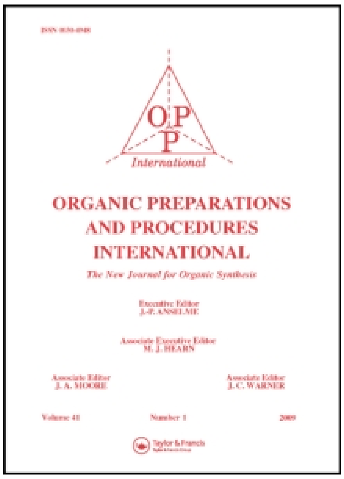


Organic Preparations and Procedures International
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t902189982

THE STEREOSELECTIVITY OF THE REDUCTION OF HOMOPROPARGYLIC ALCOHOLS TO HOMOALLYLIC ALCOHOLS

R. E. Doolittle[a]
[a] Insect Attractants, Behavior, and Basic Biology Research Laboratory, Agricultural Research, Science and Education Administration, USDA, Gainesville, FL

To cite this Article Doolittle, R. E.(1981) 'THE STEREOSELECTIVITY OF THE REDUCTION OF HOMOPROPARGYLIC ALCOHOLS TO HOMOALLYLIC ALCOHOLS', Organic Preparations and Procedures International, 13: 3, 179 — 184
To link to this Article: DOI: 10.1080/00304948109356123
URL: http://dx.doi.org/10.1080/00304948109356123

ORGANIC PREPARATIONS AND PROCEDURES INT. 13(3-4), 179-184 (1981)

THE STEREOSELECTIVITY OF THE REDUCTION OF HOMOPROPARGYLIC ALCOHOLS TO HOMOALLYLIC ALCOHOLS†

R. E. Doolittle

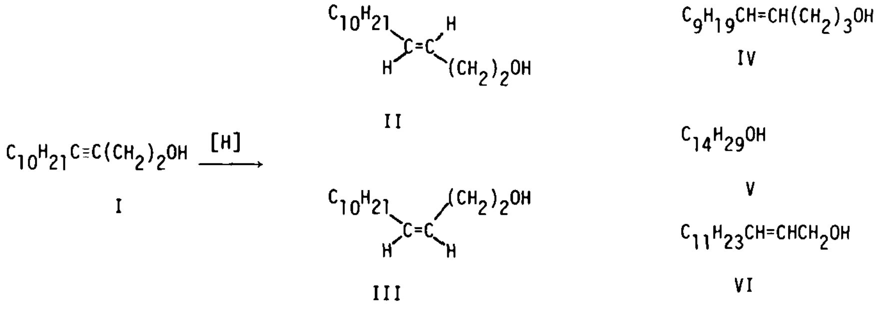
Insect Attractants, Behavior, and Basic Biology Research Laboratory,
Agricultural Research, Science and Education Administration, USDA,
Gainesville, FL 32604

In the course of the synthesis[1] of the sex pheromone produced by the female lesser peachtree borer, synanthedon pictipes, the reduction of (Z)-13-octadecen-3-yn-1-ol with sodium in ammonia and mixtures of ammonia, hexamethylphosphoric triamide (HMPA) and tetrahydrofuran (THF) produced (E,Z)-3,13-octadecadien-1-ol containing various amounts of a by-product, (Z,Z)-3,13-octadecadien-1-ol. The acetate of this by-product (obtained by acetylation of the mixture) exhibits powerful inhibitory effects[2] on the response of the lesser borer males to their pheromone (E,Z)-3,13-octadecadien-1-ol acetate. Therefore, it was necessary to eliminate the by-product either by finding suitable reduction conditions or by removing it from the final product by high performance liquid chromatography (HPLC),[3] a tedious and costly procedure.

In view of the potential usefulness of this pheromone and since the initial reduction experiments had produced variable amounts of Z configuration in the 3-position, factors that might control the stereochemical outcome of the reduction of homopropargylic alcohols to homoallylic alcohols were investigated. Since the original substrate was too inaccessible to use in this fashion, 3-tetradecyn-1-ol was chosen as a suitable model compound because of its ready availability from a previous investigation,[4] its proximity in molecular weight to the original substrate (which strongly influenced its solubility characteristics) and the availability of an analytical procedure for the determination of the reaction products (see Experimental). 3-Octadecyn-1-ol was rejected as a model after some initial experiments because of poor analytical results in the determination of reaction products.

The reduction of acetylenes with dissolved metals in ammonia has been well documented,[5] but careful examination of the stereochemical outcome of the reduction has been carried out in relatively few cases. House[6a] and Svoboda[6b] carefully examined the stereochemistry of the reduction of dialkylacetylenes by gas chromatography (GLC), but in several other cases,[7a-c] according to descriptions of the analytical methods employed, small quantities (<2%) of the Z isomer could have gone undetected. House[6a] also reported rearrangement producing olefins in which the double bond did not occupy the same position as the triple bond in the starting material.

Reduction of 3-tetradecyn-1-ol produced five products given below.



Initially the reduction was conducted with sodium and lithium in pure ammonia at rather high dilution, which had been reported[7d] to produce the E olefins in high purity, although no analytical data were provided. The first 4 entries in the Table indicated lithium to be superior to sodium in stereoselectivity, rate of reduction and lack of rearrangement. Under these conditions (-33° with no added solvent), the reduction was quite slow and did not proceed to completion even after 32 hrs. The results also indicated that a small but appreciable amount of bond migration occurred equally with either metal but that the amount of Z olefin produced was definitely less with lithium. The reduction with lithium was then carried out in mixtures of ammonia and various co-solvents. THF and diethyl ether appeared to be suitable co-solvents; they produced very little Z olefin, a small but measurably larger amount of rearranged product, and markedly increased the reaction rate (attributable to increased solubility of the substrate). HMPA was a less satisfactory solvent and produced both more rearranged product and more Z olefin.

Acetylenes have been reduced stereoselectively to olefins with a reagent called "lithium bronze".[8] This reagent was also reported for the reduction of α,β-enones.[9] It is the tetramine complex between lithium and ammonia $[Li(NH_3)_4]$ and is a bronze-colored liquid that floats on the surface

TABLE. Reduction of 3-Tetradecyn-1-ol with Alkali Metals and LAH

Run[a]	Reductant (mmol)	Solv. (ml)	Proton Source (mmol)	% Yield[b] I	II	III	IV	V	VI	Time (hrs)	Temp (°C)
1	Na(32.5)	NH_3(225)	NH_3	41.0	56.5	.7	0	0	1.3	24	-32
2	Na(32.5)	NH_3(225)	NH_3	37	51	.5	0	0	1.0	24	-32
3	Li(32.5)	NH_3(225)	NH_3	12	87.6	.1	0	0	.4	24	-32
4	Li(32.5)	NH_3(110)	NH_3	5.7	93.6	.3	0	<.5	.4	48	-32
5	Li(32.5)	NH_3(225)	NH_3	5.0	94.3	.3	0	<.5	.5	48	-32
6	Li(32.5)	NH_3/THF	NH_3	2.2	95.7	.2	4	<.2	.9	12	-32
7	Li(32.5)	NH_3/Et_2O	NH_3	13.8	85.5	0	0	0	.7	12	-32
8	Li(32.5)	NH_3/HMPA	NH_3	16.9	80	.9	.3	<.5	2.2	12	-32
9	Li(BR)22[c]	Et_2O(25)	*t*-BuOH (11)	6.4	93	0	0	.1	.2	12	27
10	Li(BR)24	Et_2O(25)	*t*-BuOH (20)	3.6	95	<.5	0	1.3	0	12	27
11	Li(BR)30	Et_2O(25)	*t*-BuOH (20)	1.4	94.9	0	0	3.5	.7	12	35
12	Li(BR)30	Et_2O(25)	*t*-BuOH (20)	.6	95	0	0	3.6	.9	12	-10
13	Li(BR)30	THF(25)	*t*-buOH (20)	39[d]	58	1.7	0	0	1.0	12	27
14[e]	LAH(5)	DIGLYME		0	94.4	2.4	1	.6	1.5	12	60
15[e]	LAH(5)	DIGLYME		0	92.8	2.0	0	<.5	1.5	12	140
16[e]	LTHA(5)	DIGLYME		0	97.4	1.9	0	<.5	.7	6	140
17[e]	LTHA(5)	DIGLYME		.6	95.1	2.1	0	<.5	2.1	10	100
18[e]	LTHA(5)	DIGLYME		2.9	93.2	2.7	0	<.5	1.2	16	100
19[e]	LTHA(5)	DIGLYME		3.7	93.3	1.0	0	<.5	2.0	6	100
20	Li(24)	ETHYLAMINE (110)		67	28	1.0	0	0	3.4	20	17

a. Ten (10) mmol of substrate used unless otherwise noted. b. By GLC.
c. BR = bronze. d. Many by-products. e. Five (5) mmol of substrate used, 10 ml of diglime was used in each case.

of the solvent. It is easier to use than lithium in large volumes of ammonia but does require an added proton source. In the present case, reduction of the substrate with lithium bronze under various conditions (Table, entries 9-13) resulted in excellent stereoselectivity and rate of reaction with very little rearrangement. The temperature appeared to have little effect on the reduction, but the ratios of substrate, reductant and proton source must be carefully controlled to avoid over- or under-reduction. The use of THF as a solvent gave very poor results.

The reduction of acetylenic alcohols with LAH in diglyme at high temperatures has been reported.[10] The results from runs 14-19 indicate that LAH does not give as good stereochemical results as some of the other reductants and produces appreciable amounts of rearrangement. In the case of homopropargylic alcohols much milder conditions than those reported suffice.[10] Lithium in a low molecular weight amine was investigated for this reduction and proved unsatisfactory. It appears from the data collected that lithium bronze in ether is the reagent of choice for the reduction of homopropargylic alcohols to homoallylic alcohols and might also be an excellent reductant for other acetylenes.

When the reduction of (Z)-13-octadecen-3-yn-1-ol was carried out with lithium bronze in ether with quantities similar to those in the table, the results were in agreement with the data in the Table (85-95% yield and 98.5+% purity) and, when combined with low temperature recrystallisation followed by acetylation with acetic anhydride provided the sex pheromone of the lesser peachtree borer in high purity (>99.5%).

EXPERIMENTAL

Elemental analyses and mass spectra of the (E)- and (Z)-3-tetradecen-1-ol were in agreement with the assigned structures. Gas chromatographic analyses were performed with a Varian® Model 2100 gas chromatograph equipped with a 50-meter glass capillary column wall coated with SP2340 operated at 150° with a linear flow velocity of He of 18 cm/sec and with a Varian Model 1400 gas chromatograph equipped with a 50-meter glass capillary column wall coated with OV-101 operated at 125° with a linear flow velocity of He of 18 cm/sec. Gas chromatographic analyses were quantitated with a Hewlett Packard Model 338A® integrator. The IR spectra were recorded with a Perkin-Elmer Model 467® spectrophotometer.

Reduction of 3-Tetradecyn-1-ol.

(a) Sodium or Lithium in Ammonia and Mixtures of Ammonia and Co-solvents. - The ammonia was collected from the tank by distillation and condensation with a cold (-84°) Dewar condenser. When a co-solvent was used, the appropriate volume was added followed by small chips of the metal until the blue color persisted. The metal for the reduction was added and the mixture stirred for 0.5 hr. The substrate (diluted with several ml of diethyl ether) was added rapidly and the mixture stirred for the indicated time. The reaction was worked up by destruction of the excess metal with sodium benzoate, allowing the ammonia to evaporate, dilution with water and extraction with ether. (E)-3-Tetradecen-1-ol had bp 105°/.05 mm Hg, n_D^{20} 1.4584.

Anal. Calcd. for $C_{14}H_{28}O$: C,79.18; H,13.29. Found: C,79.00; H, 13.14 (cm^{-1}, CCl_4): 3640 (OH); 3020 (=C-H); 1050 (C-O); 965 (E-C=C-).

(b) Lithium Bronze. - Lithium bronze was prepared by the method of Mueller.[9] The substrate was added as an ether solution and after complete reduction was diluted with water and extracted (ether). The original authors used ethanol as the proton source but we found the reduction of ethanol to be rather rapid, necessitating the use of more lithium or else resulting in unacceptably large remaining amounts of starting material. Consequently, t-butanol was used as the proton source.

(c) LAH. - The procedure of Rossi[10] was followed with the reaction conducted at a lower temperature for shorter times.

The (Z)-3-tetradecen-1-ol was prepared by reduction of 3-tetradecyn-1-ol with P-2 nickel.[11] The product had bp 105°/.05 mm Hg, n_D^{20} 1.4575.

Anal. Calcd. for $C_{14}H_{28}O$: C,79.18; H,13.29. Found: C,78.95; H,13.22. IR (cm^{-1}, CCl_4): 3640 (OH); 3005 (=C-H); 1050 (C-O).

Gas Chromatographic Analyses. - The samples of (E)-3-tetradecen-1-ol from each reduction were analyzed initially on the SP2340 capillary column, which separated the E-isomer from 3 possible by-products: 1-tetradecanol, (Z)-3-tetradecen-1-ol, and 3-tetradecyn-1-ol. It was estimated, that these impurities could be detected at levels $\leq$[.2]% by means of standards. Since the rearranged products (E)-4-tetradecen-1-ol and (E)-2-tetradecen-1-ol did not separate from the E-3-isomer on this column, the quantities of these products were determined in another fashion.

The crude reaction products were micro-ozonized[12] and analyzed on the OV-101 capillary. The 4-isomer present would produce decanal, the 3-isomer undecanal and the 2-isomer dodecenal upon ozonolysis followed by reductive work-up. The ratios of the resulting three aldehydes gave a direct analysis of the degree of bond shift during the reduction.

REFERENCES

† Mention of a commerical or proprietary product in this paper does not constitute an endorsement of that product by the USDA.

1. J. H. Tumlinson, C. E. Yonce, R. E. Doolittle, R. R. Heath, C. R. Gentry, Gentry, and E. R. Mitchell, Science, 185, 614 (1974); R. E. Doolittle, A. T. Proveaux and R. R. Heath, J. Chem. Ecol. 6, 271 (1980).

2. Addition of as little as 1% of (Z,Z)-3,13-octadecadien-1-ol acetate to the pheromone will result in a marked reduction of lesser borer male response to the pheromone (E,Z)-3,13-octadecadien-1-ol acetate.

3. R. R. Heath, J. H. Tumlinson and R. E. Doolittle, J. Chromat. Science, 15, 10 (1977).

4. R. E. Doolittle, Org. Prep. Proced. Int., 12, 1 (1980).

5. C. A. Henrick, Tetrahedron 33, 1 (1978); H. O. House, "Modern Synthetic Reactions," pp. 205-9, W. A. Benjamin, Inc., New York, 1965.

6. a) H. O. House and E. F. Kinloch, J. Org. Chem., 39, 747 (1974).
   b) M. Svoboda, J. Zavada, and S. Sicher, Chem. Commun. 30, 413 (1965).

7. a) W. L. Roelofs and H. Arn, Nature, 219, 513 (1968).
   b) J. A. Klun, O. L. Chapman, K. C. Mattes, P. W. Wojkowski, M. Beroza, and P. E. Sonnet, Science, 181, 661 (1973).
   c) P. I. Syirskaya, C. C. Lizenoff, J. Weatherston, and J. E. Laing, J. Chem. & Engr. Data 24, 152 (1979).
   d) J. D. Warthen, Jr. and M. Jacobson, Synthesis, 616 (1973).
   e) J. D. Warthen, and N. Green, J. Am. Oil. Chem. Soc. 40, 191 (1969).

8. R. H. Mueller, Private communication.

9. R. H. Mueller and J. G. Gillick, J. Org. Chem. 43, 4647 (1978).

10. R. Rossi and A. Carpita, Synthesis, 561 (1977).

11. C. A. Brown and K. K. Ahuja, Chem. Commun., 553 (1973).

12. M. Beroza and B. Bierl, Anal. Chem., 38, 176 (1966).

(Received May 5, 1980; in revised form December 1, 1980)