water gave benzamide, and from the solution containing acetic anhydride the benzonitrile was recovered.

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Conversion of a 1,4-Diol to a Lactone by Raney Nickel[1]

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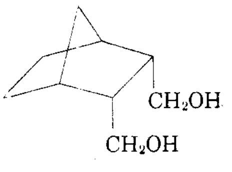
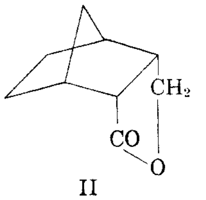
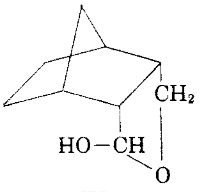
As an incidental observation in another study, we have found that the diol I is converted to the lactone II in excellent yield by a large excess of Raney nickel in boiling benzene. The structure of II is established by its empirical composition, molecular weight (Rast), and properties. Compound II is insoluble in cold alkali, dissolves slowly in hot alkali, and re-precipitates upon acidification. In the infrared spectrum of II, the O—H stretching region is clear, but a single strong absorption in the C=O region occurs at 5.68 μ, whereas I shows strong O—H absorption and no C=O absorption. Compound II is reduced by lithium aluminum hydride to I, and is also found among the neutral products of the controlled oxidation of I with cold potassium permanganate. The latter reaction constitutes an independent synthesis of II.



I



II



III

The dehydrogenation of I to II finds analogies in the nickel-catalyzed conversions of primary and secondary alcohols to aldehydes and ketones,[3] and in the conversion of diols to lactones by copper or copper-chromium oxide.[4] It should be noted that the previous dehydrogenations[3,4] were carried out at high temperatures (usually above 170° and sometimes as high as 300°). The smooth dehydrogenation under much milder conditions in our work may be a consequence of the use of large excesses of nickel, although we made no attempt to establish this point.[4a]

By analogy to the mechanism proposed by Reppe,[4] the formation of II from I would involve formation of a γ-hydroxyaldehyde, of which the cyclic hemiacetal III is a tautomer, and dehydrogenation of the latter.

EXPERIMENTAL[5]

Preparation of 2,3-di-(hydroxymethyl)norbornane (I). The diol has been prepared by Alder and Roth[6] by lithium aluminum hydride reduction of the corresponding dimethyl ester. We have prepared it by lithium aluminum hydride reduction of *endo*-norbornane-2,3-dicarboxylic anhydride. A mixture of 10 g. of lithium aluminum hydride and 250 cc. of anhydrous ether was stirred and heated at reflux. The condensate was passed through a Soxhlet apparatus containing 28.5 g. of the anhydride.[7] When all of the anhydride had dissolved, the mixture was cooled and treated dropwise with 81 cc. of isopropyl alcohol and then with 66 cc. of a saturated sodium chloride solution.[8] The mixture was stirred an additional 30 minutes, the inorganic salts were filtered off, and the filter cake was washed with 2:3 isopropyl alcohol-ether. Evaporation of the filtrate left 21 g. of gummy solid. This material was distilled at 148–150°/1.5 mm. and recrystallized from benzene-hexane to give 9.5 g. of pure I, m.p. 61–62°, reported[6] m.p. 62°.

The *di-p-toluenesulfonate* melted at 128–129°, reported[6] m.p. 131°.

Action of Raney nickel on I. Raney nickel was prepared according to Mozingo.[9] Most of the water was removed by decantation and washing with absolute ethanol. Ethanol and traces of water were removed immediately prior to use by azeotropic distillation with benzene. A mixture of 10 g. of Raney nickel thus prepared, 50 cc. of benzene, and 1.0 g. of diol I was heated at reflux for three hours. The nickel was removed by filtration, the filter cake washed well with benzene, and the filtrate evaporated. Crystallization of the

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[1] This research was supported by the United States Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command under Contract No. AF 18(600)1544.

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[3] *Cf. inter alia* borneol or isoborneol → camphor (a) M. M. Korotaeva and M. P. Kochneva, *J. Chem. Ind.* (*U.S.S.R.*), 52 (1933); *Chem. Abstr.*, **28**, 138 (1934). (b) *Elsevier's Encyclopedia of Organic Chemistry*, edited by E. Josephy and F. Radt, Elsevier Publishing Co., New York, N. Y., 1948, Vol. **12A**, p. 745. See also (c) L. Palfray and S. Sabatay, *Compt. rend.*, **208**, 109 (1939). (d) L. Palfray, S. Sabatay, and A. Halasz, *Compt. rend.*, **208**, 1654 (1939). (e) A. Halasz, *Ann. chim.*, **14**, 318 (1940).

[4] W. Reppe and co-workers, *Ann.*, **596**, 158 (1955).

[4a] A referee has pointed out the possibility that benzene may act as a hydrogen acceptor in this reaction.

[5] Melting points are corrected. The microanalyses are by Dr. Adalbert Elek, Elek Microanalytical Laboratories, 4763 W. Adams Blvd., Los Angeles, Calif.

[6] K. Alder and W. Roth, *Ber.*, **87**, 161 (1954).

[7] O. Diels and K. Alder, *Ann.*, **460**, 98 (1928).

[8] This elegant method of decomposing lithium aluminum hydride reduction mixtures to facilitate isolation of water-soluble products was devised by R. F. Brown and N. M. van Gulick, *J. Am. Chem. Soc.*, **77**, 1079 (1955).

[9] R. Mozingo, *J. Am. Chem. Soc.*, **65**, 1013 (1943).

residue from hexane gave 0.83 g. of a white solid, melting at 142–144°. The substance was purified for analysis by dissolution in warm 5% sodium hydroxide, re-precipitation with acid, and finally recrystallization from hexane. The pure lactone (II) had m.p. 145–146° (shrinking at 135–140°).

Anal. Calc'd for $C_9H_{12}O_2$: C, 71.04; H, 7.95; Molecular weight, 152. Found: C, 71.02; H, 7.95; Molecular weight (in camphor), 147.

II was insoluble in bicarbonate or cold sodium hydroxide. It gave negative tests with 2,4-dinitrophenylhydrazine and potassium permanganate.

Reduction of II *to* I. A solution of 0.570 g. of II in 25 cc. of absolute ether was added to a slurry of 0.30 g. of lithium aluminum hydride in 50 cc. of ether with vigorous stirring. The mixture was heated at reflux for 3 hours and worked up with isopropyl alcohol (3.3 cc.) and saturated sodium chloride (3.3 cc.) as above. Evaporation of the solvents and recrystallization of the residue from benzene-hexane gave 0.450 g. of I, m.p. 59–61°, alone or mixed with an authentic sample.

Permanganate oxidation of I. A mixture of 1.0 g. of I, 2 cc. of 10% sodium hydroxide, and 100 g. of ice was stirred and treated with 135 cc. of 1% potassium permanganate. The mixture was allowed to stand overnight, the manganese dioxide was removed by filtration, and the filtrate was acidified with hydrochloric acid and extracted with chloroform. The extract was dried over magnesium sulfate, filtered, evaporated, the residue leached with 3 cc. of hot 5% sodium hydroxide and the insoluble gummy residue filtered off. The filtrate was acidified and the precipitated solid was washed with 5% sodium bicarbonate and then with water to give 0.11 g. of white solid, m.p. 139–141°. Since the m.p. of pure II is rather indefinite (*vide supra*), identity was established by comparison of the infrared spectra of chloroform solutions of II and the oxidation product. These were superimposable.

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Quinoxaline Studies. IX. The Preparation of 3-Methyl-6- and -7-bromo-2-quinoxalinols[1]

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Dawson, Newbold, and Spring[2] condensed 3,4-diaminochlorobenzene with pyruvic acid; this equivocal synthesis gave a mixture of 3-methyl-6- and -7-chloro-2-quinoxalinols, from which 3-methyl-7-chloro-2-quinoxalinol was isolated and identified. The authors of this paper wish to report the syntheses by unequivocal methods of both 3-methyl-6- and -7-bromo-2-quinoxalinols. Syntheses of the bromoquinoxalinols were studied because these compounds would be expected to lend themselves more readily to subsequent transformations involving the halo group than would the corresponding chloroquinoxalinols.

Reaction of 2-nitro-4-bromoaniline with *dl*-α-bromopropionic acid gave less than 1% yield of the desired N-(2-nitro-4-bromophenyl)-*dl*-α-alanine. A second, more fruitful, method of preparing N-(2-nitro-4-bromophenyl)-*dl*-α-alanine was found to be the condensation of *dl*-α-alanine with 2,5-dibromonitrobenzene. Experimental results confirmed the expectation that the *ortho* halogen of the aromatic compound would react in this instance.

The reductive cyclization of N-(2-nitro-4-bromophenyl)-*dl*-α-alanine was carried out chemically with alcoholic hydrochloric acid and iron by the method of West,[3] with a suspension of ferrous hydroxide in ammonium hydroxide according to the procedure of Singer and Shive,[4] and, in best yield, catalytically over a Raney nickel catalyst at low hydrogen pressure. The probable intermediate, 3-methyl-3,4-dihydro-7-bromo-2-quinoxalinol, was not isolated, but was oxidized directly with basic hydrogen peroxide solution to the desired product, 3-methyl-7-bromo-2-quinoxalinol. Reductive cyclizations (followed by oxidation) over palladium and platinum catalysts resulted in hydrogenolysis of the bromo group, for only 3-methyl-2-quinoxalinol was obtained when these noble metal hydrogenation catalysts were used.

Condensation of 2,4-dibromonitrobenzene with *dl*-α-alanine gave the desired N-(2-nitro-5-bromophenyl)-*dl*-α-alanine. Ogata and Tsuchida[5] recently observed that in nucleophilic attack on *o,p*-dihalonitrobenzenes, the *ortho* halogen preferentially reacts with uncharged nucleophilic reagents such as ammonia and amines. This synthesis further confirms their observations.

The reductive cyclization of N-(2-nitro-5-bromophenyl)-*dl*-α-alanine (followed by oxidation) was successfully executed by both chemical and catalytic means to give 3-methyl-6-bromo-2-quinoxalinol.

EXPERIMENTAL PROCEDURES

N-(2-Nitro-4-bromophenyl)-dl-α-alanine. A mixture of 84.3 g. of 2,5-dibromonitrobenzene,[6] 26.7 g. of *dl*-α-alanine, 50.4 g. of sodium bicarbonate, 50 ml. of 95% ethanol, and 10 ml. of water was refluxed for 42 hours. The reaction mixture was evaporated to dryness on a steam-bath and was triturated with five 15-ml. portions of 10% sodium hydroxide solution, followed by one 25-ml. portion of water. After the triturate was filtered, it was brought to *p*H 4 with 20% hydrochloric acid to give 31.4 g. of a tan precipitate m.p. 145–155°. This material was recrystallized from benzene (24 ml./g.) 8 times, using charcoal and filter aid, to give 11.2 g. (13%) of yellow platelets m.p. 162–164°.

Anal. Calc'd for $C_9H_9BrN_2O_4$ (289.1): Br, 27.65; N, 9.69. Found: Br, 27.47; N, 9.61.

The neutral residue from the condensation gave 35.2 g. (41.8%) of 2,5-dibromonitrobenzene m.p. 81–85°; reported[6] for 2,5-dibromonitrobenzene m.p. 82–82.5°.

3-Methyl-7-bromo-2-quinoxalinol. In a Parr pressure flask

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(1) Abstracted in part from the M.S. thesis of R. V. D., University of Miami, 1955.

(2) Dawson, Newbold, and Spring, *J. Chem. Soc.*, 2579 (1949).

(3) West, *J. Chem. Soc.*, **127**, 494 (1925).

(4) Singer and Shive, *J. Org. Chem.*, **20**, 1458 (1955).

(5) Ogata and Tsuchida, *J. Org. Chem.*, **20**, 1631 (1955).

(6) Hammond and Modic, *J. Am. Chem. Soc.*, **75**, 1385 (1953).