**Determination of Water.**—The water in the acrolein–water mixture was determined with acetylpyridinium chloride reagent.[11]

**Determination of Acrolein.**—The acrolein was determined by the sulfite method.[12]

**Determination of Ester Equivalent.**—The ester equivalent was determined—by C. O. Willits and M. S. Gaspar of this Laboratory—by refluxing partially polymerized allyl ether with 0.2 *N* alcoholic sodium hydroxide, for one hour, continuing the refluxing for another hour after an equal amount of water had been added, and titrating the excess alkali electrometrically with 0.1 *N* acid.

**Determination of Allyl Groups.**—For completely substituted compounds the mercuric acetate modification of the Wijs method[13] gave the most accurate results.

**Acknowledgment.**—The assistance of Mrs. M. F. Durchsprung in making Barcroft–Warburg and allyl group determinations, and of Miss M. J. Welsh in making carbon and hydrogen analyses is acknowledged.

(11) Smith and Bryant. THIS JOURNAL, **57**, 841 (1935); also R. L. Shriner. "Quantitative Analysis of Organic Compounds," 1944, p. 40.

(12) Adams and Adkins, THIS JOURNAL, **47**, 1358 (1925); also, R. L. Shriner, ref. 11, p. 46.

(13) Hoffman and Green, *Oil and Soap*, **16**, 236 (1939); also, Boyd and Roach, *Analytical Chemistry*, **19**, 158 (1947).

## Summary

Completely substituted allyl ethers of erythritol, xylitol, arabitol, dulcitol, talitol and iditol were prepared. With the increase of the chain from three to six carbons, the gelation time decreased, from 974 minutes for allylglycerol to 900 for erythritol, to 602 for pentitols, and 502 for hexitols. On the other hand, the rate of oxygen absorption decreased with the increase of the length of carbon chain. The relation between the configuration and the time of gelation of isomeric allyl ethers is not quite clear. The possibility of the formation of acrylic ester during the oxidative polymerization of allyl ethers is suggested.

PHILADELPHIA 18, PA. RECEIVED FEBRUARY 24, 1948

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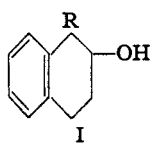
[CONTRIBUTION FROM THE CONVERSE MEMORIAL LABORATORY OF HARVARD UNIVERSITY]

# 1-Alkyl-1,2,3,4-tetrahydro-2-naphthols

BY B. C. MCKUSICK[1a]

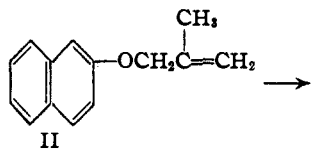
Following the finding that 1,2,3,4-tetrahydro-2-naphthol is an outstanding mosquito-repellent, several of its esters and four of its 1-alkyl homologs (I) were prepared as part of a project sponsored by the Office of Scientific Research and Development (1b) for the synthesis of new insect-repellents. The tetrahydronaphthols were prepared by hydrogenation of the corresponding 1-alkyl-2-naphthols over copper chromite.[2,3,4] The reductions were not perfectly cleancut; decahydro-2-naphthols and probably 5,6,7,8-tetrahydro-2-naphthols were by-products.



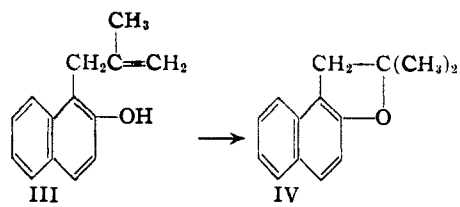

I

The 2-naphthols were synthesized by standard methods, such as reduction of 1-allyl-2-naphthol or 1-acyl-2-naphthols obtained, respectively, by the Claisen or Fries rearrangement. When an attempt was made to hydrogenate 1-*n*-butyro-2-naphthol to 1-*n*-butyl-2-naphthol over copper chromite at 130°, a major reaction was carbon–carbon hydrogenolysis to 2-naphthol and *n*-butanol. In contrast, 1-aceto-2-naphthol is reduced to 1-ethyl-2-naphthol under the same conditions.[2] Clemmensen reduction gave 1-*n*-butyl-2-naphthol in satisfactory yield.

Although allyl-2-naphthyl ether underwent a Claisen rearrangement in the normal manner, the product obtained on heating β-methylallyl-2-naphthyl ether (II) was not the expected 1-(β-methylallyl)-2-naphthol (III), but a neutral substance believed to be the isomeric dihydronaphthofuran (IV). It has been observed previously[5] that 2-(β-methylallyl)-phenols cyclize to dihydrobenzofurans much more readily than do 2-allylphenols.




II




III IV

Esters were prepared from 1,2,3,4-tetrahydro-2-naphthol and its 1-methyl homolog by treating them with acid anhydrides.

(1a) Present address: Chemical Department, Experimental Station, E. I. du Pont de Nemours and Company, Wilmington, Delaware.

(1b) Contract NDCrc-136 with Harvard University, under the direction of Paul D. Bartlett as official investigator.

(2) Musser and Adkins, THIS JOURNAL, **60**, 664 (1938).

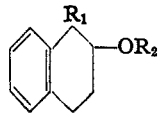
(3) Adkins and Reid, *ibid.*, **63**, 741 (1941).

(4) A paper which includes details on the hydrogenation of 2-naphthol is being prepared by Dauben, McKusick and Mueller.

(5) Bartz, Miller and Adams, THIS JOURNAL, **57**, 371 (1935); Tarbell in Adams, "Organic Reactions," Vol. 2, John Wiley and Sons, Inc, New York, N. Y., 1944, p. 16.

TABLE I

1-ALKYL-1,2,3,4-TETRAHYDRO-2-NAPHTHOLS AND THEIR ESTERS



| $R_1$ | $R_2$ | Boiling point °C. | mm. | $n^{25}D$ | Yield, % | Formula | Analyses, % Carbon Calcd. | Carbon Found | Hydrogen Calcd. | Hydrogen Found |
|---|---|---|---|---|---|---|---|---|---|---|
| H[a] | $CH_3CO$ | 138 | 11 | 1.5269 | 93 | $C_{12}H_{14}O_2$ | ... | .. | ... | .. |
| H[b] | $C_2H_5CO$ | 148 | 12 | 1.5185 | 95 | $C_{13}H_{16}O_2$ | 76.7 | 76.4 | 7.9 | 7.9 |
| H | $n$-$C_3H_7CO$ | 133–134 | 3 | 1.5129 | 93 | $C_{14}H_{18}O_2$ | 77.0 | 77.1 | 8.3 | 8.4 |
| $CH_3$ | H | 105–107 | 0.2 | 1.5570 | 58 | $C_{11}H_{14}O$ | 81.4 | 80.8 | 8.7 | 8.8 |
| $CH_3$ | $CH_3CO$ | 147–150 | 14 | 1.5234 | 85 | $C_{13}H_{16}O_2$ | 76.4 | 76.9 | 7.9 | 8.2 |
| $C_2H_5$ | H | 125–130 | 3 | 1.556[c] | 59 | $C_{12}H_{16}O$ | 81.8 | 81.1 | 9.2 | 9.5 |
| $n$-$C_3H_7$ | H | 102–107 | 0.3 | 1.540 | 89 | $C_{13}H_{18}O$ | 82.1 | 81.7 | 9.5 | 10.0 |
| $n$-$C_4H_9$ | H | 114–119 | 0.3 | 1.534 | 61 | $C_{14}H_{20}O$ | 82.3 | 82.1 | 9.9 | 10.3 |

[a] Bamberger and Lodter, *Ber.*, **23**, 197 (1890). [b] Pickard and Kenyon, *J. Chem. Soc.*, **101**, 1427 (1912), prepared the *l*-ester. [c] Did not crystallize; Musser and Adkins[2] report m. p. 88–89°.

## Experimental

**1-Alkyl-2-naphthols.**—1-Methyl-2-naphthol was obtained in 65% yield by heating 1,1-methylene-bis-(2-naphthol) with sodium methoxide[6]; it was isolated by distillation rather than extraction with hot water. 1-Ethyl-2-naphthol[7] was prepared from 1-aceto-2-naphthol by high-pressure hydrogenation over copper chromite at 130°.[3] 1-*n*-Propyl-2-naphthol,[8] m. p. 55–57° (recrystallized from hexane), was obtained in 91% yield by low-pressure hydrogenation of 1-allyl-2-naphthol[9] in 95% ethanol at 25° in the presence of Adams platinum oxide catalyst. 1-*n*-Butyl-2-naphthol, m. p. 82–83°, was prepared by the Clemmensen reduction of 1-*n*-butyro-2-naphthol.[8]

**1-Alkyl-1,2,3,4-tetrahydro-2-naphthols.**—These were obtained by hydrogenation of the corresponding 2-naphthols in the presence of copper chromite catalyst at 200° under hydrogen pressures of 3000–5000 lb./sq. in.[2,3,4] The hydrogenations were generally complete in two to five hours. They were equally successful with or without a solvent; usually none was used, but an equal volume of absolute ethanol was sometimes added. The weight of catalyst was 5–15% of the weight of naphthol. For the best results it was desirable to distil the naphthols over 2% by weight of Raney nickel before hydrogenation. Alternatively, poisons could be removed from a naphthol by shaking it at 200° with copper chromite and hydrogen under high pressure; one had then but to add a fresh batch of catalyst to the mixture and hydrogenate in the usual way.

To work up a reaction mixture,[4] it was diluted with an equal volume of benzene, the catalyst was removed by filtration, and the filtrate was extracted several times with 10% sodium hydroxide solution (no final washing with water), dried with magnesium sulfate, and distilled through a short Vigreux column.

In the case of 1-methyl-2-naphthol as with 2-naphthol,[4] there was no tendency for the reduction to go beyond the tetrahydro stage. The higher homologs slowly took up hydrogen after the calculated quantity had been absorbed and it was apparent from the fact that the fore-runs had lower indices of refraction than the main cuts that some decahydronaphthol had been formed. Contrary to experience in the preparation of 1,2,3,4-tetrahydro-2-naphthol,[4] the after-runs and residues from the distillations usually contained some unchanged starting material.

Some of the final products may well have contained several per cent. of impurities. In the first place, in contrast to the situation in the preparation of 1,2,3,4-tetrahydro-2-naphthol,[4] it was difficult to extract unchanged starting material or isomeric 5,6,7,8-tetrahydro-2-naphthol with alkali, the difficulty increasing with molecular weight. Secondly, purification by distillation was hindered by the closeness in boiling points of a product and its possible impurities, *i.e.*, the decahydronaphthol (boiling point lower), the naphthol (boiling point higher), and most troublesome of all, the isomeric 5,6,7,8-tetrahydro-2-naphthol (boiling point about the same). The presence of 5,6,7,8-tetrahydro-2-naphthols was not actually demonstrated in the present reductions but their presence is probable from the fact that 6–10% of one is formed during the hydrogenation of 2-naphthol under the same conditions.[4]

The tetrahydronaphthols together with their properties are listed in Table I.

**1,2,3,4-Tetrahydro-2-naphthyl Esters.**—The acetate, propionate and butyrate of 1,2,3,4-tetrahydro-2-naphthol[4] and the acetate of 1-methyl-1,2,3,4-tetrahydro-2-naphthol were prepared by heating the alcohols with a 20% excess of the proper anhydride for several hours on a steam-bath and distilling the reaction mixtures under reduced pressure. The properties of the esters are listed in Table I.

**1,2-Dihydro-2,2-dimethylnaphtho[2,1-b]furan** (IV).—β-Methylallyl chloride (139 g.) was added to a well-stirred mixture of 200 g. of 2-naphthol, 79 g. of 95% sodium methoxide, 3 g. of potassium iodide and 1 liter of methanol in an ice-bath. The mixture stood at room temperature for several days, was diluted with water, and the oil which precipitated was taken up in ether. The extract was washed successively with 10% sodium hydroxide solution and water, dried and distilled. The crude 6-methylallyl 2-naphthyl ether (II), 142 g. of material distilling at 90–137° (0.3 mm.), was heated at 200° under nitrogen for six hours and distilled. The product was collected at 96–99° (0.3 mm.), $n^{25}D$ 1.6024, weight 100 g. (36% yield based on 2-naphthol). It was insoluble in Claisen[10] alkali, did not reduce dilute potassium permanganate in acetone, and only very slowly decolorized bromine in carbon tetrachloride. No hydrogen was absorbed when an alcohol solution was shaken with hydrogen at 25° and a pressure of 3 atm. in the presence of Adams platinum oxide catalyst. *Anal.* Calcd. for $C_{14}H_{14}O$: C, 84.8; H, 7.1; Found: C, 84.4; H, 7.6.

**Hydrogenolysis of 1-*n*-Butyro-2-naphthol.**—A mixture of 35.8 g. of 1-*n*-butyro-2-naphthol[8] and 4 g. of copper chromite catalyst was heated at 130° under an initial hydrogen pressure of 4000 lb./sq. in. Approximately

(6) Cornforth, Cornforth and Robinson, *J. Chem. Soc.*, 682 (1942).

(7) Fries and Engle, *Ann.*, **439**, 232 (1924).

(8) Gulati, Seth and Venkataraman, *J. prakt. Chem.*, **137**, 47 (1933).

(9) Hurd and Schmerling, THIS JOURNAL, **59**, 107 (1937); Adams and Rindfusz, *ibid.*, **41**, 648 (1919); Claisen, *Ber.*, **45**, 3157 (1912).

(10) Claisen, *Ann.*, **418**, 96 (1919).

two molar equivalents of hydrogen was absorbed in twenty minutes, after which no more was absorbed. The reaction mixture was taken up in acetone, filtered and distilled. Redistillation of the fore-run gave 3.4 g. of *n*-butanol (27% yield), identified by odor, boiling point (116.5–117.5°) and refractive index ($n^{25}D$ 1.3970). The amount obtained was less than the actual yield due to accidental loss of part of the fore-run. The main distillate, a solid weighing 24 g., was collected at 117–146° (1.0 mm.). It proved to be a mixture of 2-naphthol and 1-*n*-butyl-2-naphthol, with over half of it by weight the former. Fairly pure samples of each, melting at 120–121° and 77–80°, respectively, were isolated by fractional crystallization from hexane, but complete separation by this means was not practical.


## Summary

Four 1-alkyl-1,2,3,4-tetrahydro-2-naphthols have been prepared by hydrogenation of the corresponding 1-alkyl-2-naphthols over copper chromite.

Instead of undergoing the Claisen rearrangement, β-methylallyl 2-naphthyl ether rearranges to what is believed to be a dihydronaphthofuran. Hydrogenation of 1-*n*-butyro-2-naphthol gives *n*-butanol and 2-naphthol besides the expected 1-*n*-butyl-2-naphthol.


WILMINGTON, DELAWARE RECEIVED FEBRUARY 27, 1948

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[CONTRIBUTION FROM THE COBB CHEMICAL LABORATORY, UNIVERSITY OF VIRGINIA]

# Arylcycloalkylamines. I. 2-Phenylcyclopropylamine

BY ALFRED BURGER AND WILLIAM L. YOST[1]

Both 1-phenyl-2-aminopropane and 1-amino-2-phenylpropane exhibit such striking effects on the central nervous system that structural variations of these drugs have received wide attention. It appeared of interest to investigate what changes in the pharmacological action of these drugs would result from the incorporation in a ring of the two-carbon chain separating the aryl from the amino group. The cyclopropyl ring was chosen as the first example because of the known analgesic and anesthetic properties of cyclopropane, cyclopropyl methyl ether (Cyprome), cyclopropyl ethyl ether (Cypreth), cyclopropylcarbinol, and related compounds.[2] It has been suggested[3] that "alicyclic residues might confer desirable pharmacological properties if introduced into compounds containing auxapharm groups. . . ." The auxapharm group in the compounds under consideration in this article is the phenethyl group.

The synthesis of the geometrically isomeric 2-phenylcyclopropylamines is reported here. The starting material was ethyl 2-phenylcyclopropanecarboxylate which had first been obtained by Buchner and Geronimus[4] from the condensation of styrene with ethyl diazoacetate. These authors heated the reagents in a sealed tube and had to cope with the high pressures of nitrogen from the reaction. These conditions were improved in the present work by slowly dropping a stoichiometric mixture of the diazo ester and styrene into an excess of styrene at 125°. Fractionation of the reaction mixture yielded from 75 to 85% of ethyl 2-phenylcyclopropanecarboxylate as a colorless oil of b. p. 103–105° (0.5–0.7 mm.).

Buchner and Geronimus hydrolyzed their ester to an acid of m. p. 105° to which they assigned the structure of *trans*-2-phenylcyclopropanecarboxylic acid. They arrived at this conclusion by nitrating their acid, reducing the nuclear nitro group, and oxidizing the resulting aminophenylcyclopropanecarboxylic acid with permanganate to *trans*-cyclopropanedicarboxylic acid. When we saponified our ester, a mixture of two isomeric carboxylic acids was always obtained which could be separated by fractional crystallization from water. The less soluble material, which we designate as 2-phenylcyclopropanecarboxylic acid A, crystallized as slender needles, m. p. 93°, and represented 74% of the total mixture.

Benzene extraction of the mother liquors of this acid yielded about 13% of a material melting at 106–107° for which we propose the name of 2-phenylcyclopropanecarboxylic acid B. Its identity with that described by the earlier investigators was corroborated by conversion of its chloride to the amide of m. p. 187–188° [190–191°(cor.)]. The amide reported in the literature[4] melts at 187–188°.

The relation of the two acids was established when it was found that the acid chloride of either product may be hydrolyzed to the A-acid, or ammonolyzed to the same amide of m. p. 190–191°. This indicates that the B-acid is probably inverted by thionyl chloride to the same acid chloride as that obtained from the A-acid, but the less likely possibility must be considered that a B-acid chloride first formed is inverted to derivatives of the A-series by hydrolysis or ammonolysis. These observations coupled with the predominant formation of the A-acid in their preparation from styrene, permit the conclusion that the acid of m. p. 93° is the more stable of a pair of geometrical isomers. It should be noted that the amide described by Buchner and Geronimus is a derivative of the lower-melting isomer they never isolated.

We considered the possibility that the addition of ethyl diazoacetate to styrene might have led to esters containing the ethylenic bond. This is, however, unlikely because the presence of the cy-

(1) Smith, Kline and French Laboratories Fellow.

(2) Adriani, "The Chemistry of Anesthesia," Charles C. Thomas, Publisher, Springfield, Ill., 1946, pp. 130, 174.

(3) Braker, Pribyl and Lott, THIS JOURNAL, 69, 866 (1947).

(4) Buchner and Geronimus, *Ber.*, 36, 3782 (1903).