cm^{-1}; mass spectrum, m/e 422 (m^+).

1-Acetoxy-2-butyl-3-[4-(benzylamino)butyl]cyclohex-2-ene (3). The acetoxy tosylate (2.8 g, 6.6 mmol) was dissolved in 4 mL of Me_2SO under a N_2 atmosphere. Sodium iodide (catalytic amount, ~50 mg), triethylamine (0.67 g, 6.6 mmol), and benzylamine (1.06 g, 9.9 mmol) were then added. The solution was allowed to stir at room temperature for 12 h, and then it was partitioned between 50 mL of ethyl acetate and 25 mL of brine which had been basified with 10% NaOH (pH ~10). The organic layer was separated, washed with brine (2 × 20 mL), dried over anhydrous Na_2SO_4, and concentrated at reduced pressure. The resulting oil was purified by MPLC on silica gel with ethyl acetate/methanol (15:1) as the eluant to give 1.7 g (72%) of **3** which was immediately carried on to the next reaction: ^1H NMR (100 MHz, $CDCl_3$) 7.3 (s, 5 H), 5.3 (br s, 1 H), 3.76 (s, 2 H), 2.64 (br s, 2 H), 2.0 (s, 3 H), 2.2–1.1 (m, 19 H), 0.9 (t, J = 6 Hz, 3 H); ^{13}C NMR ($CDCl_3$) 170.9, 137.9, 128.8, 128.2, (2 C), 128.1, 126.9, 70.1, 54.0, 49.3, 33.1, 31.2, 30.1, 29.5, 29.4, 29.1, 26.0, 22.9, 21.4, 18.4, 14.0; IR (CCl_4) 2940, 1735, 1455, 1370, 1240, 1005, 905 cm^{-1}; mass spectrum, m/e 357 (m^+).

7-Butyl-*N*-benzyl-1-azaspiro[5.5]undec-7-ene (4). The amino allylic acetate **3** (0.25 g, 0.68 mmol), triethylamine (0.068 g, 0.68 mmol), and $Pd(PPh_3)_4$ (0.08 g, 0.068 mmol) were dissolved in 5 mL of CH_3CN, cooled to −78 °C, and sealed in a thick-walled glass tube under a vacuum. The sealed tube was heated at 150 °C for 24 h, cooled, and opened, and the contents were partitioned between ether (20 mL) and 2 N HCl (25 mL). The aqueous acid phase was separated, basified with concentrated aqueous NH_4OH, and extracted with ethyl acetate (3 × 20 mL). The organic extracts were combined, washed with brine (10 mL), dried over anhydrous Na_2SO_4, and concentrated. The resulting oil was purified by MPLC on silica gel with hexane/ether (4:1) as the eluant. The yield of **4** was 0.13 g (65%): ^1H NMR (100 MHz, $CDCl_3$) 7.2 (m, 5 H), 5.64 (br s, 1 H), 3.84, 3.16 (AB q, J = 10 Hz), 2.8–1.2 (m, 20 H), 0.88 (t, J = 5 Hz, 3 H); ^{13}C NMR ($CDCl_3$) 144.2, 141.2, 127.9, 127.8, 126.0, 123.9, 59.8, 55.0, 45.4, 33.1, 31.7, 28.2, 26.3, 25.7, 23.0, 21.8, 20.3; IR (CCl_4) 2950, 1500, 1450, 700 cm^{-1}; mass spectrum, m/e 313 (m^+); high-resolution mass spectrum, calcd for $C_{12}H_{31}N$ m/e 297.2456, found 297.2451.

(6*RS*,7*SR*,8*SR*)-7-*n*-Butyl-*N*-benzyl-1-azaspiro[5.5]undecan-8-ol (8) and (6*RS*,7*RS*,8*RS*)-7-*n*-Butyl-*N*-benzyl-1-azaspiro[5.5]undecan-8-ol (9). The olefin **4** (0.5 g, 1.7 mmol) was dissolved in 5 mL of THF under a N_2 atmosphere at room temperature. BH_3·Me_2S (2 M in hexane, 1.85 mmol) was added dropwise, and the reaction mixture was then heated at 40 °C for 24 h. The solution was cooled and the THF removed under reduced pressure. To the resulting oil was added 10 mL of diglyme, 2.5 mL of 10% NaOH (6.0 mmol), and 0.7 mL of 30% H_2O_2 (6.0 mmol). The mixture was heated at 80 °C for 18 h, cooled, and partitioned between 30 mL of ethyl acetate and 10 mL of brine. The organic phase was separated, dried over anhydrous Na_2SO_4, and concentrated at reduced pressure. MPLC on silica gel using ether/hexane (1:1) as the eluant yielded 0.14 g (27%) of **8** (R_f 0.5) and 0.07 g (13%) of **9** (R_f 0.4).

For **8**: ^1H NMR (400 HMz, $CDCl_3$) 7.25 (5 H), 4.0, 3.6 (AB q, J = 9 Hz, 2 H), 3.85 (m, 1 H), 3.1 (pseudo t, J = 10 Hz, 1 H), 2.6 2.43 (AB q, J = 11 Hz, 2 H), 1.9 (m, 1 H), 1.68–1.06 (m, 18 H), 0.86 (t, J = 5 Hz, 3 H); IR (CCl_4) 2970, 1550, 1250, 1215, 1000, 975 cm^{-1}; mass spectrum, m/e 315 (m^+).

For **9**: ^1H NMR (400 MHZ, $CDCl_3$) 7.25 (5 H), 4.0 (br s, 1 H), 3.8, 3.55 (AB q, J = 10 Hz, 2 H), 2.55 (br d, 1 H), 2.4–1.0 (m, 21 H); mass spectrum, m/e 315 (m^+).

Deamylperhydrohistrionicotoxin (2), H_2–Pd/C Reduction. The *N*-benzyl alcohol **8** (0.048 g, 0.15 mmol) was dissolved in 2 mL of absolute ethanol and added to a Parr pressure bottle along with ca. 100 mg of 10% Pd/C. The reduction was performed on a Parr apparatus at 60 psi under H_2 for 36 h. The solution was filtered through Celite to remove the catalyst, and the filtrate was concentrated at reduced pressure. MPLC with silica gel and CH_2Cl_2/MeOH/NH_4OH (84:15:1) yielded 0.29 g (85%) of **2**. This material was found to be identical in all respects with an authentic sample produced by Brossi.[24]

(24) Takahashi, K.; Witkop, B.; Brossi, A.; Maleque, M.; Albuquerque, E. Y. *Helv. Chim. Acta* **1982**, *65*, 252.

Compounds 11 and 12 by Swern Oxidation of 8 and 9. The crude product of the BH_3·Me_2S hydroboration–oxidation of **4** (0.15 g, 0.5 mmol) was subjected to Swern oxidation under the following conditions. Freshly distilled oxalyl chloride (0.13 g, 1.0 mmol) was added to 1 mL of CH_2Cl_2 and cooled to −78 °C under a N_2 atmosphere. Me_2SO (0.15 g, 2.0 mmol) was added to the CH_2Cl_2 solution, and the mixture was stirred for 15 min. The alcohols were dissolved in 0.5 mL of CH_2Cl_2 and added to the reaction mixture. The solution was stirred for 0.5 h at −78 °C, triethylamine (0.5 g, 5.0 mmol) was added, and the mixture was allowed to warm slowly to room temperature. The workup consisted of partitioning the reaction mixture between 25 mL of CH_2Cl_2 and 10 mL of brine. The organic phase was washed with 10 mL of brine, dried over anhydrous Na_2SO_4, and concentrated at reduced pressure. MPLC on silica gel with ether/hexane (1:1) as eluant provided **11** and **12** in a 2:1 ratio (0.07 g, 44%). Epimerization in CH_2Cl_2–NaOMe at room temperature for 25 h yielded 13:1 **11**/**12**.

For **11**: ^1H NMR (400 MHz, $CDCl_3$) 7.3–7.1 (m, 5 H), 4.0, 3.15 (AB q, J = 10 Hz, 2 H), 2.6, 2.51 (AB q, J = 8 Hz, 2 H), 2.36–2.1 (m, 4 H), 2.0–1.08 (m, 14 H), 0.85 (m, 1 H), 0.75 (t, J = 5 Hz, 3 H); IR (CCl_4) 2970, 1720, 1500, 1085, 1030 cm^{-1}; mass spectrum, m/e 313 (m^+). Anal. Calcd for $C_{21}H_{31}NO$: C, 80.45; H, 9.96; N, 4.47. Found: C, 80.25; H, 9.83; N, 4.38.

For **12**: ^1H NMR (400 MHz, $CDCl_3$) 7.3–7.1 (m, 5 H), 3.65, 3.5 (AB q, J = 10 Hz, 2 H), 2.5 (m, 2 H), 2.3 (m, 2 H), 2.15 (br d, 1 H), 1.9–1.0 (m, 16 H), 1.75 (t, J = 5 Hz, 3 H); mass spectrum, m/e 313 (m^+).

Deamylperhydrohistrionicotoxin (2), Li/NH_3 Reduction. Distilled NH_3 (25 mL) was condensed into a 100-mL flask fitted with a dry ice condenser and immersed in a −78 °C bath. The spirocyclic ketone **11** (0.7 g, 2.2 mmol) was dissolved in 2 mL of THF and added to the NH_3, followed by methanol (0.14 g, 4.4 mmol). Lithium metal (0.76 g, 110 mmol) was then added and the cooling bath removed. After 5 h, 5 mL of THF was added, and the NH_3 was allowed to evaporate. The lithium was destroyed with methanol, and the residue was taken up in 25 mL of ethyl acetate. The ethyl acetate solution was washed with brine, dried over anhydrous Na_2SO_4, and concentrated. The resulting colorless oil was purified by MPLC on silica gel with CH_2Cl_2/MeOH/NH_4OH (84:15:1) as the eluant, providing 0.33 g (65%) of **2**.

Acknowledgment. We gratefully acknowledge the agencies that supported this work, including the NIH, the Merck Foundation, and the CIBA-GIEGY Corp. We are especially indebted to Professor A. J. Pearson for sharing results from his laboratories prior to publication and to A. Brossi and E. Albuquerque for providng a sample of **2**.

Registry No. (±)-**1**, 55254-30-3; (±)-**2**, 55228-77-8; (±)-**3**, 85612-37-9; (±)-**4**, 83562-28-1; **5**, 56459-18-8; **6**, 83562-29-2; **6** tosylate, 85612-39-1; **7**, 85612-88-0; **7** acetate, 85612-40-4; (±)-**8**, 83562-31-6; (±)-**9**, 83602-28-2; (±)-**11**, 83562-26-9; (±)-**12**, 83562-34-9; 4-chlorobutanol, 928-51-8; benzylamine, 100-46-9; $Pd(PPh_3)_4$, 14221-01-3.

Electroorganic Chemistry. 59. Electroreductive Synthesis of Oximes from Nitro Olefins

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Received March 18, 1982

The elongation of aldehydes and the elongating transformation of aldehydes to ketones have been desirable tools in organic synthesis, though most of the hitherto known methods are not necessarily satisfactory due to trouble-

0022-3263/83/1948-2103$01.50/0

Table I. Reduction of Aromatic Nitro Olefins

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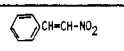
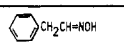
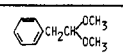
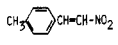
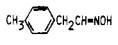
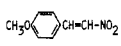
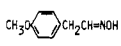
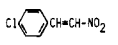
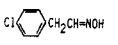
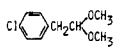
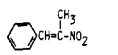
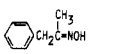
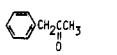
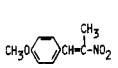
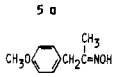
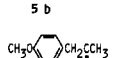
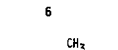
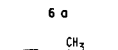
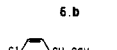
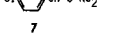
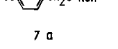
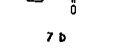
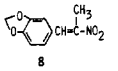
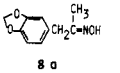
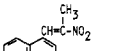
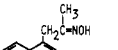
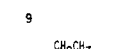
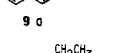
1	 1	 1a	51	 1b	7	58
2	 2	 2a	43			43
3	 3	 3a	65			65
4	 4	 4a	57	 4b	5	62
5	 5	 5a	43	 5b	6	49
6	 6	 6a	65	 6b	6	71
7	 7	 7a	45	 7b	8	53
8	 8	 8a	54	 8b	6	60
9	 9	 9a	39			39
10	 10	 10a	47			47
11	 11	 11a	61	11b	10	71

[a] See ref 8. [b] Isolated yield.

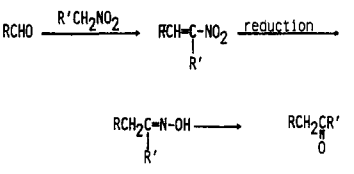
Table II. Reduction of Aliphatic Nitro Olefins

run	nitro olefin	oxime[a]	yield,[b] %	acetal or ketone[a]	yield,[b] %	total yield, %
1	$CH_3(CH_2)_6CH{=}C(CH_3)NO_2$ **12**	$CH_3(CH_2)_6CH_2C(CH_3){=}NOH$ **12a**	67			67
2	$CH_3(CH_2)_5CH{=}C(CH_3)NO_2$ **13**	$CH_3(CH_2)_5CH_2C(CH_3){=}NOH$ **13a**	58	$CH_3(CH_2)_5CH_2C(O)CH_3$ **13b**	14	72
3	$CH_3(CH_2)_5CH{=}CHNO_2$ **14**	$CH_3(CH_2)_6CH{=}NOH$ **14a**	38	$CH_3(CH_2)_6CH(OCH_3)_2$ **14b**	16	54
4	$C_6H_5(CH_2)_2CH{=}CHNO_2$ **15**	$C_6H_5(CH_2)_3CH{=}NOH$ **15a**	17	$C_6H_5(CH_2)_3CH(OCH_3)_2$ **15b**	23	40

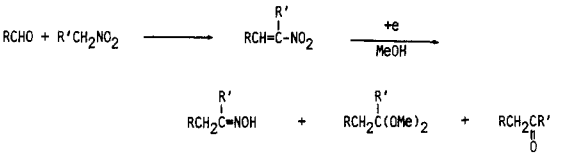
[a] See ref 8 and 9. [b] Isolated yield.

some operation.[1] Preparation of nitro olefins from aldehydes and nitroalkanes and subsequent reduction with reducing agents such as titanium trichloride seem to be a reliable method for synthesis of oximes (Scheme I),[2] while the use of titanium trichloride as the reducing agent often requires excess amounts of the reagent and a skillful technique. On the other hand, a variety of electrochemical methods have been studied in the reduction of nitro olefins. The main products were, however, the corresponding saturated amines[3] in most cases, whereas the electrore-

Scheme I



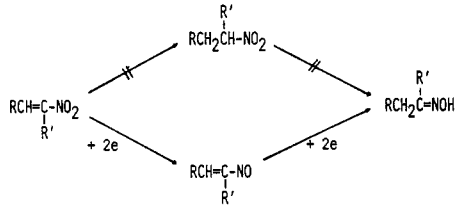
Scheme II



(1) For example: (a) Magnus, P.; Roy, C. *J. Chem. Soc., Chem. Commun.* **1979**, 822. (b) Carey, F. A.; Neergaard, J. R. *J. Org. Chem.* **1971**, *36*, 2731.

(2) (a) Ho, T. L.; Wong, C. M. *Synthesis* **1974**, 196. (b) McMurry, J. E.; Melton, J. *J. Am. Chem. Soc.* **1971**, *93*, 5309.

Scheme III



duction leading to oximes has only been studied from a mechanistic point of view.[4] In the present study, we have developed a new electroreductive method which affords the expected products in satisfactory selectivity and yields.

The cathodic reduction of a solution of nitro olefins in aqueous methanol containing sulfuric acid under the conditions of constant current[5] yielded oximes, acetals, and ketones as shown in Scheme II. A variety of aromatic[6] and aliphatic nitro olefins[7] prepared from aldehydes and nitroalkanes were reduced with this electrochemical method. All results are summarized in Tables I and II.[8,12]

Nitro olefins prepared from aromatic aldehydes gave the corresponding oximes as the main products and small amounts of acetals (runs 1 and 4) or ketones (runs 5–8 and 11). In the electroreduction of nitro olefins obtained from aliphatic aldehydes, the nitro olefins corresponding to ketones gave results similar to those for aromatic compounds, whereas the oximes of aldehydes showed a tendency to be changed to the acetals under the reaction conditions.

The intermediary formation of saturated nitro compounds is excluded in our electroreduction, since the formation of (β-nitroethyl)benzene[13] was not observed in the reduction of β-nitrostyrene, and also the electroreduction of (β-nitroethyl)benzene under our reduction conditions did not yield the oxime but gave a complex mixture of unidentified products. The reduction of the double bond may take place after the nitro group is reduced to a nitroso group, though it is not confirmed (Scheme III). It was necessary to keep the reaction medium acidic in our reduction, since in alkaline conditions nitro olefins easily polymerize through a reaction similar to the Michael addition.

Since the transformation of oximes to the carbonyl compounds has been extensively studied,[14] the present electroreductive synthesis of oximes from nitro olefins is useful for the elongation of aldehydes and elongating transformation of aldehydes to ketones.

Experimental Section

Materials. Nitro olefins were prepared according to the reported methods.[6,7]

General Procedures for Reduction of Nitro Olefins. The cathodic reduction was carried out by using a divided cell equipped with a ceramic diaphragm, carbon-rod anode, and platinum cathode.

Into the cathodic chamber was added a solution of nitro olefin (6.00 mmol) and 20% H_2SO_4 (10 mL) in methanol (80 mL), and the anolyte was a methanolic solution (5 mL) of 500 mg of *p*-toluenesulfonic acid. The catholyte was stirred with a magnetic bar and cooled with an ice–water bath to keep temperature at 0–5 °C throughout the reaction. After 4.5 F/mol of electricity was passed with a constant current of 0.1 A, the catholyte was neutralized with aqueous $NaHCO_3$, and the methanol was evaporated. The residue was poured into water, and the mixture was extracted with dichloromethane. After the solution was dried over $MgSO_4$, the solvent was evaporated. The product was purified by silica gel column chromatography (AcOEt–hexane). Yields are shown in Tables I and II.

Registry No. **1**, 102-96-5; **1a**, 7028-48-0; **1b**, 101-48-4; **2**, 7559-36-6; **2a**, 66444-17-5; **3**, 3179-10-0; **3a**, 3353-51-3; **4**, 706-07-0; **4a**, 4410-18-8; **4b**, 42866-89-7; **5**, 705-60-2; **5a**, 13213-36-0; **5b**, 103-79-7; **6**, 17354-63-1; **6a**, 52271-41-7; **6b**, 122-84-9; **7**, 710-20-3; **7a**, 1454-65-5; **7b**, 5586-88-9; **8**, 5438-41-5; **8a**, 52271-42-8; **8b**, 4676-39-5; **9**, 23854-03-7; **9a**, 85629-15-8; **10**, 1202-32-0; **10a**, 5368-18-3; **11**, 1208-78-2; **11a**, 85629-16-9; **11b**, 53917-01-4; **12**, 85629-17-0; **12a**, 13326-89-1; **13**, 4812-25-3; **13a**, 52435-37-7; **13b**, 821-55-6; **14**, 4550-05-4; **14a**, 929-55-5; **14b**, 10022-28-3; **15**, 80922-14-1; **15a**, 82543-06-4; **15b**, 85629-18-1.

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Epoxide Opening by Lithium Aluminum Deuteride. Implications for Isotopic Labeling and Proof of the Proposed Mechanism

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Received November 17, 1982

Ring-opening of epoxides by complex metal hydrides has seen widespread application in the synthesis of chiral molecules,[1] including molecules which are chiral by virtue of isotopic labeling. Trevoy and Brown[2] showed in 1949

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