the workup procedure described above, the product was purified by preparative layer chromatography. The product was chromatographed on silica gel plates which were developed with CH_2Cl_2. The band with R_f 0.46 was cut out and eluted with 3% $MeOH/CH_2Cl_2$, giving the product as a yellow oil: 40% yield; ^1H NMR ($CDCl_3$) for **7c** δ 0.90 (t, 3 H, J = 7.1 Hz), 1.84 (d, 3 H, J = 7.1 Hz), 3.33 (q, 2 H, J = 7.1 Hz), 5.70 (q, 1 H, J = 7.1 Hz), 7.32 (m, 5 H); for **6c** δ 1.46 (d, 3 H, J = 6.7 Hz), 1.48 (t, 3 H, J = 7.3 Hz), 4.18 (m, 2 H, J = 7.3 Hz), 5.14 (q, 1 H, J = 6.7 Hz), 7.31 (m, 5 H); mass spectrum, m/z (relative intensity) 179 (100, MH^+), 163 (7, $MH\text{-}O^+$), 121 (7), 105 (50, $C_7H_8CH_3^+$).

***N*-Carbobenzoxy-α-methylbenzylamine (11).** The protected amine **11** was prepared by reaction of α-methylbenzylamine in ether/water with an ether solution of benzyl chloroformate and NaOH at 0 °C for 1 h.[14] The reaction mixture was then stirred at 25 °C for 3 h. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (2 × 40 mL). The combined organic layers were dried over Na_2SO_4. The solvent was removed under reduced pressure and the product, a white solid, was dried in vacuo at 2 torr. The product **11** was isolated: 54% yield; mp 57–58 °C; ^1H NMR ($CDCl_3$) δ 1.46 (d, 3 H, J = 6.7 Hz), 4.92 (m, 1 H, J = 6.7 Hz), 5.01 (br s, 1 H), 5.07 (s, 2 H), 7.30 (s, 10 H); mass spectrum, m/z (relative intensity) 256 (100, MH^+), 152 (65, $MH^+ - CO_2CH_2C_6H_5$), 105 (64, $CH_3C_7H_6^+$).

***N*-Ethyl-*N*-carbobenzoxy-α-methylbenzylamine (12).** An oven-dried round-bottomed flask with a septum inlet, pressure-equalized addition funnel, and gas stopcock was evacuated and purged with N_2. The reaction was run under a positive N_2 atmosphere. The flask was charged with 0.8 g (17.0 mmol) of NaH which was washed with 15 mL of dry hexane. The NaH was covered with 5 mL of dry THF. The reaction mixture was cooled in an ice bath and 4.0 g (15.6 mmol) of the amine **11** in 20 mL of dry THF was added dropwise with stirring. After the addition was complete, the reaction mixture was stirred at 25 °C for 1.5 h. The reaction mixture was cooled with an ice bath, and 1.26 mL (15.8 mmol) of ethyl iodide in 10 mL of dry THF was added dropwise with stirring. After the addition was complete, the reaction mixture was stirred at 25 °C for 3 days. The reaction mixture was poured into 50 mL of saturated NaCl solution. The layers were separated, and the aqueous layer was extracted with ether (3 × 40 mL). The combined organic layers were dried over $MgSO_4$. The solvent was removed under reduced pressure. The product was a clear colorless oil: 3.89 g (88% yield); ^1H NMR ($CDCl_3$) δ 0.96 (t, 3 H, J = 7.0 Hz), 1.53 (d, 3 H, J = 7.1 Hz), 3.04 (q, 2 H, J = 7.0 Hz), 5.18 (s, 2 H), 5.54 (q, 1 H, J = 7.1 Hz), 7.28 (s, 5 H), 7.32 (s, 5 H); mass spectrum, m/z (relative intensity) 284 (100, MH^+), 180 (17), 148 (16).

***N*-Ethyl-α-methylbenzylamine Hydrochloride (13).** A flask with a gas inlet tube and a gas stopcock attached to a gas trap was charged with 0.50 g (1.7 mmol) of the protected amine **13** and 4 mL of glacial acetic acid.[15] The solution was continuously saturated with hydrogen chloride for 1 h. After the addition was complete, the reaction mixture was stirred at 25 °C for 1 h. The reaction mixture was diluted with ether. The resulting white precipitate was isolated by suction filtration. The filter cake was washed with ether (2 × 20 mL). The product was dried in vacuo at 2 torr and isolated: 40% yield; mp 198–199 °C (lit.[25] mp 199–200 °C); ^1H NMR (me_2SO-d_6) δ 1.19 (t, 3 H, J = 7.2 Hz), 1.58 (d, 3 H, J = 6.8 Hz), 2.67 (q, 2 H, J = 7.2 Hz), 4.40 (q, 1 H, J = 7.2 Hz), 7.47 (m, 5 H), 9.02 (br s, 2 H); mass spectrum, m/z (relative intensity) 150 (100, MH^+), 134 (11, $MH^+ - CH_4$), 105 (7, $CH_3C_6H_7^+$).

***N*-Nitroso-*N*-ethyl-α-methylbenzylamine (7c,d).** A flask was charged with 0.12 g (0.90 mmol) of the amine salt **13** which was dissolved in 840 μL of water and 120 μL of glacial acetic acid.[9] The reaction mixture was stirred at 25 °C, and 120 mg (2.61 mmol) of $NaNO_2$ dissolved in 300 μL of water was added dropwise over a period of 10 min. After the addition was complete, the reaction was stirred at 25 °C for 30 min. The reaction mixture was cooled in an ice bath and was treated with 500 μL of 5 M NaOH. The reaction mixture was extracted with ether (4 × 3 mL). The combined organic layers were dried over Na_2SO_4. The solvent was removed under reduced pressure, giving the product as an oil: 96 mg (60% yield); ^1H NMR ($CDCl_3$) for isomer **7c** δ 0.91 (t, 3 H, J = 7.1 Hz), 1.86 (d, 3 H, J = 7.1 Hz), 3.39 (m, 2 H, J = 7.1 Hz), 5.63 (q, 1 H, J = 7.1 Hz), 7.34 (m, 5 H); for isomer **7d** δ 1.25 (t, 3 H, J = 7.2 Hz), 1.49 (d, 3 H, J = 7.1 Hz), 3.81 (dq, 2 H, J = 7.2 Hz), 6.13 (q, 1 H, J = 7.1 Hz), 7.34 (m, 5 H); mass spectrum, m/z (relative intensity) 179 (91, MH^+), 105 (100, $CH_3C_7H_6^+$).

Acknowledgment. This work was supported by the National Institutes of Health (Grant CA26381).

Registry No. **1a**, 100-46-9; **1b**, 74-89-5; **1c**, 98-84-0; **2a**, 2621-78-5; **2b**, 105-40-8; **2c**, 1623-51-4; **3a**, 6558-76-5; **3b**, 615-53-2; **3c**, 6316-19-4; **4a**, 87014-46-8; **4b**, 87039-32-5; **4c**, 26370-44-5; **6a**, 87014-47-9; **6b**, 87014-48-0; **6c**, 26370-70-7; **7a**, 937-40-6; **7c**, 87014-49-1; **8**, 13466-29-0; **9**, 26253-98-5; **10**, 7737-14-6; **11**, 87014-50-4; **12**, 87014-51-5; **13**, 37771-39-4; ethyl chloroformate, 541-41-3; methyl iodide, 74-88-4; benzyl iodide, 620-05-3; *N*-methylbenzylamine, 103-67-3; benzaldehyde, 100-52-7; methylhydrazine, 60-34-4; ethyl iodide, 75-03-6.

(25) Novelli, A. *J. Am. Chem. Soc.* **1939**, *61*, 520.

Nucleophilic Aromatic Substitution by 3-Amino-2-butenoates

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The utility of 3-amino-2-butenoates in the preparation of 5-hydroxyindoles from quinones is well-established.[1-3] The mechanism of this transformation, as illustrated for reaction of benzoquinone (**1**) with ethyl 3-amino-2-butenoate (**2**), apparently involves nucleophilic attack by C-2 of the olefin to afford **3**, which subsequently cyclizes to give indole **4** (Scheme I). Analogous Nenitzescu-type reactions have been carried out on maleimides[4] and 3-acylchromones.[5] However, Buckler et al.[6] have recently shown that treatment of aryl acid chlorides with 3-amino-2-butenoates gives both N-acetylated and C-2-acetylated products.

As part of a synthetic program directed at the preparation of novel nitroheterocycles to serve as hypoxic cell radiosensitizers,[7] we have studied the reaction between 3-amino-2-butenoates and some halo nitro aromatics. Our intent was to prepare vinylogous amines of these nitro aromatics by displacement of halogen, as exemplified in the Nenitzescu process. Since the potency of nitro aromatics, as hypoxic cell radiosensitizers, increases with increasing stability of the molecular radical anion,[7] it was anticipated that this structural modification should enhance pharmacologic activity by increasing conjugative stabilization of the radical anion.

Results and Discussion

We have found that 3-amino-2-butenoates react with nitro aromatics that possess easily displaceable halides to give the corresponding vinylogous amines. For example,

(1) Nenitzescu, C. D. *Bull. Soc. Chim. Romania* **1929**, *11*, 37; *Chem. Abstr.* **1930**, *24*, 110.
(2) Monti, S. A. *J. Org. Chem.* **1966**, *31*, 2669.
(3) Raileanu, D.; Palaghita, M.; Nenitzescu, C. D. *Tetrahedron* **1971**, *27*, 5031.
(4) Shah, K. R.; Blanton, C. D., Jr. *J. Org. Chem.* **1982**, *47*, 502.
(5) Heber, D. *Synethsis* **1978**, 691.
(6) Buckler, R. T.; Hartzler, H. E.; Phillips, B. M. *J. Med. Chem.* **1975**, *18*, 509.
(7) Fowler, J. F.; Denekamp, J. *Pharmacol. Ther.* **1979**, *7*, 413.

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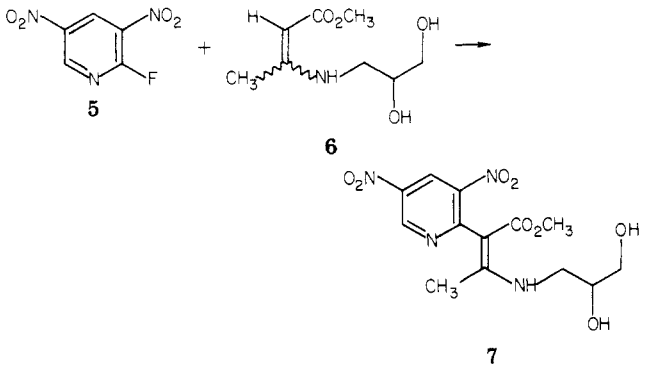
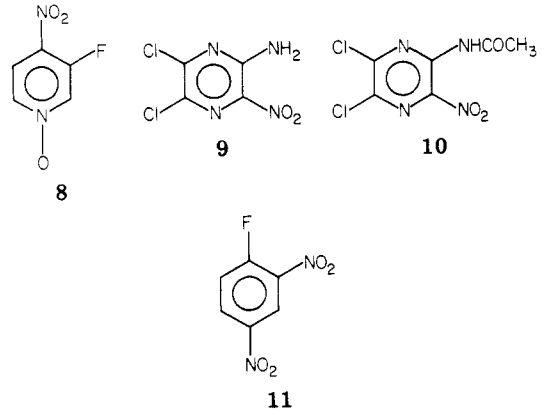
treatment of 2-fluoro-3,5-dinitropyridine (**5**)[8] with methyl 3-[(2,3-dihydroxypropyl)amino]-2-butenoate (**6**)[9] in isopropyl alcohol solution containing an equivalent amount of triethylamine afforded methyl 3-[(2,3-dihydroxypropyl)amino]-2-(3,5-dinitropyridin-2-yl)-2-butenoate (**7**) in 52% yield. We have also found that 3-fluoro-4-nitropyridine *N*-oxide (**8**),[10] 5,6-dichloro-3-nitropyrazinamine (**9**),[11] *N*-[(5,6-dichloro-3-nitropyrazinyl]acetamide (**10**),[11] and 1-fluoro-2,4-dinitrobenzene (**11**) successfully underwent analogous reacton.



5 **6** **7**



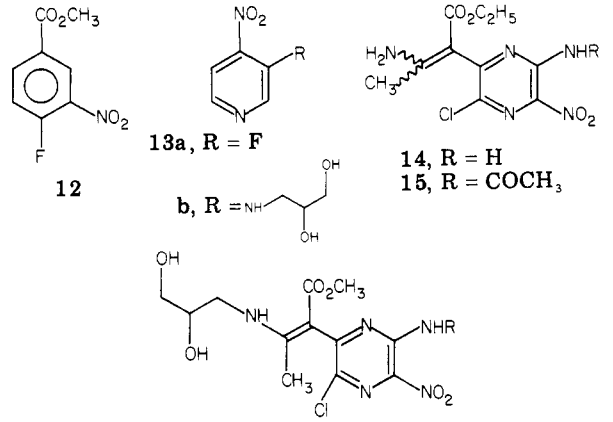
8 **9** **10**

11

Among the compounds studied, **5** proved to be the most reactive, affording **7** after 16 h at room temperature. However, longer reaction times and/or moderate heating were required with **8**–**11**, resulting in increased amounts of tarry decomposition products and somewhat lower yields of desired adducts. It was also observed that the crotonate **6** reacted with **9** approximately 2–3 times faster than did ethyl 3-amino-2-butenoate, possibly due to stabilization of the intermediate iminium species by the additional alkyl group on nitrogen in the former case.

The success of adduct formation was extremely dependent on the reactivity of the nitro aromatic. For example, treatment of **6** with molecules such as methyl 4-fluoro-3-nitrobenzoate (**12**)[12] and 3-fluoro-4-nitropyridine (**13a**),[13] containing less readily displaced halides as compared to **5** and **8**–**11**, afforded no reaction under standard conditions. Prolonged heating in the case of reaction between **6** and **13a** resulted solely in the formation of 3-[(2,3-dihydroxypropyl)amino]-4-nitropyridine (**13b**) derived from retro-Michael decomposition of **6** to 3-amino-1,2-propanediol and subsequent fluoride displacement.

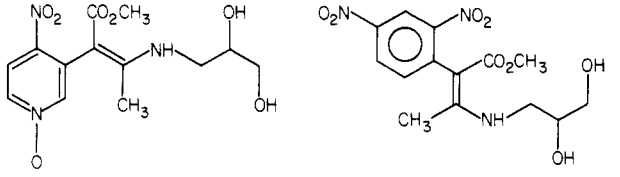
The determination of the configuration about the olefinic double bond in the products was of interest.[9] Treatment of **9** and **10** with ethyl 3-amino-2-butenoate afforded **14** and **15**, with each product mixture composed



12 **13a**, R = F **b**, R = **14**, R = H **15**, R = $COCH_3$

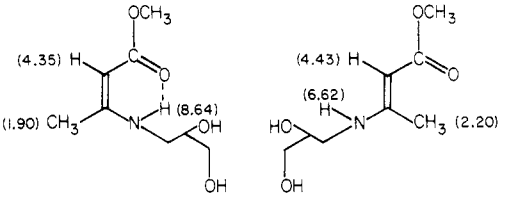
16, R = H
17, R = $COCH_3$

predominantly of the *Z* isomer but containing ~5% and ~8%, respectively, of the *E* isomer. However, treatment of **9** and **10** with **6** afforded adducts **16** and **17**, respectively, each of which, from NMR analysis, was solely the *Z* isomer. Similarly, treatment of **5**, **8**, and **11** separately with **6** gave the desired adducts **7**, **18**, and **19**, which were solely the *Z* isomer.



18 **19**

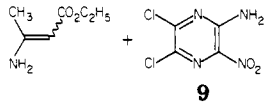
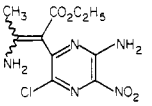
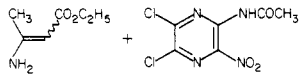
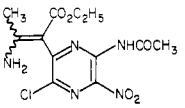
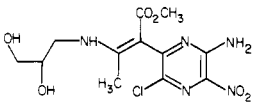
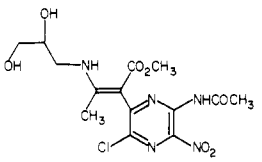
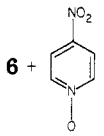
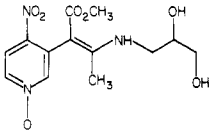
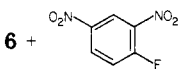
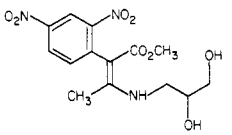
Proton NMR assignments for (*E*)- and (*Z*)-3-amino-2-butenoates were made in analogy to previous work.[6,9] See paragraph at the end of paper for supplementary material. As shown for **6**, the *Z* isomer possesses an allylic methyl group at higher field and a hydrogen-bonded NH at lower field than found in the *E* isomer. Further support for these assignments was gained by a study of the temperature dependence of the NH chemical shift in **6**. When a sample of **6** in Me_2SO-d_6 was heated from 21 °C to 70 °C, the NH absorption at 8.64 varied by only 0.05 ppm, while that at 6.62 varied by 0.32 ppm. Thus, as expected, the chemical shift of the hydrogen-bonded NH (*Z* isomer) was significantly less sensitive to variation in temperature than was the non-hydrogen-bonded NH (*E* isomer). These same



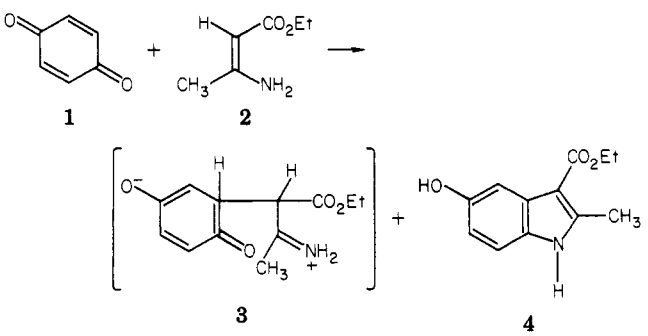
Z isomer **6** *E* isomer

(8) Talik, T.; Talik, Z. *Rocz. Chem.* **1967**, *41*, 1507.
(9) Chalchat, J.-C.; Theron, F.; Vessier, R. *Bull. Soc. Chim. Fr.* **1970**, 711.
(10) Talik, T.; Talik, Z. *Rocz. Chem.* **1966**, *40*, 1187.
(11) Hartman, G. D.; Hartman, R. D., submitted for publication.
(12) Finger, G. C., Kruse, C. W. *J. Am. Chem. Soc.* **1956**, *78*, 6034.
(13) Talik, T.; Talik, Z. *Rocz. Chem.* **1964**, *38*, 777.
(14) Analytical data. For **14**: Calcd for $C_{10}H_{12}ClN_5O_4$: C, 39.81; H, 3.98; N, 23.22. Found: C, 39.52; H, 3.80; N, 23.40. For **15**: Calcd for $C_{12}H_{14}ClN_5O_5$: C, 41.93; H, 4.11; N, 20.38. Found: C, 41.88; H, 4.05; N, 20.18. For **16**: Calcd for $C_{12}H_{16}ClN_5O_6$: C, 39.84; H, 4.46; N, 19.36. Found: C, 39.97; H, 4.49; N, 19.21. For **17**: Calcd for $C_{14}H_{18}ClN_5O_7$: C, 41.64; H, 4.49; N, 17.34; Cl, 8.78. Found: C, 41.83; H, 4.79; N, 16.36; Cl, 8.48. For **18**: Calcd for $C_{13}H_{17}N_3O_7$: 47.71; H, 5.24; N, 12.84. Found: C, 47.28; H, 5.26; N, 12.65. For **19**: Calcd for $C_{14}H_{17}N_3O_8$: C, 47.33; H, 4.82; N, 11.83. Found: C, 47.01; H, 4.88; N, 12.11.
(15) See supplementary material paragraph.

Table I. Reaction of Aminobutenoates with Halo Nitro Aromatics

reactants	product[14,15]	% yield	mp, °C
 9	 14	62	162-165
 10	 15	42	145-147
6 + 9	 16	45	184-186 dec
6 + 10	 17	41	71-74
6 +  8	 18	41	66-69 dec
6 +  11	 19	40	71-73 dec

Scheme I



chemical shift relationships have also been found to hold true in the product molecules.

In conclusion, we have found that treatment of 3-amino- and 3-(alkylamino)-2-butenoates with nitro aromatics possessing readily displaced halogen atoms affords moderate yields of vinylogous amines from nucleophilic aromatic substitution. To our knowledge, this constitutes the initial example of displacement of halogen by 2-aminobutenoates from an aromatic system.

Experimental Section

Melting points (uncorrected) were taken with a Thomas-Hoover capillary apparatus. NMR spectra were recorded either on a Varian T-60 or NT-360 spectrometer with Me_4Si as an internal standard. Mass spectra were obtained by Dr. H. Ramjit on an LKB-φ9000S mass spectrometer at 70 eV. Microanalyses were performed by the Merck analytical department. Ethyl 3-amino-2-butenoate was obtained from the Aldrich Chemical Co. and was distilled before use. Methyl 2-butynoate was obtained from Wiley Organics and was used without purification.

Methyl 3-[(2,3-Dihydroxypropyl)amino]-2-butenoate (6). A solution of 5.0 g (0.051 mol) of methyl 2-butynoate and 4.64 g (0.051 mol) of 3-amino-1,2-propanediol in 50 mL of methanol was refluxed for 36 h. The solvent was removed on the rotary evaporator and the residue subjected to flash chromatography on 230–400-mesh silica gel eluted with 10% methanol/chloroform. Removal of solvents gave the product (R_f 0.5) as a white solid: 7.3 g (76%), mp 60–90 °C; mass spectrum, m/e 189 (100), 174, 171, 158, 128, 116; IR (KBr) 3445, 3370, 3340, 1700, 1640, 1485, 1310, 1210, 825 cm^{-1}; NMR, Z isomer (Me_2SO-d_6) δ 1.90 (3 H, s), 3.21–3.60 (5 H, m), 3.47 (3 H, s), 4.35 (1 H, s), 4.67 (1 H, t, J = 7 Hz), 4.97 (1 H, d, J = 7 Hz), 8.64 (1 H, t); NMR, E isomer (Me_2SO-d_6) δ 2.20 (3 H, s), 3.20–3.60 (5 H, m), 3.45 (3 H, s), 4.43 (1 H, s), 4.62 (1 H, t, J = 7 Hz), 4.81 (1 H, d, J = 7 Hz), 6.62 (1 H, t).

(Z)-Methyl 3-[(2,3-Dihydroxypropyl)amino]-2-(3,5-dinitropyridin-2-yl)-2-butenoate (7). To 0.5 g (0.026 mol) of 2-fluoro-3,5-dintropyridine (5)[8] and 3.0 g (0.03 mol) of triethylamine in 75 mL of isopropyl alcohol was added 4.8 g (0.025 mol) of methyl 3-[(2,3-dihydroxypropyl)amino]-2-butenoate (6) in 25 mL of isopropyl alcohol in one portion. A slight exotherm ensued and the reaction mixture became dark red. After the mixture was stirred for 16 h at room temperature, the solvent was removed on the rotary evaporator. The dark residue was subjected to flash chromatography on 230–400-mesh silica gel eluted with 8% methanol/chloroform. Removal of solvents gave the desired product as an orange solid (R_f 0.5), which was recrystallized from acetonitrile/n-butyl chloride (1:1) to afford 4.95 g (52%) of 7: mp 128–129 °C; mass spectrum, m/e 356, 325, 297 (100), 263, 235; IR (KBr) 3570, 3350, 3040, 1700, 1620, 1580, 1575, 1485, 1380, 1330, 1270, 1120 cm^{-1}; NMR (Me_2SO-d_6) δ 2.08 (3 H, s), 3.35–3.58 (4 H, m), 3.40 (3 H, s), 3.68 (1 H, m), 4.46 (1 H, t, J = 7 Hz), 4.86 (1 H, d, J = 7 Hz), 8.87 (1 H, d), 9.42 (1 H, d), 10.13 (1 H, t).

Anal. Calcd for $C_{13}H_{16}N_4O_8$: C, 43.82; H, 4.52; N, 15.73. Found: C, 43.79; H, 4.64; N, 15.31.

Compounds 14-19 were prepared in analogous fashion.

Registry No. 5, 18617-38-4; (*E*)-6, 87155-48-4; (*Z*)-6, 87155-49-5; 7, 87155-50-8; 8, 769-54-0; 9, 87155-51-9; 10, 87155-52-0; 11, 70-34-8; (*E*)-14, 87155-53-1; (*Z*)-14, 87155-54-2; (*E*)-15, 87155-55-3; (*Z*)-15, 87155-56-4; 16, 87155-57-5; 17, 87155-58-6; 18, 87155-59-7; 19, 87155-60-0; methyl 2-butynoate, 23326-27-4; 3-amino-1,2-propanediol, 616-30-8; ethyl (*E*)-3-amino-2-butenoate, 41867-20-3; ethyl (*Z*)-3-amino-2-butenoate, 626-34-6.

Supplementary Material Available: Full NMR, IR, and mass spectral data for compounds 14-19 (2 pages). Ordering information is given on any current masthead page.

A Simple Photochemical Conversion of Perfluoroalkyl Hydrides to Perfluoroalkyl Bromides Using Interhalogen Compounds

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It is an accepted principle that the inductive effects of halogen substituents reduces the reactivity of hydrogen to radical abstraction by chlorine[1-3] or bromine atoms.[4] Furthermore it is accepted that resonance effects of halogen substituents have an effect on geminal-hydrogen reactivity that is opposite that of their inductive effects.[3] Copp and Tedder have shown that substitution of hydrogen by chlorine lowers the activation energy for radical abstraction of geminal hydrogen by bromine, while substitution of hydrogen or chlorine by fluorine raises the activation energy for radical abstraction by bromine.[4] The increase in activation energy for hydrogen abstraction on fluorinated and chlorofluorinated methanes for bromination would seem to apply to direct fluorinations as well. For example, fluorine substitution of neopentanes tends to produce preferentially the symmetrically substituted polyfluoroneopentanes.[5]

Despite the deactivation of hydrogens toward radical abstraction in fluorocarbons, photochemical bromination and chlorination of hydryl-*F*-alkanes have been previously reported in early work by Haszeldine[6] and by Benning and Park.[7] Thermal brominations of hydryl-*F*-alkanes have been studied by Amphlett and Whittle at temperatures in excess of 400 °C.[8] They have also shown increases in the activation energies in hydrogen abstraction by bromine in the fluoromethane series: CFH_3, CF_2H_2, CF_3H, and also document the reversibility of the bromination reaction due to its inhibition by HBr.[8]

As part of a research effort directed at the construction of highly branched fluorocarbon networks, we sought convenient ways to introduce reactive groups onto hydryl-*F*-neopentanes and other fluorocarbons. This led us to attempt several photochemical bromination schemes. We were able to confirm the very facile room-temperature, gas-phase photochlorination of hydryl-*F*-alkanes but were not able to achieve significant photobromination of these molecules at ambient temperatures. Thermal bromination was unsuccessful at 250 °C, and higher temperatures resulted in significant fluorocarbon skeletal fragmentation. Efforts were then directed toward interhalogen compounds as potential bromination reagents. It is the results of those investigations that are the basis of this report.

Results and Discussion

Because the reactivity of chlorine with hydryl-*F*-neopentane was high and that for bromine was so low, the first interhalogen that suggested itself was bromine chloride. A search of the literature produced many instances where bromine chloride was used as a reactive electrophilic brominating agent but far fewer instances where it was used as a free-radical brominating agent. These examples have been reviewed in some detail by Mills and Schneider.[9] Among the free-radical reaction examples was a reference to the bromination of fluoroform by bromine chloride, which reportedly produced exclusively bromotrifluoromethane.[10]

Bromine chloride (mp −66 °C, bp 5 °C) is approximately 40% dissociated at 25 °C ($k_d° = 0.34$) into bromine (mp −7.2 °C, bp 58.8 °C) and chlorine (mp −103 °C, bp −34.6 °C).[11] It is a polar, reactive electrophile and its selectivity as a brominating agent is apparently due to the attraction of the electron-rich radical to the positive (bromine) end of the molecular dipole of BrCl.[9] Given this hypothesis, the more electrophilic the radical, the less selective will be the bromination.

The reaction of hydryl-*F*-neopentane with bromine chloride was much slower (100 h) than the ambient temperature chlorination of that compound (10 min). The reaction was followed by gas-phase infrared spectroscopy. Although bromo-*F*-neopentane formed much faster initially than chloro-*F*-neopentane, the latter compound was negligible in yields only for overall conversions of less than 10%. As the reaction reached completion (304 h) the percentages of bromo- to chloro-*F*-neopentane was 48-43%. A slight excess of bromine to chlorine and a slightly shorter (254 h) reaction time slightly increases the yield of bromo-*F*-neopentane. The ^{19}F NMR data (Table I) are characteristic and easily interpretable.

The reactions of 1,3-dihydryl-*F*-neopentane under similar conditions are summarized in Table II. All possible products were produced. For example in reaction 1, 1,3-dibromo (31.5%), 1-bromo-3-chloro (18.6%), 1-bromo-3-hydryl (29.2%), 1,3-dichloro (6.5%), and 1-chloro-3-hydryl (11.4%) were produced. The overall ratio of chlorination to bromination was 1:2.6. Increases in chlorine concentration (reaction 2) and increases in overall reaction time (reaction 3) markedly increased the yield of 1-bromo-3-chloro-*F*-neopentane (29.4% and 32%, respectively). Decreases in chlorine concentration (or increases in bromine concentration), reaction 4, significantly increased the yield of 1-bromo-3-hydryl-*F*-neopentane (48%) and recovered starting material (10%). The optimum reaction (reaction 1) for making 1,3-dibromo-*F*-neopentane produced 2.6 times as much bromination as chlorination products; however, optimal bromination (4.4:1) occurred for reaction 4, which produced predominately 1-bromo-3-

(1) Brown, H. C.; Ash, A. B. *J. Am. Chem. Soc.* **1955**, *77*, 4019.
(2) Singh, H.; Tedder, J. M. *J. Chem. Soc. B* **1966**, 612.
(3) Moore, L. O.; Rectenwald, C. E.; Clark, J. W. *Int. J. Chem. Kinet.* **1972**, *4*, 331-338.
(4) Copp, D. E.; Tedder, J. M. *Int. J. Chem. Kinet.* **1972**, *4*, 69-77.
(5) Adcock, J. L.; Horita, K.; Renk, E. B. *J. Am. Chem. Soc.* **1981**, *103*, 6937-47.
(6) Haszeldine, R. N. *J. Chem. Soc.* **1953**, 3761-8.
(7) Benning, A. F.; Park, J. D. U.S. Patent 2490764, 1949.
(8) Amphlett, J. C.; Whittle, E. *Trans. Faraday Soc.*, **1968**, *64*, 2130.
(9) Mills, J. F.; Schneider, J. A. *Ind. Eng. Chem. Prod. Res. Devel.* **1973**, *12*, 161-5.
(10) Ruh, R. P.; Davis, R. A. The Dow Chemical Co., U.S. Patent 2658086, 1953.
(11) Cotton, F. A.; Wilkinson, G. "Advances in Inorganic Chemistry", 4th ed.; Wiley Interscience: New York, 1980; pp 562-5.

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