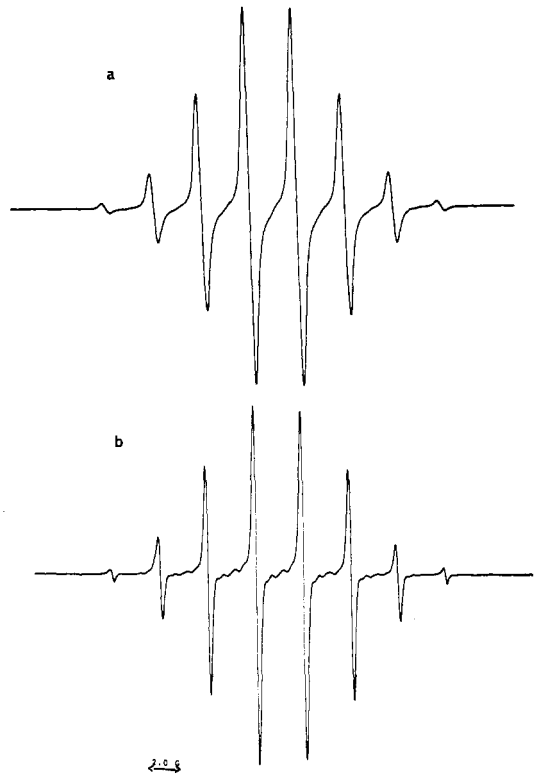

Figure 3. (a) ESR spectrum of III^{-}· generated by sodium reduction in HMPA. Note that the spectral lines are well resolved as opposed to the spectra in Figures 1a and 2. (b) ESR spectrum of III-d_9^{-}· generated by sodium reduction in HMPA. Although the line widths are somewhat smaller than those in 3a, the improvement is hardly comparable to that observed in Figure 1.

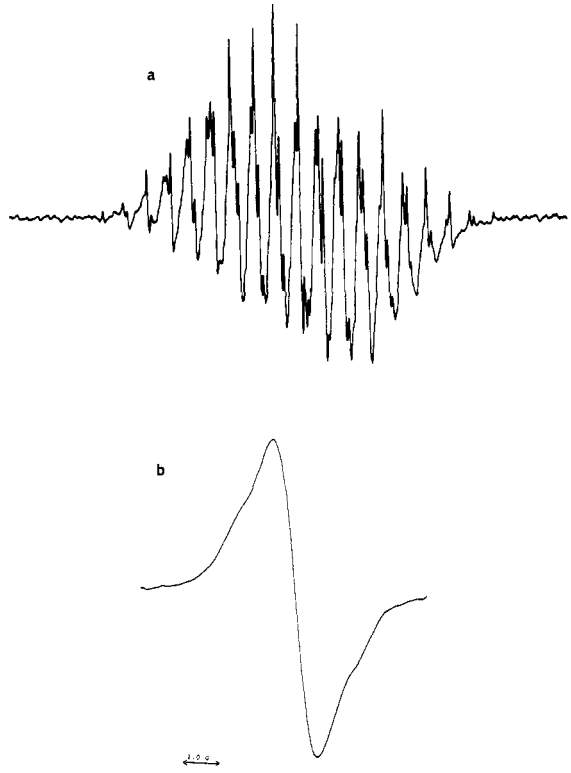

Figure 4. (a) ESR spectrum observed after further sodium reduction of the solution, giving rise to spectrum 3a. Although not fully interpreted, this spectrum has been assigned to III, with most of the spin density residing in the anthracenyl moiety. (b) ESR spectrum observed after further sodium reduction of the solution, giving rise to spectrum 3b. The observation of this broad line is consistent with spin localization in the deuterated anthracenyl moiety. This spectrum is assigned to (III-d_9)$^{3-}$·.

equally spaced lines of relatively small line width, indicative of an ϵ value very close to zero. No separate pentets or quartets were detected as in the previous cases. The spectrum is thus composed of one single splitting by seven equivalent hydrogens (a = 3.50 G), indicating equal spin populations in ψn^{+} and ψn^{-}. The obvious explanation for this observation falls in line with the steric effect argument already presented. In III, two peri hydrogen interactions are present, thus twisting the substituent out of planarity with the COT, much more so than in I. In order to try to resolve splittings, III-d_9^{-}· was generated and its ESR spectrum recorded (Figure 3b). The resulting octet pattern is much sharper than that of III^{-}·, with a peak to peak line width of 0.15 G, but no further splittings can be detected. Therefore, COT orbital splitting by anthracenyl has $\epsilon \cong 0$ ($\epsilon < 0.15$ G).

Interestingly, further alkali metal reduction of III and III-d_9 resulted in the observation of different ESR spectra (see Figures 4a and 4b, respectively). Spectrum a of Figure 4 contains many hyperfine coupling constants and, although not fully interpreted, suggests spin localization primarily in the polyacene moiety (162 theoretical spectral lines). This observation can be explained by invoking the formation of a trianion radical. Spectrum b of Figure 4 is consistent with the formation of a trianion radical of III-d_9, where most of the spin density resides on the aryl moiety. Unresolved splittings from the many deuterons result in a single, relatively broad signal.

Formation of these trianion radicals of III and III-d_9 is only possible if the dihedral angle between the two bonded moieties is very close to 90°. If this is the case, the unpaired electron density can reside in an orbital which is essentially orthogonal to the dianionic COT moiety.

Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, the National Science Foundation (Grant CHE-79-15201), and the National Institutes of Health (Grant RR-8102-07). We gratefully acknowledge the National Science Foundation (Grant CHE-79-1462) for funds used to purchase the JEOL FX-90Q NMR spectrometer.

Registry No. I, 83463-20-1; I^{-}, 83463-22-3; I-d_7, 83463-21-2; (I-d_7)$^{-}$, 83463-23-4; II, 83463-24-5; II^{-}, 83463-25-6; III, 83463-26-7; III^{-}, 83463-28-9; III^{3-}, 83463-19-8; III-d_9, 83463-27-8; (III-d_9)$^{-}$, 83463-29-0; (III-d_9)$^{3-}$, 83476-29-3; COT, 629-20-9; 1-bromonaphthalene, 90-11-9; 2-bromonaphthalene, 580-13-2; 9-bromoanthracene, 1564-64-3; naphthalene-d_8, 1146-65-2; anthracene-d_{10}, 1719-06-8.

Nitration of *s*-Triazolo[3,4-*a*]phthalazine

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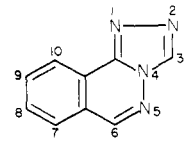
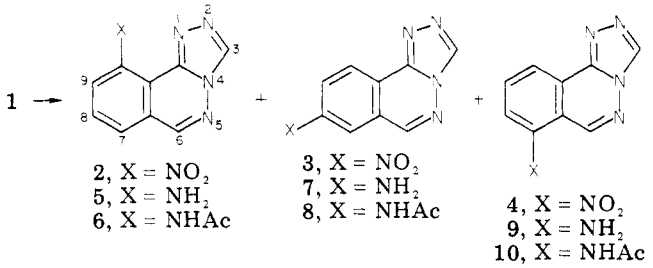
During the course of preparation of several derivatives of *s*-triazol[3,4-*a*]phthalazine (1), we had need of the 8-nitro



1

Scheme I



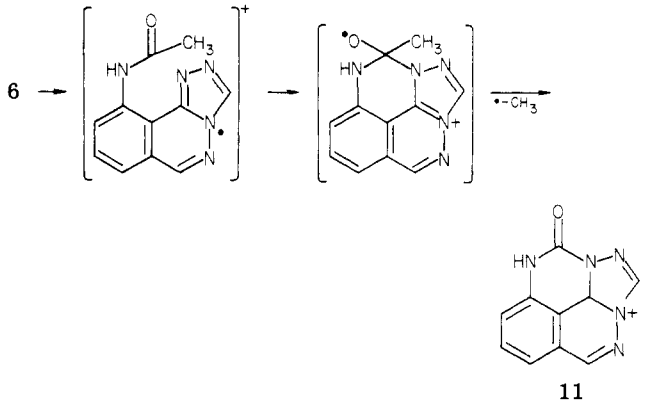
derivative **3** previously reported by Potts et al.[1] In our hands, when **1** was nitrated in the described manner (fuming nitric acid in 98% sulfuric acid), the product obtained had a broad melting point lower than reported. Repeated recrystallization of this product from acetone gave successive crops of material whose melting points increased and bracketed the reported value of 285 °C.[1] Subsequent investigation of the crude reaction product revealed the presence of three mononitro derivatives of **1** as well as some unreacted **1**.[2] Further, we found that concentrated sulfuric acid containing potassium nitrate was the preferred nitration medium.[3] Product distribution from this reaction of **1** was similar to that of the literature product, and the workup was substantially easier with far less base required to neutralize the reaction mixture.

Separation and isolation of these isomers were accomplished by silica column chromatography and subsequent recrystallization of isolated impure fractions. By comparison of the ^{1}H NMR spectra of the thus purified isomers with that of the crude mixture, the ratio of isomers in the crude was determined to be approximately 3:1:1.[4] When the crude product was recrystallized from acetone, the major and one minor isomer cocrystallized, and the ratio of these changed only slightly upon further recrystallization (Scheme I).

Structural assignment of nitration products **2–4** is based on ^{1}H NMR and mass spectral analysis, as well as on similar analysis of their respective amino and acetamido derivatives **5–10**. All isomers had singlet absorptions for protons H_3 and H_6; as a result, only the 7-, 8-, 9-, and 10-isomers are possible structures for the nitro compounds. Symmetry arguments separate these possibilities into two pairs of similarly substituted structures, namely, the 7- and 10-isomers (1, 2, 3 arrangement of protons) and the 8- and 9-isomers (1, 2, 4, arrangement). The first-order splitting pattern expected from the former pair (assuming approximately equal ortho coupling constants) would be a triplet and two doublets with additional fine coupling, and this pattern was observed for **4**. The latter symmetry pair would be expected to have a first-order splitting pattern consisting of a pair of doublets (for the ortho protons) with one of the pair fine coupled to the remaining "meta" proton. This pattern is observed for amine **7** and acetamide **8**, which are derived from **3**. By these arguments, **4** is either the 7- or 10-isomer and **3** is either the 8- or 9-isomer.

Mass spectral analysis of acetamides **6**, **8**, and **10** permit final structural assignment for **6**. Strong enhancment[5] of the M − 15 peak (CH_3) shows **6** (and hence its precursor **2**) to be the 10-isomer. This enhancement may be rationalized by the formation of tetracyclic cation **11** (Scheme II). Since nitro derivative **2** is thus the 10-isomer, the minor nitro product **4**, which was assigned either the 7- or 10-substituted structure, must be the 7-isomer.

Scheme II



The remaining nitro compound **3** has a deceptively simple ^{1}H NMR spectrum. Protons H_3 and H_6 absorb as two sharp singlets, and the remaining three protons appear as two slightly broadened singlets at δ 8.71 and 9.13, integrating for two and one proton, respectively. These three protons form an AA′X system wherein $\Delta\nu_{AA'}$ is almost zero and $J_{AX} + J_{A'X}$ is small.[6] The value of $J_{AX} + J_{A'X}$ can be derived from the ^{1}H NMR spectrum and is approximately 2–3 Hz (the width of the X absorption).[6] This allows assignment of the ortho protons as A and A′ at δ 8.71 and the isolated proton as X at δ 9.13. As a result, the 8-nitro isomer would have the 10-proton absorption at δ 8.71; likewise, the 9-nitro isomer would have this absorption at δ 9.13.

The 10-proton of unsubstituted **1** absorbs at δ 8.42. Using the values for nitro group effects upon the chemical shifts of the protons in naphthalene[7] as an approximation for this system, the predicted chemical shift for the 10-proton in the 8-nitro isomer[8] is δ 8.71, while that predicted for the 9-isomer is δ 9.48. Since the observed spectrum for **3** is in good agreement with that predicted for the 8-nitro isomer, the structure of **3** was thus assigned.

The fact that nitration occurs predominantly at the 10-position and that none is observed at the 9-position of **1** is confirmed by simple Huckel and CNDO[8] calculations. The most reactive position toward electrophilic attack is predicted to be the 10-position, and the least reaction is the 9-position. The 7- and 8-position have intermediate reactivities.

In contrast to published results, the major reaction produced was the 10-nitro derivative **2**, with 8- and 7-nitro isomers **3** and **4** formed in nearly equal amounts. Unfortunately, the nitration of **1** does not seem to be a useful preparative (gram quantities) procedure unless a conven-

(1) Potts, K. T.; Lovellette, C. *J. Org. Chem.* **1969**, *34*, 3221.
(2) Analytical HPLC analysis with a μ-Porosil column with 30% acetonitrile in methylene chloride as eluant.
(3) Serdenfaden, W.; Pawellek, D. *Methoden Org. Chem. (Houben-Weyl)* **1971**; *10*(1), 767.
(4) This was a relative ratio of the nitro compounds present in the crude reaction product and as determined by HPLC chromatographic analysis. Quantitation was obtained by determination of relative detector response for each pure isomer with extinction coefficients measured in the same solvent system.
(5) A 72-fold enhancement relative to the base peak (M − 42) was observed for **6** as compared to **8** and **10**.
(6) Bikle, R. H. "Interpretation of NMR Spectra, An Empirical Approach", Plenum Press: New York, 1965; pp 77–104.
(7) Wells, P. R. *J. Chem Soc.* **1963**, 1967.
(8) Partial atomic charges were calculated by the CNDO/2 method,[9,10] based upon a molecular geometry computed with the ADAPT system.[11]
(9) Pople, J. A.; Beveridge, D. C. "Approximate Molecular Orbital Theory"; McGraw-Hill: New York, 1970.
(10) Quantum Chemistry Program Exchange, program 141.
(11) Stupor, A. J.; Brugger, W. E.; Jurs, P. C. "Computer Assisted Studies of Chemical Structure and Biological Function"; Wiley-Interscience: New York, 1979, p 83ff.

ient method of isomer separation is developed.

Experimental Section

Melting points were determined on a Mel-Temp capillary block melting point apparatus and are uncorrected. All compounds are homogenous by thin-layer chromatographic analysis with Analtech silica gel GF 250-μm TLC plates. ^{1}H NMR measurements were obtained on a Varian Associates EM-390 or CFT 20 spectrometer with tetramethylsilane as the internal standard in Me_2SO-d_6 solution. Mass spectral measurements were obtained on a Varian CH7 mass spectrometer.

Nitration of *s*-Triazolo[3,4-*a*]phthalazine (1). Method A.[1] To a solution of *s*-triazolo[3,4-*a*]phthalazine (6.8 g, 40 mmol) in sulfuric acid (80 mL, 98%) at 0 °C was added a solution of fuming nitirc acid (37 mL, 90%) in sulfuric acid (160 mL, 98%) over 5 min with stirring. The reaction was kept at 0 °C for 45 min, warmed to room temperature for 2 h, and poured over 2 L of crushed ice brought to pH 8 with ammonium hydroxide. The crude product was filtered, and the filtrate was washed with water and dried over P_2O_5 under vacuum, yielding 2.73 g, mp 260–268 °C. Four successive recrystallizations of this product from acetone gave the following melting points 268–278, 278–283, 280–286, 281–288 °C.

Method B. To a solution of potassium nitrate (100 g, 0.99 mol) in sulfuric acid (250 mL, 96%) was added *s*-triazolo[3,4-*a*]-phthalazine (30 g, 0.176 mol). A slight exotherm was noted as the reaction mixture turned light orange. After stirring overnight, the pale yellow reaction mixture was worked up as in method A to give the crude nitro product: 21.2 g of yellow solid. The isomers were separated by column chromatography on silica gel eluting with 2% methanol in chloroform and subsequent recrystallization of selected fractions. The 10-isomer (**2**) was eluted first, followed by the 8-isomer (**3**) and then the 7-isomer (**4**).

10-Nitro-*s*-triazolo[3,4-*a*]phthalazine (2) recrystallized from acetone: mp 300–301 °C; mass spectrum, *m/e* 215 (M^+); ^{1}H NMR δ 9.63 (s, 1, H_3), 9.16 (s, 1, H_6), 8.38 (AB, 2, H_7 and H_9), 8.03 (X, 1, H_8, $J_{AX} \cong J_{BX} \cong 8$).

Anal. Calcd for $C_9H_5N_5O_2$: C, 50.24; H, 2.34; N, 32.55. Found: C, 50.43; H, 2.27; N, 32.28.

8-Nitro-*s*-triazolo[3,4-*a*]phthalazine (3) recrystallized from acetonitrile: mp 334 °C; mass spectrum, *m/e* 215 (M^+); ^{1}H NMR δ 9.69 (s, 1, H_3), 9.24 (s, 1, H_6), 9.13 (X, 1, H_7, $J_{AX} + J_{BX} \cong$ 2–3 Hz), 8.71 (AB, 2, H_9 and H_{10}).

Anal. Calcd for $C_9H_5N_5O_2$: C, 50.24; H, 2.34; N, 32.55. Found: C, 49.72; H, 2.29; N, 32.57.

This material was not further purified but was subsequently fully characterized by derivatives **7** and **8**.

7-Nitro-*s*-triazolo[3,4-*a*]phthalazine (4) recrystallized from acetonitrile: mp 213–214 °C; mass spectrum, *m/e* 215 (M^+); ^{1}H NMR δ 9.68 (s, 1, H_3), 9.29 (s, 1, H_6), 8.83 (d, 1, H_{10}, J = 8 Hz), 8.52 (d, 1, H_8, J = 8 Hz).

Anal. Calcd for $C_9H_5N_5O_2$: C, 50.24; H, 2.34; N, 32.55. Found: C, 50.38; H, 2.37; N, 32.69.

Reduction of the Nitro-*s*-triazolo[3,4-*a*]phthalazines. Reduction of the acetone-recrystallized crude nitro compound, which is a mixture of the 8- and 10-isomers (**3** and **2**) uses typical conditions. A 6.6-g (37 mmol) sample of the mixture was slurried in 100 mL of ethanol. To this was added 0.75 g of 10% Pd/carbon, and the mixture was hydrogenated at 50 psi on a Parr apparatus until uptake of hydrogen stopped. The reduction mixture was filtered and the filtrate was washed with ethanol (50 mL) and then with hot acetic acid. The ethanol filtrate and wash containing the 8-amino isomer (**7**) was evaporated to dryness and triturated with chloroform to remove any of the remaining 10-amino derivative (**5**). The combined chloroform triturate and acetic acid extract was evaporated and recrystallized from ethanol, yielding 10-amino derivative **5** (3.59 g). The chloroform-insoluble solid was recrystallized from acetonitrile to give the 8-amino isomer **7** (0.80 g): total yield 4.39 g (80%).

10-Amino-*s*-triazolo[3,4-*a*]phthalazine (5): mp 247–248 °C; mass spectrum, *m/e* 185 (M^+); ^{1}H NMR δ 9.41 (s, 1, H_3), 8.79 (s, 1, H_6), 7.53 (X, 1, H_8, $J_{AX} \cong J_{BX} \cong$ 8 Hz), 7.20 (AB, 2, H_7 and H_9), 6.89 (br s, 2, NH_2).

Anal. Calcd for $C_9H_7N_5$: C, 58.37; H, 3.81; N, 37.82. Found: C, 58.06; H, 3.92; N, 37.84.

8-Amino-*s*-triazolo[3,4-*a*]phthalazine (7): mp 274–275 °C; mass spectrum, *m/e* 185 (M^+); ^{1}H NMR δ 9.25 (s, 1, H_3), 8.70 (s, 1, H_6), 8.08 (d, 1, H_{10}, J = 8 Hz), 7.19 (dd, 1, H_9, J = 8 and 2 Hz), 7.02 (d, 1, H_7, J = 2 Hz), 6.10 (br s, 2, NH_2).

Anal. Calcd for $C_9H_7H_5$: C, 58.37; H, 3.81; N, 37.82. Found: C, 58.14; H, 3.72; N, 38.03.

7-Amino-*s*-triazolo[3,4-*a*]phthalazine (9) recrystallized from acetonitrile: mp 290 °C dec; mass spectrum, *m/e* 185 (M^+); ^{1}H NMR δ 9.38 (s, 1, H_3), 9.08 (s, 1, H_6), 7.51 (AB, 2, H_9 and H_{10}), 6.97 (X, 1, H_8, $J_{AX} \cong$ 8 Hz and $J_{BX} \cong$ 2 Hz), 6.62 (br s, 2, NH_2).

Anal. Calcd for $C_9H_7H_5$: C, 58.37; H, 3.81, N, 37.82. Found: C, 58.21; H, 3.74; N, 38.15.

Acetylation of the Amino-*s*-triazolo[3,4-*a*]phthalazines. Acetylation of the 8-amino derivative (**7**) is typical. A mixture 8-amino-*s*-triazolo[3,4-*a*]phthalazine (0.40 g, 2.1 mmol) and acetic anhydride (5 mL) was heated to a gentle reflux for 1 h, cooled to room temperature, and filtered. The product was washed with acetic anhydirde (2 mL) and ether (10 mL) and dried in vacuo to give the 8-acetamido derivative (**8**), 0.37 g (75%).

10-Acetamido-*s*-triazolo[3,4-*a*]phthalazine (6) recrystallized from acetic anhydride: mp 254–255 °C; mass spectrum, *m/e* 227 (M^+), 212 ($M^+ - CH_3$), 185 (M^+ – ketene; ^{1}H NMR δ 9.50 (s, 1, H_3), 8.95 (s, 1, H_6), 8.90 (X, 1, H_9, J_{AX} and $J_{BX} \cong$ 10 Hz), 7.78 (AB, 2, H_7 and H_8), 2.32 (s, 3, CH_3).

Anal. Calcd for $C_{11}H_9N_5O$: C, 58.14; H, 3.99; N, 30.82. Found: C, 58.07; H, 4.07; N, 30.87.

8-Acetamido-*s*-triazolo[3,4-*a*]phthalazine (8): mp 329–330 °C; mass spectrum, *m/e* 227 (M^+); ^{1}H NMR δ 9.43 (s, 1, H_3), 8.98 (s, 1, H_6), 8.50 (d, 1, H_7, $J \cong$ 2), 8.37 (d, 1, H_{10}, J = 8 Hz), 8.01 (dd, 1, H_9, J = 8 and $\cong$2 Hz), 2.19 (s, 3, CH_3).

Anal. Calcd for $C_{11}H_9N_5O$: C, 58.14; H, 3.99; N, 30.82. Found: C, 57.71; H, 3.93; N, 30.95.

7-Acetamido-*s*-triazolo[3,4-*a*]phthalazine (10): mp 279–280 °C dec; mass spectrum, *m/e* 227 (M^+); ^{1}H NMR δ 9.51 (s, 1, H_3), 9.08 (s, 1, H_6), 7.99 (AB, 2, H_9 and H_{10}), 8.30 (X, 1, H_8, $J_{AX} + J_{BX} \cong$ 10 Hz), 2.23 (s, 3, CH_3); mass spectrum, *m/e* calcd for $C_{11}H_9N_5O$, 227.0807; *m/e* found, 227.0808.

Anal. Calcd for $C_{11}H_9N_5O$: C, 58.14; H, 3.99; N, 30.82. Found: C, 57.14; H, 3.90; N, 30.36.

Acknowledgment. The authors thank Professor Kevin Potts for interesting discussions during the course of this work, George Morton for information concerning NMR data, and Drs. Tom McKenzie and Ray Carhart for their help in the Huckel and CNDO calculations.

Registry No. **1**, 234-80-0; **2**, 83633-05-0; **3**, 21517-40-8; **4**, 83633-06-1; **5**, 83633-07-2; **6**, 83633-08-3; **7**, 83633-09-4; **8**, 83633-10-7; **9**, 83633-11-8; **10**, 83649-35-8.

Improved Synthesis of 1-Ethoxy-1,3-dihydroisobenzofuran, a Useful Precursor to Isobenzofuran

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Brown[1] was the first to observe that in situ generated carbenium ions could be reduced by $NaBH_4$, although solvolysis and elimination reactions may compete depending on the substrate used. Some time ago we applied this approach to the formation of 1,3-dioxolanes, using $NaBH_4$ in refluxing pyridine to trap the ions formed by solvolysis with ester neighboring group participation.[2]

(1) Brown, H. C.; Bell, H. M. *J. Org. Chem.* **1962**, *27*, 1928. Bell, H. M.; Brown, H. C. *J. Am. Chem. Soc.* **1966**, *88*, 1473.

(2) Johnson, M. R.; Rickborn, B. *Org. Synth.* **1971**, *51*, 11. In this work, in situ generated 1,3-dioxolan-2-ylium ions derived from 2,3-butanediol were reduced in good yields by $NaBH_4$ in pyridine.

0022-3263/82/1947-5391$01.25/0