hydrogen delivery to the more encumbered β-face of the penicillin molecule.[22] The coordination of a molecule of methanol with the metal could increase the acidity of the hydroxylic hydrogen, giving rise to the idea that the hydrogen might be transferred as proton, rather than as a hydride transfer from the metal complex. Here, we suppose that hydrogen could be transferred intramolecularly from the methanol coordinated to the metal in a suprafacial-type fashion. (See Figure 2).

The lack of stereoselectivity when the hydrogenolytic reactions were performed by using ethyl acetate as the unique solvent suggests that in these cases the mechanism of the hydrogen transfer may be different to those reactions carried out in methanol as cosolvent.

At the present stage of our work, the experimental results do not permit an exact knowledge of the nature of the interaction between the substrate, the catalyst, and the hydrogen donor.

The significance of the present findings is not only the elucidation of the stereochemistry of the reaction but also its application to the synthesis of deuterium- or tritium-labeled penam derivatives, since regiospecific and stereoselective labeling of C6β is now possible. This result is complementary to dehalogenation with tributyltin deuteride or tritide $Bu_3SnD(T)$ at C6α.[19] Labeling the carbon-6 of penam derivatives, inter alia, of 6β-bromo-, 6β-iodopenicillanic acid,[23] 6α-chloro- and penicillanic acid sulfone,[24] should be useful in mechanistic studies of these β-lactamase inactivators for various β-lactamases.[25]

Experimental Section

^1H NMR spectra were taken on a Bruker WP 80 SY spectrometer at 80.13 MHz, and chemical shift are expressed in parts per million downfield from internal tetramethylsilane. Low-resolution mass spectra (electron impact, 70 eV) was obtained with a Varian MAT CH-7A spectrometer interfaced to a Varian-MAT Data System 166 computer. The Wilkinson's catalyst, monodeuteriomethanol, and deuterium were obtained from Fluka. The ethyl acetate and methanol were purified by distillation. Pom 6β-iodo-6α-bromo- (**1**),[15a] 6,6-diiodo- (**3**),[15b] 6,6-dibromo- (**5**),[15b] 6α-bromo- (**2a**),[15b] 6β-bromo- (**2b**),[26] 6β-iodo- (**4b**),[26] and 6α-iodo- (**4a**)[27] penicillanates were synthesized and described as previously reported.

General Procedure for Catalytic Dehalogenation. The hydrogenolytic reactions were performed at room temperature in a two-necked, round-bottomed flask connected to a hydrogen reservoir maintaned at ambient pressure. The catalyst was placed in the flask and flushed with H_2 several times to remove any air.

A typical experiment for catalytic dehalogenation is as follow: In a 5-mL round-bottom flask, fitted with a magnetic stirring bar, 4 mg (0.005 mmol) of $RhCl(PPh_3)_3$ and 40 mg (0.4 mmol) of calcium carbonate were suspended in methanol (1 mL). After a period of 20 min of stirring under H_2 at 25 °C (prehydrogenation), Pom 6,6-dihalo- or Pom 6-halopenicillanate (0.05 mol) dissolved in ethyl acetate (0.6 mL) was added. After the period of time indicated in Table I, the solution was filtered through silica gel, and the products were identified by TLC and spectroscopic comparison with authentic materials.

Catalytic Deuteriation of Pom 6β-Iodo-6α-bromopenicillanate (1). The procedure followed was as described above. **Entry 7**: Methanol-d_1 (99.5% D) was used. The analysis of the product by ^1H NMR, indicated ca. 90% of deuterium incorporation in **6a** and **6b** in a ratio of 10:1. **Entry 8**: Analysis of the products by mass spectrometry indicated 2% of deuterium incorporation.[28] **Entries 10 and 11**: The procedure described above was repeated by using 0.05 mmol of $RhCl(PPh_3)_3$, under an atmosphere of nitrogen.

2a: ^1H NMR ($CDCl_3$) δ 1.22 (s, 9 H), 1.49 (s, 3 H), 1.60 (s, 3 H), 4.56 (s, 1 H), 4.80 (d, 1 H, J = 1.6 Hz), 5.40 (d, 1 H, J = 1.6 Hz), 5.81 (d, 1 H, C-9H, AB system, J = 5.6 Hz), 5.84 (d, 1 H, C-9H, system, J = 5.6 Hz).

6a: ^1H NMR ($CDCl_3$) δ 1.22 (s, 9 H), 1.49 (s, 3 H), 1.60 (s, 3 H), 4.56 (s, 1 H), 5.40 (br s, 1 H), 5.81 (d, 1 H, C-9H, AB system, J = 5.6 Hz), 5.84 (d, 1 H, C-9H, AB system, J = 5.6 Hz).

6b: ^1H NMR ($CDCl_3$) δ 1.22 (s, 9 H), 1.50 (s, 3 H), 1.67 (s, 3 H), 4.54 (s, 1 H), 5.56 (s, 1 H), 5.78 (d, 1 H, C-9H, AB system, J = 5.6 Hz), 5.85 (d, 1 H, C-9H, AB system, J = 5.6 Hz).

7: ^1H NMR ($CDCl_3$) δ 1.22 (s, 9 H), 1.49 (s, 3 H), 1.63 (s, 3 H), 4.56 (s, 1 H), 5.45 (br s, 1 H), 5.78 (d, 1 H, C-9H, AB system, J = 5.6 Hz), 5.85 (d, 1 H, C-9H, AB system, J = 5.6 Hz).

8: ^1H NMR ($CDCl_3$) δ 1.22 (s, 9 H), 1.49 (s, 3 H), 1.66 (s, 3 H), 3.54 (m, 1 H), after irradiation of H(5) became a broad singlet, 4.47 (s, 1 H), 5.28 (br d, 1 H, J = 4.0 Hz), 5.80 (d, 1 H, C-9H, AB system, J = 5.6 Hz), 5.81 (d, 1 H, C-9H, AB system, J = 5.6 Hz).

9: ^1H NMR ($CDCl_3$) δ 1.22 (s, 9 H), 1.49 (s, 3 H), 1.66 (s, 3 H), 4.47 (s, 1 H), 5.28 (s, 1 H), 5.80 (d, 1 H, C-9H, AB system, J = 5.6 Hz), 5.81 (d, 1 H, C-9H, AB system, J = 5.6 Hz).

Acknowledgment. We thank CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas) for financial support and fellowship (E. L. Setti), Prof. R. A. Corral and J. Zinczuk (Universidad de La Plata) for their generous gift of deuterium, Prof. E. Gross (UMYMFOR) for the low-resolution spectral data. We are also grateful to Dr. Eric J. Thomas and Dr. John M. Brown (University of Oxford, U.K.) for helpful comments on the manuscript.

Registry No. **1**, 99277-03-9; **2a**, 76468-87-6; **2b**, 74772-33-1; **3**, 76517-03-8; **4a**, 75722-94-0; **4b**, 74772-35-3; **5**, 69388-93-8; **6a**, 116724-90-4; **6b**, 116724-92-6; **8a**, 116724-91-5; **8b**, 116724-93-7; $RhCl(PPh_3)_3$, 14694-95-2.

(21) (a) For examples involving thioethers as coordinative ligands, see: Cotton, F. A.; Wilkinson, G. *Advanced Inorganic Chemistry, 5th ed.*; Wiley: New York, 1988; p 532 and references therein. (b) For a review on the directing effect in homogeneous hydrogenation, see: Brown, J. M. *Angew. Chem., Int. Ed. Engl.* **1987**, *26*, 190.

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(23) For the synthesis and applications of [6α-^{3}H]-6β-bromopenicillanic acid, see: (a) Loosemore, M. J.; Cohen, S. A.; Pratt, R. F. *Biochemistry* **1980**, *19*, 3990. (b) Cohen, S. A.; Pratt, R. F. *Ibid.* 3996.

(24) For an example of the use of monodeuteriated penicillanic acid sulfone in mechanistic studies of β-lactamase inhibition, see: Brenner, D. G.; Knowles, J. R. *Biochemistry* **1981**, *20*, 3680.

(25) For a recent review, see: Knowles, J. R. *Acc. Chem. Res.* **1985**, *18*, 97.

(26) Setti, E. L.; Mascaretti, O. A. *J. Org. Chem.* **1986**, *51*, 3217.

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Highly Chemoselective and Stereocontrolled Catalytic Hydrogenolysis of the Carbon-6–Halogen Bond of (Pivaloyloxy)methyl 6,6-Dihalo- and 6-Halopenicillanates by 5% Palladium on Calcium Carbonate and 5% Rhodium on Alumina

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Introduction

Although the hydrogenolysis of carbon–halogen bonds, also termed dehalogenation or reductive dehalogenation, has been extensively investigated,[2] the mechanism of the

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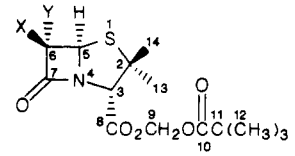
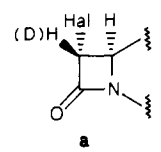
0022-3263/89/1954-2235$01.50/0

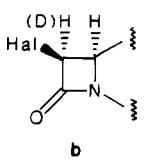
Table I. Hydrogenolysis of the Carbon–Halogen Bond in Pom 6,6-Dihalo- and 6-Halopenicillanates at 25 °C under 1 atm of Pressure of H_2 (or D_2) in Heterogenerous Phase



1: X = I; Y = Br
3: X = Y = I
5: X = Y = Br
6: X = I; Y = Cl
10a: X = D; Y = H
10b: X = H; Y = D
10c: X = Y = H



a



b

2: Hal = Br, H
4: Hal = I, H
7: Hal = Cl, H
8: Hal = Br, D
9: Hal = Cl, D

entry	substrate	conditions: catalyst[a]	conditions: solvent[b]	atm/t', h	products	ratio	yield a + b	% D incorp
1	1	Pd	A	H_2/8[c]	**2a + 2b**	9:1	95	
2	1	Rh	A	H_2/1[c]	**2a + 2b**	9:1	95	
3	3	Rh	A	H_2/1.15[c]	**4a + 4b**	7:1	93	
4	5	Pd	A	H_2/8[c]	**2a + 2b**	9:1	95	
5	5	Rh	A	H_2/0.25[c]	**2a + 2b**	7:1	95	
6	6	Pd	A	H_2/48[c]	**7a + 7b**	9:1	98	
7	1	Pd	B	H_2/72	**2a + 2b**	1.5:1	93	
8	1	Rh	B	H_2/72	**2a + 2b**	1.5:1	90	
9	5	Pd	B	H_2/72	**2a + 2b**	1.5:1	98	
10	5	Rh	B	H_2/72	**2a + 2b**	1.5:1	95	
11	6	Pd[g]	C	H_2/48[d]	nr[h]			
12	1	Pd	D	H_2/10[c]	**2a + 8a + 8b**	1:9:1	97	90[e]
13	1	Pd	D	H_2/48[d]	**8a + 8b**	9:1	98	90[e]
14	6	Pd	D	H_2/48[d]	**9a + 9b**	9:1	98	90[e]
15	1	Pd	A	D_2/40[d]	**2a + 2b**	9:1	96	2[f]
16	**2a**	Pd	D	H_2/24	**10a + 10b + 10c**	4:2:1	70	85[e]
17	**2b**	Pd	D	H_2/24	**10a + 10b + 10c**	4:2:1	70	85[2]

[a] The ratio catalyst/substrate was 0.01/1.0 equiv, unless otherwise indicated. Pd = 5% $Pd/CaCO_3$, Rh = 5% $Rh/Al_2O_3/CaCO_3$. [b] A = ethyl acetate–methanol, 5:8 (v/v); B = ethyl acetate; C = ethyl acetate–acetic acid-d^4, 15:1 (v/v); D = ethyl acetate–methanol-d_1, 5:8 (v/v). [c] Method A. [d] Method B. [e] Determined by ^1H NMR. [f] Determined by mass spectrometry. [g] Without $CaCO_3$. [h] No reaction. [i] Stoichiometric amount.

hydrogenolysis of α-*gem*-dihalocarbonyl compounds has not received much attention in the literature.[3]

We recently have described[4] the chemo- and stereoselectivity of catalytic hydrogenolysis of the 6-halogen bond in Pom 6,6-dihalo- and 6-halopenicillanates by $RhCl(PPh_3)_3$. We now report studies of the heterogeneous catalytic hydrogenolysis with 5% $Pd/CaCO_3$ and 5% Rh/Al_2O_3 in an atmosphere of H_2 and in its absence.

Results

Before any detailed study, it was desirable to examine the effect of methanol on the heterogeneously catalyzed hydrogenolysis.[4,5] (Pivaloyloxy)methyl (Pom) 6α-bromo-6β-iodo-, 6,6-diiodo-, and 6α-chloro-6β-iodopenicillanates (**1**, **3**, and **6**, respectively) on treatment with H_2–5% $Pd/CaCO_3$ or H_2–5% Rh/Al_2O_3 in a mixture of ethyl acetate–methanol (5:8, v/v) were rapidly and selectively dehalogenated by either catalyst (See Table I, entries 1–6). On the other hand, with ethyl acetate as the only solvent, compounds **1** and **5** produced after 72 h a mixture of **2a** and **2b** in a ratio 1.5:1 (entries 7–10). In agreement with our previous finding on dehalogenations by $RhCl(PPh_3)_3$, these results indicate that the presence of methanol strongly enhances the dehalogenation rates and the site selectivity.[4] One aspect of the solvent effect in these heterogeneously catalyzed hydrogenolytic reactions was the marked differences in rates exhibited when the catalyst was prehydrogenated in methanol (method B) or in ethyl acetate (method A). Compounds **1** and **5** were hydrogenolyzed faster when the reactions were performed following method A as compared to B. These results are in accordance with the explanation given by Augustine et al.[5] who reports that ethanol competes with hydrogen for adsorption on active sites of the noble-metal catalyst, decreasing the amount of hydrogen present on the catalyst surface.

We also examined the effect of acidic solvent on palladium catalysis. Hydrogenolysis of compound **6** in a mixture of ethyl acetate–acetic acid-d_4 (entry 11) gave partial decomposition of starting material, instead of dehalogenation.

To test the origin of the hydrogen transferred to carbon 6, the dehalogenations of compound **1** and **6** were carried out in ethyl acetate–methanol-d_1/H_2 and complementarily in ethyl acetate–methanol/D_2, under the conditions summarized in Table I (entries 12–15). The composition of the products of these experiments unequivocally establish that the hydroxylic hydrogen of methanol is stereoselectively transferred to carbon 6 of the penicillin molecule.

In order to determine whether or not the Pd^0 and Rh^0 behave as reagents of hydrogen transfer in the absence of H_2, we carried out the hydrogenolytic reaction of compound **1** with a stoichiometric amount of 5% $Pd/CaCO_3$

(2) (a) Pinder, A. R. *Synthesis* **1980**, 425. (b) Rylander, P. *Catalytic Hydrogenation in Organic Synthesis*; Academic Press: New York, 1979; pp 235–250. (c) Bartők, M. *Stereochemistry of Heterogeneous Metal Catalysis*; J. Wiley & Sons: Chichester, New York, 1985; pp 525–527 and references therein.

(3) Denton, D. A.; McQuillin, F. J.; Simpson, P. L. *J. Chem. Soc.* **1964**, 5535.

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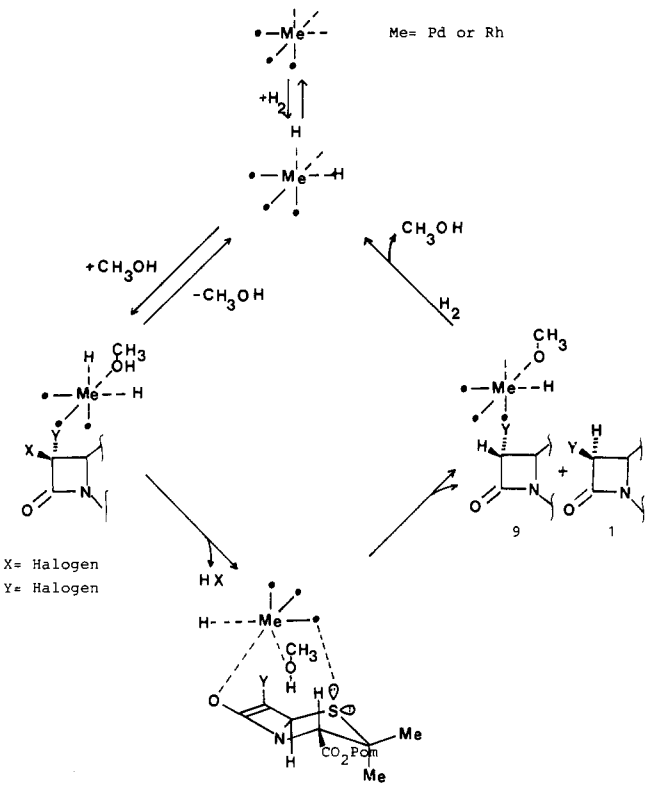
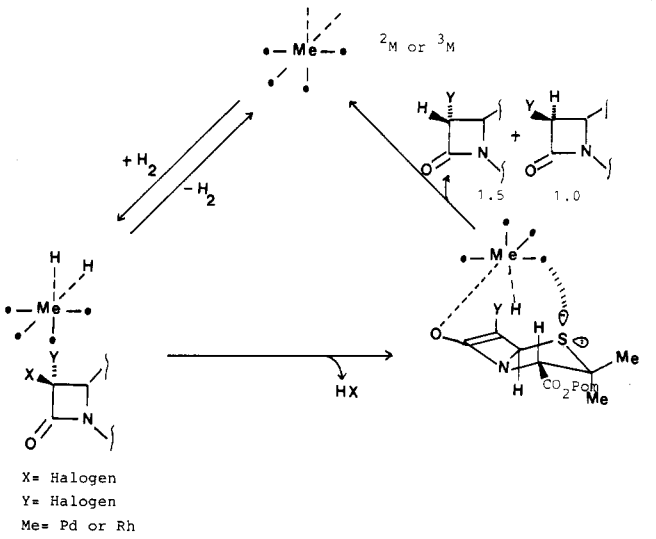
(5) Augustine, R. L.; Warner, R. W.; Melnick, M. J. *J. Org. Chem.* **1984**, *49*, 4863.

Scheme I



Scheme II



or 5% Rh/Al_2O_3 in the mixture of ethyl acetate–methanol in an atmosphere of N_2 at 25 °C. No reaction was observed after 48 h in either case, indicating that the Pd and Rh, in the absence of H_2, do not act as reagents of hydrogen transfer, contrary to our finding with $RhCl(PPh_3)_3$. The reason is surely that the stoichiometric quantity of active centres is very low (about 10^{-5} mol/mol Pd).[6]

When Pom 6α-bromo- and 6β-bromopenicillanates (**2a** and **2b**, respectively) were dehalogenated (entries 16 and 17, Table I), both reactions yielded a mixture of Pom 6β-deuterio-6α-hydro-, 6α-deuterio-6β-hydro-, and 6,6-dihydropenicillanates (**10a–c**, respectively) in a ratio of 4:2:1, respectively. The configuration in compounds **10a** and **10b** was assigned by ^1H NMR spectroscopy on the basis of two broad singlets centered at δ 3.05 (6β-H) and 3.54 (6α-H), on irradiation of H(5). The ^1H NMR spectra of both reaction products were identical. These observations lead to the suggestion that the dehalogenation of compound **2a** and **2b** takes place through a common planar intermediate, where the transfer of hydrogen (or deuterium) to the encumbered β-face is favored.

To prove that no isomerization takes place, under the experimental conditions of hydrogenolysis, compound **2b** or **7b** dissolved in a mixture of ethyl acetate–methanol was stirred with 5% $Pd/CaCO_3$ or 5% $Rh/Al_2O_3/CaCO_3$ for 24 h. Since **2b** and **7b** were recovered without modifications, we conclude that isomerization does not occur.

Discussion

The active sites on the catalyst were looked on as surface complexes having different degrees of cordinative unsaturation. Siegel et al.[7] have defined those surface atoms that are capable of adsorbing three additional ligands (reacting atoms or molecules) as ^3M sites. ^2M sites are those in which two distinct species can be adsorbed, while sites on which only a single moiety can be adsorbed are classed as ^1M.

In the discussion of the mechanism of the noble metal catalyzed hydrogenolysis of Pom 6,6-dihalo- and 6-halopenicillanates, the catalytic cycle may be divided into five steps (see Scheme I): (1) activation of molecular hydrogen; here we believe that the H_2 can be activated by adsorption on ^3M sites; (2) adsorption on the active sites of the catalyst of a molecule of methanol; (3) reaction with the substrate; (4) hydrogen (or deuterium) transfer from methanol (or monodeuteriomethanol); and (5) regeneration of the active form of the catalyst by elimination of a molecule of methanol. Step 3 would produce the elimination of hydrogen halide with concomitant formation of palladium enolate. In step 4 we assume that the penicillin molecule is coordinated with the catalyst through the β-lone electron pair of the sulfur atom of the thiazolidine ring, allowing hydrogen to be transferred selectively to the β-face. Furthermore, the coordination of a molecule of methanol with the metal could increase the acidity of the hydroxylic hydrogen, promoting that hydrogen being transferred, as a proton, to the penicillin–metal intermediate to yield the dehalogenated penicillanate.

The lesser stereoselectivity when the hydrogenolytic reactions were performed by using ethyl acetate as the only solvent could be explained considering that the hydrogen adsorbed on the metal is directly transferred to a planar penicillin intermedate (see Scheme II). Unlike the case when the reactions are run in the presence of methanol, we assume that the hydrogen comes from the methanol adsorbed on the metal surface.

From the present study, we conclude that Pd and Rh in the absence of molecular hydrogen cannot be used as a stoichiometric hydrogen transfer reagent as well as catalyst. The present work provides a correlation of catalytic hydrogenolysis run over noble-metal catalyst palladium and rhodium in heterogeneous phase, with our previous study of catalytic hydrogenolysis on $RhCl(PPh_3)_3$ in homogeneous phase. Since the stereochemistry is similar, a common mechanism is likely to be involved.

Experimental Section

For a general description of experimental conditions, see ref 4. The synthesis of Pom 6α-chloro-6β-iodopenicillanate (**6**),[8] Pom

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(8) Belinzoni, D. U.; Mascaretti, O. A.; Alzari, P. M.; Punte, G.; Faerman, C. H.; Podjarny, A. D. *Can. J. Chem.* **1985**, *63*, 3177.

6α-chloropenicillanates (**7a**)[9] and 6β-chloropenicillanates (**7b**)[10] were previously described.

General Procedure for Catalytic Dehalogenation. The hydrogenolytic reactions were performed at room temperature in a two-necked, round-bottomed flask connected to a hydrogen reservoir maintained at ambient pressure. The catalyst was placed in the flask and flushed with H_2 several times to remove any air.

Method A. In a 5-mL round-bottom flask, fitted with a magnetic stirring bar, 7 mg (ca. 0.006 mmol) of $Pd/CaCO_3$ or Rh/Al_2O_3 and 40 mg (0.4 mmol) of calcium carbonate were suspended in ethyl acetate (0.6 mL). After a period of 20 min of stirring under H_2 at 25 °C (prehydrogenation), Pom 6,6-dihalo- or 6-halopenicillanate (0.05 mmol) dissolved in methanol (1 mL) was added. After the period of time indicated in Table I the solution was filtered through silica gel, and products were identified by TLC and spectroscopic comparison with authentic materials.

Method B. The same procedure was followed as in method A, except the prehydrogenation is carried out in methanol.

Acknowledgment. We thank CONICET (Consejo Nacional de Investigaciones Cientificas y Tecnicas) for financial support and Fellowships (E.L.S. and D.U.B.), Prof. R. A. Corral and J. Zinczuk (Universidad de La Plata) for their generous gift of deuterium, Prof. E. Gross (UMYMFOR) for the low-resolution spectral data. We are also grateful to Dr. John M. Brown and Dr. Eric J. Thomas (University of Oxford, U.K.) for helpful comments on the manuscript.

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Preparation of Stereoisomeric 2,4-Diols: Synthesis and Conformational Study of Bicyclo Derivatives, Isomeric Components of a Pheromone of *Trypodendron lineatum*†

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In previous work, we showed that acyclic 2,4-diketones could be readily reduced by microbial cells to 2-hydroxy 4-ketones. By appropriate choice of microorganisms, either 2*S* ketols[1] or 2*R* ketols[2] can be obtained, with very high optical purity. These chiral β-hydroxy ketones are useful synthons for the preparation of molecules with several chiral centers. Among them, optically active β-diols are of particular interest. One such molecule, 8-nonene-2,4-diol, can be cyclized to give 1,3-dimethyl-2,9-dioxabicyclo[3.3.1]nonane, which is the pheromone of the beetle *Trypodendron lineatum*.[3] We report here a novel synthesis of the four stereoisomers of 8-nonene-2,4-diol (**3**) by microbiological reduction of 8-nonene-2,4-dione (**1**) followed by chemical reduction of the two enantiomers of 2-hydroxy-8-nonen-4-one **2**. Subsequent cyclization of each diastereoisomer of **3** gave the four isomers of the pheromone (Scheme I), the structure and conformation of which were analyzed by 1-D and 2-D ^1H and ^{13}C NMR spectroscopy.

† Use of Biological Systems for the Preparation of Chiral Molecules. 6.

Results and Discussion

Synthesis of the Stereoisomers of 8-Nonene-2,4-diol (3). The starting material was 8-nonene-2,4-dione (**1**), easily obtained from pentane-2,4-dione according to Gerlach et al.[4] As already described,[1] 8-nonene-2,4-dione (**1**) is reduced by bakers' yeast (*Saccharomyces cerevisiae*) yielding, after 3 days, (+)-(2*S*)-2-hydroxy-8-nonen-4-one (**2a**) in good yield and an enantiomeric excess close to 99% as shown by GC analysis on a chiral phase.

Two of the diastereoisomers of 8-nonene-2,4-diol were prepared from **2a**. Recently, several methods for the diastereoselective chemical reduction of β-hydroxy ketones have been described. Either the *erythro* or the *threo* diol can be obtained by appropriate choice of reagents.[5,6] We reduced the ketol **2a** using the method of Narasaka et al.,[5c] which gave predominantly the corresponding *erythro* diol. The two diastereoisomers proved easy to separate on a simple silica gel column. Accordingly, rather than use two methods of reduction to obtain each of the diastereoisomers, we carried out a simple reduction of **2a** with $NaBH_4$ and separated the two resulting isomeric diols, obtained in the ratio 54/46, by column chromatography.

Gerlach et al.[4] report that *erythro* 8-methyl-8-nonene-2,4-diol has a higher R_f (0.54) than the *threo* isomer (0.45). For the same diol, Redlich et al.[7] determined the values of the ^{13}C NMR chemical shifts of the carbons bearing the hydroxy groups. Those obtained for the *erythro* isomers were greater than those for the *threo* isomer.

The isomer of 8-nonene-2,4-diol that was eluted first from the column had chemical shift values for the 2 and 4 carbons of 72.1 and 68.7 ppm. The isomer eluted second had corresponding values of 69.3 and 65.6 ppm. By analogy with the results reported for 8-methyl-8-nonene-2,4-diol, we can therefore assign the *erythro* configuration to the diol eluted first. The configuration of the 2 carbon is known to be 2*S*;[1] hence the absolute configuration of this diol is (+)-(2*S*,4*R*)-**3a**. The diol eluted subsequently from the column is therefore (+)-(2*S*,4*S*)-8-nonene-2,4-diol (**3b**) as confirmed by ^1H and ^{13}C NMR analyses. The optical purity of **3a** and **3b** was very high as measured by chromatography on a chiral capillary column[1] (ee >99%).

The other two diastereoisomers of 8-nonene-2,4-diol were prepared in the same way starting from 8-nonene-2,4-dione, via the β-hydroxy ketone **2'a** of absolute configuration 2*R*. This hydroxy ketone was obtained by reduction with *Geotrichum candidum* in 70% yield and with 99% enantiomeric excess as already published.[2]

Hydroxy ketone **2'a** was then reduced with $NaBH_4$, giving a mixture of *erythro* and *threo* isomers (58/42) in 77% yield. Separation on a silica gel column yielded the *erythro* isomer first. Its configuration was confirmed by ^{13}C NMR. The configuration of the 2 carbon is known to be 2*R*;[2] hence the absolute configuration of the diol is (−)-(2*R*,4*S*)-**3'a**. The diol eluted subsequently was therefore (−)-(2*R*,4*R*)-8-nonene-2,4-diol (**3'b**). Both **3'a** and **3'b** were optically pure as measured by chromatography on a chiral capillary column.

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