evaporated. The first material to come out of solution was filtered, and recrystallized from acetone, m.p. 156–157°. Mixed melting point of this with an authentic sample of succinamic acid, prepared from succinic anhydride and ammonia, showed no depression. It was also identified by heating to 200°. Water was given off, and the resulting solid melted at 126–127°, corresponding to the melting point of succinimide. Further evaporation of the acidified solution yield a white solid, m.p. 244–245°; mixed m.p. with an authentic sample of piperidine hydrochloride showed no depression. The original mother liquor was stripped to a residue which did not crystallize. The residue was soluble in water and released piperidine when made basic, indicating it to be a salt.

(c) **With 1,1,3,3-Tetramethylbutylamine.**—The stripped reaction mixture crystallized in isopropyl alcohol. 1,1,3,3-Tetramethylbutylammonium succinamate was isolated by filtration in 20% yield, m.p. 176–178°. *Anal.* Calcd. for $C_{12}H_{26}O_3N_2$: N, 11.4. Found: N, 11.2. By titration with perchloric acid in glacial acetic acid, there was obtained an equivalent weight of 250, theory 246. Acidification of the product with hydrochloric acid yielded a solid, m.p. 257–259°, mixed m.p. with a sample of 1,1,3,3-tetramethylbutylammonium chloride gave no depression. Mixed m.p. of the reaction product with the salt prepared by the reaction of *t*-octylamine with succinamic acid, m.p. 180–181°, showed no depression below 176°. The residue failed to crystallize further. It was found to be water soluble and to contain more salt as seen by the release of the free amine when treated with cold alkali.

(d) **With Aniline.**—After the refluxing period, the reaction mixture was distilled to yield 99% of the starting aniline, b.p. 183°, and 94% of the starting nitrile, b.p. 142° (22 mm.).

Attempted Aqueous Reactions of Mononitriles with Amines. (a) **Methylamine and Acetonitrile.**—A solution of the nitrile, amine and water in the molar ratio of 1:2:5.6 was heated in an autoclave at 100° for eight hours. On distillation of the reaction mixture, no material boiling as high as N-methylacetamide was obtained.

(b) **Piperidine and *n*-Butyronitrile.**—A solution of 69 g. (1.0 mole) of butyronitrile, 170 g. (2.0 moles) of piperidine and 108 g. (6.0 moles) of water was refluxed for 48 hours. No ammonia was detected. On distillation at atmospheric pressure, the entire reaction mixture distilled up to 100°, leaving essentially no residue. The distillate was acidified with concentrated hydrochloric acid. The nitrile layer which separated was distilled, yielding 63.5 g. (92%) of starting *n*-butyronitrile, b.p. 118°.

(c) **Morpholine and *n*-Butyronitrile.**—The nitrile, amine and water ratio (1:2:6) and the reaction conditions were the same as that described in (b) above. A 93% recovery of *n*-butyronitrile was obtained on two distillations.

(d) **Benzylamine and Benzonitrile.**—The reaction conditions were the same as those described in (b) above. The reaction mixture was acidified with concentrated hydrochloric acid and the starting benzylamine was recovered in 98% yield as benzylammonium chloride, m.p. 248°; mixed m.p. with an authentic sample did not depress.

PHILADELPHIA, PA.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, COLUMBIA UNIVERSITY]

The Axial Effect in the Rearrangement with Nitrous Acid of *cis*- and *trans*-2-Amino-1-phenylcyclohexanol[1]

BY DAVID Y. CURTIN[2a] AND SEYMOUR SCHMUKLER[2b]

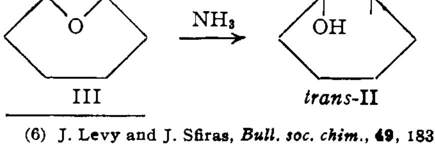
RECEIVED SEPTEMBER 20, 1954

cis-2-Amino-1-phenylcyclohexanol and *cis*-2-amino-1-*p*-methoxyphenylcyclohexanol have been shown to rearrange with 99 and 98.8% alkyl migration (*i.e.*, ring contraction) and only about 1 or 1.2%, respectively, of aryl migration. These migration ratios contrast sharply with results obtained previously by other workers with acyclic compounds. The difference is interpreted as due to steric strain in the transition state for aryl migration when the aryl group is in an axial position in a cyclohexane ring. *cis*-2-Chloro-1-phenylcyclohexanol reacts with silver oxide in hexane to give, principally, ring contraction, but also extensive amounts of 2-phenylcyclohexanone which may or may not be formed by phenyl migration. *trans*-2-Amino-1-phenylcyclohexanol yields with nitrous acid a mixture of glycols, glycol esters and ketones. Since under the reaction conditions 1-phenylcyclohexene oxide gives a similar mixture, it is inferred that the oxide or its conjugate acid is a probable intermediate in the principal reaction path.

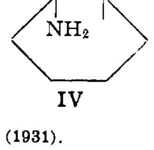
Both *cis*- and *trans*-2-chloro-1-phenylcyclohexanol[3] (*cis*- and *trans*-I) have been reported to yield only 2-phenylcyclohexanone (with phenyl migration) when caused to rearrange by treatment with ethylmagnesium bromide.[4] In other reactions related as this one appears to be, to the pinacol rearrangement such a preference of aryl migration over migration of an alkyl group is well known.[5] It appeared surprising, however, on stereochemical grounds to be discussed below, that a phenyl group should migrate readily when attached to a cyclohexane ring.

For this reason it was decided to examine the rearrangement with nitrous acid of the *cis*- and *trans*-amino alcohols (*cis*- and *trans*-II) and to reexamine the rearrangement of the *cis*-chlorohydrin (*cis*-I) under other conditions.

Syntheses and Establishment of Configuration of Compounds to be Studied.—Levy and Sfiras[6] had prepared an amino alcohol (m.p. 105°, hydrochloride m.p. 140°) by the reaction of 1-phenylcyclohexene oxide (III) with ammonia. No evidence for the structure or configuration was advanced, however. Repetition of their work gave an amino alcohol (m.p. 111–112°, hydrochloride, m.p. 216–217°) which was shown to be *trans*-2-amino-1-phenylcyclohexanol (*trans*-II) rather than the alternative 2-amino-2-phenylcyclohexanol (IV).



III *trans*-II



IV

---

[1] From the Ph.D. Dissertation submitted to Columbia University by Seymour Schmukler. Presented at the 124th Meeting of the American Chemical Society, Chicago, Ill., 1953, Abstracts, p. 18-O.

[2] (a) Department of Chemistry, University of Illinois, Urbana, Ill. (b) American Cyanamid Predoctoral Fellow, 1951–1952.

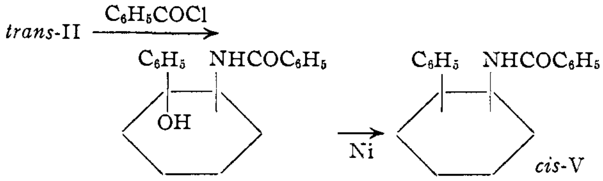
[3] Throughout this paper the designations "*cis*" and "*trans*" will be used to refer to the relative positions of the hydroxyl and chlorine or hydroxyl and amine groups.

[4] M. Tiffeneau, B. Tchoubar and S. LeTellier, *Compt. rend.*, **217**, 588 (1943).

[5] C. K. Ingold, "Structure and Mechanisms in Organic Chemistry," Cornell University Press, Ithaca, N. Y., 1953, p. 477.

[6] J. Levy and J. Sfiras, *Bull. soc. chim.*, **49**, 1830 (1931).

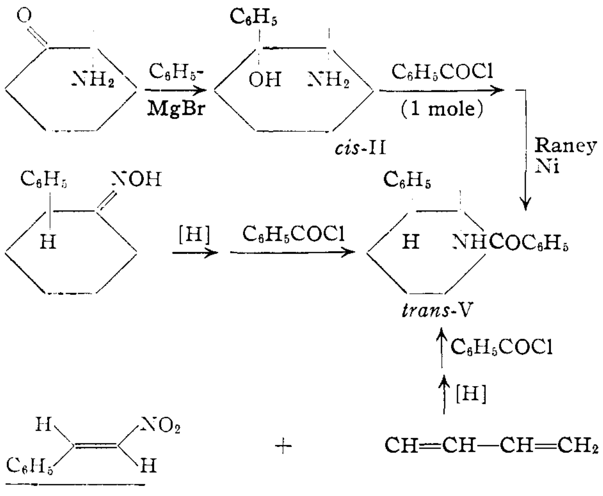
When *trans*-II was converted to the N-benzoyl derivative and the latter treated with Raney nickel, a phenylcyclohexylamide (*cis*-V) was obtained.



The loss of the hydroxyl function in this reaction indicates that it is attached to the carbon atom adjacent to the phenyl ring. This follows because such hydrogenolyses are characteristic only of benzyl-type alcohols.[7,8] The configuration of the reduction product V will be discussed below.

Since α-chloro- and α-hydroxycyclohexanones have been shown[9] to react with Grignard reagents to yield a preponderance of *cis* product, the synthesis of the *cis*-amino alcohol (*cis*-II) by the addition of phenylmagnesium bromide to 2-aminocyclohexanone was undertaken. This reaction was indeed found to lead to an amino alcohol which differed from *trans*-II, and was assigned the structure *cis*-II.

When *cis*-II was converted to its N-benzoyl derivative and the latter treated with Raney nickel it was converted to an N-benzoylphenylcyclohexylamine. This substance had the m.p. reported for the benzoyl derivative of the 2-phenylcyclohexylamine previously prepared by the reduction of 2-phenylcyclohexanone oxime[10] with sodium and ethanol or hydrogen over platinum in acetic acid, or by the condensation of butadiene with *trans*-β-nitrosyrene followed by reduction over Raney nickel in methanol.[11] It was different from the *cis*-V described above.

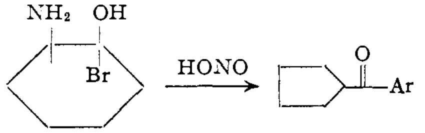


Bonner, Zderic and Casalette[12] have shown that optically active α-hydroxy-α-phenylpropionic acid is converted to optically active α-phenylpropionic acid with retention of configuration. If the removal of the hydroxyl groups of the amino alcohols, *cis*- and *trans*-II follows a similar steric course, the configurations of *cis*- and *trans*-V as indicated above and the configurational assignment previously made[10] to *trans*-V is confirmed.[13] At the same time the configurational assignments made to *cis*- and *trans*-II on the basis of their methods of preparation as well as the steric course of the hydrogenolysis reaction are strengthened.

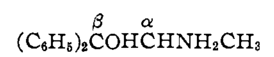
cis-2-Amino-1-*p*-methoxyphenylcyclohexanol (*cis*-VI) was prepared and its structure assigned by analogy with the related phenyl compound (*cis*-II).

cis-2-Chloro-1-phenylcyclohexanol (*cis*-I) had been prepared as an oil by the addition of phenylmagnesium bromide to 2-chlorocyclohexanol.[3,14] Repetition of their work yielded *cis*-I as a solid, m.p. 41°.

Rearrangement of the *cis* Isomers (*cis*-II, *cis*-VI and *cis*-I).—The rearrangements of the amino alcohols (*cis*-II and *cis*-VI) were effected with nitrous acid in 50% acetic acid at 0°. Comparison of the infrared spectra with known mixtures indicated that the phenylamino alcohol (*cis*-II) had rearranged with alkyl migration (*i.e.*, ring contraction) to the extent of more than 99% to form cyclopentyl phenyl ketone, while the rearrangement of *cis*-VI had led to some 99% of ring contraction to yield *p*-anisyl cyclopentyl ketone.



The rearrangement of amino alcohols such as



$$(C_6H_5)_2\overset{\beta}{C}OH\overset{\alpha}{C}HNH_2CH_3$$

VII

VII has been shown by Bernstein and Whitmore[15] to proceed with inversion of configuration at the α-carbon. A number of such rearrangements have been examined and appeared to proceed with a high degree of specificity.[16] Although there is no direct evidence which bears on this point, it is commonly assumed that the amine group reacts initially with nitrous acid to form a diazonium ion, behavior analogous to that demonstrated for simple amines.[17]

If the reaction of the amino alcohol *cis*-II is assumed to involve such a displacement from the rear (by the phenyl group) of nitrogen it is seen that the rearrangement step must proceed from the diazonium ion (*cis*-II-i) (an equilibrium mixture of

---

(7) H. Adkins and R. L. Shriner, in "Organic Chemistry," Vol. II, edited by H. Gilman, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 820.

(8) The argument is very much strengthened by the observation that *cis*-2-phenylcyclohexanol can be prepared (and hence is stable) in the presence of Raney nickel under conditions considerably more rigorous than those employed here [C. C. Price and J. V. Karabinos, This Journal, **62**, 1160 (1940)].

(9) P. D. Bartlett and R. H. Rosenwald, *ibid.*, **56**, 1990 (1934).

(10) D. V. Nightingale, J. D. Kerr, J. A. Gallagher and M. Maienthal, *J. Org. Chem.*, **17**, 1017 (1952).

(11) D. V. Nightingale and V. Tweedie, This Journal, **66**, 1969 (1944).

(12) W. A. Bonner, J. A. Zderic and G. A. Casalette, *ibid.*, **74**, 5086 (1952).

(13) Since the completion of the present work, R. T. Arnold and P. N. Richardson [*ibid.*, **76**, 3649 (1954)] have presented additional convincing evidence that this assignment is correct.

(14) M. Mousseron, R. Jacquier and R. Fontaine, *Bull. soc. chim. France*, 211 (1950).

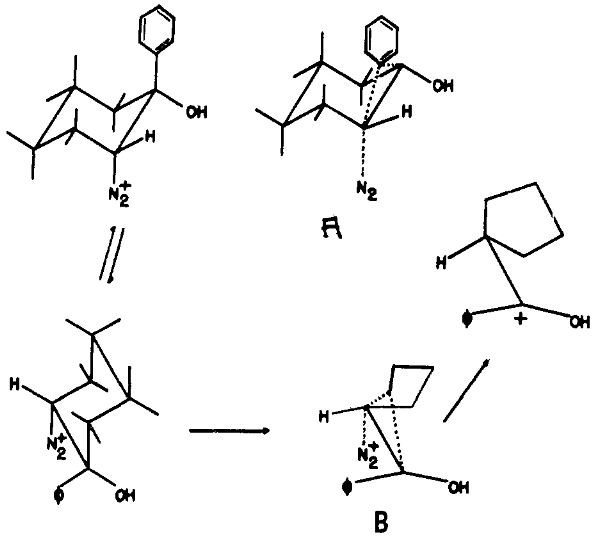
(15) I. Bernstein and F. W. Whitmore, This Journal, **61**, 1324 (1939).

(16) See D. Y. Curtin and M. C. Crew, *ibid.*, in press.

(17) Reference 5, p. 398.

the two conformations indicated) through the transition state (A) with the migrating phenyl group in an axial position. Considerable study[18] has shown that cyclohexane rings bearing atoms or groups such as methyl or the halogens are, in general, destabilized when the larger functional groups are in axial as compared with equatorial positions.

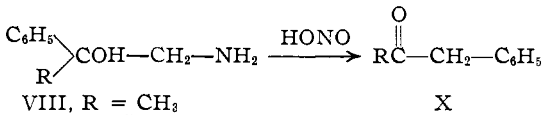
It had been, in fact, anticipated that, as the present results indicate, the transition state for aryl migration is of prohibitively high energy with the result that the natural preference for aryl over alkyl migration found in acyclic systems is not observed in the rearrangement of *cis*-II. Instead the molecule rearranges almost entirely through the transition state (B) to cyclopentyl phenyl ketone.



cis-II-i

It is convenient to employ the term "axial effect" analogous to "*cis* effect"[16,19] to refer to the destabilization of the transition state due to a substituent in an axial position.

While no precise estimate can be made of the magnitude of the axial effect on the course of the rearrangement of *cis*-II or *cis*-VI, it is possible to set a lower limit for this quantity. In the rearrangement of the amino alcohols VIII and IX Tiffeneau and Cahnmann[20] reported that the semicarbazones of the ketones X formed by phenyl migra-

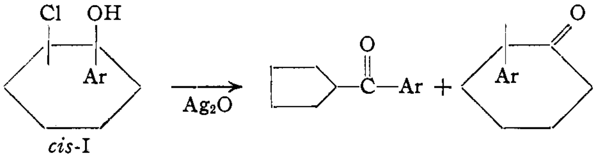


$$\begin{matrix} C_6H_5 \\ R \end{matrix}\!\!>\!COH\text{—}CH_2\text{—}NH_2 \xrightarrow{HONO} R\overset{O}{\overset{\|}{C}}\text{—}CH_2\text{—}C_6H_5$$

VIII, R = CH_3 X
IX, R = C_2H_5

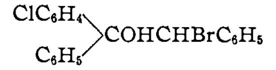
tion were isolated in yields of 87 and 95%, respectively, and that a search for a second semicarbazone failed in each case. It would appear, then, that 10 is a conservative estimate for the phenyl/alkyl migration ratio in such a system. It is seen that the axial effect not only compensates for the factor of at least 10 in favor of phenyl migration but is responsible for an observed alkyl/phenyl migration ratio of about 100. Thus, the total axial effect in this reaction might be said to lead to a suppression of aryl migration in favor of alkyl migration by a factor of at least 1000.[21]

The rearrangement of the chlorohydrin (*cis*-I) was best carried out with silver oxide suspended in refluxing hexane for 96 hours. A chlorine analysis of the resulting oil indicated the presence of some 10% of unreacted starting material (or possibly other chlorine-containing product). Examination of the infrared spectrum of the oil and comparison with spectra of the pure products indicated that about 68% cyclopentyl phenyl ketone (formed with ring contraction) and 22% of 2-phenyl cyclohexanone (formed with phenyl migration) (based on unreacted starting material) had been formed.



cis-I

It is seen that the preponderance of ring contraction over phenyl migration is in qualitative agreement with the results obtained in the rearrangement with nitrous acid of *cis*-II and *cis*-VI and quite different from the result obtained by Tiffeneau, Tchoubar and Le Tellier[4] who found only phenyl migration when the catalyst for rearrangement was ethylmagnesium bromide. A similar dramatic difference in the products of rearrangement of the bromohydrins (*erythro*- and *threo*- XIII) with the Grignard reagent on the one hand and with



$$\begin{matrix} ClC_6H_4 \\ C_6H_5 \end{matrix}\!\!>\!COHCHBrC_6H_5$$

XIII

silver nitrate on the other has been observed.[22] The explanation given[22] for the behavior of XIII may well apply to the present case.

Although the alkyl/aryl ratio of the rearrangement of the chlorohydrin *cis*-I is in qualitative agreement with that of the nitrous acid rearrangement of *cis*-II and *cis*-VI, there is a considerable difference between the value of 3 obtained in the chlorohydrin rearrangement and 100 in that of the amino alcohol. A possible partial explanation is to be found in the demonstration by Ciereszko and Burr[23] and Curtin and Crew[24] that migration ratios in amine–nitrous acid rearrangements are considerably smaller than those in other reactions more closely related to the chlorohydrin rearrangement studied here. On the other hand, we have not excluded the possibility that part or all of the 2-phenylcyclohexanone may have come by some other

---

[18] See H. D. Orloff, *Chem. Revs.*, **54**, 347 (1954).

[19] D. Y. Curtin, 13th National Organic Chemistry Symposium of the American Chemical Society, Ann Arbor, Mich., June, 1953; D. Y. Curtin and D. B. Kellom, THIS JOURNAL, **75**, 6011 (1953). D. Y. Curtin, *Record Chem. Progress* (*Kresge Hooker Sci. Lib.*) **15**, 111 (1954)).

[20] M. Tiffeneau and H. Cahnmann, *Bull. soc. chim.*, 1876 (1935).

[21] The magnitude of the axial effect of migrating phenyl is even more impressive when it is noted that the transition state for ring contraction might be expected to be somewhat less stable than the corresponding transition state in an acyclic system because of the opposition of hydrogens in the five-membered ring which is in the process of being formed (see R. Spitzer and H. Huffman, THIS JOURNAL, **69**, 211 (1947).

[22] D. Y. Curtin and E. K. Meislich, *ibid.*, **74**, 5905 (1952).

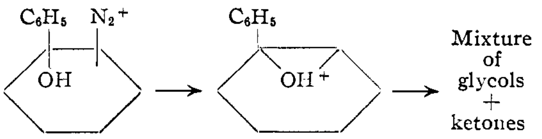
[23] L. S. Ciereszko and J. G. Burr, Jr., *ibid.*, **74**, 5431 (1952).

[24] D. Y. Curtin and M. C. Crew, *ibid.*, **76**, 3719 (1954).

path such as, for example, isomerization of *cis*-I to *trans*-I, oxide formation, and thermal rearrangement of the oxide with hydrogen migration. Attempts to prepare the *trans*-chlorohydrin (*trans*-I) in a pure form in order to compare its behavior with silver oxide were unsuccessful.

When the *trans*-amino alcohol (*trans*-II) was allowed to react with nitrous acid under the same conditions employed in the rearrangement of the *cis* isomer, a complex mixture of phenylcyclohexane-1,2-diols, cyclopentyl phenyl ketone, a small amount of 2-phenylcyclohexanone, and a nitrate ester, probably of the diols above, was obtained.

It seems likely that the major part of this reaction proceeds chiefly by way of the epoxide III. Such a reaction has ample analogy.[25]



III

In order to test this hypothesis, the epoxide (III) was subjected to the deamination conditions. Examination of the infrared spectrum of the product mixture indicated that the same products were obtained with the exception that cyclopentyl phenyl ketone was absent. It seems likely that this ketone was formed by a direct rearrangement of the diazotized amino alcohol (*trans*-II).

It is of interest that the axial effect in this case might be expected to favor epoxide formation at the expense of rearrangement to cyclopentyl phenyl ketone.

Experimental[26]

1-Phenylcyclohexene oxide (III), n^{25}D 1.5422 (reported[27] n^{20}D 1.5434) was prepared by the oxidation with perbenzoic acid[28] of 1-phenylcyclohexene[29] in chloroform at a temperature of less than 2°. The disappearance of perbenzoic acid was followed by titration and was complete after 72 hours. The reaction mixture was washed with sodium hydroxide solution, dried with anhydrous sodium sulfate and the chloroform removed under reduced pressure at room temperature in an atmosphere of nitrogen. The crude oil was generally used directly. Attempts to purify it by distillation led to partial rearrangement to carbonyl compounds. Even "flash distillation" gave carbonyl compounds in the later fractions as shown by a test with hydroxylamine hydrochloride reagent.

***trans*-2-Amino-1-phenylcyclohexanol** (*trans*-II) was prepared by a modification of the method of Levy and Sfiras.[6] Crude epoxide (III) (77.7 g., 0.45 mole) was heated and shaken at 150° for 21 hours with 1.25 l. of concentrated aqueous ammonia. Extraction of the basic fraction with 10% hydrochloric acid followed by addition of sodium hydroxide, extraction of the amine into diethyl ether and removal of the ether left an oil which crystallized. Recrystallization from benzene yielded 34 g. (40% yield) of *trans*-II, m.p. 109–111°. Further recrystallization from benzene and ethanol gave m.p. 111–112° (reported[6] m.p. 105°).

Anal. Calcd. for $C_{12}H_{17}NO$: C, 75.4; H, 9.0; N, 7.3. Found: C, 75.2; H, 8.7; N, 7.2.

The hydrochloride, recrystallized from absolute ethanol, melted at 216–217° dec. (reported[6] 140°).

Anal. Calcd. for $C_{12}H_{18}ClNO$: C, 63.3; H, 8.0; N, 6.2; Cl, 15.6. Found: C, 63.3; H, 7.7; N, 6.0; Cl, 15.3.

The N-acetyl derivative was best prepared by the following procedure since it was recovered from water only with difficulty.

trans-II (10 g., 0.52 mole) was heated for 5 minutes with 4.4 g. of sodium acetate in 50 ml. of acetic anhydride. After standing overnight the acetic anhydride was evaporated under reduced pressure. The solid remaining was extracted with hot ethyl acetate to yield 8.7 g. (71%) of crude *trans*-amide from the filtrate, m.p. 160–165°. Recrystallization from chloroform, toluene and, finally, ethyl acetate brought the m.p. to 166.5–167°.

Anal. Calcd. for $C_{14}H_{19}NO_2$: C, 72.1; H, 8.2; N, 6.0. Found: C, 72.2; H, 8.1; N, 6.1.

The benzamide, m.p. 150–155°, was obtained from the reaction of *trans*-II with benzoyl chloride in benzene shaken with aqueous sodium hydroxide. Recrystallization from acetonitrile gave prisms of the benzamide containing one-half mole of acetonitrile of crystallization even when dried at 54° over phosphorus pentoxide.

Anal. Calcd. for $C_{19}H_{21}NO_2\cdot{}^1/_2C_2H_3N$: C, 76.0; H, 7.2; N, 6.7. Found: C, 75.9; H, 7.1; N, 6.5.

After drying at 110° the amide was solvent-free and had m.p. 157–158°.

Anal. Calcd. for $C_{19}H_{21}NO_2$: C, 77.3; H, 7.2; N, 4.7. Found: C, 77.2; H, 6.8; N, 5.0.

***trans*-2-Phthalimidocyclohexanol.**—To 10 g. (0.087 mole) of *trans*-2-aminocyclohexanol, prepared from *trans*-2-chlorocyclohexanol by the method of Wilson and Read,[30] in 200 ml. of dioxane were added 12.9 g. (0.087 mole) of phthalic anhydride and 15 ml. of pyridine. After 1 hour the solvent was removed under vacuum and heating was then continued at 150–170° for 15 minutes. When cooled, the product solidified to a glass which was powdered to yield 17 g. (79%) of crude product, m.p. 165–168°. After repeated recrystallization from ethyl acetate the m.p. rose to 168–169°.

Anal. Calcd. for $C_{14}H_{15}NO_3$: C, 68.6; H, 6.2; N, 5.7. Found: C, 68.9; H, 6.0; N, 5.8.

2-Phthalimidocyclohexanone. (a) **From *trans*-2-Phthalimidocyclohexanol.**—To 3.0 g. of chromium trioxide in 5 ml. of 70% acetic acid was added 5 g. of the phthalimidocyclohexanol. After 1 hour at 70–80°, the product crystallized on cooling to 0°. When collected by filtration and washed with 50 ml. of water, the ketone weighed 3.6 g. (70% yield); and when recrystallized from ethyl acetate, had m.p. 174–175°. A m.p. of a mixture with starting material was depressed.

(b) **From 2-Chlorocyclohexanone.**—To 500 g. (2.7 moles) of potassium phthalimide in 2 l. of dimethylformamide was added 500 g. (3.8 moles) of 2-chlorocyclohexanone. The mixture was stirred at 95° for 8 hours. The orange solid obtained by pouring the reaction into 15 l. of water was recrystallized twice from ethanol (and decolorized with charcoal) to give 500 g. (76%) of phthalimido ketone, m.p. 172–174°. Recrystallization from benzene and then ethyl acetate gave a m.p. of 174–175°. There was no depression of the m.p. upon admixture with crystals obtained from method a.

Anal. Calcd. for $C_{14}H_{13}NO_3$: C, 69.1; H, 5.4; N, 5.8. Found: C, 69.1; H, 5.6; N, 5.9.

***cis*-2-Amino-1-phenylcyclohexanol** (*cis*-II).—Hydrolysis of the 2-phthalimidocyclohexanone (50 g., 0.21 mole) was carried out by heating it under reflux either with 250 ml. of 48% hydrobromic acid and 250 ml. of glacial acetic acid or with 100 ml. of concentrated hydrochloric acid and 100 ml. of glacial acetic acid for 4 hours. Phthalic acid (32 g., 90%), which precipitated, was removed by filtration; and the filtrate evaporated to dryness to yield the crude amine hydrohalide. The hydrobromide was purified by precipitation with ether from a concentrated absolute ethanol solution (yield 24 g., 60%, m.p. 151–154° dec.).

The crude hydrobromide (50 g., 0.26 mole) was added to a solution in 500 ml. of dry ether of phenylmagnesium bromide prepared from 34 g. (1.4 g.-atoms) of magnesium

---

(25) S. Winstein and R. B. Henderson in "Heterocyclic Compounds," Vol. I, Edited by R. B. Elderfield, John Wiley and Sons, Inc., New York, N. Y., 1950, p. 18.

(26) All melting points are corrected. Microanalyses were carried out by the Clark Microanalytical Laboratories, Urbana, Ill., and the Schwarzkopf Microanalytical Laboratories, Woodside, N. Y.

(27) S. Nametkin, *Ber.*, **56**, 1805 (1925).

(28) I. M. Kolthoff, T. S. Lee and M. A. Mairs, *J. Polymer Sci.*, **2**, 199 (1947).

(29) K. V. Auwers and W. Treppmann, *Ber.*, **48**, 1207 (1915).

(30) N. A. B. Wilson and J. Read, *J. Chem. Soc.*, 1269 (1935).

and 238 g. (1.5 moles) of bromobenzene. After 6 hours at reflux temperature the mixture was poured onto a mixture of 800 g. of ice and 150 ml. of concentrated hydrochloric acid. Addition of concentrated aqueous ammonia until the solution was basic, followed by extraction with ether and evaporation of the ether gave 19.4 g. (39%) of *cis*-II, m.p. 81–86°. Recrystallization from benzene and hexane yielded *cis*-II, m.p. 92–93°.

Anal. Calcd. for $C_{12}H_{17}NO$: C, 75.4; H, 9.0; N, 7.3. Found: C, 75.8; H, 8.8; N, 7.4.

The hydrochloride melted at 210–211° dec.

Anal. Calcd. for $C_{12}H_{18}ClNO$: C, 63.3; H, 8.0; N, 6.2; Cl, 15.6. Found: C, 63.3; H, 7.9; N, 6.0; Cl, 15.5.

The benzamide (0.65 g., 85%, m.p. 166–175°) was prepared by treating 0.49 g. (0.0020 mole) of *cis*-II and 0.37 g. (0.0026 mole) of benzoyl chloride in 7.5 ml. of benzene with 12 ml. of 0.5% aqueous sodium hydroxide followed by filtration. Recrystallization from benzene and then ethanol gave m.p. 182.5–183°.

Anal. Calcd. for $C_{19}H_{21}NO_2$: C, 77.3; H, 7.2; N, 4.7. Found: C, 77.1; H, 7.2; N, 4.7.

cis-**2-Amino-1-*p*-methoxyphenylcyclohexanol** (*cis*-VI), m.p. 85–95°, was prepared in 72% yield by the method described above for *cis*-II. Recrystallization of the product from hexane gave only the *cis*-amino alcohol, m.p. 102–103°.

Anal. Calcd. for $C_{13}H_{19}NO_2$: C, 70.2; H, 8.6; N, 6.3. Found: C, 70.6; H, 8.4; N, 6.2.

Hydrogenolysis of the Benzamide of *trans*-II. N-*cis*-2-Phenylcyclohexylbenzamide.—The benzamide (2.56 g., 0.0087 mole) of *cis*-II in 300 ml. of ethanol was heated under reflux for 12 hours with 30 g. of wet Raney nickel (from the Raney Catalyst Co.). After removal of the nickel by filtration, 2.05 g. (0.0074 mole, 85%) of *cis*-2-phenylcyclohexylbenzamide, m.p. 125–127°, was obtained. After several recrystallizations from ethanol the m.p. was 126.5–127°.

Anal. Calcd. for $C_{19}H_{21}NO$: C, 81.7; H, 7.6; N, 5.0. Found: C, 81.7; H, 7.6; N, 5.2.

Hydrogenolysis of the Benzamide of *cis*-II. N-*trans*-2-Phenylcyclohexylbenzamide.—The crude product, m.p. 172–177°, was obtained in 83% yield by the procedure described above for the *cis* isomer. Recrystallization from ethanol gave m.p. 179–180° and additional recrystallization from ethanol and acetonitrile gave m.p. 180–181° (reported[11] 180–181°).

Reduction of 2-phenylcyclohexanone oxime by the method previously described[12] gave N-*trans*-2-phenylcyclohexylbenzamide, m.p. 180–181°, which showed no depression when admixed with the sample above.

2-Phenylcyclohexanone, m.p. 57.2–59° (reported 53–55°,[31] 59.5–60°[32]), was prepared by the method of Newman and Farbman.[31]

Cyclopentyl phenyl ketone, b.p. 93–96° (1.5 mm.), $n^{25}\mathrm{D}$ 1.5425 (reported[33] b.p. 102.5–107.5° (2 mm., $n^{20}\mathrm{D}$ 1.5426) was prepared in 27% yield by the reaction of cyclopentylmagnesium bromide with benzonitrile.

2-*p*-Methoxyphenylcyclohexanone, m.p. 88–89° (reported[34] m.p. 88.5–89.5°), was synthesized by the method of Bachmann, *et al.*[31]

Cyclopentyl *p*-Methoxyphenyl Ketone.—To cyclopentylmagnesium bromide prepared from 33 g. (1.36 g.-atoms) of magnesium and 212 g. (1.36 moles) of cyclopentyl bromide in 800 ml. of dry ether was added 45 g. (0.34 mole) of *p*-methoxybenzonitrile in 475 ml. of dry ether. After 65 hours under reflux the mixture was poured onto 500 g. of ice in 600 ml. of 10% hydrochloric acid, extracted with ether. The ether was removed and the product distilled to yield 33 g. (50%) of ketone, b.p. 139.5–141.5° (1.4 mm.), $n^{25}\mathrm{D}$ 1.5562 (reported[35] 105.5–106°, $n^{25}\mathrm{D}$ 1.5546).

2-Phenylcyclopentanecarboxaldehyde.—To 1-phenylcyclopentyl cyanide[36] (40 g., 0.23 mole) in 250 ml. of dry ether at −70° was added slowly with vigorous stirring, 2.22 g. (0.06 mole) of lithium aluminum hydride in 250 ml. of dry ether.[37] The mixture was allowed to warm slowly to room temperature and after decomposition with cold 10% hydrochloric acid extracted with ether. Distillation gave 9.2 g. of material, b.p. 90–91° (1.5 mm.), $n^{25}\mathrm{D}$ 1.5350, which on redistillation had b.p. 112° (10 mm.), $n^{25}\mathrm{D}$ 1.5352.

Anal. Calcd. for $C_{12}H_{14}O$: C, 82.7; H, 8.1. Found: C, 82.2; H, 8.2.

The 2,4-dinitrophenylhydrazone, m.p. 164.5–166°, was obtained in 88% yield. Recrystallization from ethyl acetate, ethanol and benzene–ligroin gave m.p. 166.5–167°.

Anal. Calcd. for $C_{18}H_{18}N_4O_4$: C, 61.0; H, 5.1; N, 15.8. Found: C, 61.3; H, 5.0; N, 15.9.

cis-**2-Chloro-1-phenylcyclohexenol** (*cis*-I).—Phenylmagnesium bromide prepared from 118.4 g. (0.76 mole) of bromobenzene and 18.4 g. (0.76 g.-atom) of magnesium in 350 ml. of ether was added slowly to 100 g. (0.76 mole) of 2-chlorocyclohexanone in 325 ml. of dry ether at 0°. After completion of the addition, the mixture was immediately poured onto ice in aqueous ammonium chloride and the chlorohydrin extracted into ether. Removal of the ether and distillation of the product at 0.8–1.2 mm. pressure gave 81.4 g. (56% yield) of *cis*-I, b.p. 109–111°. The chloroketone crystallized when allowed to stand at 10° and had m.p. 36–39°. After repeated recrystallization from hexane it had m.p. 40–40.8°.

Anal. Calcd. for $C_{12}H_{15}ClO$: C, 68.4; H, 7.2; Cl, 16.8. Found: C, 68.3; H, 6.9; Cl, 17.2.

To remove any *trans*-chlorohydrin which might be present[38] the *cis*-I was heated under reflux for 13.5 hours with potassium cyanide solution. The infrared spectrum was unchanged by this treatment.

Reaction of *cis*-II with Nitrous Acid.—To a solution of *cis*-II (1.000 g., 0.0523 mole) in 70 ml. of 50% aqueous acetic acid at 1° was added slowly with stirring a solution of 1.0 g. (0.012 mole) of sodium nitrite in 10 ml. of water. The mixture was stirred at 1° for 48 hours. Excess nitrous acid was destroyed with a few drops of 10% sulfamic acid solution. The neutral products were isolated by extraction with pentane, and the pentane removed by distillation under reduced pressure and finally by evaporation with a stream of air to give 0.677 g. (74.5%) of neutral product, $n^{25}\mathrm{D}$ 1.5410, 92% based on unrecovered starting material.

The neutral oil was subjected to infrared analysis with a Baird double beam spectrophotometer as follows.[39] The spectrum of an accurately weighed solution of 60–80 mg. of product in 1.0 ml. of carbon tetrachloride, was compared with the spectra of phenyl cyclopentyl ketone and 2-phenylcyclohexanone and no absorption maximum of the latter could be discerned. The spectra of known solutions of 2-phenylcyclohexanone in concentrations of 0.95, 1.95 and 3.08% in cyclopentyl phenyl ketone (no solvent) were then obtained in a 0.05-mm. cell (with a salt plate in the compensating beam to equalize light scattering). Comparison of the unknown sample with these spectra in the carbonyl region indicated that it consisted of cyclopentyl phenyl ketone with less than 1% of 2-phenylcyclohexanone.

Treatment of the product (0.200 g.) with 2,4-dinitrophenylhydrazine gave 0.401 g. of yellow plates, m.p. 135–138.5°, which after recrystallization from benzene–methanol amounted to 0.314 g., m.p. 143–144.6°, and after a second recrystallization amounted to 0.244 g., m.p. 144.5–145.4°. A mixed m.p. with authentic cyclopentyl phenyl ketone dinitrophenylhydrazone showed no depression.

Addition of 10% sodium hydroxide solution to the original acidic aqueous layer remaining from the cyclopentane extraction followed by extraction with ether gave 0.190 g. (19%) of starting material (*cis*-II), m.p. 90–92°.

Reaction of 2-Amino-*p*-methoxyphenylcyclohexanol (*cis*-VI) with Nitrous Acid.—The reaction of *cis*-VI (3.820 g., 0.0170 mole) with 4.4 g. (0.052 mole) of sodium nitrite in 100 ml. of acetic acid and 60 ml. of water at 1° was carried

---

(31) M. S. Newman and M. D. Farbman, THIS JOURNAL, **66**, 1551 (1944).

(32) W. E. Bachmann, G. I. Fujimoto and L. B. Wick, *ibid.*, **72**, 1997 (1950).

(33) F. S. Bridson-Jones and G. D. Buckley, *J. Chem. Soc.*, 3015 (1951).

(34) G. P. Mueller and R. May, THIS JOURNAL, **71**, 3313 (1949).

(35) D. H. Hey and O. C. Musgrave, *J. Chem. Soc.*, 3156 (1944).

(36) C. H. Tilford, M. G. Van Campen and R. S. Shelton, THIS JOURNAL, **69**, 2903 (1947).

(37) L. Friedman, Abstracts of the 116th Meeting at the American Chemical Society, 1949, p. 5M.

(38) M. Mousseron, J. Jullien and F. Winteritz, *Bull. soc. chim., France*, 882 (1948).

(39) The infrared spectra of the products of this and the other rearrangement reactions will be made available in the Ph.D. Dissertation of Seymour Schmukler at Columbia University and reproduced by Univ. Microfilms, Ann Arbor, Michigan.

out as above to give 2.670 g. (0.13 mole, 74 or 93% based on unrecovered starting material) of oil, $n^{25}D$ 1.5564.

Infrared analysis[39] carried out as above showed 98.8% of cyclopentyl *p*-methoxyphenyl and 1.2% of 2-*p*-methoxyphenylcyclohexanone.

Starting material (*cis*-III) recovered from the acid extracts amounted to 0.680 g. (0.0031 mole, 18%).

Reaction of *cis*-I with Silver Oxide.—*cis*-I (3.10 g., 0.015 mole) in 200 ml. of hexane was heated under reflux with stirring with 8 g. of freshly prepared and thoroughly washed silver oxide for 96 hours. The hot mixture was filtered to remove silver salts and concentrated under vacuum under nitrogen at room temperature to leave 2.51 g. of yellow oil. Microanalysis showed 2.06 ± 0.05% chlorine (Found: Cl, 2.14, 2.06, 1.98). Assuming that all the chlorine is present as *cis*- (or *trans*)-I this corresponds to 0.318 g. of chlorohydrin (I) (9.8% of starting material or 12.4% of the oil).

The infrared spectrum[39] in carbon tetrachloride showed hydroxyl absorption and carbonyl absorptions at 1715 and 1677 cm.$^{-1}$ corresponding to 2-phenylcyclohexanone and cyclopentyl phenyl ketone, respectively. A solution of 88.5 mg./ml. was prepared and the percentage transmission at 1350 and 1122 cm.$^{-1}$ used to obtain the concentrations of cyclopentyl phenyl ketone and 2-phenylcyclohexanone.

Reaction of *cis*-I with 3% ethanolic silver nitrate for 108 hours and analysis as above gave 70 wt. % of oil, which chlorine analysis indicated contained 12% of I. The infrared spectrum[39] showed three carbonyl bands at 1677, 1715 and 1727 cm.$^{-1}$ corresponding to the two ketones above and 1-phenylcyclopentanecarboxaldehyde. In addition there was nitrate ester absorption at 1560 cm.$^{-1}$ and a test for nitrogen was positive. Repetition of this rearrangement with added calcium carbonate to neutralize the acid formed eliminated the band at 1727 cm.$^{-1}$. These rearrangement conditions were not examined further.

Reaction with Nitrous Acid of *trans*-II.—*trans*-II (6.00 g., 0.031 mole) in 420 ml. of 50% aqueous acetic acid was treated with 6 g. (0.87 mole) of sodium nitrite under the conditions used with the *cis* isomer above. In this case the neutral fraction was extracted into ether, the evaporation of which left 4.53 g. of solid. The infrared spectrum[39] of this solid showed bands for hydroxyl (3571 and 3484 cm.$^{-1}$) and carbonyl (1721, 1677 cm.$^{-1}$). Nitrogen was shown to be present. The mixture was heated under reflux for 1.5 hours with 30 ml. of 10% sodium hydroxide and 20 ml. of ethanol. Extraction with pentane gave 1.43 g. of solid. The infrared spectrum[39] of this solid had no carbonyl at 1723 cm.$^{-1}$ but had intense hydroxyl bands and also carbonyl bands at 1715 and 1677 cm.$^{-1}$ characteristic of 2-phenylcyclohexanone and cyclopentyl phenyl ketone, respectively. Further extraction of the saponification mixture with ether gave 3.21 g. of liquid which crystallized slowly to give 1.96 g. (33%) of solid. Comparison of the infrared spectrum[39] with that of an authentic sample indicated it to be a mixture of phenylcyclohexanediols.

Reaction of 1-Phenylcyclohexene Oxide (III) with Nitrous Acid in Aqueous Acetic Acid.—The reaction of III (5.0 g. 0.029 mole) with 7.3 g. (0.10 mole) of sodium nitrite in 190 ml. of water containing 100 ml. of glacial acetic acid was carried out as described above for the rearrangement of *trans*-II. The reaction mixture was extracted with chloroform and ether. Trituration of the product obtained after evaporation of the solvents with pentane left 2.49 g. of solid, m.p. 62–89°, which had an infrared spectrum characteristic of the phenylcyclohexanediols.

The pentane extract gave 1.63 g. of solid which infrared analysis indicated was cyclohexanediol acetate (1721 cm.$^{-1}$) and a nitrite ester band at 1560 cm.$^{-1}$. Saponification with 10% sodium hydroxide in ethanol gave a solid with no infrared absorption[39] at 1721 cm.$^{-1}$ and a weak band for 2-phenylcyclohexanone at 1715 cm.$^{-1}$.

NEW YORK, N. Y.

[CONTRIBUTION FROM THE METCALF LABORATORIES, BROWN UNIVERSITY]

Reaction of 1,1-Dinitroethane with its Salts[1]

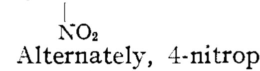
BY JOHN S. BELEW, CHARLES E. GRABIEL AND LEALLYN B. CLAPP

RECEIVED MARCH 12, 1954

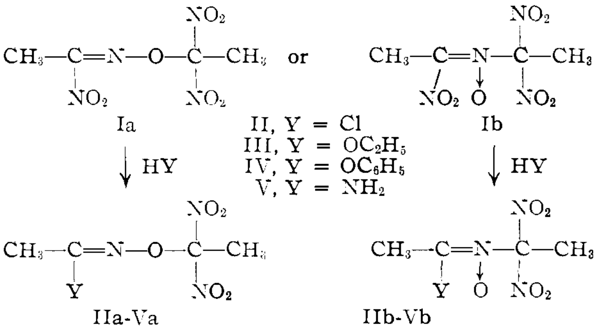
Reaction of 1,1-dinitroethane with certain amine (and ethylenimine) salts of 1,1-dinitroethane resulted in a trinitro compound identified as 2,5,5-trinitro-3-aza-4-oxa-2-hexene (or 2,4,4-trinitro-3-aza-2-pentene 3-oxide) (I). Assignment of these structures was made on the basis of reactions, degradations and infrared spectra.

During the course of trying to open the ethylenimine ring with a variety of nucleophilic agents, mononitroparaffins have been used and found only to catalyze polymerization of the imine. However, when 2,2-dimethylethylenimine was allowed to react with 1,1-dinitroethane, an acid[2] of strength comparable to propionic, a salt was formed. With a second molecule of 1,1-dinitroethane, the salt reacted to give a white crystalline compound which on the basis of reactions, degradations, and infrared spectra has been assigned the alternate structures, 2,5,5-trinitro-3-aza-4-oxa-2-hexene, (Ia) and 2,4,4-trinitro-3-aza-2-pentene 3-oxide, (Ib).

On the basis of these structures one may reasonably account for the replacement of one nitro group on carbon 2 by chlorine (II) in a reaction with alcoholic hydrogen chloride, by ethoxy (III) or phenoxy (IV) groups with the appropriate base, or by an amine group (V) with aqueous ammonia. Replacement of a nitro group by chlorine is reminiscent of a comparable displacement in a nitrolic acid,[3] and suggests the presence of the structure



$CH_3—\underset{NO_2}{C}=N—O—$ in Ia.



$$CH_3—\underset{NO_2}{C}=N—O—\overset{NO_2}{\underset{NO_2}{C}}—CH_3 \quad \text{or} \quad CH_3—\underset{NO_2}{C}=\underset{\downarrow O}{N}—\overset{NO_2}{\underset{NO_2}{C}}—CH_3$$

Ia Ib

II, Y = Cl
III, Y = OC_2H_5
IV, Y = OC_6H_5
V, Y = NH_2

$$CH_3—\underset{Y}{C}=N—O—\overset{NO_2}{\underset{NO_2}{C}}—CH_3 \qquad CH_3—\underset{Y}{C}=\underset{\downarrow O}{N}—\overset{NO_2}{\underset{NO_2}{C}}—CH_3$$

IIa-Va IIb-Vb

Alternately, 4-nitropyridine oxide is a vinylog of the nitrone structure Ib; since 4-nitropyridine oxide undergoes displacement of the nitro group by

---

[1] Presented at the Symposium on Oxides of Nitrogen, sponsored by the Office of Ordnance Research, at Chicago, Ill., September 3–4, 1953. This work was supported by Office of Ordnance Research Contract DA-19-020-ORD-592 with Brown University.

[2] H. W. Jacobson, Ph.D. Thesis, Purdue University, 1942.

[3] A. Werner and H. Buss, *Ber.*, **28**, 1280 (1895); M. Z. Jowitschitsch, *ibid.*, **39**, 786 (1906).