yield of the hydrocarbon product.

The foregoing syntheses of benzo[a]fluoranthene and naphtho[2,1-a]fluoranthene provide more convenient synthetic access to these hydrocarbons than previous methods.[7,8]

Naphtho[2,1-a]fluoranthene is reported to be weakly carcinogenic;[9] the biological activity, if any, of benzo[a]-fluoranthene is apparently unknown.

Experimental Section

General Methods. *N,N*-Diethyl-1-naphthamide was prepared as previously described.[3] *N,N,N',N'*-tetramethylethylenediamine (TMEDA) was distilled from KOH prior to use. *sec*-Butyllithium in cyclohexane (1.25 M) and 9-fluorenone were purchased from the Aldrich Chemical Co. The NMR spectra were recorded on a Varian EM360 and/or the University of Chicago 500-MHz spectrometer with tetramethylsilane as an internal standard. Melting points are uncorrected. All new compounds gave satisfactory analyses for C and H within ±0.3%.

Synthesis of Benzo[a]fluoranthene. (1) Condensation of 9-Fluorenone with 1. A solution of *N,N*-diethylbenzamide (1.4 g, 8 mmol), TMEDA (1.2 mL), and triphenylmethyl chloride (a few milligrams to serve as an indicator) in anhydrous ether (80 mL) under a nitrogen atmosphere was cooled to −75 °C and allowed to stand for 10 min. *sec*-Butyllithium (8 mL, 1.25 M) was added, and the resulting solution was stirred at −75 °C for 1 h. 9-Fluorenone (1.4 g, 8 mmol) was added, the cooling bath was removed, and the solution was stirred overnight. A conventional workup furnished the crude product (3 g) which was refluxed in benzene (300 mL) with *p*-toluenesulfonic acid (300 mg) with a Dean–Stark trap for 4 h. The usual workup afforded **2**: 1.6 g (70%); mp 224 °C (EtOAc) (lit.[7] mp 226 °C); NMR (60 MHz) δ 8.0–8.1 (d, 1, *J* = 7 Hz), 6.9–7.8 (m, 11, aromatic).

(2) Reduction of the Lactone. A solution of **2** (300 mg) in pyridine (5 mL) was heated with zinc dust (5 g, activated as described)[3] in a solution of KOH (50 mL of 10% solution) at reflux for 21 h. The usual workup gave the acid **3**: 260 mg (86%); mp 245 °C (EtOAc) (lit.[8] mp 241–242 °C); NMR (60 MHz) δ 6.59–8.11 (m, 12, aromatic), 6.39 (s, 1, benzylic).

(3) Benzo[a]fluoranthene. The acid **3** (200 mg) was stirred in liquid HF (~50 mL) for 12 h. The HF was evaporated under a stream of N_2 to yield crude **4** (170 mg). TLC of the crude product on Florisil showed on elution with benzene–hexane only a single spot corresponding to **4**; other product components remained adsorbed at the origin. Passage through a short column of silica gel eluted with hexane furnished pure **4**: 36%; mp 147 °C (ether–hexane) (lit.[7,8] mp 145–146 °C); UV max (EtOH) 257 and 225 nm, in agreement with the reported spectrum;[10] NMR (500 MHz) δ 8.76 (d, 1, H_{12}), 8.48 (s, 1, H_8), 8.39 (d, 1, H_1), 8.15 (d, 1, H_5), 8.02 (br s, 2, $H_{4,7,9}$), 7.67 (t, 1, H_{10} or H_{11}), 7.66 (t, 1, H_{10} or H_{11}), 7.53 (t, 1, H_6), 7.48 (d, 1, H_2 or H_3), 7.40 (d, 1, H_2 or H_3); $J_{1,2}$ = 7.5 Hz, $J_{2,3}$ = 7.2 Hz, $J_{5,6}$ = 8.6 Hz, $J_{11,12}$ = 8.8 Hz; MS (70 eV), *m/e* 252 (M^+). The hydrocarbon was dissolved in concentrated H_2SO_4, giving a yellow solution which changed to violet on standing, as reported by Stubbs and Tucker.[7] A similar experiment conducted in the presence of triphenylmethane (2 molar equiv) gave **4** (71%; mp 144–145 °C); a mixture melting point with authentic **4** did not depress. TLC on Florisil (benzene–hexane) showed a single spot.

Synthesis of Naphtho[2,1-a]fluoranthene. Condensation of 9-fluorenone (1.8 g, 10 mmol) with 2-lithio-*N,N*-diethyl-1-naphthamide was carried out essentially as in the preparation of **2**, except that 1 h was allowed for the metalation reaction. A similar workup gave **10**; (2.53 g (76%); mp 192 °C (ether–benzene); NMR δ 9.10–9.25 (d, 1, *J* = 7 Hz, aromatic), 6.75–8.05 (m, 13, aromatic); IR (Nujol) 1755 cm^{-1} (C=O). Reduction of **10** (300 mg) with zinc and alkali provided the free acid: 270 mg (90%); mp 237 °C (EtOAc); NMR δ 6.3–8.3 (m, 14, aromatic), 5.5 (s, 1, benzylic). Reductive cyclization of this acid (200 mg) in liquid HF in the usual manner and purification of the product by chromatography on silica gel gave pure **11**: 30%; mp 180 °C (benzene–ether) (lit.[10] mp 181–181.3 °C cor); NMR (500 MHz) δ 9.25 (s, 1, H_{14}), 8.88 (d, 1, H_1), 8.62 (d, 1, H_6), 8.40 (d, 1, H_7), 8.08 (d, 1, H_{11}), 8.04 (d, 1, H_{13}), 8.02 (d, 1, H_{10}), 7.89 (d, 1, H_4), 7.84 (d, 1, H_5), 7.71 (dd, 1, H_2 or H_{12}), 7.64 (t, 1, H_3), 7.48 (d, 1, H_8), 7.42 (t, 1, H_9); $J_{1,2}$ = 8.2 Hz, $J_{2,3}$ = 7.3 Hz, $J_{3,4}$ 7.5 Hz, $J_{5,6}$ = 9.3 Hz, $J_{7,8}$ = 7.5 Hz, $J_{8,9}$ = 7.2 Hz, $J_{9,10}$ = 7.8 Hz, $J_{11,12}$ = 8.2 Hz, $J_{12,13}$ = 8.2 Hz, $J_{12,13}$ = 6.7 Hz; MS (70 eV), *m/e* 302 (M^+).

A similar experiment with triphenylmethane present (2 molar equiv) provided **11**: 60%; mp and mmp 177–179 °C. TLC on Florisil (benzene–hexane) gave a single spot.

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Registry No. **2**, 82111-99-7; **3**, 64611-30-9; **4**, 199-54-2; **10**, 82112-00-3; **10** free acid, 82112-01-4; **11**, 203-07-6; *N,N*-diethylbenzamide, 1696-17-9; 9-fluorenone, 486-25-9; *N,N*-diethyl-1-naphthamide, 5454-10-4.

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N-Methyl-*N*-(*tert*-butyldimethylsilyl)trifluoroacetamide and Related *N*-*tert*-Butyldimethylsilyl Amides as Protective Silyl Donors[1]

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Within recent years silylation as a protective method in the synthesis of organic compounds has been increasing in use.[2] Foremost in growing utility among the many trialkylsilyl derivatives used to protect hydroxylic groups is the *tert*-butyldimethylsilyl (TBDMS) derivative.[3] Reasons for this include ease in transforming alcohols to their corresponding TBDMS ethers, selective removal of the TBDMS function under mildly acidic or nonacidic conditions,[4] and the stability of the TBDMS ethers to acetate saponification conditions, Wittig reagent, Jones (CrO_3) reagent, Grignard reagent, and hydrogenation. In addition, the TBDMS ether is approximately 10^4 times more stable to solvolysis than the corresponding trimethylsilyl (Me_3Si) ether. Because of these characteristics the TBDMS function has been employed to protect hydroxyl groups during the synthesis of many diversified compounds including ribonucleosides,[5] deoxyribonucleosides,[6,7] carbohydrates,[8-11] and analogues of throm-

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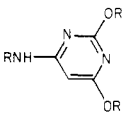
Table I. *tert*-Butyldimethylsilylated Products and Isolated Yields[a]

substrate	product[b]	mp, °C	yield, % MTBSTFA[c]	MTBSA[d]	TBDMSCl[e]
1,3-propanediol	$RO(CH_2)_3OR$	115-117	100	100	100
glycerol	$ROCH_2CHORCH_2OR$	127-130	100	100	52
phenol	C_6H_5OR	108-109	98	96	98
1-propanethiol	$CH_3CH_2CH_2SR$	144-147	100	98	0
2-propanethiol	$(CH_3)_2CHSR$	142-143	100	100	0
1,3-propanedithiol	$RS(CH_2)_3SR$	oil	98	96	0
3-mercapto-1,2-propanediol	$RSCH_2CH(OR)CH_2OR$	148-150	96	95	0 (43)[f]
2-mercaptoethanol	$RSCH_2CH_2OR$	137-140	100	100	0 (38)[f]
mercaptoacetic acid	$RSCH_2COOR$	163-164	98	100	0
3-hydroxypropionic acid	$ROCH_2CH_2COOR$	159-162	100	100	76 (66)[f]
m-hydroxybenzoic acid	ROC_6H_4COOR	137-139	98	97	67 (71)[f]
2-hydroxybenzyl alcohol	$ROC_6H_4CH_2OR$	126-127	100	100	100
p-hydroxyphenylpyruvic acid	$ROC_6H_4CH_2COCOOR$	172-175	100	98	63 (76)[f]
DL-2-aminobutyric acid	$C_2H_5CH(NHR)COOR$	160-163	97	95	0
2-amino-1-butanol	$C_2H_5CH(NHR)CH_2OR$	157-158	100	96	4 (22)[f]
2-amino-1-propanol	$CH_3CN(NHR)CH_2OR$	149-151	100	100	6 (37)[f]
4-amino-2,6-dihydroxypyrimidine		181-182	100	100	0 (43)[f]
benzylmethylamine	$C_6H_5CH_2NR(CH_3)$	178-180	97[g]	92[g]	0

[a] See footnote 21. [b] R = *tert*-butyldimethylsilyl. [c] Reaction with *N*-methyl-*N*-(*tert*-butyldimethylsilyl)trifluoroacetamide (MTBSTFA) in acetonitrile for 5 min at room temperature and the sublimation of the product. [d] Reaction with *N*-methyl-*N*-(*tert*-butyldimethylsilyl)acetamide (MTBSA) in acetonitrile for 5 min at room temperature and sublimation of the product. [e] Reaction with *tert*-butyldimethylsilyl chloride in DMF containing imidazole after 10 h at 40 °C and sublimation or extraction of the product. [f] Percent of total hydroxyl groups, only, found to be *tert*-butyldimethylsilylated. [g] Yield after 15 min.

boxane A_2,[12] leukotrienes,[13] steroids,[14] vitamid D,[15,16] and prostaglandins.[17] The method used in the making of TBDMS ethers generally utilizes an excess of *tert*-butyldimethylsilyl chloride (TBDMSCl) in *N*,*N*-dimethylformamide (DMF) containing imidazole which acts both as an acid acceptor and as an intermediary silyl donor as the *N*-TBDMS-substituted imidazole. Isolation of the silylated compound is performed by aqueous extraction to remove DMF and imidazole, followed by sublimation or distillation of the *tert*-butyldimethylsilylated product. For many compounds possessing hydroxyl groups this TBDMSCl/DMF/imidazole cocktail produces the corresponding TBDMS ethers in high yields. One drawback to the use of this cocktail is that the time required for each reaction may vary from 1 h to 2 days or may require elevated temperatures. More importantly, though, with the use of the above *tert*-butyldimethylsilylating cocktail on compounds possessing vicinal hydroxyl groups and especially on compounds concomitantly possessing hydroxyl functions and other groups having "active" protons (i.e., SH, COOH, and NH_2) the actual yields of TBDMS ethers are seldom quantitative and are often low. This is for several reasons. The first is the ineffectiveness of the TBDMSCl/DMF/imidazole mixture to silylate thiols, primary and secondary amines, and slightly hindered hydroxyl groups. Second, the presence of the base imidazole in the cocktail both directly interferes with the quantitative silylation of carboxylated compounds and diminishes the actual yields of the desired compound due to the required extraction steps to remove it. Finally, substitution of other solvents for DMF in the cocktail, which is required for the dissolution of both imidazole and TBDMSCl, may result in very low yields of the desired product. This study was undertaken to investigate several *tert*-butyldimethylsilylating compounds that could quantitatively and rapidly *tert*-butyldimethylsilylate alcohols and carboxylates as well as thiols and primary and secondary amines. Furthermore, these reagents should permit greater selectivitiy in reaction solvents and simplify the protocol for the isolation of the final *tert*-butyldimethylsilylated product.

Utilizing the fact that silyl-proton transfer occurs between silyl amides and appropriate "active" protic functions,[18,19] we now report on our investigations of four potent TBDMS donors. *N*-Methyl-*N*-(*tert*-butyldimethylsilyl)-trifluoroacetamide (MTBSTFA), *N*-methyl-*N*-(*tert*-butyldimethylsilyl)acetamide (MTBSA), *N*-methyl-*N*-(*tert*-butyldimethylsilyl)formamide (MTBSF), and *N*,*O*-bis-(*tert*-butyldimethylsilyl)acetamide (BMTBSA) are readily produced in high yields. Except for MTBSF, which is a solid, these *tert*-butyldimethylsilylating reagents are clear, moisture-sensitive liquids, are easily transferable with a gas-tight syringe, are readily soluble in most aprotic organic solvents, and yield neutral side products following a reaction.

In order to determine the *tert*-butyldimethylsilylating potential of these reagents, we tested them on various

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substrates possessing different silylatable functions, in addition to alcohols. The substrates, investigated, the resulting *tert*-butyldimethylsilylated products, and the isolated yields acquired with MTBSTFA, MTBSA[20] and the TBDMSCl/DMF/imidazole cocktail are presented in Table I. All *tert*-butyldimethylsilylations with MTBSTFA and MTBSA[21] were complete in less than 1 min at room temperature for alcohols, thiols, and primary amines, producing compounds that generally were crystalline. Silylation of secondary amines required slightly longer reaction times. On the other hand, TBDMSCl/DMF/imidazole did not exhibit any reaction with thiols, gave poor yields with amines, and varible results with carboxylated compounds. *tert*-Butyldimethylsilylation of most compounds possessing unhindered primary and secondary alcohols with the latter cocktail was generally complete in 5 h. With compounds having slightly hindered hydroxy functions, *tert*-butyldimethylsilylation was always incomplete. Furthermore, in contrast to MTBSTFA and MTBSA, the TBDMSCl/DMF/imidazole cocktail produced TBDMS ethers in low yields with substrates concomitantly possessing other "active" protic functions. Similar results were obtained when we substituted *N*-methylimidazole[22] or 4-(dimethylamino)pyridine[23] for imidazole in the cocktail. In addition, we have found that *tert*-butyldimethylsilylation of compounds listed in Table I with several new TBDMS donors such as TBDMS perchlorate,[24] TBDMS triflate,[25] TBDMSCl in the presence of lithium sulfide,[26] TBDMS enols of pentane-2,4-dione in the presence of methyl acetoacetate,[27] and allyl-*tert*-butyldimethylsilane[28] gave yields identical with or poorer than those achieved with TBDMSCl/DMF/imidazole. All attempts to synthesize the TBDMS donor analogue of the ketene methyl trialkylsilyl acetals have failed.[27,29]

On consideration of the isolation of the final *tert*-butyldimethylsilylated product, the use of these TBDMS donor silylamides, by virtue of their excellent reactivity in easily removed volatile organic solvents and their production of unreactive, neutral side products, greatly simplifies product purification. Notably, *tert*-butyldimethylsilylations with MTBSTFA are ideal reactions designed for the isolation of the final product since MTBSTFA, *N*-methyltrifluoroacetamide, TBDMSCl, and any *tert*-butyldimethylsilanol (produced from the reaction of these reagents with water) are readily sublimed from the reaction mixture at low temperature, leaving a clear product residue of high purity (>97%) that can be used directly, sublimed at higher temperatures, or distilled. Protected from moisture, all products completely *tert*-butyldimethylsilylated with one of the above *tert*-butyldimethylsilyl amides were stable for over 6 months at room temperature. In contrast, products, following *tert*-butyldimethylsilylation with TBDMSCl/DMF/imidazole, that concomitantly possessed TBDMS ethers and unsubstituted thiols or amines demonstrated gradual and sometimes rapid decomposition of the existing ether.

In the presence of TBDMS ethers and primary amines selective removal of the labile TBDMS group from thiols and carboxylates is easily effected within 30 min at room temperature in hexane containing a slight excess of dry ethanol. The TBDMS amine, which is ca. 10^2 times more stable than the labile trimethylsilyl ether to solvolysis,[30] can similarly be removed in the presence of the TBDMS ether by heating the above hexane/ethanol solvent at 50 °C for 15 min.

These studies indicate that MTBSTFA and the other *tert*-butyldimethylsilyl amides may be useful in the quantitative production of the synthetically stable TBDMS ethers. They may be especially useful in the quantitative formation of TBDMS ethers on intermediary synthetic compounds that also contain other "active" protic functions.

Experimental Section

Melting points were determined on a Thomas-Hoover melting point apparatus and are uncorrected. ^{1}H NMR spectra were recorded on a Varian T-60 spectrometer with chemical shifts reported in parts per million (δ) downfield from tetramethylsilane as an internal standard. Reactions were monitored on a Perkin-Elmer Sigma III gas chromatograph with dual flame-ionization detectors and equipped with a 3% GE SE-52 on Chromosorb W-HP (100/120 mesh) nickel column (1 m × 0.21 cm o.d.). Mass spectra were recorded on a CEC Model 21-110C mass spectrometer. Elemental analyses were performed by Galbraith Laboratories.

tert-Butyldimethylsilyl chloride, *N*-methylacetamide, *N*-methylformamide, and acetamide were obtained from Aldrich Chemical Co. *N*-Methyltrifluoroacetamide was synthesized by the procedure of Bissell and Finger.[31]

N-Methyl-N-(*tert*-butyldimethylsilyl)trifluoroacetamide (MTBSTFA). To 800 mL of dry benzene/acetonitrile (1:1 v/v) was added 127 g (1.0 mol) of *N*-methyltrifluoroacetamide. To this solution, with stirring and maintaining of the temperature at 0 °C, was slowly added 23.5 g (0.98 mol) of sodium hydride. The solution was then stirred for 4 h at 4 °C. At this time, 173.34 g (1.15 mol) of *tert*-butyldimethylsilyl chloride was added in four equal aliquots over a period of 80 min. After the last addition the solution was stirred for 2 h at 4 °C. The precipitate of sodium chloride was then removed from the reaction mixture by filtration under dry nitrogen, with the resulting filter cake being washed twice with 100 mL each of dry benzene. The washings and filtrate were combined and concentrated. The remaining yellow solution was fractionally distilled, with the distillate at 158–172 °C being collected. Redistillation of this fraction gave MTBSTFA: yield 91.3%; bp 168–170 °C (760 mm); d^{20}_4 1.121; ^{1}H NMR ($CDCl_3$) δ 0.28 (s, 6 H, *N*-Si $(CH_3)_2$), 0.98 (s, 9 H, SiC $(CH_3)_3$), 3.08 (s, 3 H, NCH_3); mass spectrum, *m/e* (relative intensity) 241 (M^+, 18), 226 (22), 184 (100), 147 (79), 145 (52), 130 (18), 127 (33), 113 (20). Anal. Calcd for $C_9H_{18}F_3NOSi$: C, 44.79; H, 7.52; N, 5.80; Si, 11.64. Found: C, 44.47; H, 7.46; N, 5.69; Si, 11.50.

N-Methyl-N-(*tert*-butyldimethylsilyl)acetamide (MTBSA). To a vigorously stirred solution of 73.1 g (1.0 mol) of *N*-methylacetamide dissolved in 1400 mL of dry triethylamine was added 196 g (1.30 mole) of *tert*-butyldimethylsilyl chloride. The flask was purged with dry nitrogen and then equipped with a drying tube. Hard stirring of the mixture was continued for 24 h at room temperature. Then, under a layer of dry air, the reaction mixture was filtered to remove the precipitate of triethylamine hydrochloride. The resulting filter cake was then washed three times with 150 mL each of dry triethylamine. The filtrate and washings were combined and reduced in volume by distillation at 35 °C (10 mmHg). The remaining straw-colored

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liquid was then fractionally distilled: yield 88%; bp 57–59 °C (1.0 mm); d^{20}_4 0.8997; ^{1}H NMR ($CDCl_3$) δ 0.26 (s, 6 H, *N*-Si(CH_3)$_2$), 0.94 (s, 9 H, *N*-Si(CH_3)$_3$), 2.05 (s, 3 H, CH_3C), 2.79 (s, 3 H, NCH_3); mass spectrum, *m/e* (relative intensity) 187 (M^+, 11), 127 (17), 130 (100), 147 (74), 73 (66), 59 (93). Anal. Calcd for $C_9H_{21}NOSi$: C, 57.70; H, 11.30; N, 7.48; Si, 14.99. Found: C, 57.32; H, 11.12; N, 7.59; Si, 14.96.

***N*-Methyl-*N*-(*tert*-butyldimethylsilyl)formamide (MTBSF).** Synthesis of MTBSF is the same as that for MTBSA except that 59.01 g (1.0 mol) of *N*-methylformamide was used in place of *N*-methylacetamide: yield 93%; bp 84–85 °C (1.2 mm); mp 32 °C (moist solid); ^{1}H NMR ($CDCl_3$) δ 0.29 (s, 6 H, *N*-Si(CH_3)$_2$), 0.93 (s, 9 H, SiC(CH_3)$_3$), 2.76 (s, 3 H, NCH_3), 8.27 (s, 1 H, HC); mass spectrum, *m/e* (relative intensity) 173 (M^+, 18), 158 (22), 147 (67), 116 (100), 59 (86). Anal. Calcd for $C_8H_{19}NOSi$: C, 55.44; H, 11.05; N, 8.08; Si, 16.20. Found: C, 55.63; H, 10.88; N, 8.19; Si, 15.99.

***N*, *O*-Bis(*tert*-butyldimethylsilyl)acetamide (BMTBSA).** Synthesis of BMTBSA is the same as for MTBSA except that 29.5 g (0.5 mol) of acetamide was used in place of *N*-methylacetamide: yield 88.7%; bp 91–92 °C (2.0 mm); d^{20}_4 0.859; ^{1}H NMR ($CDCl_3$) δ 0.06 (s, 6 H, *O*-Si(CH_3)$_2$), 0.22 (s, 6 H, *N*-Si(CH_3)$_2$), 0.87 (s, 18 H, 2 SiC(CH_3)$_3$), 1.93 (s, 3 H, CH_3C); mass spectrum, *m/e* (relative intensity) 287 (M^+, 15), 272 (13), 230 (100), 189 (33), 155 (78), 147 (74), 116 (22). Anal. Calcd for $C_{14}H_{33}NOSi_2$: C, 58.47; H, 11.57; N, 4.87; Si, 19.53. Found: C, 58.28; H, 11.52; N, 4.81; Si, 19.44.

***tert*-Butyldimethylsilylation.** All derivatizations were performed under dry nitrogen in Teflon-faced septum-capped reaction vials and flasks. Prior to silylation the organic compounds, if solid, were dissolved in a minimal amount of either dry acetonitrile or tetrahydrofuran or, if liquid, were mixed with an equal volume of acetonitrile. In all experiments performed 0.1 μM, 1.0 mM, and 50 mM concentrations of each compound were used. *tert*-Butyldimethylsilylation was accomplished by adding, via a gas-tight syringe, 10.0 equiv (based on the number of silylatable functions), of one of the following reagents: (A) MTBSTFA + 1% TBDMSCl, (B) MTBSA + 1% TBDMSCl, (C) 1.0 m TBDMSCl + 2.0 M imidazole in DMF. *tert*-Butyldimethylsilylation with reagents A and B were allowed to proceed at room temperature for 5 min and for 20 minutes. Reaction mixtures with reagent C were heated at 40 °C, with the progress of the reaction being determined by gas–liquid chromatography every 30 min for 10 h.

Isolation of compounds following *tert*-butyldimethylsilylation with reagent A was accomplished by removal of the acetonitrile or tetrahydrofuran in vacuo followed by the concomitant sublimation at 35 °C (15 torr) of the MTBSTFA, *N*-methyltrifluoroacetamide, and TBDMSCl from the mixture. The remaining clear residues (≥97% purity by GLC) were then sublimed or distilled. Compounds *tert*-butyldimethylsilylated with reagent B were sublimed immediately following the removal of the reaction solvent. Compounds *tert*-butyldimethylsilylated with reagent C were generally isolated by adding the final reaction mixture to one volume of benzene or hexane and washing the mixture several times with water. The organic layer was then reduced in volume in vacuo, and the contaminating *tert*-butyldimethylsilanol was removed by sublimation at 35 °C (15 torr). Due to the presence of DMF in reagent C, sublimation or distillation of the silylated product from the initial reaction was impossible.

Registry No. MTBSTFA, 77377-52-7; MTBSA, 82112-20-7; MTBSF, 68944-33-2; MtBSA, 82112-21-8; RO(CH_2)$_3$OR (R = *tert*-butyldimethylsilyl), 82112-22-9; ROCH$_2$CH(OR)CH$_2$OR (R = *tert*-butyldimethylsilyl), 82112-23-0; C_6HsOR (R = *tert*-butyldimethylsilyl), 18052-27-2; $CH_3CH_2CH_2SR$ (R = *tert*-butyldimethylsilyl), 82112-24-1; $(CH_3)_2CHSR$ (R = *tert*-butyldimethylsilyl), 82112-25-2; RS(CH_2)$_3$SR (R = *tert*-butyldimethylsilyl), 82112-26-3; RSCH$_2$CH(OR)CH$_2$OR (R = *tert*-butyldimethylsilyl), 82112-27-4; RSCH$_2$CH$_2$OR (R = *tert*-butyldimethylsilyl), 82112-28-5; RSCH$_2$COOR (R = *tert*-butyldimethylsilyl), 82112-29-6; ROCH$_2$CH$_2$COOR (R = *tert*-butyldimethylsilyl), 82112-30-9; RO-*m*-C_6H_4COOR (R = *tert*-butyldimethylsilyl), 67226-77-1; RO-*o*-$C_6H_4CH_2OR$ (R = *tert*-butyldimethylsilyl), 82112-31-0; RO-*p*-$C_6H_4CH_2COCOOR$ (R = *tert*-butyldimethylsilyl), 82112-32-1; DL-C_2HsCH(NHR)COOR (R = *tert*-butyldimethylsilyl), 82112-33-2; C_2HsCH(NHR)CH$_2$OR (R = *tert*-butyldimethylsilyl), 82112-34-3; $CH_3CH(NHR)CH_2OR$ (R = *tert*-butyldimethylsilyl), 82134-49-4; 2,4-(OR)-6-(RNH)pyrimidine (R = *tert*-butyldimethylsilyl), 82112-35-4; $C_6HsCH_2NR(CH_3)$ (R = *tert*-butyldimethylsilyl), 82112-36-5; 1,3-propanediol, 504-63-2; glycerol, 56-81-5; phenol, 108-95-2; 1-propanethiol, 107-03-9; 2-propanethiol, 75-33-2; 1,3-propanedithiol, 109-80-8; 2-mercapto-1,2-propanediol, 96-27-5; 2-mercaptoethanol, 60-24-2; mercaptoacetic acid, 68-11-1; 3-hydroxypropionic acid, 503-66-2; *m*-hydroxybenzoic acid, 99-06-9; 2-hydroxybenzyl alcohol, 90-01-7; *p*-hydroxyphenylpyruvic acid, 156-39-8; DL-2-aminobutyric acid, 2835-81-6; 2-amino-1-butanol, 96-20-8; 2-amino-1-propanol, 78-91-1; 4-amino-2,6-dihydroxypyrimidine, 873-83-6; benzylmethylamine, 103-67-3; *tert*-butyldimethylsilyl chloride, 18162-48-6; *N*-methyltrifluoroacetamide, 815-06-5; *N*-methylacetamide, 79-16-3; *N*-methylformamide, 123-39-7; acetamide, 60-35-5.

Reactions of Enamines with Trifluoroacetic Anhydride: Trifluoroacetylation and the Formation of 1,3-Oxazines

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In relation to our work on the synthesis of analogues of the antitumor antibiotic mitomycin C, we are currently interested in the reactions of pyrrolizines, prepared by reaction of 1-(1-pyrrolidinyl)cycloalkenes and dimethyl acetylenedicarboxylate (DMAD), with trifluoroacetic anhydride (TFA). Kametani et al. used this reagent for the conversion of pyrroloindoles into azocines.[1] Recently, we have reported that one of the pyrroloindoles that we have synthesized, viz., methyl 7a,8,9,10-tetrahydro-7-(methoxycarbonyl)-7*H*-benzo[*g*]pyrrolo[1,2-*a*]indole-7-acetate, reacted in a different way with TFA, namely, via trifluoroacetylation of the aromatic ring.[2] This result led us to investigate reactions of other pyrrolizines with TFA.

We found that methyl 1,2,3,5,6,7,7a,8-octahydro-8-(methoxycarbonyl)cyclopenta[*b*]pyrrolizine-8-acetate (**1**, E = $COOCH_3$)[3] reacted smoothly with TFA at room temperature to give one product in 65% yield. According to the mass spectrum and elemental analysis, the elemental composition of the reaction product was $C_{17}H_{20}F_3NO_5$, indicating that trifluoroacetylation had taken place.

In the ^{1}H NMR spectrum, the characteristic NCH absorption at δ 4.74 (dd, *J* = 5 and 12 Hz) was still present. X-ray diffraction showed that the compound had the methyl 1,2,5,6,7,7a,8,8a-octahydro-8-(methoxycarbonyl)-3-(trifluoroacetyl)cyclopenta[*b*]pyrrolizine-8-acetate (**3**) structure (Figure 1). We assume that this reaction of **1** proceeds via its tautomeric form **2** (Scheme I) in which trifluoroacetylation takes place at the β-enamine carbon atom.

The surprising result of the reaction of **1**, which possesses an enamine moiety, with TFA led us to study the reaction of other enamines with this reagent. To our knowledge such reactions have not been reported in the literature, although reactions with acetic anhydride[4,5] and

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