the diethyl phosphate **5** was isolated in agreement with the known reactions of simple sulfenyl chlorides.[9]

Consequently, we would like to propose that the initial attack of triphenylphosphine in the synthesis of the thioketones occurs at the *C*-chlorine atom to form a carbanion stabilized by the strong π-electron acceptors (eq. 1). Alternatively, the formation of the dichloro disulfide might be a result of another attack on the sulfur or *S*-chlorine atom and subsequent intermolecular reaction in the case of comparatively weak π-electron accepting substituents. The fact that the reverse addition of the reagent or the dilution technique did not affect the experimental results suggests that disulfide formation may be very facile and occur through an *S*-phosphonium chloride as a possible intermediate (eq 2).

Experimental Section

IR spectra were obtained using a Hitachi Model 215. ^{1}H NMR and ^{13}C NMR spectra were determined on JNM-PS-100 and JNM-FX-100, respectively. Mass spectra were obtained using a Hitachi RMU-7L. The unstable sulfenyl chlorides were applied to the TLC plates made of Wako-Gel B5-FM (Wako Pure Chem. Co., Osaka, Japan) and silica gel columns made of Wako-Gel C-100.

Ethyl α-Chloro-α-(chlorosulfenyl)phenylacetate (1e). To a solution of 9 g of the sulfenyl chloride **1c** in 50 mL of absolute benzene was added 2.65 g of NaOEt. The mixture was stirred at room temperature overnight. The solvent was evaporated in vacuo, and the resulting oil was purified on a silica gel column (200 g) using a mixture of EtOAc–*n*-hexane (1:50) as the solvent system. Evaporation of the first eluate gave 5.4 g (58%) of slightly yellow oil: IR (neat) 1742, 1715 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.29 (t, 3 H), 4.34 (q, 2 H), 7.26–7.50 (m, 3 H), 7.56–7.76 (m, 2 H); ^{13}C NMR ($CDCl_3$) δ 166.5 (C=O), 134.0, 130.1, 128.6, 127.5 (Ph), 83.8 (C–S), 64.1, 13.9 (Et); MS *m/e* 264 (M, 3), 229 (M − Cl, 3), 197 (M − SCl, 81), 194 (M − Cl_2, 14), 191 (M − COOEt, 14), 121 (PhCS, 100).

Ethyl α-Chloro-α-(chlorosulfenyl)propionate (1f). A mixture of 5 g of propionic acid, 0.15 mL of pyridine, and 50 mL of thionyl chloride was refluxed for 72 h. The NMR spectrum of the resulting solution exhibited a single peak at δ 2.18 which was attributed to methyl hydrogens of the sulfenyl chloride **1d.** Excess thionyl chloride was evaporated in vacuo, and the resulting material was triturated with *n*-hexane. Precipitated pyridinium salts were filtered off. The filtrate was concentrated to dryness, and the residue was dissolved in 100 mL of absolute benzene. The solution was treated with 5.05 g of NaOEt at room temperature overnight. The solvent was evaporated, and the residue was purified on a silica gel column (150 g) using 1.5% EtOAc in *n*-hexane as the solvent system. Evaporation of the first eluate gave 5.8 g (43%) of slightly yellow oil: IR (neat) 2976, 1745, 1732 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.34 (t, 3 H), 2.16 (s, 3 H), 4.32 (q, 2 H); ^{13}C NMR ($CDCl_3$) δ 166.8 (C=O), 75.0 (C–S), 63.7, 14.0 (Et), 28.0 (Me); MS *m/e* 202 (M, 44), 135 (M − SCl, 9), 132 (M − Cl_2, 9), 129 (M − COOEt, 64).

2,2,4,4-Tetrakis(ethoxycarbonyl)-1,3-dithietane (3a). To a solution of 2.015 g (7.69 mmol) of Ph_3P in 20 mL of absolute benzene was added a solution of 2.0 g (7.69 mmol) of the sulfenyl chloride **1a** in absolute benzene at 5–10 °C. The resulting mixture was stirred for 10 min and then evaporated to dryness. The residue was triturated with 20 mL of absolute ether and 0.15 mL (~8 mmol) of water. After the evolution of HCl gas, the resulting Ph_3PO (1.55 g, 72%) was filtered off and the filtrate was evaporated to dryness. The residue was further triturated with 30 mL of *n*-hexane to remove another crop of Ph_3PO (0.48 g, 22%). Complete removal of Ph_3PO was accomplished by LC using 30 g of 50-μm irregular shaped silica gel and a 4% EtOAc–*n*-hexane mixture as the solvent system. The eluate was evaporated to give 1.35 g (93%) of crystals which was further recrystallized from *n*-hexane to afford plates: mp (uncorrected) 51–51.5 °C (lit.[10] mp 59.5–60 °C); IR and NMR spectra were identical with reported ones.[10] Anal. Calcd for $C_{14}H_{20}O_8S_2$: C, 44.20; H, 5.30; S, 16.85. Found: C, 44.11; H, 5.35; S, 16.85.

Monothiobenzil (2b). A solution of 1.5 g of the sulfenyl chloride **1b** in 10 mL of absolute benzene was treated with 1.33 g of Ph_3P in the same manner as described above to give 1.15 g (72%) of the product as a glassy polymer: IR spectrum was identical with reported one;[11] MS *m/e* 226 (M, 58), 121 (PhCS, 89), 105 (PhCO, 100). When this polymer was dissolved in dichloromethane, absorption of the solution at 608 nm, identical with that of **2b,** was observed as described in the literature.[5]

2,4-Bis(ethoxycarbonyl)-2,4-diphenyl-1,3-dithietane (3b). A solution of 1 g of the sulfenyl chloride **1e** in 10 mL of absolute benzene was treated with 993 mg of Ph_3P in the same manner as described above. The resulting crystals (610 mg, 83%), obtained after column chromatography using 30 g of silica gel and a mixture of EtOAc–*n*-hexane (1:30) as the solvent system, were recrystallized from *n*-hexane as needles: mp 103–103.5 °C (lit.[4] mp 89–91 °C); IR (KBr) 1725, 1715, 1221, 1019 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.25 (t, 6 H), 4.26 (q, 4 H), 7.18–7.35 (m, 6 H), 7.41–7.58 (m, 4 H); MS *m/e* 388 (M, 1.2), 355 (M − SH, 1.4), 324 (M − S_2, 1.8), 315 (M − COOEt, 51), 194 (M/2, 10), 121 (PhCS, 100). Anal. Calcd for $C_{20}H_{20}O_4S_2$: C, 61.83; H, 5.19; S, 16.50. Found: C, 62.10; H, 5.24; S, 16.51.

Bis[1-chloro-1-(ethoxycarbonyl)ethyl] Disulfide (4). A solution of 500 mg of the sulfenyl chloride **1f** in 10 mL of absolute benzene was also treated with 649 mg of Ph_3P. The crude product was purified on a silica gel column (20 g) using a mixture of *n*-hexane and EtOAc (100:1) as the solvent system. Evaporation of the solvent from the first eluate gave 269 mg (65%) of colorless oil: IR (neat) 1730 cm^{-1}; ^{1}H NMR (CCl_4) δ 1.35 (t, 6 H), 2.12 (s, 6 H), 4.28 (q, 4 H); MS *m/e* 334 (M, 16).

Diethyl *S*-[1-Chloro-1-(ethoxycarbonyl)ethyl] Thiolphosphate (5). To a solution of 400 mg of the sulfenyl chloride **1f** was added 600 mg of $(EtO)_3P$. Evaporation of the solvent and column chromatography of the resulting oil on 20 g of silica gel using a mixture of *n*-hexane–EtOAc (10:1) gave 289 mg (48%) of colorless oil: IR (neat) 1739 cm^{-1}; ^{1}H NMR (CCl_4) δ 1.37 (t, 9 H), 2.27 (s, 3 H), 4.02–4.43 (m, 6 H); MS *m/e* 304 (M, 7).

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Registry No.—**1a,** 51270-73-6; **1b,** 63369-91-5; **1c,** 31076-68-3; **1d,** 69439-77-6; **1e,** 69439-78-7; **1f,** 52414-78-0; **2b,** 16939-18-7; **2b** polymer, 69439-74-3; **3a,** 17239-56-4; **3b,** 55970-45-1; **4,** 69439-79-8; **5,** 69439-80-1; propionic acid, 79-09-4; thionyl chloride, 7719-09-7.

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Synthesis of 5-(Methylthio)-, 5-(Methanesulfinyl)-, and 5-(Methanesulfonyl)uracil and Reaction of the Methyl Hypobromite Adduct of 5-Bromouracil with Carbonylmethylene Compounds

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The reaction of dimethyl sulfoxide with chloromethyl methyl ether or acetyl chloride has been shown to give methylal, dimethyl sulfide, dimethyl disulfide, methyl methanethiolsulfonate, methyl chloride, and paraformaldehyde.[1] When uracil was present in the reaction mixture, it was converted to 5-(methylthio)uracil (**1**) in good yield. However, on treatment with a mixture of dimethyl sulfoxide and acetic anhydride,[2] uracil was found to be stable. Few papers on using dimethyl sulfoxide as a methylthiation reagent have appeared,[3] and a mixture of dimethyl sulfoxide and

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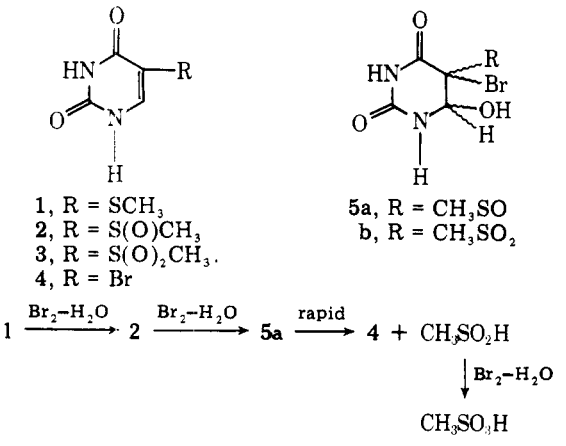
Scheme I



chloromethyl methyl ether or acetyl chloride also served as a methylthiomethylating reagent[4] as was the case of the Pfitzner–Moffatt reagent.[5] A possibility that methanesulfenyl chloride was a reactive species was suggested.[1]

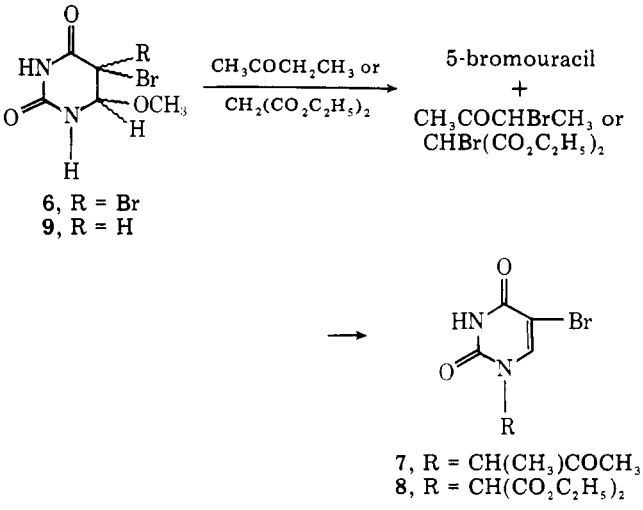
In fact, uracil reacted with methanesulfenyl chloride in dimethylformamide to give **1**, which was converted to 5-(methanesulfinyl)uracil (**2**) and 5-(methanesulfonyl)uracil (**3**) on treatment with stoichiometric amounts of *m*-chloroperbenzoic acid in trifluoroacetic acid. However, when **1** was treated with excess bromine in the presence of water, 5-bromouracil (**4**) was obtained. The reaction was monitored by NMR using a mixture of DMF-d_7 and D_2O as the solvent. Thus, **1** was converted to the sulfoxide **2** with equimolar bromine, and for conversion of **2** to **4**, 2 equiv of bromine was needed, suggesting the mechanism working as shown in Scheme I, which involved an unstable and thus undetectable intermediate **5a**. The fact that the reaction path did not involve the sulfone **3** was shown as follows. NMR showed that, though **3** was partly converted to an adduct **5b** with equimolar bromine in the presence of D_2O, accompanying the shift of a CH_3SO signal at δ 3.28 in **3** to δ 3.44 in **5b** and the shift of a C_6H signal at δ 8.58 in **3** to δ 5.40 in **5b**, further conversion to **4** was not observed even under forced conditions (90 °C, 3 h). The equilibrium was almost completely shifted to **5b** with 3 equiv of bromine, and attempts at isolating **5b** failed, resulting in recovery of 3.

The mechanism proposed here has a similarity to that of the bromination of uracil.[8] It is worthwhile to quote that the methanesulfinyl group is eliminated here as a cation in contrast to the reported cases where the corresponding anion or its rearranged species is a leaving group.[11]

Treatment of **2** with excess bromine in methanolic dimethylformamide gave the methyl hypobromite adduct **6**[6] of **4**. The reaction of the adduct **6** with 2-butanone or with diethyl malonate afforded the corresponding N-substituted compound **7** or **8**, which was also provided on treatment of **4** with 3-bromo-2-butanone or with diethyl bromomalonate (Scheme II). These facts suggest that **6** served as a brominating reagent in these reactions. On the other hand, the methyl hypobromite adduct **9** of uracil was found to be too unstable[7] to use for the similar purpose. Relating to the present work, addition of methyl hypobromite to 5-fluorouracil has been studied by Duschinsky et al.[12]

The position of substitution in **7** was confirmed by the ^{13}C NMR spectrum, which exhibited a C-6 signal at δ 143.7 showing one-bond ^{13}C–^1H coupling of J = 185.5 Hz. Furthermore, it coupled with the hydrogen of the methine at N-1 (J = 4.9 Hz), being detected by weakly and selectively irradiating[9] this hydrogen, whose signal was found at δ 4.98 (q, J = 8 Hz) on ^1H NMR. If **7** is an N-3 substituted compound, such a long range (five-bond) coupling is not expected.

Scheme II



Experimental Section

5-(Methylthio)uracil[1] (1). Improved Method 1. To a solution of uracil (1 g) in Me_2SO (20 mL) was added chloromethyl methyl ether (10 mL) at once, and the mixture was stirred at room temperature for 16 h. The volatile material produced was allowed to evaporate through a calcium chloride tube. Ice water (100 mL) was added, and the mixture was allowed to stand for 3 h. The precipitate was taken by filtration, washed with water, and dried to yield 1.2 g of a solid whose analysis and UV spectrum showed had a purity of 90%, contaminated with paraformaldehyde. The crude product was used for further processes. An analytical sample was obtained by crystallization from Me_2SO and EtOH, mp >300 °C.

Anal. Calcd for $C_5H_6O_2S$: C, 37.96; H, 3.82; N, 17.71; S, 20.27. Found: C, 37.70; H, 3.75; N, 17.46; S, 20.04.

Improved Method 2. Uracil was treated with methanesulfenyl chloride, which was generated from CH_3SSCH_3 and SO_2Cl_2[10] and used in situ. Thus, a solution (10 mL) of methanesulfenyl chloride prepared by adding SO_2Cl_2 (34 g) to a solution of CH_3SSCH_3 (23.6 g) in 1,1,2,2-tetrachloroethane (75 mL) at −15 to −20 °C was added to a solution of uracil (500 mg) in DMF (40 mL). The mixture was allowed to stand at room temperature for 16 h. MeOH was added, and after concentration to dryness the residue was crystallized from Me_2SO and EtOH, yielding 170 mg of **1**.

5-(Methanesulfinyl)uracil (2). To a stirred solution of 5-(methylthio)uracil (474 mg, 3 mmol) in trifluoroacetic acid (6 mL) cooled at −15 °C was added *m*-chloroperbenzoic acid (517.5 mg, 3 mmol) portionwise. After the mixture was allowed to stand overnight at room temperature, the solvent was evaporated to dryness in a hood. The residue was washed with acetone and crystallized from Me_2SO and EtOH, yielding 380 mg of **2**: mp 237 °C dec; UV λ_{max} (MeOH) 270 nm (ϵ 7800); MS *m/e* 174 (M^+), 159 ($M^+ - CH_3$), 158 ($M^+ - O$), 125 ($M^+ - CH_3SOH$).

Anal. Calcd for $C_5H_6N_2O_3S$: C, 34.47; H, 3.47; N, 16.09; S, 18.41. Found: C, 34.82; H, 3.78; N, 15.74; S, 18.58.

5-(Methanesulfonyl)uracil (3). 5-(Methylthio)uracil (474 mg, 3 mmol) was treated with *m*-chloroperbenzoic acid (1.035 g, 6 mL) in trifluoroacetic acid (6 mL) as mentioned in the preceding section. After the solvent was evaporated, the residue was washed with EtOH and crystallized from Me_2SO and EtOH: yield 500 mg; mp >300 °C; UV λ_{max} (MeOH) 262 nm (ϵ 8600); MS *m/e* 190 (M^+), 175 ($M^+ - CH_3$), 126 ($M^+ - SO_2$).

Anal. Calcd for $C_5H_6N_2O_4S$: C, 31.57; H, 3.18; N, 14.73; S, 16.86. Found: C, 31.42; H, 3.20; N, 14.79; S, 16.92.

Reaction of 5-(Methylthio)uracil with Excess Bromine and Water. To a solution of 5-(methylthio)uracil (500 mg, 3.16 mmol) in DMF (20 mL) was added bromine (1.6 g, 10 mmol) and water (20 mL). The mixture was allowed to stand at room temperature for 30 min. After concentration to dryness, the residue was crystallized from water and acetone, yielding 300 mg of 5-bromouracil.

$BrOCH_3$ Adduct (6) of 5-Bromouracil. A solution of 5-(methanesulfinyl)uracil (87 mg, 0.5 mmol) and bromine (500 mg, 3.125 mmol) in a mixture of DMF (10 mL) and MeOH (20 mL) was refluxed for 1 h and then concentrated to dryness. The residue was treated with hot acetone, and the undissolved crystalline dimethylamine hydrobromide (101 mg) was removed by filtration. The product was obtained by concentration of the filtrate and crystallization of the residue from acetone and water, yielding 66 mg of **6**. It showed no UV

absorption, and the IR spectrum was identical with that of the sample prepared from 5-bromouracil,[6] mp 212–213 °C.

Anal. Calcd for $C_5H_6N_2O_3Br_2$: C, 19.89; H, 2.00; N, 9.48; Br, 52.93. Found: C, 19.99; H, 2.00; N, 9.60; Br, 52.73.

1-(2-Butanon-3-yl)-5-bromouracil (7). A. A solution of **6** (1 g, 8.9 mmol) in a mixture of triethylamine (1 g, 9.9 mmol) and 2-butanone (30 mL) was allowed to stand at 37 °C overnight. Crystals of triethylamine hydrobromide were precipitated. The mixture was condensed to dryness, and after the amine hydrobromide was removed by washing with water the residue was crystallized from propanol: yield 276 mg; mp 210–212 °C; UV λ_{max} (MeOH) 280 nm (ϵ 16 600); NMR (Me_2SO-d_6–D_2O) δ 2.16 (s, 3 H, CH_3CO), 2.53 (d, 3 H, CH_3CH, J = 7 Hz), 4.97 (q, 1 H, CH_3CH, J = 7 Hz), 8.04 (s, 1 H, C_6H); MS *m/e* 262 and 260 (M^+), 219 and 217 ($M^+ - CH_3CO$).

Anal. Calcd for $C_8H_9N_2O_3Br$: C, 36.80; H, 3.47; N, 10.73; Br, 30.61. Found: C, 36.90; H, 3.51; N, 10.68; Br, 30.20.

B. A solution of 5-bromouracil (382 mg, 2 mmol), 3-bromo-2-butanone (400 mg, 2.5 mmol), and triethylamine (1 mL) in DMF (20 mL) was allowed to stand at 37 °C overnight. Evaporation of the solvent and crystallization of the residue afforded 417 mg of **7**.

The IR spectra of the samples obtained by these two methods were the same.

1-[Bis(ethoxycarbonyl)methyl]-5-bromouracil (8). A. A solution of **6** (602 mg, 2 mmol), diethyl malonate (400 mg, 2.5 mmol), and triethylamine (1 mL) in DMF (10 mL) was allowed to stand at room temperature overnight and was concentrated to dryness. The residue was distributed between $CHCl_3$ and water, with the organic layer being taken. Silica gel chromatography eluting with a mixture of benzene and ethyl acetate (1–2:1) afforded 344 mg of a syrup, which gradually changed to crystals melting at 108–111 °C: UV λ_{max} (MeOH) 276 nm (ϵ 9100); NMR ($CDCl_3$–D_2O) δ 2.33 (t, 6 H, $2CH_3CH_2$, J = 7 Hz), 4.33 (q, 4 H, $2CH_3CH_2$, J = 7 Hz), 6.08 (s, 1 H, $CH(COOC_2H_5)_2$), 7.82 (s, 1 H, C_6H); MS *m/e* 450 and 348 (M^+), 277 and 275 ($M^+ - C_2H_5OCO$), 232 and 230 ($M^+ - C_2H_5OCO - C_2H_5O$, base peak).

Anal. Calcd for $C_{11}H_{13}N_2O_6Br$: C, 37.84; H, 3.75; N, 8.03; Br, 22.89. Found: C, 37.99; H, 3.83; N, 8.05; Br, 22.71.

B. A solution of **4** (382 mg, 2 mmol), diethyl bromomalonate (600 mg, 2.85 mmol), and triethylamine (1 mL) in DMF (20 mL) was allowed to stand at 37 °C overnight, and the product was isolated as mentioned in method A, yield 622 mg.

The IR spectra of the samples obtained by these two methods were the same.

Registry No.—**1**, 16350-59-7; **2**, 16350-60-0; **3**, 16417-11-1; **4**, 51-20-7; **6**, 28743-58-0; **7**, 66449-45-4; **8**, 66449-35-2; uracil, 66-22-8; chloromethyl methyl ether, 107-30-2; methanesulfenyl chloride, 5813-48-9; 2-butanone, 78-93-3; 3-bromo-2-butanone, 814-75-5; diethyl malonate, 105-53-3; diethyl bromomalonate, 685-87-0.

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Communications

Reaction of Alkyl Halides and Alkyl Methyl Ethers with Nitronium Tetrafluoroborate in Acetonitrile

Summary: The reaction of alkyl halides and alkyl ethers with nitronium tetrafluoroborate in acetonitrile affords acetamides by electrophilic cleavage of the carbon–heteroatom bond and trapping the resulting trivalent carbenium ion with acetonitrile.

Sir: The electron-deficient nitronium ion interacts strongly with π systems and has been used extensively in aromatic nitration. Nitronium salts are also powerful oxidizing agents as evidenced by their substitution (nitration) and cleavage (nitrolysis) of σ-donor single bonds in hydrocarbons.[1] The heterolytic cleavage of C–C and C–H bonds has been observed in low yield with NO_2PF_6 in aprotic solvents.[2] More recently, we have found that NO_2BF_4 in acetonitrile will abstract hydride ion from a variety of hydrocarbons affording transient trivalent carbenium ions.[3]

In addition to the reaction of nitronium ion reagents with aromatic compounds, alkenes, and hydrocarbons, there have been several reports on the reaction of alkyl halides with nitronium ion.[4] Nascent nitronium ion, generated in situ by the reaction of hydrogen halide with nitric acid, was postulated to transform an alkyl iodide into a carbenium ion which was subsequently captured by halide and nitrate ions. Primary alkyl chlorides and alkyl fluorides were shown to be resistant to further reaction.[4] More recently, Olah has reported the oxidation of alkyl methyl ethers to carbonyl compounds in good yield utilizing nitronium tetrafluoroborate in dichloromethane solvent (eq 1).[5]

$$R_2CHOMe + NO_2^+BF_4^- \xrightarrow{CH_2Cl_2} \xrightarrow{H_2O} R_2C{=}O + CH_3OH \quad (1)$$

We now report a novel convenient procedure for the conversion of selected alkyl halides and alkyl methyl ethers to their corresponding acetamides. Our results, which are summarized in Table I, demonstrate the utility and limitations of this reaction for electrophilic attack on lone pair donor molecules.

The experimental procedure is extremely easy to carry out. In a typical experiment 10 mmol of substrate in 20 mL of dry CH_3CN was added to 13–20 mmol of NO_2BF_4 under a nitrogen atmosphere.[6,7] After stirring at room temperature for 1–15 h (Table I) the reaction was quenched by the addition of water and the acetamide product was isolated by simple extraction (Scheme I). The alkyl iodides, bromides, and methyl ethers were sufficiently reactive to warrant addition of the substrate at 0 °C. These highly exothermic reactions were allowed to stir 15 min at 0 °C and an additional 1–6 h at room temperature. The reactivity trends noted were RI > RBr ~ ROMe ≫ RH ~ RCl > RF.[8] In general, the ease of the abstraction of X^- or

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