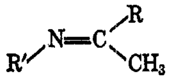
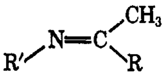
due to the more stable isomer **2A** which seems to make up 87% of the mixture.



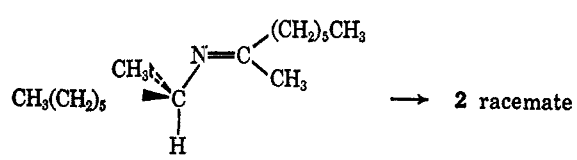
2A



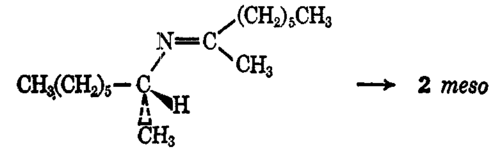
2B

R = n-hexyl
R′ = 2-octyl

Of the various conformations which can result from rotation about the single CN bond in **2A**, the two most likely to be present in the transition state leading to reduction are shown in the diagrams below. When the tertiary hydrogen lies in the plane of the paper, the attacking hydride ion is more likely to approach the olefinic carbon from below the plane of the paper for the particular enantiomer shown. In this case, the incoming ion encounters the methyl group rather than the bulkier six-carbon chain and the amine is produced as the racemic diastereoisomer.



A second likely conformation for this enantiomer would occur when the tertiary hydrogen and the methyl group are both staggered on either side of the plane of the paper. Then the attacking hydride ion would prefer to approach from above the plane of the paper and so encounter the hydrogen atom rather than the bulkier methyl group. Consequently, the amine would be produced in the *meso* form when the ketimine is reduced in this conformation.



The observation that **3** is formed as an isomeric mixture containing 62% of the racemate indicates that the first conformation is more favored than the second. Other factors, however, in addition to those described above may well be involved.

Experimental Section

N-(2-Octyl)methylhexylketimine (**2**).—A solution of 2-octanone (157.5 g, 1.24 mol) and 2-aminooctane (158.9 g,1.24 mol) in toluene (1.5 l.) was refluxed overnight with a Dean–Stark trap in which water (20.2 g, 1.13 mol) was collected. The solvent was evaporated and the residue distilled under nitrogen to give a small forerun of starting materials, bp 45–95° (1 mm), followed by the ketimine (190 g, 62%): bp 96–97° (52 μ); $n^{27}\text{D}$ 1.4414; uv max (isooctane) 245 mμ (ε 112); ir (liquid film) 1658 cm^{-1} (C═N); nmr (neat) τ 6.62 (m, 1, C**H**—N═C), 7.87 (t, 2, *J* = 6 Hz, C**H**$_2$—C═N), 8.16 and 8.30 (S, 3, C**H**$_3$═N) ppm. Analysis by glpc on several different columns showed one peak.

Anal. Calcd for $C_{16}H_{33}N$: N, 5.85. Found: N, 5.70.

Bis(1-methylheptyl)amine (**3**).—N-(2-Octyl)methylhexylketimine (150.0 g, 0.772 mol) was added to a stirred solution of lithium aluminum hydride (29.3 g, 0.772 mol) in tetrahydrofuran (1 l.) at room temperature under a nitrogen atmosphere. After refluxing for 24 hr, the metal complex was decomposed by treatment with aqueous base in the usual manner,[6] the resulting suspension was filtered, and the organic layer of the filtrate was dried ($MgSO_4$) and evaporated. The residue was distilled to give bis(1-methylheptyl)amine (105.4 g, 69%), bp 102–105° (60 μ), $n^{26}\text{D}$ 1.4363–1.4372; nmr (neat) τ 7.36 (broad, 2, C**H**-N) ppm.

Anal. Calcd for $C_{16}H_{35}N$: C, 79.59; H, 14.61; N, 5.80. Found: C, 80.08; H, 14.85; N, 5.79.

Treatment of a sample of the amine in hexane with aqueous hydrochloric acid gave the amine hydrochloride salt, mp 104–107°, after two recrystallizations from heptane.

Anal. Calcd for $C_{16}H_{36}NCl$: C, 69.01; H, 13.05; N, 5.04. Found: C, 68.92; 13.51; N, 4.96.

A second sample of the amine was converted to the trifluoroacetyl derivative by treatment of a 10% solution of the amine in hexane (1 ml) with trifluoroacetic anhydride (100 μl). The solution was analyzed at 200° on a 6 ft × $^1/_4$ in. glpc column containing 15% Apiezon L and shown to contain two isomers in a 62:38 ratio.

A third sample of the amine (50 mg, 0.21 μmol) in chloroform (2 ml) was treated with a 0.1 *M* solution of N-trifluoroacetyl-L-prolyl chloride in chloroform (2.3 ml), as obtained from Regis Chemical Co. After stirring for 1 min, triethylamine (40 μl, 0.23 μmol) was added and the solution stirred for 15 min at room temperature when 6 *N* hydrochloric acid (3 ml) was added. The organic layer was washed with water, dried ($MgSO_4$), and most of the solvent evaporated in a stream of nitrogen. The remaining derivative of **3** was analyzed directly at 225° on an 8 ft × $^1/_4$ in. column containing 10% of diethylene glycol succinate.

Bis(1-methylheptyl)butyramide (**4**).—Bis(1-methylheptyl)amine (85.6 g, 0.356 mol) was refluxed overnight in toluene (600 ml) containing butyryl chloride (20.6 g, 0.193 mol). The toluene was evaporated and hexane (600 ml) was added when the amine hydrochloride was removed by filtration and the filtrate washed with aqueous base and water before drying ($MgSO_4$). The hexane was evaporated and the residue distilled, giving a small forerun of bis(1-methylheptyl)amine, bp 80–83° (8 μ), followed by bis(1-methylheptyl)butyramide (38.6 g, 64%) bp, 127–130° (8 μ), $n^{26}\text{D}$ 1.4550, ir (liquid film) 1640 cm^{-1} (C═O).

It had two broad absorptions at τ 6.09 and 6.84 ppm in the nmr. These two peaks, which are due to the tertiary hydrogens in two distinct conformations, coalesced to one broad peak on warming above room temperature. The nmr also showed a peak at τ 7.71 ppm (t, 2 C**H**$_2$CO), while the glpc analysis gave two well-resolved peaks on Apiezon L at 250°.

Anal. Calcd for $C_{20}H_{41}NO$: C, 77.10; H, 13.27; N, 4.50. Found: C, 77.21; H, 13.26; N, 4.54.

Registry No.—**2A,** 20273-75-0; **2B,** 20273-76-1; (±)-**3,** 20221-59-4; (±)-**3** HCl, 20273-77-2; *meso*-**3,** 20273-78-3; *meso*-**3** HCl, 20273-79-4; (±)-**4,** 20273-80-7; *meso*-**4,** 20273-81-8.

Acknowledgment.—The author wishes to express his gratitude to Dr. J. J. Conradi and Dr. H. A. Harris for helpful discussions.

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[6] N. G. Gaylord, "Reduction with the Complex Metal Hydrides," Interscience Publishers, Inc., New York and London, 1956, p 1011.

Alkoxyl Exchange Reactions of Naphthalene Ethers

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Received January 27, 1969

During the course of our work on the photooxidation of aromatic systems[2] we had occasion to prepare 1,2,4-trimethoxynaphthalene. In order to do this we hydrolyzed 1,4-diacetoxy-2-methoxynaphthalene[3] (**1**) with

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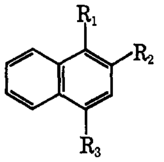
[1] To whom all communications should be addressed.

[2] J. E. Baldwin, H. H. Basson, and H. C. Krauss, *Chem. Commun.*, 984 (1968).

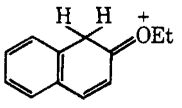
[3] L. F. Fieser, *J. Amer. Chem. Soc.*, **48**, 2933 (1926).

methanolic hydrogen chloride. Surprisingly the product isolated in quantitative yield after 1 min at 60° was 2,4-dimethoxy-1-naphthol (**2**). Hydrolysis of **1** with ethanolic hydrogen chloride yielded, under the same conditions, 2,4-diethoxy-1-naphthol (**3**) and, furthermore, the products **2** and **3** were found to be interconvertible under the same conditions of reaction and time.



1, $R_1 = R_3 = OAc$; $R_2 = OCH_3$
2, $R_1 = OH$; $R_2 = R_3 = OCH_3$
3, $R_1 = OH$; $R_2 = R_3 = OCH_2CH_3$
5, $R_1 = R_3 = OH$; $R_2 = OCH_3$
8, $R_1 = OH$; $R_2 = Cl$; $R_3 = OCH_3$
11, $R_1 = OAc$; $R_2 = R_3 = OCH_3$
12, $R_1 = OAc$; $R_2 = R_3 = OCH_2CH_3$
13, $R_1 = OAc$; $R_2 = Cl$; $R_3 = OCH_3$
14, $R_1 = OCH_3$; $R_2 = H$; $R_3 = OAc$

There are in the literature a number of studies of acid-catalyzed conversions of phenols to phenol ethers.[4,5] These and related deuterium exchange studies[6] have demonstrated that the carbon-protonated species, *e.g.*, **4**, is the reactive exchanging intermediate. However the generally vigorous conditions required,[7] completely different from those we used, suggested the possibility of an alternate mechanism for the conversion of **1** into **2**. Acid-catalyzed ketonization of **5** would produce **6** which could readily lose the elements of methanol to give 1,4-naphthoquinone. Michael addition of solvent ethanol to the quinone would give **7**. Enolization of **7** followed by acid-catalyzed ether exchange[4,5] of **7** at the less hindered 4 position would then provide the product **3** To test this possibility we subjected 1,4-naphthoquinone to methanolic hydrogen chloride under the same conditions as before and obtained in quantitative yield a chlorine-containing compound. This substance was shown to be the phenolic ether **8** by hydrogenolysis to 4-methoxy-1-naphthol.[8] The position of the chlorine atom in **8** was confirmed by the observation that the phenol **8** did not exchange with deuterium under conditions in which 4-methoxy-1-naphthol rapidly exchanged its 2-hydrogen atom. 1,4-Naphthoquinone can therefore not mediate in the ether exchange reaction of **1** and the conversion to **8** is best understood in terms of a simple addition of hydrogen chloride to the double bond[9] yielding the diketone **9**. Exchange of the less hindered carbonyl followed by aromatization would provide the observed product.



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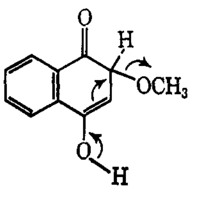

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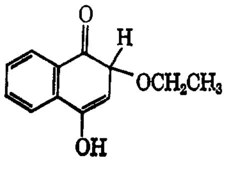

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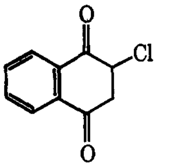

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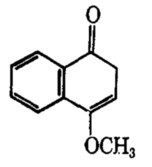
We conclude from these observations that the exchange proceeds by the protonation process already described[4–6] with three additional qualifications: first, that an increased number of electron-releasing groups causes a large increase in the rate of protonation and hence in the rate of exchange; second, that β-alkoxyl exchange occurs more rapidly[6] and a *meta* orientation of two alkoxyls is particularly favorable. Thus whereas 1,4-dimethoxynaphthalene[10] did not exchange under our usual conditions, 1,3-dimethoxynaphthalene[11] proceeded to a 1,3-substituted monomethoxylmonoethoxylnaphthalene which was not further characterized. However the ethoxyl function could readily be replaced by a methoxyl function again in methanolic hydrogen chloride to give the original 1,3-dimethoxynaphthalene. Finally, that a *para*-hydroxyl group strongly assists the exchange of an alkoxyl function, as was noted when 1-acetoxy-4-methoxynaphthalene[12] **14** was treated under usual conditions with ethanolic hydrogen chloride to give 4-ethoxy-1-naphthol[8] while α-naphthyl methyl ether showed no exchange under the same conditions.

We believe that the origin of this last effect is to be found in the facile tautomerism to the keto form **10**, in



10

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[4] K. B. Wiberg and K. A. Saegebarth, *J. Org. Chem.*, **25**, 832 (1960).

[5] S. Oae and R. Kiritani, *Bull. Chem. Soc. Jap.*, **39**, 611 (1966).

[6] P. F. Tryon, W. G. Brown, and M. S. Kharasch, *J. Amer. Chem. Soc.*, **70**, 2003 (1948).

[7] For example Kharasch[6] observed that the deuterium exchange of **4** required 112 hr at 120° in ethanolic sulfuric acid.

[8] A. Inoue, N. Kuroki, and K. Konishi, *Yuki Gosei Kagaku Kyokai Shi*, **17**, 773 (1959).

[9] L. F. Fieser and M. Fieser, "Advanced Organic Chemistry," Reinhold Publishing Corp., New York, N. Y., 1963, p 860.

[10] P. P. T. Sah, *Rec. Trav. Chim. Pays-Bas*, **59**, 1021 (1940).

[11] Ng. Ph. Buu-Hoï and D. Lavit, *J. Org. Chem.*, **21**, 1022 (1956).

[12] F. Wessely, J. Kotlan, and W. Metlesics, *Monatsh. Chem.*, **85**, 69 (1954).

keeping with the generally faster deuteration of the free phenol relative to the ether,[5] followed by acid-catalyzed exchange of the free enol ether function, which has many precedents.[4,13] In summary we have observed rapid exchange reactions of various naphthols and their ethers which may be of use for the preparation of polyalkoxynaphthalenes by a process of aryl oxygen fission.

Experimental Section[14]

Melting points were measured on a Kofler hot stage and are uncorrected. Ultraviolet spectra were recorded in MeOH on a Coleman-Hitachi 124 double-beam spectrophotometer. Infrared spectra were recorded on a Perkin-Elmer 257 spectrophotometer. Nmr spectra were recorded on a Varian A-60 spectrometer with tetramethylsilane as internal reference. Mass spectra were measured on an AEI MS 9 mass spectrometer.

Alcoholic hydrogen chloride solutions were prepared by absorbing dry HCl gas (1.0 g) in 9.0 g of the respective alcohol. The three naphthols **2**, **3**, and **8** were characterized as the colorless crystalline acetate derivatives **11**, **12**, and **13**, respectively. The acetates **11**, **12**, **13**, and **14** were readily formed by heating the parent naphthol in Ac_2O in the presence of 2 equiv of NaOAc for 10 min at 80°.

2,4-Dimethoxy-1-naphthol (**2**).—**1** (0.5 g) was dissolved in 10 ml of methanolic HCl. The solution was heated to 60° for 1 min and then evaporated to yield pinkish crystals. This product was then redissolved in 10 ml of MeOH and evaporated down again in order to remove any remaining HCl gas. Another aliquot of MeOH was added to the product and then again evaporated off to yield a colorless crystalline compound **2**: mp 77–82°; uv max 242 mμ (ε 27,400), 313 (4080); ir ($CHCl_3$) 3560 (OH), 2940, 2840 (OMe), 1640, 1600, 1590 cm^{-1}; nmr ($CDCl_3$) δ 3.85 (s, 3), 3.90 (s, 3), 5.10 (bs, 1), 6.60 (s, 1), 7.40 (m, 2), 8.15 (m, 2); mass spectrum (70 eV) *m/e* (relative intensity) 204 (25), 189 (17), 174 (2), 161 (5).

2,4-Dimethoxy-1-naphthol acetate (**11**) had mp 90.5–91.5°; uv max 253 mμ (ε 40,200), 301 (4680); ir ($CHCl_3$) 2940, 2840 (OMe), 1760 (ester C=O), 1640, 1600, 1560 cm^{-1}; nmr ($CDCl_3$) δ 2.34 (s, 3), 3.76 (s, 3), 3.80 (s, 3), 6.47 (s, 1), 7.35 (m, 2), 7.56 (m, 1), 8.08 (m, 1); mass spectrum (70 eV) *m/e* (relative intensity) 246 (5), 204 (22), 189 (12).

Anal. Calcd for $C_{14}H_{14}O_4$: C, 68.28; H, 5.73. Found: C, 68.36; H, 5.85.

2,4-Diethoxy-1-naphthol (**3**).—Ethanolic HCl was substituted for methanolic HCl and the preparation proceeded as that for **2**: nmr ($CDCl_3$) δ 1.40 (t, 3), 1.46 (t, 3), 4.10 (q, 2), 4.12 (q, 2), 5.20 (bs, 1), 6.64 (s, 1), 7.35 (m, 2), 8.12 (m, 2).

2,4-Diethoxy-1-naphthol acetate (**12**) had mp 110.5–111.5°; uv max 236 mμ (ε 35,400), 301 (4130); ir ($CHCl_3$) 2980–2900 (m), 1760 (ester C=O), 1640, 1600, 1570 cm^{-1}; nmr ($CDCl_3$) δ 1.37 (t, 3), 1.48 (t, 3), 2.40 (s, 3), 4.14 (q, 4), 6.64 (s, 1), 7.36 (m, 2), 7.66 (m, 1), 8.20 (m, 1); mass spectrum (70 eV), *m/e* (relative intensity) 274 (3), 231 (11), 175 (16).

Anal. Calcd for $C_{16}H_{18}O_4$: C, 70.05; H, 6.61. Found: C, 69.96; H, 6.84.

2-Chloro-4-methoxy-1-naphthol (**8**).—1,4-Naphthoquinone (0.5 g) was substituted for **1** and the preparation proceeded as that for **2**: nmr ($CDCl_3$) δ 3.90 (s, 3), 5.55 (bs, 1), 6.67 (s, 1), 7.50 (m, 2), 8.16 (m, 2).

2-Chloro-4-methoxy-1-naphthol acetate (**13**) had mp 74–75.5°; uv max 235 mμ (ε 43,000), 295 (9200); ir (CCl_4) 3180–2950 (m), 2850 (OMe), 1790 (ester C=O), 1630, 1590; nmr ($CDCl_3$) δ 2.36 (s, 3), 3.82 (s, 3), 6.67 (s, 1), 7.40 (m, 2), 7.58 (m, 1), 8.14 (m, 1); mass spectrum (70 eV) *m/e* (relative intensity) 252 (3), 250 (10), 210 (30), 208 (50), 195 (20), 193 (55), 157 (10).

Anal. Calcd for $C_{13}H_{11}ClO_3$: C, 62.28; H, 4.42; Cl, 14.14. Found: C, 62.57; H, 4.37; Cl, 14.00.

Registry No.—**2**, 20352-27-6; **3**, 20352-28-7; **8**, 20352-29-8; **11**, 20352-30-1; **12**, 20352-35-6; **13**, 20352-36-7.

Acknowledgment.—We would like to thank Eli Lilly and Co. for generous financial support.

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(13) W. F. Gannon and H. O. House, *Org. Syn.*, **40**, 41 (1960).

(14) Elemental analyses were performed by the Midwest Microlab Inc., Indianapolis, Ind. 46226.

The Stereochemistry of the Hydroformylation of Norbornene

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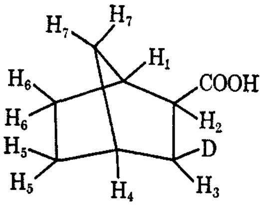
Received September 4, 1968

We recently reported that the hydrogenation of 1,2-diphenylcyclobutene with cobalt hydrocarbonyl, $HCo(CO)_4$, is primarily a *cis* process.[1] The stereochemistry of the stoichiometric hydroformylation of olefins has never been established, although two previous studies of the high-pressure catalytic oxo reaction indicated a cleanly *cis* hydroformylation of unsaturated carbohydrates possessing a vinyl ether structure.[2,3] We now wish to report that the stoichiometric hydroformylation of an olefin, norbornene, is largely, if not entirely, a *cis* process.

When a hexane solution of $DCo(CO)_4$ was added to norbornene under an atmosphere of carbon monoxide at room temperature, slow absorption of carbon monoxide occurred and deuterated norbornane-2-carboxaldehyde[4] was isolated in about 20% yield. The product was oxidized with potassium permanganate to give *exo*-norbornane-2-carboxylic acid which, were the hydroformylation *cis*, would have structure **1**, and were it *trans*, would have structure **2**. The nmr of the acid from the hydroformylated product was essentially identical with that of an authentic sample[5] of **1** (Figure 1). We consider it quite unlikely that **2** would give a spectrum identical with **1**, since the coupling constant $J_{H_2-H_3}$ between two *endo* hydrogens in norbornyl systems is about 8 cps and that between an *endo,exo* pair is about 2 cps.[6]



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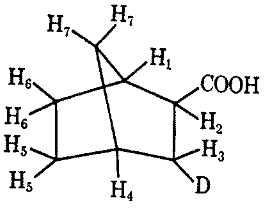

2

Experimental Section

Melting points were taken on a Fisher–Johns block and are uncorrected. Nmr spectra were obtained with a Varian A-60 spectrometer and infrared spectra were determined with a Perkin-Elmer Infracord 337. Norbornene was purchased from Aldrich Chemicals.

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(1) W. Fichteman and M. Orchin, *J. Org. Chem.*, **33**, 1281 (1968). Although a small amount of *trans* product was observed, it can be accounted for by olefin isomerization, followed by *cis* addition.

(2) A. Rosenthal and D. Abson, *Can. J. Chem.*, **42**, 1811 (1964).

(3) A. Rosenthal and H. J. Koch, *ibid.*, **43**, 1375 (1965).

(4) Y. Colleuille and P. Perras, French Patent 1,352,841, *Chem. Abstr.*, **61**, 593*a* (1964), reports that when norbornene is treated with dicobaltoctacarbonyl in cyclohexane solvent under high carbon monoxide pressure, a low yield of norbornane-2-carboxaldehyde is obtained along with other products. We found that under catalytic oxo conditions using dicobaltoctacarbonyl as catalyst, norbornene hydroformylates quite readily to give a good yield of norbornane-2-carboxaldehyde.

(5) Supplied by Dr. John Hudec; see C. W. Bird, R. C. Cookson, J. Hudec, and R. O. Williams, *J. Chem. Soc.*, 410 (1963), who report here the *cis* hydrocarboxylation of norbornene by $Ni(CO)_4$ and H_2O.

(6) A. Factor and T. G. Traylor, *J. Org. Chem.*, **33**, 2607 (1968).