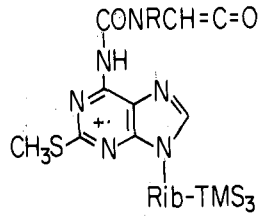
Complete high resolution mass spectra were photographically recorded.[7] Exact molecular masses of permethyl[5] and trimethylsilyl[8] derivatives were established by calculating mean values derived from experimentally measured molecular ion and base series of ions,[9] in which the unknown parameter (the exact mass of the base) is associated in each measurement with known mass differences (e.g., M − CH_3, base + H). Determination of the number of blocking groups introduced by comparison of molecular weights (**2** vs. **3**, **6** vs. **7**) then permitted calculation of the masses of **1** and its degradation product **8**, as shown.

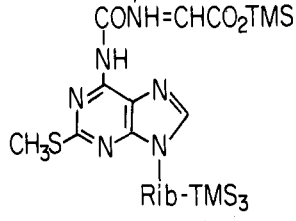
The structure elucidation of nucleoside N followed the characterization of **8** based on the premise that the identity of **8** would permit selection of the basic skeleton from the four major bases. The exact mass of **2** results in 11 computer generated candidates for composition, which can be narrowed by application of a set of restrictions which are generally applicable to nucleosides: (1) total number of rings and double bonds between 4 and 12, (2) oxygen ≥4, (3) nitrogen ≥2, (4) the nitrogen rule. As a result, no candidates emerge which contain only C, H, D, N, and O, while inclusion of S results in a single possibility for **2**: $C_{16}H_{10}D_{15}N_5O_4S$. The mass spectrum of **2** shows an unmodified sugar (*m/e* 149, 183),[5] an ion of *m/e* 120 ($C_6H_4D_5O_2$) generally characteristic of adenosine derivatives,[5] and loss of CD_2ND from the base + H species, thus revealing **8** to have a free exocyclic amino group.[5,10] These data, plus a detailed analysis of the high resolution mass spectra of **2** and **3**, lead to structure **8**. An isomer bearing a methylenethiol function is excluded by the extent of methylation (5 instead of 6); substitution of C-8 is excluded by incorporation of one deuterium (D_2O, 100 °C for 1 h, then cold H_2O).

The mass difference between **1** and **8** (146.0467) permits three compositions within the limits $C_{\leq 10}H_{\leq 20}N_{\leq 5}O_{\leq 6}S_{\leq 1}$ (±0.004 amu): $C_6H_4N_5$, $C_3H_8N_5S$, and $C_5H_8NO_4$. The N_5



R = H, 612.2020 (−1.7)
R = Me_3Si, 684.2415 (−1.8)

candidates are rejected as structurally implausible. The third corresponds to threonine plus CO, leading to structure **1**. Support for the N^6-carbamoylthreonine structure is gained from the high resolution spectra of **6** and **7**, which includes fragment ions of *m/e* 612, 684, and 701,[11] which have analogy in the mass spectra of *N*-[(9-β-D-ribofuranosylpurin-6-yl)-carbamoyl]threonine (t^6A)[12] and its N^6-methyladenosine analogue (mt^6A).[13]



701.2462 (0.2)

The present finding is the first case in which the methylthio group has been found in mammalian tRNA,[14,15] while t^6A and mt^6A occur in both prokaryotic and eukaryotic sources.[16] The new nucleoside (**1**, ms^2t^6A) has recently been located adjacent to the 3′ position of the anticodon in $tRNA_3^{Lys}$ from rabbit liver.[17] Its presence thus satisfies the empirical rule that tRNAs which contain t^6A or its derivatives recognize messenger RNA codons which begin with A.[1,2]

Acknowledgment. This work was supported by NATO Grant No. 907 to H.J.G., and NIH Grant CA 18024 to J.A.M.

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Silyl Ketone Chemistry. A New Regiospecific Route to Silyl Enol Ethers

Sir:

The reversible rearrangement of silyl groups from carbon to oxygen in α-silyl alkoxides (**1** ⇌ **2**)[1] provides an unusual route to potentially useful carbanions. We are investigating several synthetic applications of this rearrangement and report here the development of a new regiospecific silyl enol ether

1 2

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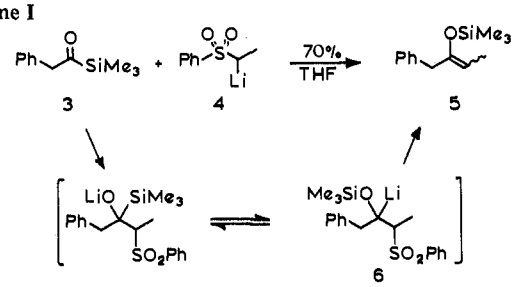
synthesis.[4] Our approach is to generate silyl alkoxides **1** by addition of suitable organometallic reagents (RLi) to silyl ketones (acylsilanes, $R'COSiMe_3$). If either R or R′ in **2** contains an α leaving group, the carbanion can undergo β elimination to form a silyl enol ether (see Scheme I). Two potential constraints on the wide applicability of such a process are that (1) the reaction of organolithium and Grignard reagents with silyl ketones frequently gives complex product mixtures;[5] (2) the silyl alkoxide rearrangement **1** → **2** is rapid only when R or R′ is a carbanion stabilizing group such as aryl.[2] Limited precedent for the formation of silyl enol ethers by the process outlined above is provided by some early work of Brook and Fieldhouse:[6] the reaction of phenyl trimethylsilyl ketone with methylenetriphenylphosphorane gives the enol silyl ether derived from acetophenone. In agreement with limitation 2 above, methyl triphenylsilyl ketone gave only normal Wittig product.

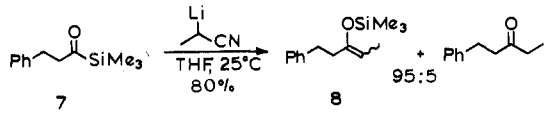
That both of the limitations outlined can be circumvented is demonstrated by the successful reaction of benzyl trimethylsilyl ketone (**3**) with **4** to give the silyl enol ether **5** as shown in Scheme I. The intermediate **6** is drawn for illustrative pur-

Scheme I



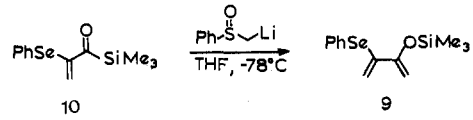
poses only. This high energy intermediate can be avoided by a concerted silyl migration and departure of the leaving group. The importance of this synthesis of **5** lies in the fact that enolization of 1-phenyl-2-butanone does not give pure **5** under either kinetic or thermodynamic conditions.[7]

2-Phenylethyl trimethylsilyl ketone (**7**) gives the expected silyl enol ethers when treated with several lithium reagents bearing α leaving groups, including those prepared by deprotonation ($LiN(i\text{-}Pr)_2$) of ethyl phenyl sulfone (**4**), 2-phenylpropyl phenyl sulfone, ethyl phenyl selenoxide,[8] and bisphenylselenomethane.[9] More remarkable is the reaction of **7** with α-lithiopropionitrile which gives the silyl enol ether **8** in high yield. This transformation, in which cyanide is expelled,[10]

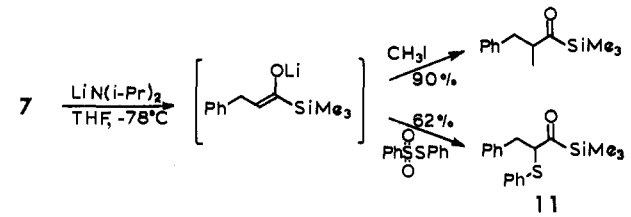


speaks for the development of significant carbanionic character in the intermediate.

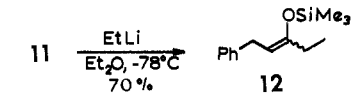
The sequence is also applicable to more complicated systems, as in the synthesis of the diene **9**[11] in 89% yield[12] by addition of benzenesulfinylmethyllithium to the rather sensitive vinyl silyl ketone **10**.[13]



The chemistry described above is amplified by our observation that alkyl silyl ketones form enolates under normal conditions, and that these can be alkylated, silylated, selenenylated,[14] and sulfenylated.[15,16] The α-phenylthio silyl ketone **11** prepared in this way permits a reversal of the earlier procedure: the leaving group is now found in the silyl ketone. Thus



both regioisomers (**8** and **12**) are available in pure form from a single precursor, the silyl ketone **7**.[17]



In the experiments described, predominantly a single reaction pathway of silyl ketone with organometallic reagent was observed. A number of other pathways are possible, and some have been found. For example, in THF, rather than in ether, the reaction of **11** with ethyllithium gives a significant amount of deprotonation (enolate formation). Some unrearranged adduct (α-silyl alcohol) can also be isolated. Sato, Abe, and Kuwajima have found that the chloro analogue of **11** (PhS replaced by Cl) gives a product of carbon to carbon silyl migration (3-trimethylsilyl-4-phenyl-2-butanone) with methylmagnesium iodide and products resulting from hydride transfer with *n*-butylmagnesium bromide.[5d]

Silyl ketones are rather unreactive carbonyl compounds, a result of both steric hindrance and electronic deactivation of the carbonyl group. We have, as a consequence, been unable to isolate good yields of silyl enol ethers from reactions of silyl ketones with more hindered lithium reagents such as those formed by deprotonation of 2-methylpropionitrile or isopropyl phenyl sulfone. Nevertheless, it is clear that with some limitations precursors to enolates of dialkyl ketones with undifferentiating substituents can be prepared in a regiospecific manner.[18]

The following procedure for the preparation of **8** illustrates the method. To a cooled (−78 °C) solution of lithium diisopropylamide (4.2 mmol) in 10 mL of THF, stirred under nitrogen, was slowly added 0.286 mL (4.0 mmol) of propionitrile. The resulting solution was stirred for 1.5 h and then 0.864 mL (824 mg, 4.0 mmol) of 2-phenylethyl trimethylsilyl ketone was added, dropwise over 1 min. The solution was allowed to warm to room temperature, stirred for 3 h, and then partitioned between cold aqueous $NaHCO_3$ (7%) and 2:1 pentane–ether. The organic layer was washed with brine, dried (anhydrous Na_2SO_4), concentrated, and distilled (Kugelrohr, 0.2 mm, 62–70 °C) to give 0.752 g (80%) of silyl enol ether **8** as a colorless liquid. NMR (270 MHz) analysis showed a 32:68 mixture (*Z*:*E*) of double-bond isomers, and the presence of 5% 1-phenyl-2-pentanone. Less than 4% **12** was formed.

The silyl ketones **3** and **7** were prepared using dithiane chemistry.[19] For the hydrolysis of the dithiane precursor to **7**, chloramine-T in aqueous methanol was found to be superior (81% yield) to mercury salt based procedures.

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Chemically Induced Dynamic Nuclear Polarization from the Selective Recombination of Radical Pairs in Micelles

Sir:

Chemically induced nuclear polarization (CIDNP) effects in homogeneous solutions are generally interpreted on the basis of spin selection in competing radical-pair reactions, e.g., recombination, an electron spin dependent reaction, and diffusional separation, an electron spin independent reaction.[1,2] A radical pair that is generated in a micelle is in a qualitatively different situation: the micelle limits the diffusional migration and thereby prevents complete separation of the pair. It is of interest to compare CIDNP effects generated in homogeneous solutions with those observed in micelle-forming detergent solutions, in order to evaluate the impact of the restricted dimensionality imposed by the micelle.

In homogeneous solution, the photolysis of 1,3-diphenylacetone leads to photodecarbonylation[3] accompanied by strong CIDNP effects for the starting material and for the decarbonylation product, 1,2-diphenylethane.[4] The photolysis of asymmetrical diarylacetones, e.g., 1-(*p*-tolyl)-3-phenylacetone (**1**), results in the formation of three coupling products in exactly the ratio (1:2:1) expected for the statistical coupling of the free radicals, benzyl and *p*-methylbenzyl.[5] During this photolysis the methylene protons of the starting material (3.36, 3.39 ppm) appear in emission and its methyl group (2.24 ppm) appears in enhanced absorption (Figure 1).

These effects can be ascribed to the radical pairs, A and B. An analysis of the signal directions in terms of the formalism suggested by Kaptein[6] indicates that these pairs are generated from a triplet precursor ($\mu > 0$) since the benzyl radical has

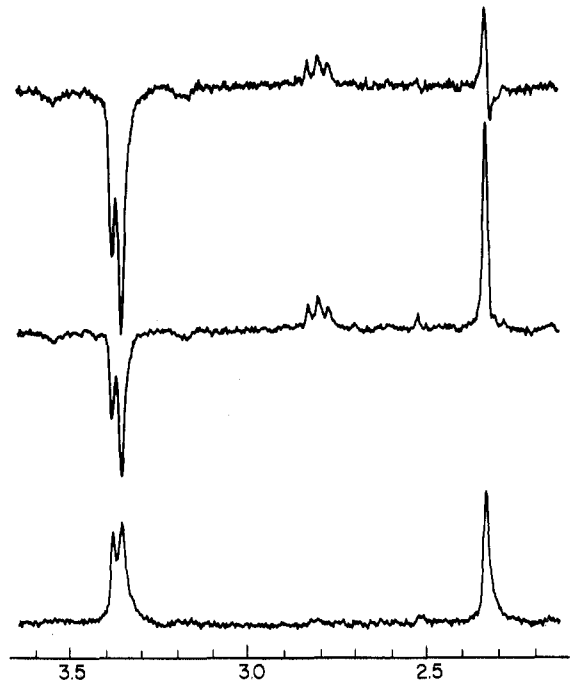

Figure 1. ^1H NMR spectrum (90 MHz) of *p*-methylbenzyl benzyl ketone in the dark (bottom) and during UV irradiation (center). The top trace represents the difference between the dark spectrum and that observed during irradiation.

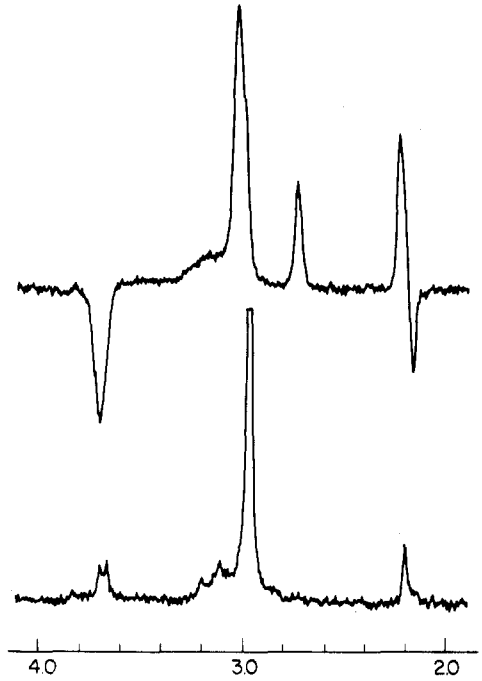

Figure 2. ^1H NMR spectrum (90 MHz) of *p*-methylbenzyl benzyl ketone in an aqueous solution containing hexadecyltrimethylammonium chloride in the dark (bottom) and during UV irradiation (top).

a negative hyperfine coupling constant ($a < 0$) and a larger *g* factor (2.0025)[7] than the acyl radical (2.0007;[8] $\Delta g > 0$). At the same time, three polarized bibenzyls (**2a–c**) are observed; their polarization is complementary to that of the ketone, enhanced absorption for the methylene protons (2.77, 2.80, 2.84 ppm) and emission for the methyl signal (2.33 ppm), indicating that these products are formed via a free-radical mechanism ($\epsilon < 0$) but from the same precursor pairs. The signal intensity of the bibenzyls is substantially lower than that of the ketone. This is in part due to the slightly shorter spin-lattice relaxation times of **2a–c** (1.5 ± 0.1 s compared with 2.1 ± 0.2 s for **1**) but mainly to the fact that the free benzyl radicals suffer relaxation

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