable. Preparation of the pure reagents requires tedious procedures in low yield. We have previously described that allylsilanes can be viewed as useful nucleophilic acetonyl equivalents.[5]

In this report we show that 3-chloro-2-(trimethylsiloxy)-1-propene (**1**) serves as a novel and convenient electrophilic acetonylating reagent toward several α-metalated species of imines, hydrazones, and activated methylene compounds. Moreover, we show that highly regioselective acetonylation at either the tertiary or secondary α-carbon of 2-methylcyclohexanone can be carried out by selecting the reaction condition.

The requisite acetonylation reagent 3-chloro-2-(trimethylsiloxy)-1-propene (**1**) was prepared as reported previously.[6] The corresponding bromo (**2**) and iodo (**3**) derivatives are prepared as shown in eq 1.



$$Me_3SiCH_2Cl \xrightarrow[Et_2O]{Mg} Me_3SiCH_2MgCl \xrightarrow{(XCH_2CO)_2O}$$

4

$$Me_3SiCH_2COCH_2X \xrightarrow{HgI_2} CH_2{=}C(OSiMe_3)CH_2X$$

1, X = Cl (62% from **4**)
2, X = Br (55% from **4**)

$$\mathbf{1} \xrightarrow[acetone]{NaI} CH_2{=}C(OSiMe_3)CH_2I \quad (1)$$

3 (57%)

1 was thermally and photochemically quite stable and was used most conveniently. Although the reactivity of **2** and **3** are expected to be higher than **1**, these are rather unstable compounds.

For the acetonylation, **1** was allowed to react with metalloenamines (**6**), prepared from imines (**5**) of enolizable ketones and lithium diisopropylamide (LDA) or *sec*-bu-

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[1] Chemistry of Organosilicon Compounds. 148.

(2) For reviews, see (a) Harris, T. M.; Harris, C. N. *Org. React.* **1969**, *17*, 155. (b) Reiff, H. *Newer Meth. Prep. Org. Chem.* **1971**, *6*, 48. (c) Nakai, T. *J. Syn. Org. Chem., Jpn.* **1978**, *36*, 49.

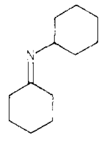
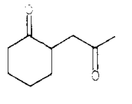
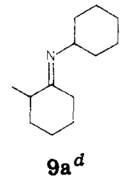
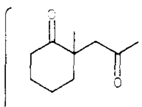
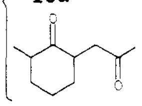
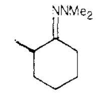
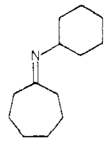
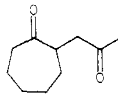
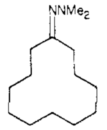
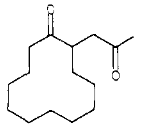
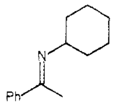
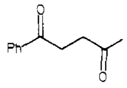
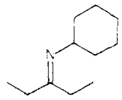
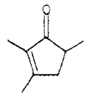
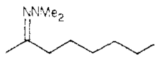
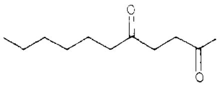
(3) (a) Grieco, P. A.; Pogonowski, C. S. *J. Org. Chem.* **1974**, *39*, 732. (b) Hegedus, L. S.; Stiverton, R. K. *J. Am. Chem. Soc.* **1974**, *96*, 3250. (c) Nakai, T.; Shiono, H.; Okawara, M. *Tetrahedron Lett.* **1975**, 4027. (d) Ito, Y.; Konoike, T.; Harada, T.; Saegusa, T. *J. Am. Chem. Soc.* **1977**, *99*, 1487 and references cited therein.

(4) (a) Stork, G.; Jung, M. E. *J. Am. Chem. Soc.* **1974**, *96*, 3682. (b) Stork, G.; Borch, R. *Ibid.* **1964**, *86*, 935. (c) Nienhouse, N. J.; Irwin, R. M.; Finni, G. R. *Ibid.* **1967**, *89*, 4557. (c) Dox, A. W.; Houston, B. *Ibid.* **1924**, *46*, 252. (e) Miyashita, M.; Yanami, T.; Yoshikoshi, A. *Ibid.* **1976**, *98*, 4679. (f) Islam, A. M.; Raphael, R. A. *J. Chem. Soc.* **1952**, 4086. (g) Miller, R. M. *Synth. Commun.* **1972**, *2*, 267. (h) Deboer, A.; Ellwanger, R. E. *J. Org. Chem.* **1974**, *39*, 77. (i) Miyano, M.; Dorn, C. R. *Ibid* **1972**, *37*, 268. (j) Greenwood, G.; Hoffmann, H. M. R. *Ibid.* **1972**, *37*, 611. (k) Horning, D. E.; Kavadias, G.; Muchowski, J. M. *Can. J. Chem.* **1970**, *48*, 975. (l) Jacobson, R. M.; Raths, R. A.; McDonald III, J. H. *J. Org. Chem.* **1977**, *42*, 2545 and references cited therein.

(5) Hosomi, A.; Kobayashi, H.; Sakurai, H. *Tetrahedron Lett.* **1980**, *21*, 955.

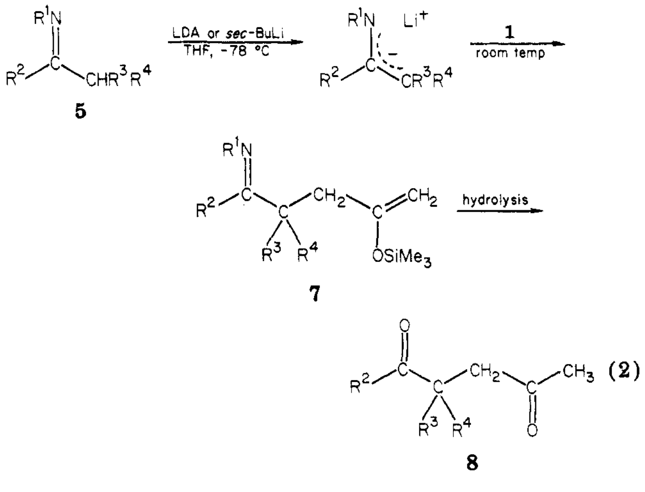
(6) Sakurai, H.; Shirahata, A.; Araki, Y.; Hosomi, A. *Tetrahedron Lett.* **1980**, *21*, 2325. **1**, bp 61–63 °C (35–37 mmHg); IR (neat) 2960, 2900, 1635, 1315, 1260, 1225, 1160, 1030, 915, 850 cm^{-1}; NMR (CCl_4) δ 0.40 (s, 9 H), 3.92 (s, 2 H), 4.28 (br s, 1 H), 4.50 (br s, 1 H). 3-Bromo-2-(trimethylsiloxy)-1-propene (**2**), bp 57 °C (15 mmHg), was prepared similarly from bromoacetic anhydride in 55% yield. The iodo derivative (**3**) was obtained by the Finkelstein reaction of **1** with NaI in acetone in 57% yield. **1** was thermally and photochemically quite stable, but both **2** and **3** were not.

Table I. Reactions of α-Lithiated Imines and Hydrazones with 3-Chloro-2-(trimethylsiloxy)-2-propene (1)[a]

entry	substrate	hydrolysis condition	products	% yield[b]
1	 **19**	aq $(CO_2H)_2$, room temp, 4 h	 **13a**[4e,4k,13]	82
2	**19**[c]	aq NaOAc, reflux, 5 h	**13a**	
3	 **9a**[d]	aq NaOAc, reflux, 20 h	 **10a**[e,4a,4e]  **10b**[e,f,4e]	63 8
4	 **9b**	1 M HCl, room temp, 2 h	**10b**[g]	97
5		aq NaOAc, reflux, 15 h	 **13b**[4f,4k]	94
6		1 M HCl, room temp, 3 h	 **(13c)**	63
7		aq NaOAc, reflux, 15 h		77
8		aq NaOAc, reflux, 15 h		96
9	 **11**	1 M HCl, room temp, 3 h		92

[a] Metalloenamines were prepared by the addition of *sec*-BuLi to imines and hydrazones in THF at −78 °C unless otherwise noted and the allylation was carried out at room temperature for 30 min. [b] Yields after isolation. [c] LDA was used as a base. [d] The metalloenamine was prepared by the addition of **9a** to *sec*-BuLi. [e] Isolated by HPLC. [f] A 4:6 diastereomeric mixture. The ratio was determined by HPLC. [g] A 3:7 diastereomeric mixture.

tyllithium in THF, to yield the corresponding alkylated imines (**7**), which were readily converted to 1,4-dicarbonyl compounds (**8**) after careful hydrolysis,[8,9] (eq 2). As shown in Table I, a wide range of imines gave the desired acetonylation products normally in excellent yields. The



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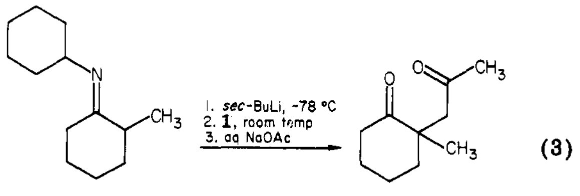
(7) Lutsenko, I. F.; Bankov, Y. I.; Dudukina, O. V.; Karamanowa, E. N. *J. Organometal. Chem.* **1968**, *11*, 35.

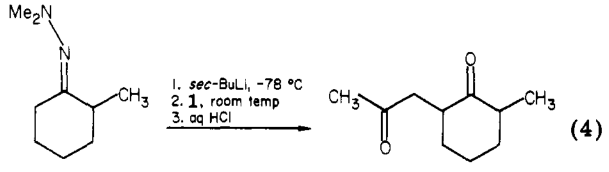
(8) The following procedure is typical. To a solution of *N*-(cyclohexylidene)cyclohexylamine (358 mg, 2 mmol) in THF (6 mL) was added 1.5 M *sec*-butyllithium (1.6 mL, 2.4 mmol) in pentane at −78 °C. Then **1** (659 mg, 4 mmol) was added at room temperature and the mixture was stirred for 30 min. The reaction mixture was carefully hydrolyzed with aqueous oxalic acid and extracted with ether. The organic layer was dried over $MgSO_4$ and concentrated. The residue was purified by column chromatography packed with silica gel, using *n*-hexane as an eluant, to give a 1,4-diketone **13a** (250 mg, 1.6 mmol) in 82% yield.

(9) Satisfactory IR, NMR, and low- and high-resolution mass spectra, and elemental analysis were obtained for all products in this paper.



(3)

9a **10a**



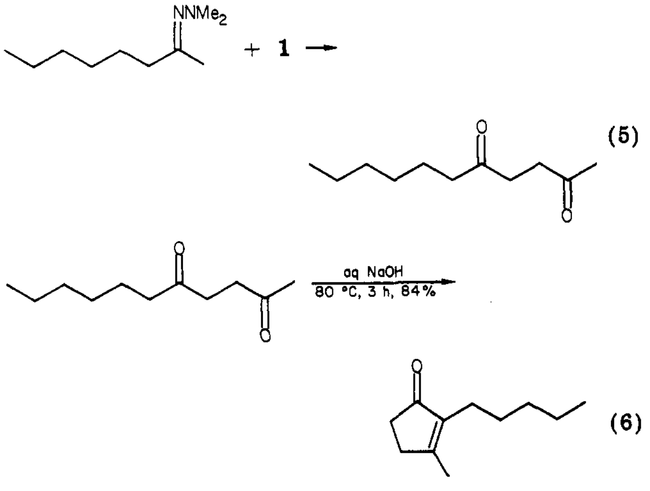
(4)

9b **10b**

acetonylation of α-metalated hydrazones also took place very smoothly.

Interestingly, the regioselective acetonylation can be achieved by changing the substituent on the nitrogen atom of the imines (5). Thus, the metalloenamine of *N*-(2-methylcyclohexylidene)cyclohexylamine (**9a**) reacted with **1** very selectively at the sterically more hindered carbon atom (entry 3, eq 3),[10] in sharp contrast to the work of Stork and Fraser.[10a,c] On the other hand, acetonylation at the less alkylated carbon atom occurred with the α-lithiated dimethylhydrazone[11] (entry 4 and 9, eq 4).

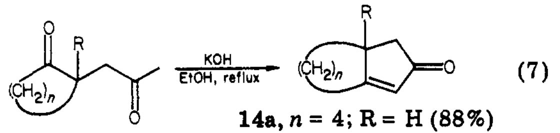
The 1,4-diketones, thus obtained, can be easily cyclized to cyclopentenones with base.[4,5] One of the most simple synthesis of dihydrojasmone (**12**) can be achieved from **1** and the dimethylhydrazone of 2-octanone (**11**) in two steps[3a,4e,12] (eq 5 and 6)



(5)

(6)

12

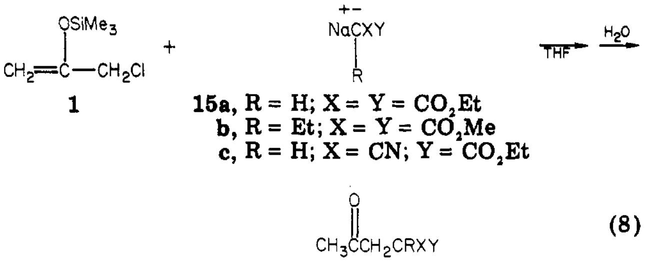


(7)

13a, $n = 4$; R = H
b, $n = 5$; R = H
c, $n = 10$; R = H
d, $n = 4$; R = Me

14a, $n = 4$; R = H (88%)
b, $n = 5$; R = H (73%)
c, $n = 10$; R = H (75%)[14]
d, $n = 4$; R = Me (100%)

Diethyl sodiomalonate (**15a**) and ethyl sodiocyanoacetate (**15c**), prepared by the reaction of the corresponding malonate and cyanoacetate with sodium hydride in THF, also react with **1** very smoothly to give acetonylated esters **16a** and **16c**, respectively, after hydrolysis (eq 8).



15a, R = H; X = Y = CO_2Et
b, R = Et; X = Y = CO_2Me
c, R = H; X = CN; Y = CO_2Et

(8)

16a, R = H; X = Y = CO_2Et (97%)
b, R = Et; X = Y = CO_2Me (86%)
c, R = H; X = CN; Y = CO_2Et (63%)

Although the reaction of dimethyl sodioethylmalonate (**15b**) with **1** was extremely slow, presumably due to the steric hindrance, it is noteworthy that the reaction was accelerated dramatically by the addition of a catalytic amount of sodium iodide, apparently owing to an initial formation of more reactive 3-iodo-2-(trimethylsiloxy)-1-propene (**3**), which was indeed obtained by the reaction of **1** with sodium iodide in THF or acetone.[6]

Acknowledgment. We thank Toshiba Silicone Co., Ltd., for a gift of chlorosilanes.

Registry No. **1**, 76634-95-2; **2**, 78804-07-6; **3**, 78804-08-7; **4**, 2344-80-1; **9a**, 20007-02-7; **9b**, 5758-08-7; **10a**, 27943-50-6; *cis*-**10b**, 60450-46-6; *trans*-**10b**, 60416-04-8; **11**, 60676-12-2; **12**, 1128-08-1; **13a**, 6126-53-0; **13b**, 61154-45-8; **13c**, 56666-10-5; **13d**, 27943-50-6; **14a**, 39163-29-6; **14b**, 61154-46-9; **14c**, 56975-50-9; **14d**, 16508-51-3; **15a**, 996-82-7; **15b**, 18424-76-5; **15c**, 18852-51-2; **16a**, 23193-18-2; **16b**, 78804-09-8; **16c**, 62981-80-0; **19**, 10468-40-3; *N*-cycloheptylidenecyclohexanamine, 6114-69-8; cyclododecanone dimethylhydrazone, 78804-10-1; *N*-(1-phenylethylidene)cyclohexanamine, 1562-62-5; *N*-(1-ethylpropylidene)cyclohexanamine, 6125-73-1; 2-octanone dimethylhydrazone, 60676-12-2; 1-phenyl-1,4-pentanedione, 583-05-1; 2,3,5-trimethylcyclopent-2-en-1-one, 54562-24-2; 2,5-undecanedione, 7018-92-0.

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(10) The scope of this interesting regioselective alkylation as a synthetic procedure is now under examination and further investigation of the origin of regiocontrol is proceeding. Hosomi, A.; Araki, Y.; Sakurai, H., manuscript to be published. See also (a) Stork, G.; Dowd, S. R. *J. Am. Chem. Soc.* **1963**, *85*, 2178. (b) Cuvigny, T.; Larcheveque, M.; Normant, H. *Justus Liebigs Ann. Chem.* **1975**, 719. (c) Fraser, R. R.; Banville, J.; Dhawan, K. L. *J. Am. Chem. Soc.* **1978**, *100*, 7999. (d) Houk, K. N.; Storozier, R. W.; Rondan, N. G.; Fraser, R. R.; Chuaqui-Offermanns, N. *Ibid.* **1980**, *102*, 1426.

(11) Corey, E. J.; Enders, D. *Tetrahedron Lett.* **1976**, *3*.

(12) The product **12** exhibited spectral properties in agreement with published data. See Ho, H. C.; Ho, Y. L.; Wong, C. M. *Can. J. Chem.* **1972**, *50*, 2718 and references cited therein.

(13) Baumgarten, H. E.; Greger, P. L.; Villars, G. E. *J. Am. Chem. Soc.* **1958**, *80*, 6609.

(14) **14c** is an important precursor to muscone and exaltone. See Tsuji, J.; Yamada, T.; Shimizu, I. *J. Org. Chem.* **1980**, *45*, 5209.