In eleven other experiments the yield of 1,2,3,4,6,7,8,9-octahydrophenazine varied from 39–53%, average yield, 48%. In small scale experiments the product was best isolated by extraction with ether. Evaporation of the ether caused the product to crystallize in large, colorless needles.

(d) One-sixth of the solution was treated as in (c) except that no hydrogen peroxide was added and the mixture was allowed to stand for one week. On first adding the potassium hydroxide a copious precipitate formed which slowly dissolved or reformed to a more compact precipitate, which was slowly oxidized by air to 1,2,3,4,6,7,8,9-octahydrophenazine, yield 2.2 g. (38%).

Reaction of N,N-Dichloro-β-phenylethylamine with Sodium Methoxide.—N,N-Dichloro-β-phenylethylamine was prepared in 95% crude yield by the procedure described above for N,N-dichloro-α-phenylethylamine. The crude product was treated with sodium methoxide and the product was worked up as described for N,N-dichloro-α-phenylethylamine. Evaporation of the acidic aqueous solution produced only sodium and ammonium chlorides. Distillation of the ethereal solution yielded (from 0.1 mole of the amine) 4.7 g. (40%) of phenylacetonitrile, b.p. 121–125° (15 mm.), identified by hydrolysis in aqueous acetic–hydrochloric acid solution (in poor yield) to phenylacetic acid.

LINCOLN 8, NEBRASKA

The Demyanov Ring Expansion. II. Comparison of the Expansion of Five- and Six-Membered Rings[1]

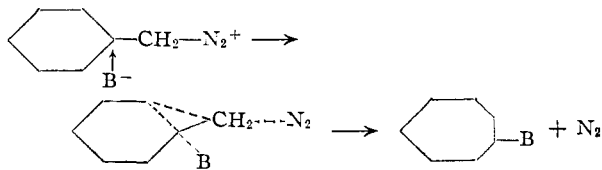BY PETER A. S. SMITH, DONALD R. BAER AND SEYHAN N. EGE

The Demyanov rearrangement has been attempted with cyclopentylcarbinylamine, 1-(1-phenylcyclopentyl)-ethylamine, cyclopentylphenylcarbinylamine, 1-cyclopentyl, 1-cyclohexyl- and 1-(4-methylcyclohexyl)-ethylamine. The composition of the alcohols produced was examined by infrared spectroscopy. Ring expansion was complete in only one case, and only occurred to a detectable extent when such expansion could be expressed as the conversion of a less stable to a more stable carbonium ion. Isomeric tertiary alcohols were formed in most cases in small to moderate amounts. n-Butylamine gave n-butyl chloride when treated with nitrosyl chloride. A number of alicyclic alcohols were characterized as their p-phenylazophenylurethans, but initial attempts to separate alcohol mixtures by chromatography of this derivative were unsatisfactory. A number of new alkylcyclopentylcarbinylamines has been prepared and characterized.

The Demyanov ring expansion is accomplished usually by treating an aminomethylcycloalkane with nitrous acid, and results in the formation of a cyclic alcohol containing one more carbon atom in the ring, usually accompanied by some olefin.[2] It has in practice been limited to compounds in which the amino group is separated from the alicyclic ring by an unsubstituted methylene group, although no extensive investigations of its limitations in this direction have been made. Occasional hypotheses regarding the mechanism of the reaction have been published[3]; it would seem to be best regarded as a special case of the type of rearrangement generally accompanying the treatment of primary aliphatic amines with nitrous acid. Perhaps the most widely accepted view of the nature of such rearrangements is that they involve the formation of a more stable carbonium ion from one of higher energy.[3a,c] The stability of carbonium ions is empirically correlatable with the number and nature of the substituents on the electron-deficient carbon, and such effects have been the subject of theoretical interpretation.[3a,4]

Three principal questions are apparent concerning the Demyanov ring-expansion. One is an explanation for the predominance of alkyl migration, leading to an apparent secondary carbonium ion by ring expansion, over hydrogen migration, leading to

a presumably more stable tertiary carbonium ion without ring expansion. The analogous open-chain situation, the formation from isobutylamine of sec-butyl alcohol by methyl migration vs. the formation of t-butyl alcohol by hydrogen migration, appears to result in complete predominance of hydrogen migration.[5] Another question is the extent to which the nature of the anion (chloride, hydroxide, acetate, etc.) to which the alkyl group is found attached in the final products has influenced the rearrangement. The third question is the relative importance of stereochemical and electrical effects in determining the direction of expansion of unsymmetrical rings.

In connection with these questions, our present work is influenced by the consideration that the loss of nitrogen from an aliphatic diazonium ion may not be a purely unimolecular process leading to the corresponding carbonium ion. It may well occur by two competitive processes: a displacement reaction by a nucleophilic agent, leading to an alkyl derivative of unrearranged structure; and an internal displacement by the migrating species (hydrogen or alkyl), leading to a carbonium ion of rearranged structure.[6] Furthermore, the latter process may be combined with the former in a con-

(1) Partly from the doctoral dissertation of D. R. Baer, 1952. Presented at the National Meeting, Am. Chem. Soc., Atlantic City, N. J., Sept., 1952.

(2) T. W. J. Taylor and W. Baker, "Sidgwick's Organic Chemistry of Nitrogen," Oxford University Press, London, 1952, p. 23, et seq.

(3) E.g., (a) E. R. Alexander, "Principles of Ionic Organic Reactions," John Wiley and Sons, Inc., New York, N. Y., 1950, pp. 41, 49–50; (b) G. Darzens and M. Meyer, Compt. rend., 233, 749 (1951); (c) I. Elphimoff-Felkin and B. Tchoubar, ibid., 237, 726 (1953).

(4) I. Dostrovsky, E. D. Hughes and C. K. Ingold, J. Chem. Soc., 173 (1946).

(5) L. Henry and A. deWael, Compt. rend., 145, 899 (1907); E. Linnemann, Ann., 162, 24 (1872).

(6) Cf. J. D. Roberts and J. A. Yancey, THIS JOURNAL, 74, 5943 (1952); J. D. Roberts and C. M. Regan, ibid., 75, 2069 (1953); J. D. Roberts and M. Halmann, ibid., 75, 5759 (1953).

certed operation, in which a nucleophilic agent attacks the carbon atom from which the hydrogen or alkyl group is migrating.

There are reported in this paper the results of the Demyanov reaction on a group of amines so chosen as to distinguish the influence of ring strain from certain of the effects common to both cyclic and non-cyclic systems. In addition to the structural effects to be expected in open chain systems, there is in the Demyanov rearrangement the possibility of the relief of ring strain as a component of the driving force. The behavior of cyclohexylcarbinylamine already has been reported[7]; ring expansion is incomplete, and under the customary conditions (aqueous acetic acid solution), large amounts of acetate esters are formed. To avoid the latter complication, the reactions described in the present work were mostly run in sodium dihydrogen phosphate solution. The alcohols produced were separated from accompanying olefins by distillation, and were then examined by infrared spectroscopy without a solvent. The analysis of the curves so obtained was accomplished by comparison with those of the several isomeric alcohols which might conceivably be derived from the amine used. In the case of α-(1-phenylcyclopentyl)-ethylamine, the alcoholic product was deduced to be a mixture of stereoisomeric 1-phenyl-2-methylcyclopentanols from the absence of the characteristic absorption bands of either the alcohol of unrearranged structure or of the tertiary alcohol (phenyl migration). A synthetic sample of 1-phenyl-2-methylcyclopentanol of uncertain stereochemical composition gave an infrared spectrum qualitatively similar to but quantitatively partly different from the Demyanov product. All attempts to prepare derivatives of either sample cause dehydration. The analytical results are collected in Table I; the synthesis of the amines and the reference alcohols is described in the Experimental section.
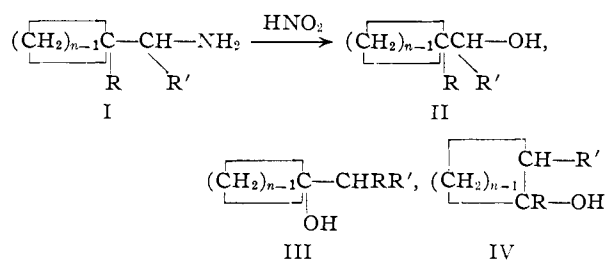

TABLE I

COMPOSITION OF THE ALCOHOLS PRODUCED IN DEMYANOV
EXPANSION OF FIVE- AND SIX-MEMBERED RINGS

n	Amine I R	R'	Unrearranged alcohol II, %	Tertiary alcohol III, %	Expanded alcohol IV, %
5	H	H	5	19	76
6	H	H[7]	32	5	63
5	H	CH₃	41	28	31 (trans)
6	H	CH₃	58	42	0
5	H	C₆H₅	100	0	0
5	C₆H₅	CH₃	0	0	ca. 100 (cis and trans)

(7) P. A. S. Smith and D. R. Baer, THIS JOURNAL, 74, 6135 (1952) (paper I of this series).

These results can be summarized in the observation that ring-expansion occurred when: a primary alkyl group was converted to a secondary or tertiary one; strain was relieved in a five-membered ring, or a benzyl alcohol was produced from a β-phenylethylamine. Where none of these circumstances held, noticeable ring-expansion did not occur. This corresponds exactly to the concept that the essential change is the transition to a more stable carbonium ion, if the added influence of ring-strain is taken into account. In terms of this view it becomes understandable why the Demyanov rearrangement is not the most satisfactory synthetic method for expanding six-membered and larger rings.[8] Furthermore, the "reversed Demyanov reaction" a ring-contraction resulting from the treatment with nitrous acid of 2-phenylcyclohexylamine,[9] but not from 4-phenyl- or 2-alkylcyclohexyl amines,[10] is but another example of the same principle in operation. It was thus to be expected that α-cyclopentylbenzylamine should not rearrange, even though α-cyclopentylethylamine does so appreciably.
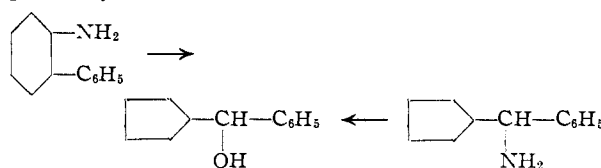
In aminomethylcycloalkanes, a shift of the 1-hydrogen (I, R = H) would give rise to a tertiary alcohol III, and would thus appear to bring about a greater stabilization than ring-expansion which would give rise to a secondary alcohol, except that ring-strain is not relieved by the hydride shift. In the experimental results it can be seen that such a hydride shift occurs, to varying extents, but is never the major event, although it is more important when it is not competing with either relief of ring strain or with the conversion of a primary to a secondary alkyl group accompanying ring expansion.

The formation of tertiary alcohols in the Demyanov rearrangement by hydride shift now appears to be more general than has hitherto been thought. It had been reported previously in only a single instance, from 3,3,5-trimethylcyclohexanemethylamine,[11] and its general absence has been cause for comment.[12] It may, however, be somewhat more extensive than the present results indicate. From α-cyclopentylethylamine the only tertiary alcohol definitely detected was 1-ethylcyclopentanol; however, 1-methylcyclohexanol might have been expected in at least small amounts. Moreover, cis-2-methylcyclohexylamine, from which is derived the same carbonium ion as would arise from 1-cyclopentylethylamine by ring-expansion, has been reported to yield in addition to large amounts of trans-2-methylcyclohexanol an "unidentified" alco-

(8) E.g., L. Ruzicka and W. Brugger, Helv. Chim. Acta, 9, 399 (1926), and ref. 7.

(9) D. Nightingale and M. Maienthal, THIS JOURNAL, 72, 4823 (1950).

(10) J. D. Kerr, Univ. of Missouri Thesis, Microfilm Abstracts, II, 1951, p. 833.

(11) H. Barbier, Helv. Chim. Acta, 23, 519 (1940).

(12) G. Wheland, "Advanced Organic Chemistry," John Wiley and Sons, Inc., New York, N. Y., 1949, p. 514, and reference 3a, pp. 49–51.

hol with phenylurethan m.p. 103°.[13] Its properties correspond suggestively with those of 1-methylcyclohexanol, phenylurethan m.p. 105°.[14] The small amounts of this alcohol to be expected in our product could not be detected with certainty in the infrared spectrum.

It should be pointed out that, although the yields of alcohols from the amines were usually high, significant amounts of olefins accompanied them in most cases. These were presumably mixtures, in proportions not necessarily the same as those of the skeletally related alcohols, but no attempt was made to determine their composition. It is conceivable that the olefins are formed to an enhanced extent from the carbonium ions which would otherwise form tertiary alcohols. The quantitative significance of the composition of the alcohol mixtures is thereby limited. Nevertheless, although formation of tertiary alcohols now appears to be established as fairly general, the extent to which it occurs is often very small compared to expectations based only on the relative stability of carbonium ions.

Ring expansion by the Demyanov method is paralleled by the behavior of some of the corresponding alcohols under so-called carbonium ion forming conditions. Cyclopentylcarbinol gives cyclohexyl iodide together with some unrearranged iodide,[15] and when treated with benzene and aluminum chloride gives cyclohexylbenzene.[16] Cyclohexylcarbinol expands incompletely when dehydrated to give cycloheptene and methylenecyclohexane.[17] Phenylcyclohexylcarbinol, however, gives only unrearranged benzylidenecyclohexane.[18] It is noteworthy that in none of these reactions is a product reported which results from hydrogen migration.

In our earlier report on the Demyanov synthesis of cycloheptanol a disagreement was noted between the spectrographically determined composition of the alcoholic product and the composition determined by selective esterification with phthalic anhydride.[7] A possible explanation was pointed out in that the esterification had been carried out on a product which must have been considerably contaminated with acetate esters; however, an alternative explanation is available if it is considered that the usual differentiation made by phthalic anhydride between primary and secondary alcohols may be inoperative in the case of cyclohexylcarbinol and cycloheptanol. We have now resolved the question by successfully separating these alcohols as their crystalline hydrogen phthalates by stepwise phthaloylation, with results consistent with the analysis of these mixtures by infrared spectrophotometry.

1-(4-Methylcyclohexyl)-ethylamine, reported by

Wallach[19] to give only unrearranged alcohol, was reinvestigated and the earlier results confirmed. Infrared spectroscopy was not conveniently applicable to the investigation of this system, due to the complexity arising from the many possible stereoisomers. However, oxidation to ketones followed by Schmidt reaction would give N-4-methylcyclohexylacetamide from the unrearranged alcohol, and the lactam of 4-methyl-7-aminoöctanoic acid from the ring-expanded alcohol; tertiary alcohols would be destroyed by this scheme. Hydrolysis of the product so obtained gave only 4-methylcyclohexylamine and no isolable amino acid, indicating absence of significant ring expansion.

As a preliminary to an attempt to use nitrosyl chloride in a Demyanov reaction, with the expectation of obtaining cycloalkyl chlorides instead of alcohols, an experiment was run with n-butylamine and nitrosyl chloride. The yield of purified alkyl chloride was not high, owing in part to the formation of nitrogenous products. It did appear, however, that n-butyl chloride essentially free from sec-butyl chloride was produced, which is in contrast to the considerable amount of isomerization which occurs when aqueous nitrous acid is used.[20] An experiment with cyclohexylcarbinylamine gave such a mixture of products that no pure alkyl chloride could be isolated. This quite limited evidence suggests that the nature of the nucleophilic agent involved may have an appreciable influence on the extent of rearrangement.[21]

As a means of analyzing the mixtures of alcohols anticipated in this work, chromatography of the p-phenylazophenylurethans of the alcohols was explored. Although some alcohol mixtures have been successfully separated by this means,[22] our preliminary attempts, which were not satisfactory, were discontinued when the spectrographic method was adopted.

Experimental

Melting points are corrected, and analyses are by Mr. Goji Kodama of this Department unless otherwise indicated.

α-Cyclopentylethylamine.—A mixture of 56 g. (0.5 mole) of cyclopentyl methyl ketone, 155 g. (2.5 moles) of ammonium formate and 46 g. (1.0 mole) of formic acid was heated slowly under distilling conditions. When the temperature reached 148°, the ketone which had distilled was separated and returned to the reaction, which was allowed to reach a temperature of 174° and was then refluxed for 13 hours. The cooled mixture was next refluxed with 150 ml. of 1:1 hydrochloric acid, for three hours, after which unreacted ketone was removed by steam distillation. Further steam distillation after addition of excess alkali removed the amine, which was extracted from the distillate with ether, dried over sodium hydroxide pellets, and distilled: b.p. 149° (750 mm.), n^{25}D 1.4491, d^{25}_{25} 0.8487; mol. refraction calcd. 35.88, found 35.78.

Anal. Calcd. for $C_7H_{15}N$: C, 74.27; H, 13.45. Found: C, 74.30; H, 13.47.

The benzoyl derivative formed needles from aqueous ethanol, m.p. 102–102.5°. *Anal.* Calcd. for $C_{14}H_{19}ON$: C, 77.41; H, 8.78. Found: C, 77.73; H, 8.65.

(13) P. Anziani and R. Cornubert, *Bull. soc. chim.*, 857 (1948).

(14) (a) V. Grignard and G. Vignon, *Compt. rend.*, **144**, 1358 (1907); (b) P. Sabatier and A. Mailhe, *Ann. chim. phys.*, [8] **10**, 527 (1907).

(15) N. D. Zelinsky, S. E. Micklina and M. S. Eventowa, *Ber.*, **66**, 1422 (1933).

(16) Ng. Ph. Buu-Hoï, P. Cagniant and L. Palfrey, *Bull. soc. chim.*, **12**, 975 (1945).

(17) N. A. Rozanov, *J. Russ. Phys. Chem. Soc.*, **48**, 309 (1916); *C. A.*, **11**, 583 (1917).

(18) C. Prevost, P. Donzelot and E. Balla, *Compt. rend.*, **198**, 101 (1934).

(19) O. Wallach and F. Pohle, *Nachr. kgl. Ges. Wiss. Göttingen*, **161**, 1 (1915).

(20) F. C. Whitmore and D. P. Langlois, THIS JOURNAL, **54**, 3441 (1932).

(21) However, *cf.* H. Felkin, *Compt. rend.*, **236**, 298 (1953).

(22) (a) S. Masuyama, *J. Chem. Soc. Japan, Pure Chem. Soc.*, **71**, 47 (1950)(*C. A.*, **45**, 6994 (1951)); (b) *ibid.*, **70**, 232 (1949)(*C. A.*, **45**, 5606 (1951)); (c) J. B. Davenport and M. D. Sutherland, Univ. of Queensland Papers, Dept. of Chem., **1**, No. 39 (1950).

The picrate formed yellow needles from hot water, m.p. 165.5–166.8°. *Anal.* Calcd. for $C_{13}H_{18}O_7N_4$: C, 45.64; H, 5.30. Found: C, 46.00; H, 5.27.

α-Cyclopentylethanol was prepared in 63% yield by reduction of cyclopentyl methyl ketone with sodium and moist ether, as described for 2-methylcyclopentanol; b.p. 161° (747 mm.).[23]

1-Ethylcyclopentanol was prepared from ethylmagnesium bromide and cyclopentanone; b.p. 152–154° (750 mm.) (reported[24] 154.5–155.2° (760 mm.)).

trans-2-Methylcyclohexanol was obtained by the fractional crystallization of the acid phthalate of commercial 2-methylcyclohexanol according to Hückel and Hagenguth.[25] Hydrolysis of 13.7 g. of the ester, m.p. 125–126°, with 20% sodium hydroxide gave 5.0 g. (90%) of the alcohol, b.p. 164–166° (748 mm.); a redistilled spectrographic sample had b.p. 165° (748 mm.).

α-Cyclohexylethylamine was prepared from cyclohexyl methyl ketone[26] by the method of Blicke and Zienty[27]; b.p. 174–176° (750 mm.).

1-Ethylcyclohexanol was prepared from ethylmagnesium bromide and cyclohexanone in 74% yield; b.p. 77–80° (20 mm.) (reported 76° (20 mm.)[14b].

α-Cyclohexylethanol was prepared in 54% yield by the reduction of cyclohexyl methyl ketone with lithium aluminum hydride; b.p. 91–92° (23 mm.) (reported[28] 82–83° (12 mm.)).

α-(4-Methylcyclohexyl)-ethylamine was prepared in 44% yield by the Leuckart reaction on 4-methylcyclohexyl methyl ketone with ammonium formate and formic acid; b.p. 188–192° (752 mm.). A non-basic liquid, b.p. 172–174° (752 mm.), also was obtained in 10% yield; it gave a phenylurethan of m.p. 123–125°, and is presumably *trans*-4-methylcyclohexanol, b.p. 173–174.5° (745 mm.), phenylurethan m.p. 124–125°,[29] and may have been an impurity in the starting ketone.

Cyclopentyl phenyl ketone was prepared in 51% yield from cyclopentylmagnesium bromide and benzonitrile; b.p. 145–146° (15 mm.) (reported[9] 103–105° (5 mm.)). The oxime formed colorless needles from aqueous ethanol, m.p. 119.5–120°.

Anal. Calcd. for $C_{12}H_{15}NO$: C, 76.16; H, 7.99. Found: C, 76.42; H. 7.95.

α-Cyclopentylbenzylamine.—Cyclopentyl phenyl ketone (59.3 g.) was converted to 38 g. (65%) of amine by the Leuckart reaction with formic acid and formamide[30]; b.p. 146° (21 mm.), n^{25}D 1.5455, d^{25}_{25} 0.9915.

Anal. Calcd. for $C_{12}H_{17}N$: C, 82.22; H, 9.77; N, 8.00. Found: C, 82.16; H, 9.65; N, 7.90.

The acetyl derivative formed colorless needles from ethanol, m.p. 109–111°. *Anal.* Calcd. for $C_{14}H_{19}ON$: C, 77.38; H, 8.81. Found: C, 77.65; H, 8.87.

The benzoyl derivative formed colorless needles from aqueous ethanol, m.p. 166–167°.

Anal. Calcd. for $C_{19}H_{21}ON$: C, 81.67; H, 7.58. Found: C, 82.11; H, 7.32.

The hydrochloride precipitated as white flocks from ether, m.p. 280°. *Anal.* Calcd. for $C_{12}H_{18}NCl$: C, 68.08; H, 8.57. Found: C, 68.20; H, 8.54.

1-Phenylcyclopentyl Methyl Ketone.—To a solution of methylmagnesium iodide prepared from 64 g. of methyl iodide and 10.9 g. of magnesium in 300 ml. of ether was added 25.7 g. of 1-phenylcyclopentyl cyanide[31] in an equal volume of ether. After 18 hours of refluxing, the mixture was poured into ice and hydrochloric acid, and the aqueous layer was separated and boiled to hydrolyze the ketimine.

The oil which separated was taken up in benzene, dried, and distilled; b.p. 142–148° (18 mm.), wt. 16.1 g. (57%). Redistillation at 110° (3 mm.) gave a pale yellow product, n^{25}D 1.5398.

Anal. Calcd. for $C_{13}H_{16}O$: C, 82.92; H, 8.56. Found: C, 82.62; H, 8.60.

The dinitrophenylhydrazone formed orange needles from ethanol, m.p. 145.6–146.2°. *Anal.* Calcd. for $C_{19}H_{20}O_4N_4$: C, 61.94; H, 5.47. Found: C, 61.83; H, 5.88.

The semicarbazone formed colorless rods from 50% ethanol, m.p. 228.5–231° dec. *Anal.* Calcd. for $C_{14}H_{19}ON_3$: C, 68.54; H, 7.81. Found: C, 68.52; H, 7.82.

α-(1-Phenylcyclopentyl)-ethylamine.—A mixture of 21.5 g. of 1-phenylcyclopentyl methyl ketone and 27 g. of formamide was refluxed for 15 hours. After cooling, the black mass was shaken with 50 ml. of water, which was decanted. The residue was then refluxed for 1.5 hours with 150 ml. of concd. hydrochloric acid, and steam distilled to remove unreacted ketone. The amine was set free with alkali and the steam distillation continued, yielding a heavy, yellow oil in about 2 l. of distillate. The oil was taken up in benzene and distilled; b.p. 103–107° (2.2 mm.), wt. 14.3 g. (66%). A sample redistilled for analysis had b.p. 103° (2.2 mm.), n^{25}D 1.5407, d^{25}_{25} 1.0008.

Anal. Calcd. for $C_{13}H_{18}N$: C, 82.47; H, 10.12; N, 7.39. Found: C, 82.25; H, 9.94; N, 7.30.

The hydrochloride was precipitated from ether with hydrogen chloride; m.p. 200°. *Anal.* Calcd. for $C_{13}H_{20}NCl$: C, 69.15; H, 8.91. Found: C, 69.12; H, 8.77.

The benzoyl derivative formed needles from aqueous ethanol; m.p. 101°. *Anal.* Calcd. for $C_{20}H_{23}ON$: C, 81.87; H, 7.89. Found: C, 81.78; H, 8.02.

(1-Phenylcyclopentyl)-methylcarbinol.—1-Phenylcyclopentyl methyl ketone (10.9 g.) was reduced in ether solution with 0.76 g. of lithium aluminum hydride. There was obtained 10.6 g. (99%) of white solid, m.p. 54–56° by crystallization of the hydrolyzed reaction product from aqueous methanol. When dried in vacuum over phosphorus pentoxide, the solid liquefied; it was then distilled at 110° (2 mm.) for analysis.

Anal. Calcd. for $C_{13}H_{18}O$: C, 82.06; H, 9.54. Found: C, 81.96; H, 9.32.

The undried solid appeared to be hemihydrate, and was regenerated when the dried liquid was exposed to moist air.

Anal. Calcd. for $C_{13}H_{18}O \cdot 1/2H_2O$: C, 78.34; H, 10.12. Found: C, 78.45; H, 9.73.

The 3,5-dinitrobenzoate, prepared in 65% yield from the hemihydrate, formed jagged needles from ethanol, m.p. 128.5–129.5°. *Anal.* Calcd. for $C_{20}H_{20}O_6N_2$: C, 62.49; H, 5.24. Found: C, 62.57; H, 5.33.

α-Cyclopentyl-α-methylbenzyl Alcohol.—An initial attempt to prepare this alcohol from cyclopentylmagnesium bromide and acetophenone resulted almost entirely in reduction of the ketone to α-phenylethyl alcohol.[32]

Phenyl cyclopentyl ketone (16.7 g.) in 50 ml. of ether was added dropwise to ethereal methylmagnesium iodide prepared from 21.3 g. of methyl iodide and 3.4 g. of magnesium in 200 ml. of ether. After 12 hours the mixture was poured on ice and neutralized with ammonium chloride. The ethereal layer was washed with sodium carbonate, then with water, and dried over magnesium sulfate. Distillation gave 14.3 g. (75%), b.p. 116–118° (3 mm.). Redistillation for analysis gave b.p. 91–92° (0.6 mm.).

A sample of this alcohol (8.66 g.) was dehydrated by refluxing for 10 minutes with 100 ml. of 85% orthophosphoric acid. The neutralized and washed organic layer was dried and distilled, b.p. 116–118° (12 mm.), wt. 6.70 g. (86%). It is presumed to be essentially α-cyclopentylidene-ethylbenzene.

Anal. Calcd. for $C_{13}H_{16}$: C, 90.61; H, 9.39. Found: C, 90.16; H, 9.29.

1-Phenyl-2-methylcyclohexanol was kindly supplied by Dr. R. B. Carlin.[33] It was spectrographically similar, although not quite identical, with a sample which we prepared from 2-methylcyclohexanone and phenylmagnesium bromide; the small differences in stereochemical composition are presumed to be responsible for the slight discrepan-

(23) M. Godchot and P. Bedos, *Bull. soc. chim.*, [4] 37, 1455 (1925), as corrected by P. D. Bartlett and C. M. Berry, THIS JOURNAL, 56, 2683 (1934).

(24) G. Chavanne and P. Becker, *Bull. soc. chim. Belg.*, 36, 591 (1927).

(25) W. Hückel and K. Hagenguth, *Ber.*, 64, 2892 (1931).

(26) M. S. Newman and W. T. Booth, THIS JOURNAL, 67, 154 (1945).

(27) F. F. Blicke and F. B. Zienty, *ibid.*, 61, 193 (1939).

(28) G. Domleo and J. Kenyon, *J. Chem. Soc.*, 1842 (1926).

(29) A. Skita and W. Faust, *Ber.*, 64, 2878 (1931).

(30) M. L. Moore in R. Adams, "Organic Reactions," Vol. V, John Wiley and Sons, Inc., New York, N. Y., 1949, p. 320.

(31) C. H. Tifford, M. G. Van Campen and R. S. Shelton, THIS JOURNAL, 69, 2902 (1947).

(32) Cyclopentyl Grignard reagents reduce exceptionally readily; M. S. Kharasch and S. Weinhouse, *J. Org. Chem.*, 1, 209 (1936).

(33) R. B. Carlin and H. P. Landerl, THIS JOURNAL, 75, 3969 (1953).

TABLE II

PRODUCTS FROM ATTEMPTED DEMYANOV REARRANGEMENTS

Amine	Olefin, %	B.p., °C.	Mm.	Alcohols, %	B.p., °C.	Mm.	Recovered amines, %
α-Cyclopentylethylamine	9	80–150	740	55[a]	158–165	740	11
α-Cyclohexylethylamine	3	34	30	40	82–93	26	15
α-(4-Methylcyclohexyl)-ethylamine	25	58–62	34	39	101–109	30	9
Cyclopentanemethylamine				40	65–70	11	
α-Cyclopentylbenzylamine				70	151–156	19	<1
α-(1-Phenylcyclopentyl)-ethylamine				73	90–105	1	..

[a] As prepared by method A, before saponification of acetate esters.

cies. All attempts to prepare a 3,5-dinitrobenzoate in pyridine solution failed.

Ethyl Hydratropate and 1-(α-Phenylethyl)-cyclopentanol.—Hydratropaldehyde was converted in one step into ethyl hydratropate by a combination of the Schmidt reaction[34] with alcoholysis of the resulting nitrile.

A solution of hydrogen chloride in 400 ml. of 95% ethanol saturated at 0–5° was mixed with 94.3 g. (0.7 mole) of hydratropic aldehyde (Eastman Kodak Co.) in a 1-l. three-necked flask equipped with a stirrer, reflux condenser and ice-bath. Sodium azide (68 g., 1.05 moles) was added in small portions with stirring and cooling. After the solution had been stirred in the cold for about three hours and then allowed to warm to room temperature, the vigorous evolution of nitrogen had subsided. The reaction mixture was refluxed gently for four hours, cooled, and then poured into an equal volume of water. The oil layer was separated and the water layer was diluted further and extracted three times with ether. The combined organic layers were washed three times with sodium bicarbonate solution and twice with saturated calcium chloride solution, and dried over sodium sulfate. After removal of the ether, ethyl hydratropate distilled at 107–110° (13 mm.) (reported[35] 100.5° (8 mm.)), yield 63 g. (51%).

The double Grignard reagent from tetramethylene dibromide[36] was used to convert the foregoing ester into 1-(α-phenylethyl)-cyclopentanol.

The Grignard reagent was prepared in the usual way from 19.4 g. (0.80 mole) of magnesium turnings and 82 g. (0.38 mole) of tetramethylene dibromide. Ethyl hydratropate (51 g., 0.31 mole) was added slowly with stirring. After the usual work-up, 31 g. (52.5%) of crude product distilling at 100–104° (1 mm.) was obtained. This product was purified by treatment with alcoholic potassium hydroxide for six hours. Distillation of the water-washed product gave 1-(α-phenylethyl)-cyclopentanol as a clear, viscous liquid, b.p. 112° (1.6 mm.). Analyses were low in carbon and high in hydrogen, suggesting hydrate formation similar to (1-phenylcyclopentyl)-methylcarbinol, until the sample had been dried for several days in a vacuum desiccator.

Anal. Calcd. for $C_{13}H_{18}O$: C, 82.06; H, 9.54. Found: C, 82.28; H, 9.48.

The **3,5-dinitrobenzoate**, fine needles from methanol, had m.p. 112–113°. *Anal.* Calcd. for $C_{20}H_{20}O_6N_2$: C, 62.49; H, 5.24. Found: C, 62.60; H, 5.34.

The **p-nitrobenzoate**, fine needles from methanol, had m.p. 70°. *Anal.*[37] Calcd. for $C_{20}H_{21}O_4N$: C, 70.78; H, 6.24. Found: C, 70.90; H, 6.29.

Demyanov Rearrangements.—Two general procedures were used, in which the amine is treated with sodium nitrite in a water solution of acetic acid or sodium dihydrogen phosphate, respectively. The first method (A) has been described by Ruzicka and Brugger,[6] and the second (B) we have already described.[7] The results of these reactions are summarized in Table II.

The compositions of the Demyanov alcohol mixtures were determined with the aid of plots of the percentage transmission *vs.* composition of synthetic mixtures, at one or more wave lengths characteristic of each component. The data from which these plots were constructed, together with the pertinent figures from the spectra of the Demyanov

(34) C. Schuerch, Jr., THIS JOURNAL, **70**, 2293 (1948); W. E. McEwen, W. E. Conrad and C. A. Vanderwerf, *ibid.*, **74**, 1168 (1952).

(35) H. Olsson, *Z. physik. Chem.*, **125**, 247 (1927).

(36) C. D. Nenitzescu and I. Necsoui, THIS JOURNAL, **72**, 3483 (1950).

(37) Analysis by Clark Microanalytical Laboratory, Urbana, Ill.

alcohols, are given in Tables IV, V and VI. A final synthetic mixture was made up having the composition initially estimated for the Demyanov alcohols, and from its spectrum a refinement of the estimation could be made. The spectra of the final mixtures showed detailed qualitative agreement with those of the Demyanov alcohols, and very nearly quantitative agreement. The compositions so determined appear in Table I. For examples of the complete spectra in a very similar system (alcohols from cyclohexanemethylamine) see paper I of this series.[7]

TABLE III

INFRARED ABSORPTION OF ALCOHOLS FROM α-CYCLOPENTYL-ETHYLAMINE

α-Cyclopentyl-ethanol, %	trans-2-Methyl-cyclo-hexanol, %	1-Ethyl-cyclo-pentanol, %	Transmission in 0.045-mm. cell at wave lengths in μ					
			8.35	8.94	10.29	10.75	11.05	11.85	12.05
100	0	0	40	4	28	42	55	75	79
0	0	100	5.5	50	0	38	15.5	48	40
0	100	0	50	38	30	4	42	10	28
50	25	25	24	8	6.5	19.5	36.5	36	46.5
45	30	30	22	10	5	17	33.5	33	43
37.8	19.4	42.8	16.5	11	3.8	21	29	37	
29.4	36	34.6	20.5	16	4	11	31.5	24.5	39
Demyanov product			23	9.5	5.8	13	33	28	44

TABLE IV

INFRARED ABSORPTION OF ALCOHOLS FROM α-CYCLOHEXYL ETHYLAMINE

α-Cyclo-hexyl-ethanol, %	1-Ethylcyclo-hexanol, %	Transmission in 0.045-mm. cell at wave lengths in μ		
		8.5	11.1	11.8
100	0	55	55	67
0	100	10	3	13
80	20	45	28	52
67	33	39	22	42
50	50	27	10	29.5
Demyanov product		31.5	16	36.5

TABLE V

INFRARED ABSORPTION OF ALCOHOLS FROM CYCLOPENTANE METHYLAMINE

Cyclo-pentyl-carbi-nol, %	Cyclo-hexanol, %	1-Methyl-cyclo-pentanol, %	Transmission in 0.045-mm. cell at wave lengths in μ			
			3.80	9.60	11.08	11.88	12.70
100	0	0	65	1	38	66	43
0	100	0	39	21	65	11	25
0	0	100[a]	(80)	(2.5)	(1.6)	(48)	(48)
0	80	20	45	9	31	13	26
0	70	30	50	10	21	15	28
0	50	50	58	8	11	19	29
5.2	75.6	19.2	46	11	32	15	27
Demyanov product			46	10	40	15	28

[a] Extrapolated.

The alcohol obtained from α-cyclopentylbenzylamine had an infrared spectrum identical throughout with that of au-

TABLE VI

ALKYLCYCLOPENTYLCARBINYLAMINES AND DERIVATIVES

Substituent	2-Methyl	2-Ethyl	3-Methyl	3-i-Propyl	3-t-Butyl
Cnhdrn.,[a] b.p., °C. (mm).		93–96 (1.5)	122–124 (17)		
Yield, %		64	73		
Nitrile,[b] b.p., °C. (mm.)	73–76 (20)	85–95 (21)	79–82 (19)	100–106 (21)	104–109 (15)
Yield, %	64[c]	62	43[c]	20[c]	12[c]
Amine, b.p., °C. (mm.)	147–157 (740)	175–176 (745)	46–48 (15)	192–193.5 (750)	88.5 (15)
Yield, %	66	55	52	60	63
Anal. Calcd. for	$C_7H_{15}N$	$C_8H_{17}N$	$C_7H_{15}N$	$C_9H_{19}N$	$C_{10}H_{21}N$
C, %	74.26	75.53	74.26	76.49	77.34
H, %	13.36	13.46	13.36	13.55	13.63
N, %	12.38	11.01	12.38	9.96	9.02
Found: C, %	74.27	75.70	74.21	76.45	77.38
H, %	13.06	13.17	13.07	13.39	13.36
N, %	12.16	11.21	12.40	9.90	9.26
n^{25}D	1.4500	1.4559	1.4478	1.4512	1.4559
$d^{25}{}_{25}$	0.8551	0.8600	0.8486	0.8483	0.8538
Mol. refraction	35.55	40.21	35.70	44.86	49.43
Picrate, m.p., °C.	179–179.5	179.5–181	189–191 d.	193.5–194.5 d.	178–178.5
Anal. Calcd. for	$C_{13}H_{18}O_7N_4$	$C_{14}H_{20}O_7N_4$	$C_{13}H_{18}O_7N_4$	$C_{16}H_{22}O_7N_4$	$C_{17}H_{24}O_7N_4$
C, %	45.61	47.19	45.61	48.64	49.99
H, %	5.30	5.66	5.30	5.99	6.27
Found: C, %	46.02	47.42	45.72	48.46	50.39
H, %	5.20	5.44	5.27	5.85	5.96
B·HCl,[d] m.p., °C.	259–260 d.	192–193 d.	226 d.	165	238.5–239.5 d.
Anal. Calcd. for	$C_7H_{16}NCl$	$C_8H_{18}NCl$	$C_7H_{16}NCl$	$C_9H_{20}NCl$	$C_{10}H_{22}NCl$
C, %	56.12	58.69	56.12	60.83	62.62
H, %	10.77	11.08	10.77	11.34	11.56
Found: C, %	56.02	58.61	56.03	61.03	62.37
H, %	10.50	11.09	10.59	11.17	11.35

[a] Cyanohydrin. [b] Alkylcyclopentenyl cyanide. [c] From ketone. [d] Amine hydrochloride.

thentic α-cyclopentylbenzyl alcohol. The alcohol obtained from α-(4-methylcyclohexyl)-ethylamine had an infrared spectrum similar in large part with that of α-(4-methylcyclohexyl)-ethanol; the several significant differences in the 10.5–12.5 μ region are presumably due to differences in stereochemical composition and to the presence of 1-ethyl-4-methylcyclohexanol in the Demyanov product.

α-(1-Phenylcyclopentyl)-ethanol shows absorption at 9.15, 9.65 and 11.25 μ, *inter alia*, and 1-(α-phenylethyl)-cyclopentanol shows absorption at 8.95, 9.13, 10.10 and 12.9–13.05 μ, wave lengths at which the Demyanov product from α-(1-phenylcyclopentyl)-ethylamine shows no transmission minima. 1-Phenyl-2-methylcyclohexanol (of uncertain stereochemical composition) has a spectrum very similar to that of the Demyanov alcohols; some differences, notably near 10 and 11 μ, are probably due to stereochemical differences. The Demyanov alcohol could not be made to yield a 3,5-dinitrobenzoate, which further distinguishes it from α-(1-phenylcyclopentyl)-ethanol.

Separation of the Demyanov Alcohols from Cyclohexanemethylamine.—The alcohols and olefins from 56.5 g. of cyclohexanemethylamine, 42.5 g. of sodium nitrite and 47.5 g. of 85% orthophosphoric acid in ca. 500 ml. of water were collected in petroleum ether (b.p. 30–40°) and the solvent was stripped off with an 18-in. Vigreux column. To the residue was added 10 g. of phthalic anhydride, the mixture was heated to a maximum of 150° during 0.5 hour, and was then allowed to cool overnight. The acidic and neutral products were separated with the aid of 50 ml. of petroleum ether and 8.5 g. of sodium carbonate monohydrate in 350 ml. of water. Acidification of the aqueous layer precipitated a brown oil which soon crystallized. Recrystallization from petroleum ether (b.p. 60–75°) and from aqueous acetic acid gave a total of 11 g. in several crops having melting points from 101–107° to 112–116°. Further recrystallization raised this to 115–119° with only small losses. The melting point when mixed with hexahydrobenzyl hydrogen phthalate was undepressed, while that with cycloheptyl hydrogen phthalate was 87–107°.

Distillation of the neutral portion of the esterification products gave 5.5 g. (11%) of olefin, b.p. 103–123°, and 22.5 g. (39%) of alcohol, b.p. 128–181° (largely 155–180°), from which a redistillation gave 20 g. (35%) of crude cycloheptanol, b.p. 160–180°. The redistilled alcohol was heated on a steam-bath with 29 g. of phthalic anhydride and 32 g. of pyridine for two hours, allowed to stand overnight, and then heated for another hour. The mixture was then cooled, poured into water, acidified with hydrochloric acid, and the oil which separated was taken up in chloroform. The residue after removal of the chloroform was crystallized from hot ligroin (b.p. 90–100°); several crops totaling 29.5 g. were obtained, showing m.p. *ca.* 87–92°. Recrystallization once from aqueous acetic acid and once from ligroin–benzene mixture gave 15 g., m.p. 90–95°. The melting point when mixed with cycloheptyl hydrogen phthalate was undepressed, while that with hexahydrobenzyl hydrogen phthalate was 70–105°.

The **hexahydrobenzyl hydrogen phthalate** used for these comparisons was prepared from alcohol obtained by the reduction of hexahydrobenzoic acid,[7] and formed prisms from petroleum ether, m.p. 119–120°.

Anal.[37] Calcd. for $C_{15}H_{18}O_4$: C, 68.68; H, 6.92. Found: C, 68.40; H, 7.20.

The **cycloheptyl hydrogen phthalate** was prepared by the reduction of cycloheptanone,[7] and formed slender prisms from petroleum ether, m.p. 100–102°.

Anal.[37] Calcd. for $C_{15}H_{18}O_4$: C, 68.68; H, 6.92. Found: C, 68.66; H, 6.64.

Reaction of *n*-Butylamine with Nitrosyl Chloride.—To a solution of 37 g. of *n*-butylamine in 200 ml. of dry ether, cooled in a Dry Ice–acetone-bath, was added an ethereal solution of 36.8 g. of nitrosyl chloride dropwise with stirring. Immediate, vigorous reaction occurred, giving a white precipitate; toward the end of the addition the mixture turned green and then orange-red. The mixture was allowed to warm slowly after completion of the addition; at about 0° a vigorous evolution of gas began and the precipitated solid

disappeared. After 13 hours, gas evolution had ceased and two liquid phases were present. The mixture was extracted three times with water, and from the combined extracts 21% of unreacted amine hydrochloride was recovered. The ethereal solution was washed with sodium carbonate solution, then water, and dried over sodium sulfate and calcium sulfate. Distillation through an 8-in. column packed with glass helices gave a principal fraction of wt. 8.74 g. at 58–70° (746 mm.), as a cloudy, yellow liquid. About 7 g. of higher-boiling material was obtained over the range 70–130° as sweet-smelling yellow liquids. Redistillation of the dried low-boiling fraction gave a colorless product of b.p. 74.5–76° (743 mm.) (n-butyl chloride has b.p. 77.9° (763 mm.), sec-butyl chloride, 67.8° (767 mm.)). The infrared spectrum was nearly superimposable on that of authentic n-butyl chloride, and vastly different from that of sec-butyl chloride. The higher-boiling material, most of which distilled above 100°, was not further investigated.

Ring-substituted Cyclopentylcarbinylamines. 2-Ethylcyclopentylcarbinylamine.—A mixture of 45.5 g. (0.405 mole) of 2-ethylcyclopentanone[36] and 27 g. (0.41 mole) of potassium cyanide was added to 100 ml. of water and cooled in an ice-bath. A solution of 40 g. (0.41 mole) of sulfuric acid in 94 ml. of water was added at such a rate that the temperature stayed between 2 and 5°. The cyanohydrin layer was then separated, dried over sodium sulfate, and distilled; b.p. 93–96° (1.5 mm.), wt. 35.9 g. (64%). This was dissolved in 61.4 g. of pyridine, and 61.4 g. of thionyl chloride was added with cooling and shaking. After 12 hours at room-temperature, the black mixture was heated for one hour on a steam-bath. The mixture was then decomposed with ice and hydrochloric acid and extracted with ether. The extracts were filtered from tar, washed with sodium hydroxide solution and dried over sodium sulfate, and distilled; b.p. 85–95° (21 mm.), wt. 19.6 g. (62%). This entire amount was dissolved in 250 ml. of isoamyl alcohol and 23 g. of sodium was added. Most of the sodium reacted in the first 10 minutes, and the mixture was then heated until all the metal had dissolved. Ice and hydrochloric acid were added, and the isoamyl alcohol was removed by steam distillation. Further steam distillation after alkalizing with sodium hydroxide separated the amine, which was extracted with ether from the distillate. Distillation of the dried (sodium hydroxide) extracts gave 11.2 g. (55%) of 2-ethylcyclopentylcarbinylamine, b.p. 170–183° (745 mm.). A sample redistilled for analysis had b.p. 175–176° (745 mm.).

The other ring-substituted cyclopentylcarbinylamines were prepared in an analogous manner. The data concerning them and their derivatives are given in Table VI.

Preparation of p-Phenylazophenylurethans.—The general procedure of Davenport and Sutherland[22c] was used in this work and is illustrated for cyclohexanol.

The phenylazophenylurethans which have been prepared are listed in Table VII. They all crystallize as fine orange needles from 60–70° petroleum ether, except the derivatives of cyclohexanol and 3-methylcyclohexanol, which form rosettes. It should be noted that in the cases of the substituted cyclohexanols, the stereochemistry is uncertain, except in

(38) F. H. Case and E. E. Reid, This Journal, **50**, 3062 (1928).

the case of the trans-2-methylcyclohexanol, which was prepared by fractional recrystallization of the acid phthalate of commercial 2-methylcyclohexanol. The trans-acid phthalate, m.p. 125–126° (reported 123.5–125°,[29] 124–125°[25]) was hydrolyzed with 20% sodium hydroxide. The other alcohols are the commercial products.

TABLE VII

CYCLOALKYL p-PHENYLAZOPHENYLURETHANS

p-Phenylazo-phenylurethan of	M.p., °C.[a]	Yield, %	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found
Cyclohexanol	160.5–162	97[b]	70.56	70.47	6.55	6.43
trans-2-Methyl-[c]	145.5–146.5	61[b]	71.19	71.24	6.87	6.96
3-Methyl-[d]	122–124	75[b]	71.19	71.40	6.87	6.64
4-Methyl-[d]	177.5–178.5	65[b]	71.19	71.39	6.87	6.76
4-Isopropyl-[e]	157–158.5	41	72.29	72.37	7.45	7.19
4-t-Butyl-[e]	173.5–174	45	72.79	73.03	7.70	7.68
Cycloheptanol	119–120	75,[b] 35	71.19	71.49	6.87	6.87

[a] All melting points are corrected. [b] The pyridine that was used as a solvent was distilled from barium oxide. [c] Commercial 2-methylcyclohexanol (Paragon) gave a crystalline derivative which, after two recrystallizations, melted at 124–149°. [d] Paragon. [e] Dow Chemical Co.

Attempts were made to separate chromatographically a synthetic mixture of the p-phenylazophenylurethans of 3- and 4-methylcyclohexanols without success. The adsorbents used were alumina, "heavy" magnesium oxide, magnesol–celite and silicic acid. The urethan mixture traveled down the column as a single band when eluted by benzene–petroleum ether mixtures or more polar solvents. A second, yellow band was identified as p-aminoazobenzene, and an unidentified mixture of colored products remained strongly adsorbed on the top of the column. No further attempts were made after it was determined that the composition of the mixtures could be found from the infrared spectra of the original alcohols.

p-Phenylazophenylurethan of Cyclohexanol.—To a solution of 0.50 g. (0.005 mole) of cyclohexanol in 10 ml. of anhydrous pyridine (distilled from barium oxide) was added 2.0 g. (0.009 mole) of slightly impure p-phenylazophenyl isocyanate (m.p. 93–98°). Heat was generated and not all of the isocyanate dissolved. After having been sealed tightly, the flask was allowed to stand in the refrigerator for 3 to 4 days. At this time three drops of water were added to decompose the excess reagent and the flask allowed to stand one day longer in the cold. The solution was boiled for 5 min. and filtered hot in order to remove the insoluble urea that is formed. The filtrate was now washed with an aqueous solution of citric acid to remove the remaining pyridine, and then once with water. The organic layer was evaporated to about 50 ml. and the urethan allowed to crystallize. The orange solid obtained by filtration weighed 1.55 g. (96.5%), m.p. 155–160°. After three recrystallizations from petroleum ether it melted at 160.5–162°.

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