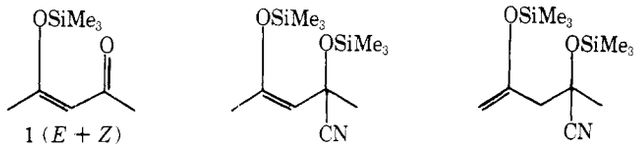
Communications

Dimethyldicyanosilane: A Reagent for Concurrent Silylation and Cyanosilylation of β-Diketones[1]

Summary: Six-membered rings (5-cyano-2,6-dioxa-1-silacyclohex-3-enes) are obtained by the reaction of β-diketones with dimethyldicyanosilane, in which concurrent silylation and cyanosilylation of the two carbonyl groups of β-diketones occur.

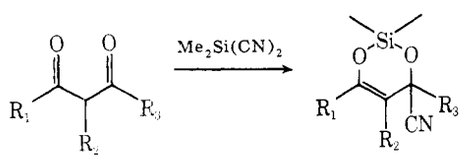
Sir: Recently cyanosilylation by trimethylcyanosilane has been developed as a useful method for the protection of carbonyl groups.[2] In connection with our study on the reactions of enol ethers, synthesis of cyanosilylated derivatives (such as **2**) of monosilylated β-diketones (such as **1**) were required.[3] Attempts to mask the carbonyl group of monosilylated β-diketone **1** with trimethylcyanosilane with the aid of heat or some catalyst such as zinc iodide[2] were unsuccessful. These reactions always afforded significant amounts of isomeric product **3** in addition to desired **2**.[4]



1 (*E* + *Z*) **2** (*E* + *Z*) **3**

To overcome this problem, the use of a bifunctional organosilicon reagent occurred to us, and we have now developed a method for the preparation of analogues of **2** in an efficient and selective manner from β-diketones.

We wish to report that dimethyldicyanosilane [$Me_2Si(CN)_2$][5] readily reacts with β-diketones to give high yields of six-membered ring products **4**. The compounds **4** were the desired ones in which enol and carbonyl portions of β-diketones were concurrently silylated and cyanosilylated without generation of side products analogous to **3**.

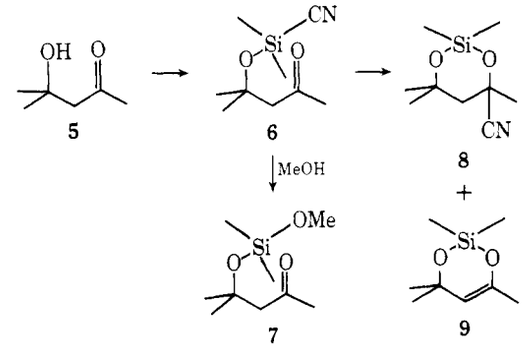


4

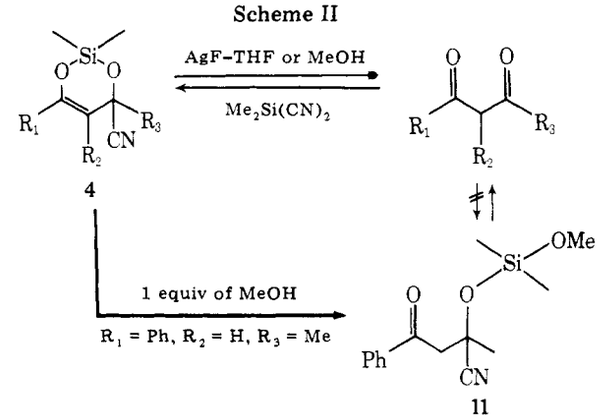
The reaction takes place exothermically with the evolution of hydrogen cyanide at room temperature to give **4**. In a representative procedure dimethyldicyanosilane (12 mmol) is dissolved in dichloromethane (3 mL) and the solution is cooled to −40 °C. The β-diketone (10 mmol) is slowly added to the solution by a hypodermic syringe, and the mixture is allowed to warm to room temperature over 1 h. After removal of hydrogen cyanide and the solvent, purification is effected by distillation or recrystallization. The products obtained are very hygroscopic and should be manipulated under an atmosphere of dry nitrogen. The results are summarized in Table I.

Except for the case of one difficultly enolized β-diketone[6] (entry 2 in Table I), the reaction proceeded immediately without any catalysts. The orientation of enolization in β-diketones is reflected in the structure of the products. In the case of β-diketones in which the orientation of enolization is distinctly determined by conjugation, a single regioisomer was obtained (see entry 5 and also entries 7 and 8 in Table I). It is noteworthy that the present reaction involves the silylation

Scheme I

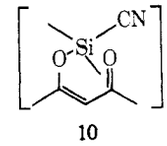


Scheme II



to give the *Z* form product selectively, despite the fact that the other methods for silylation of β-diketones give a mixture of *E* and *Z* isomers.[7]

The reaction of dimethyldicyanosilane with diacetone alcohol (**5**) in Scheme I follows a path that may be consistent with that followed by the reaction described in this study. The major products of this reaction were **8** and **9**.[8] The NMR spectrum of the reaction mixture after 1 h showed the predominant formation of cyanoalkoxysilane **6**, which seemed to be stable at low temperature (−30 °C) and could be intercepted to afford dialkoxysilane **7** in 76% yield upon treatment with methanol.[9] By analogy, the reaction of dimethyldicyanosilane with β-diketones may start with the silylation of the enolic portion to give **10** followed by intramolecular cyanosi-



10

lylation. However, we were unable to intercept the initial product **10** corresponding to **6**. This suggests that the intramolecular cyanosilylation must be very fast in the case of **10**.[10,11]

The six-membered ring products are moisture sensitive and can be easily converted to parent β-diketones on treatment with methanol or silver fluoride in THF (Scheme II).[12] Interestingly, the reaction of the cyclic product of benzoyl acetone with 1 equiv of methanol gave **11** in 76% yield. This result implies that methanolysis proceeds stepwise (the enol silyl

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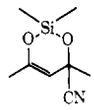
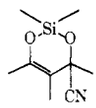
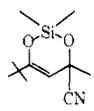
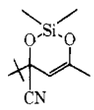
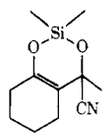
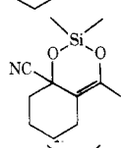
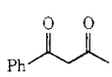
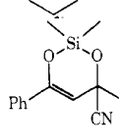
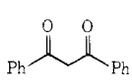
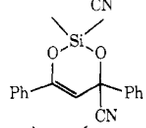
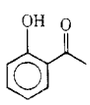
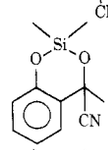
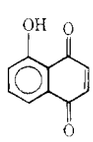
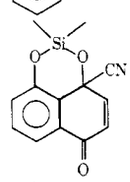
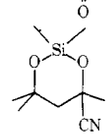
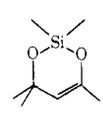
Table I. Concurrent Silylation and Cyanosilylation of β-Diketones and Related Compounds

Entry	β-Diketone	Products[a]	% yield[b]	Bp, °C (mp, °C)	IR, cm^{-1}	NMR (CCl_4), δ[c]
1			91	87-90 (20 mm)	1668	0.26 (s, 3 H) 0.41 (s, 3 H) 1.58 (s, 3 H) 1.79 (s, 3 H) 4.52 (s, 1 H)
2[d]			81	101-103 (26 mm)	1663	0.24 (s, 3 H) 0.35 (s, 3 H) 1.66 (s, 3 H) 1.70 (s, 3 H) 1.85 (s, 3 H)
3			86 (38:62)[e]	108-110 (23 mm)	1663	0.22 (s, 3 H) 0.38 (s, 3 H) 1.06 (s, 9 H) 1.60 (s, 3 H) 4.59 (s, 1 H)
						0.22 (s, 3 H) 0.38 (s, 3 H) 1.01 (s, 9 H) 1.84 (s, 3 H) 4.55 (s, 1 H)
4			98 (68:32)[e]	109-111 (7 mm)	1663	0.25 (s, 3 H) 0.37 (s, 3 H) 1.62 (s, 3 H) 140-2.50 (c, 8 H)
						0.25 (s, 3 H) 0.38 (s, 3 H) 1.80 (s, 3 H) 1.40-2.50 (c, 8 H)
5			97	101-104 (0.3 mm)	1643	0.36 (s, 3 H) 0.51 (s, 3 H) 1.73 (s, 3 H) 5.30 (s, 1 H) 7.20-7.58 (m, 5 H)
6			95	(68.5-70.0)	1640	0.40 (s, 3 H) 0.59 (s, 3 H) 5.53 (s, 1 H) 7.18-7.80 (m, 10 H)
7[f]			85	77-78 (0.35 mm)	1610	0.32 (s, 3 H) 0.43 (s, 3 H) 1.89 (s, 3 H) 6.70-7.37 (m, 4 H)
8[f]			62	(132-134)	1637 1680	0.24 (s, 3 H) 0.66 (s, 3 H) 0.68 (d-d, 2 H) 7.09-7.40 (m, 3 H)
9[f,g]		 8	7	63-64 (8 mm)		0.14 (s, 3 H) 0.26 (s, 3 H) 1.28 (s, 3 H) 1.59 (s, 3 H) 1.61 (s, 3 H) 1.99 (s, 1 H) 2.03 (s, 1 H)
		 9	41	56-58 (38 mm)	1665	0.17 (s, 6 H) 1.23 (s, 6 H) 1.68 (s, 3 H) 4.37 (s, 1 H)

[a] All products except **8** gave satisfactory analytical data. [b] Isolated yields. [c] The assignment of structures is based on the fact that a methyl group on an sp^3 carbon atom generally resonates at higher field than that on an sp^2 carbon, for example, $(CH_3)_2C(CN)OSiMe_3$ δ 1.54 (CCl_4) and $CH_2{=}C(CH_3)OSiMe_3$ δ 1.67 (CCl_4). [d] Catalytic amount of zinc iodide was used. [e] Determined by NMR. [f] 2 equiv of dimethyldicyanosilane were used. [g] With 1 equiv of dimethyldicyanosilane, $(RO)_2SiMe_2$ (ROH = diacetone alcohol) was also formed: NMR (CCl_4) δ 0.12 (s, 6 H), 1.34 (s, 12 H), 2.11 (s, 6 H), 2.52 (s, 4 H).

ether moiety was methanolized in the first stage). This partially methanolyzed product **11** has the structure of a monocyanosilylated β-diketone which appears to be otherwise inaccessible, since the reaction of trimethylcyanosilane with β-diketones does not give monocyanosilylated products.[13]

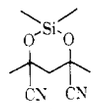
It should be noted that the present transformation may be useful for the protection of β-dicarbonyl or β-hydroxycarbonyl moieties. In addition, the results for juglone (entry 8) provide

a new method of differentiation of one carbonyl group from the other.

Various synthetic applications of the product 4 may be envisaged.[14]

References and Notes

(1) Synthesis via Silyl Alkenyl Ethers. Part 14. Part 13: I. Ryu, S. Murai, and N. Sonoda, *Tetrahedron Lett.*, 4611 (1977).
(2) D. A. Evans and J. M. Hoffman, *J. Am. Chem. Soc.*, **98**, 1983 (1976); D. A. Evans, J. M. Hoffman, and L. K. Truesdale, *ibid.*, *95*, 5822 (1973); D. A. Evans, L. K. Truesdale, and G. L. Carroll, *J. Chem. Soc., Chem. Commun.*, 55 (1973).
(3) Cyanosilylated derivatives of monosilylated β-diketones should have electron rich C=C double bonds to allow interesting reactions with various electrophiles.
(4) **3**: IR (neat) 1640 cm^{-1}; NMR (CCl_4) δ 0.23 (s, 18 H), 1.55 (s, 3 H), 2.18–2.56 (d-d, 2 H), 4.08 (s, 2 H); MS *m/e* 271 (M^+).
(5) J. J. McBride, Jr., and H. C. Beachell, *J. Am. Chem. Soc.*, **74**, 5247 (1952); J. Hundeck, *Z. Anorg. Allg. Chem.*, **345**, 23 (1966). Also commercially available from Petrarch Systems, U.S.A. Recently we developed an improved procedure for dimethyldicyanosilane from dimethyldichlorosilane and silver cyanide: I. Ryu, S. Murai, T. Horiike, A. Shinonaga, and N. Sonoda, *Synthesis*, in press.
(6) For enolization of β-diketones, see: S. Forsen and M. Nilsson in "The Chemistry of the Carbonyl Group", Vol 2, J. Zabicky, Ed., Interscience, London, 1970, Chapter 3; H. O. House, "Modern Synthetic Reactions", 2nd ed, W. A. Benjamin, Menlo Park, Calif., 1972, pp 157–240.
(7) S. Torkelson and C. Ainworth, *Synthesis*, 722 (1976), and references cited therein.
(8) It is not clear whether **9** was formed from dehydrocyanation of **8** or directly from **6**.
(9) **6**: NMR (CH_2Cl_2) δ 0.33 (s, 6 H), 1.34 (s, 6 H), 2.06 (s, 3 H), 2.56 (s, 2 H). **7**: IR 1720 cm^{-1}; NMR (CCl_4) δ 0.07 (s, 6 H), 1.33 (s, 6 H), 2.09 (s, 3 H), 2.48 (s, 2 H), 3.39 (s, 3 H); MS *m/e* 189 (P − 15).
(10) Well accepted 1,6 interaction of silicon and oxygen may be responsible for this: see T. J. Pinnavaia and J. A. McClarin, *J. Am. Chem. Soc.*, **96**, 3012 (1974), and references cited therein.
(11) The possibility that the initial formation of doubly cyanosilylated product i followed by dehydrocyanation might afford **4** is not precluded at the present stage.



i

(12) For example, the parent β-diketone of 5-cyano-1,1,3,5-tetramethyl-2,6-dioxa-1-silacyclohex-3-ene was regenerated on treatment with methanol (2 mL for 4 mmol of **4**) in 85% (room temperature, 20 h).
(13) The reaction of trimethylcyanosilane with 1 equiv of acetylacetone gave the enol silyl ether **1** (*E* + *Z*) in a high yield.
(14) Attempts of cyclopropanation of the product **4**, which may promise the one carbon homologation of β-diketones, are now in progress.

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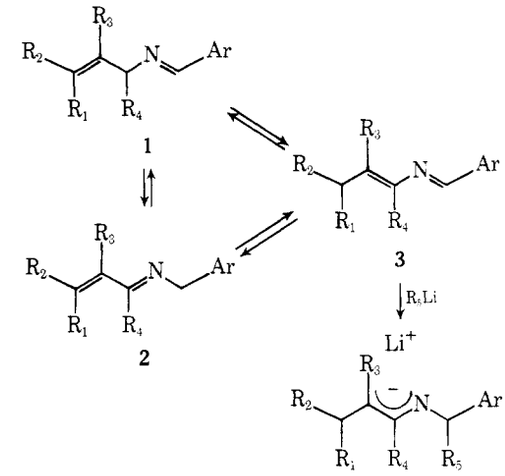
Imine Prototropy: Synthetic Consequences in the Generation of Metalloenamines

Summary: *N*-allylic imines and α,β-unsaturated imines undergo facile prototropic isomerization to *N*-alkenylimines which, upon reaction with *tert*-butyllithium, are converted into metalloenamines; the overall process allows for the regiocontrolled, sterically unimpeded generation of these organometallic intermediates.

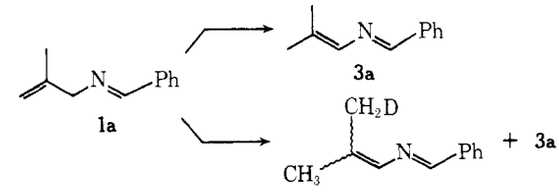
Sir: Initial reports from the laboratories of Stork[1a] and Wittig[1b] on the utility of metalloenamines in controlled alkylation and directed aldol processes, respectively, have fostered in subsequent years a rapid expansion of methodology[2] and synthetic strategies[3] based on these intermediates. Notwithstanding this record, the preparation of metalloenamines is confined presently to imine deprotonation with strong base, a procedure which is only useful for metalation (and hence bond formation) at the less-substituted α site of an unsymmetrically substituted ketimine.[4] Moreover, the efficiency of imine metalation with various bases is found to decrease with increasing substitution at the deprotonation site.[1b] We recently reported on methods which circumvent these limitations by the regiospecific, reductive generation of metalloenamines from α,β-unsaturated imines.[5] A further solution to the above noted problems is described herein.

Two studies bear on the genesis of the present method. In 1929, Ingold and associates[6] reported that *N*-benzylimines undergo prototropic isomerization with base to provide a thermodynamic mixture of imine isomers (eq 1). More recently, it has been proposed[7] (albeit not demonstrated) that the enzyme inactivation produced by suicide enzyme substrates, such as propargylamine, involves a similar prototropic isomerization of an active site bound *N*-propargylimine. By analogy with these studies and the results of our previous work, we reasoned that the readily available *N*-allylic imines (**1**) of arylaldehydes would be sufficiently activated for base-catalyzed rearrangement to *N*-alkenylimines (**3**) (eq 2). Nucleophilic addition to these intermediates would then be expected to provide the corresponding metalloenamines in a regiospecific, sterically unimpeded manner.



(2)

In order to explore this rationale the proclivity of imine **1a** to prototropic isomerization was initially examined. Addition of this imine to a solution of potassium *tert*-butoxide (*t*-BuOK) in tetrahydrofuran (THF) was accompanied by an instantaneous reaction which upon workup provided alkenylimine **3a**[8] in essentially quantitative yield. The facility of this transformation at ambient temperature precluded an accurate determination of its half-life; however, at −78 °C a value of ~60 min was obtained. When the isomerization was conducted at 5 °C with 0.33 mol equiv of *t*-BuOK in the presence of 7.6 mol equiv of *t*-BuOD, the reaction was complete within 10 s and provided on workup d_1 and d_0 alkenylimines[9] in a ratio (1:2, respectively, as determined by NMR and mass spectroscopy) which is consistent with competing inter-



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