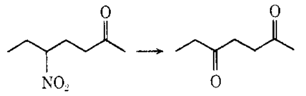
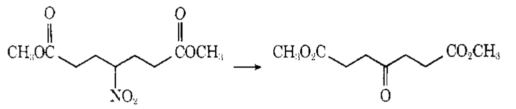
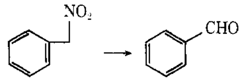
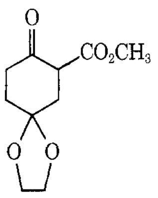
Table I
Ozonolysis of Nitronate Salts

Reaction	Yield, %
 1 → 2	83
 3 → 4	88
 5 → 6	68
$CH_3(CH_2)_6CH_2NO_2 \longrightarrow CH_3(CH_2)_6CHO$ 7 → 8	65



9

Experimental Section

General Reaction Procedure. The nitro compound (0.020 mol) in 50 ml of anhydrous methanol was treated with 1 equiv of sodium methoxide (1.08 g, 0.020 mol) and stirred for 10 min to form the nitronate salt. This methanolic solution was then cooled to −78°, and a stream of ozone-oxygen was passed through.[9] For secondary nitro compounds, ozonolysis was continued until the reaction mixture was light blue (excess O_3). For primary nitro compounds, however, it was found necessary to meter in only 1 equiv of O_3 since an excess led to further reaction and consequent lower yields of aldehyde product.

After 30 min, the reaction mixture was purged with a nitrogen stream to remove excess ozone, and was then treated with 5 ml of dimethyl sulfide at −78° and slowly allowed to come to room temperature. After standing for 16 hr, volatile material was removed at the rotary evaporator. The residue was taken up in ether and washed with water and brine, then dried (Na_2SO_4), concentrated, and purified either by distillation or crystallization.

In this manner, the following compounds were prepared.

Heptane-2,5-dione (2) was prepared from 5-nitroheptan-2-one,[5] and identified by spectral comparison with an authentic sample,[5] 83% yield.

Dimethyl 4-oxopimelate (4) was prepared from dimethyl 4-nitropimelate,[7] and purified by crystallization from hexane, mp 49–50° (lit.[8] mp 49–50°), 88% yield.

Benzaldehyde (6) was prepared from α-nitrotoluene,[10] purified by distillation, and identified by spectral comparison with an authentic sample, 68% yield, bp 70–75° (20 mm).

Octanal (8) was prepared from 1-nitrooctane,[11] purified by distillation, and identified by spectral comparison with an authentic sample, 65% yield, bp 80° (30 mm).

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Registry No. 1, 42397-25-1; **2,** 1703-51-1; **3,** 7766-83-8; **4,** 22634-92-0; **5,** 622-42-4; **6,** 100-52-7; **7,** 629-37-8; **8,** 124-13-0.

References and Notes

(1) W. E. Nolan, *Chem. Rev.*, **55**, 137 (1955).
(2) H. Shechter and F. T. Williams, *J. Org. Chem.*, **27**, 3699 (1962).
(3) A. H. Pagano and H. Shechter, *J. Org. Chem.*, **35**, 295 (1970).
(4) N. Kornblum and P. A. Wade, *J. Org. Chem.*, **38**, 1418 (1973).
(5) (a) J. E. McMurry and J. Melton, *J. Amer. Chem. Soc.*, **93**, 5309 (1971); (b) *J. Org. Chem.*, in press.
(6) *Cf.* G. A. Fleisher and E. C. Kendall, *J. Org. Chem.*, **16**, 556 (1951).
(7) S. Kambe and H. Yasuda, *Bull. Chem. Soc. Jap.*, **39**, 2549 (1966).
(8) R. M. Lukes, G. I. Poos, and L. H. Sarett, *J. Amer. Chem. Soc.*, **74**, 1401 (1952).
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(10) W. Emmons, *J. Amer. Chem. Soc.*, **77**, 4558 (1955).
(11) N. Kornblum and J. W. Powers, *J. Org. Chem.*, **22**, 455 (1957).

Ruthenium-Catalyzed Hydrogen-Deuterium Exchange in Alcohols. A Convenient Method for Deuterium Labeling of Primary Alcohols

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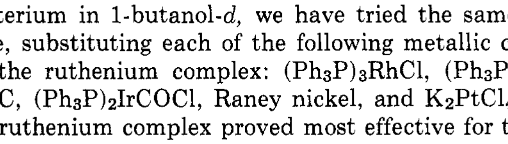
The most commonly used method for deuterating primary alcohols in the C-1 position is oxidation of the alcohol to either the corresponding aldehyde or carboxylic acid followed by reduction with lithium aluminum deuteride.[1] Although this approach works well in most instances, it requires two separate reactions and uses an expensive reagent (lithium aluminum deuteride).

We wish to report a unique transition metal catalyzed hydrogen–deuterium exchange reaction which provides the basis for a convenient alternate procedure for the introduction of deuterium into certain primary alcohols and which uses deuterium oxide as the isotopic source.

When 1-butanol-*d* was heated to 200° for 1 hr in the presence of 0.2 mol % of tris(triphenylphosphine)ruthenium dichloride, deuterium bound to oxygen exchanged with hydrogen exclusively at the C-1 carbon atom;[2] the distribution of deuterium at the C-1 position is that shown below.[3]



$$CH_3(CH_2)_2CH_2OD \xrightarrow[200°]{(Ph_3P)_3RuCl_2} CH_3(CH_2)_2\overset{\overset{X}{|}}{\underset{\underset{Y}{|}}{C}}OH(D)$$

1a, X = Y = H (55%)
b, X = H; Y = D (35%)
c, X = Y = D (10%)

In an effort to determine whether the ruthenium complex is a unique catalyst for exchanging hydrogen with deuterium in 1-butanol-*d*, we have tried the same procedure, substituting each of the following metallic catalysts for the ruthenium complex: $(Ph_3P)_3RhCl$, $(Ph_3P)_2PtCl_2$, Pd/C, $(Ph_3P)_2IrCOCl$, Raney nickel, and K_2PtCl_4. While the ruthenium complex proved most effective for this conversion, all of the other metals exhibited no detectable catalytic activity.

Although we have found that primary alcohols readily undergo hydrogen exchange, those secondary alcohols investigated gave poor results (Table I). Little exchange was detected in the case of 2-propanol and cyclododecanol, and prolonged heating resulted in considerable dehydration. For primary alcohols, we detected no decomposition (<0.1%) under the reaction conditions described.[4]

We have found that, by adding deuterium oxide to a mixture of the ruthenium catalyst and any one of the primary alcohols tested, this exchange reaction becomes a synthetically useful method for deuterium labeling. For example, when 1-decanol and deuterium oxide were heated in the presence of the ruthenium catalyst, the recovered alcohol contained a significant amount of deuterium incorporated in the C-1 position. The amount of deuteri-

Table I
Ruthenium-Catalyzed Hydrogen–Deuterium Exchange in Alcohols[a]

Alcohol	Isotopic composition, % d_0	d_1	d_2
Ethanol-d^b	42	43	15
1-Butanol-d^b	55	35	10
2-Propanol-d^b	>98	<2	
1-Decanol[c]	7	35	58
1-Decanol	0	5	95
1-Dodecanol	0	6	94
1-Octanol	0	3	97
Cyclododecanol	95	5	

[a] The percentage of deuterium indicated represents the isotopic distribution at the C-1 carbon atom. Unless noted otherwise, reactions were carried out using procedures similar to that described for the deuteration of 1-decanol; the reaction temperature was 200°. The molar ratio of deuterium oxide to alcohol used was 50:1. [b] The alcohol was heated directly with the ruthenium catalyst in the absence of deuterium oxide. [c] The molar ratio of deuterium oxide to alcohol used was 5:1.

um introduced into the alcohol was dependent upon the molar ratio of deuterium oxide to alcohol employed.

The advantages of this procedure for isotopic labeling of primary alcohols in the C-1 position lie in its simplicity, its low cost, its avoidance of reactive oxidants and reductants, and its ability to be carried out under neutral pH.

Experimental Section[5]

General Methods. Unless stated otherwise, all reagents were obtained commercially and were used without further purification. Deuterated alcohols (Aldrich Chemical Co.) were greater than 99% pure. Tetrahydrofuran was dried by distillation from calcium hydride under a nitrogen atmosphere. Commercial catalysts were obtained from the following sources: $(Ph_3P)_3RuCl_2$, $(Ph_3P)_3RhCl$, and $(Ph_3P)_2IrCOCl$ (Strem Chemical Co.); K_2PtCl_4 (Alfa Inorganics); Pd/C and Raney nickel (K & K Laboratories).

General Procedure for Hydrogen–Deuterium Exchange in Deuterated Alcohols. Procedures similar to that described for the hydrogen–deuterium exchange in 1-butanol-*d* were followed for all deuterated alcohols. A mixture of 2 mg (0.002 mmol) of tris(triphenylphosphine)ruthenium dichloride and 150 μl (1.6 mmol) of 1-butanol-*d* was sealed under a nitrogen atmosphere in a 4-in. 5-mm Pyrex glass tube. The tube was placed in an oil bath, maintained at 200° for 1 hr, withdrawn, and cooled. The purity of the alcohol was determined by glpc using both a UC-W98 on Chromosorb W column and a Carbowax on Chromosorb W column. Alcohols were collected for mass spectral analysis by glpc using a F & M Model 720 thermal conductivity instrument. Isotopic compositions were determined from $(M - H_2O)^+$ peaks and were corrected for contributions from ^{13}C.[6]

1-Decanol-*1,1*-d_2. A mixture of 100 mg (0.1 mmol) of tris(triphenylphosphine)ruthenium dichloride, 1.58 g (10.0 mmol) of 1-decanol, and 10.0 g (0.5 mol) of 99.7% deuterium oxide was sealed under a nitrogen atmosphere in a 14-in. 12-mm Pyrex glass tube. The tube was placed in an oil bath, maintained at 200° for 0.5 hr, withdrawn, and cooled to room temperature. The contents of the tube was poured into 50 ml of ether and the organic phase was dried (Na_2SO_4), concentrated, and distilled (short-path distillation), giving 1.47 g (93%) of 1-decanol, bp 123-125° (20 mm). Mass spectral analysis indicated that the recovered alcohol was a mixture of 95% d_2, 5% d_1, and 0% d_0 material.

Acknowledgment. We are grateful to the Marquette University Committee on Research and Chemistry Department for their financial support.

Registry No. Tris(triphenylphosphine)ruthenium chloride, 15529-49-4; 1-decanol, 112-30-1; 1-decanol-*1,1*-d_2, 42006-99-5.

References and Notes

(1) A. Murray and D. L. Williams, "Organic Synthesis with Isotopes," Interscience, New York, N. Y., 1958, p 1341.

(2) We have found that temperatures in excess of 180° are necessary for rapid exchange to occur. Thus, when 1-butanol-*d* was heated in the presence of the ruthenium catalyst for 15 hr at 140°, the ^1H nmr spectrum of the resulting alcohol showed no evidence of hydrogen–deuterium exchange.

(3) The ^1H nmr spectrum of the resulting isotopic mixture of alcohols confirmed that only the C-1 carbon atom had become deuterated.

(4) The purity of the alcohol was measured by glpc using both a UC-W98 on Chromosorb W column and a Carbowax on Chromosorb W column.

(5) Boiling points are uncorrected. Mass spectra were recorded on a Consolidated Electrodynamics Corp. mass spectrometer, Type 21-103 C. All ^1H nmr spectra were recorded using a Varian A-60 spectrometer. The alcohols were analyzed by glpc on a Beckman GC-2A flame ionization instrument.

(6) Biemann has established that aliphatic alcohols, under electron impact, lose water exclusively *via* 1,3, 1,4, and 1,5 eliminations: W. Benz and K. Biemann, *J. Amer. Chem. Soc.*, **86,** 2375 (1964).

The Chemistry of Flavandiones.[1] Reaction with Base[2]

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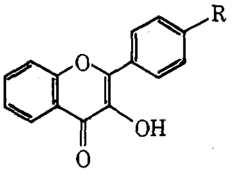
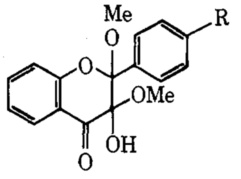
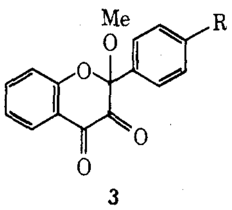
Flavolon (1) is oxidized by 1 mol of periodic acid. From the reaction in methanol, the methyl 3-hemiketal 2 of 2-methoxy-3,4-flavandione (3) can be isolated.[3] Solutions of 2 are always yellow, indicating that some 3 is always present. We have found that the hemiketal 2 undergoes a normal benzilic acid rearrangement. In aqueous methanol, the product is the hydroxy acid 4; in anhydrous methanol, the methyl ester 5. These products are readily accounted for in terms of the ionic reaction mechanism usually formulated for the benzilic acid rearrangement.[4] This result was not entirely predictable. Compound 2 is a mixed ketal of an *o*-hydroxydiphenylpropanetrione, and the reactions of 1,2,3-triketones with base are more complex.[5,6]



1, R = H
9, R = CH_3



2, R = H
10, R = CH_3



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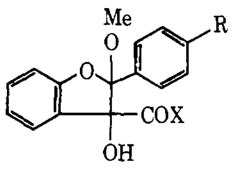
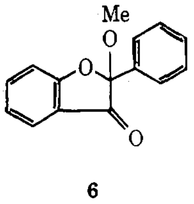


4, R = H; X = OH
5, R = H; X = OCH_3
11, R = CH_3; X = OH
12, R = CH_3; X = OCH_3



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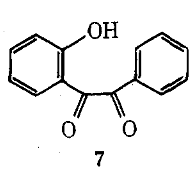

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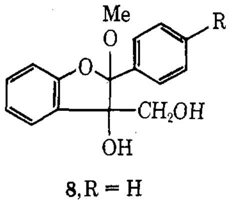

8, R = H
13, R = CH_3

The ester 5 is obtained by the reaction of 2 with a solution of sodium methoxide in anhydrous methanol or by passing a methanol solution of 2 through the hydroxide form of an anion exchange resin. The assigned structure is supported by spectra and analyses. The saponification of 5