[CONTRIBUTION FROM NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

Control by the Axial Effect of the Course of Reaction of Cyclohexyltrimethylammonium Salts[1a]

BY DAVID Y. CURTIN, ROBERT D. STOLOW[1b] AND WALTER MAYA[1c]

RECEIVED DECEMBER 15, 1958

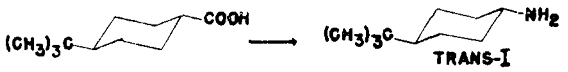
The reactions of *cis*- and *trans*-4-*t*-butylcyclohexyltrimethylammonium chloride (*cis*- and *trans*-II) and cyclohexyltrimethylammonium chloride (III) with potassium *t*-butoxide in *t*-butyl alcohol at 75° have been studied. The *cis* isomer (*cis*-II) gave 90% of the theoretical amount of trimethylamine and 10% of *cis*-4-*t*-butyl-N,N-dimethylcyclohexylamine (*cis*-IV) corresponding to 90% Hofmann elimination and 10% displacement. The *trans* isomer (*trans*-II) gave no detectable amount of Hofmann elimination products but, instead, a quantitative yield of *trans*-4-*t*-butyl-N,N-dimethylcyclohexylamine (*trans*-IV) corresponding to 100% displacement. Under these conditions, cyclohexyltrimethylammonium chloride gave 93% displacement with the formation of N,N-dimethylcyclohexylamine and 7% Hofmann elimination. These results are interpreted in terms of the axial effects of the *t*-butyl and trimethylammonium groups, and the differing steric requirements of the transition states for elimination and displacement.

In a study of the pyrolysis of the stereoisomeric menthyl- and carbomenthyltrimethylammonium hydroxides, McNiven and Read[2] observed two competing courses of reaction, elimination to give menthenes and trimethylamine on the one hand and displacement resulting in menthyldimethylamine and (presumably) methanol on the other. The major course of the reaction was controlled by the steric configuration of the quaternary salt. These results have been interpreted in terms of the axial effect.[3,4]

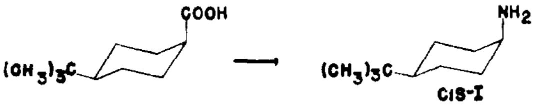
Differences in the behavior of axial and equatorial trimethylammonium groups on Hofmann elimination have been reported in the 3-substituted cholestane and coprostane systems.[5,6] In these systems, that isomer in which the trimethylammonium group is axial in the more stable conformation gave chiefly (but not exclusively) olefin and trimethylamine while the equatorial isomer gave principally the steroid tertiary amine and (presumably) methanol. The reactions were carried out by heating the dry quaternary hydroxide (or methoxide) to 160–180°.

With the objective of obtaining information about a structurally simpler system a study of the behavior in the Hofmann elimination reaction of *cis*- and *trans*-4-*t*-butylcyclohexyltrimethylammonium chloride (*cis*- and *trans*-II) was undertaken.

The reduction of 4-*t*-butylcyclohexanone oxime with sodium in ethanol had previously been reported[7] to yield *trans*-4-*t*-butylcyclohexylamine (*trans*-I). The assignment of configuration was apparently made on the basis of the method of synthesis and is supported[8] by the course of the nitrous acid deamination.[7] In the present work reduction of 4-*t*-butylcyclohexanone oxime with hydrogen and Raney nickel gave principally the same isomer (*trans*-I) as indicated by the agreement of the m.p. of the benzamide with that previously reported.[7] Catalytic hydrogenation of 4-*t*-butylcyclohexanone oxime with platinum oxide in acetic acid gave predominantly a second amine to which we have assigned the structure *cis*-4-*t*-butylcyclohexylamine (*cis*-I). The reduction conditions are those which would be expected to give *cis* product.[9,10] The amine, *cis*-I, can be more conveniently synthesized free from its isomer (*trans*-I) by treatment of *cis*-4-*t*-butylcyclohexanecarboxylic acid with hydroazoic acid (the Schmidt reaction), a procedure which has been shown to preserve the configuration at the migrating carbon atom.[11] The amines (*cis*- and *trans*-I) were readily converted to the (4-*t*-butylcyclohexyl)-trimethylammonium chlorides (*cis*- and *trans*-II) by treatment with excess methyl iodide and sodium hydroxide and then with silver chloride in order to exchange chloride for the iodide ion. The parent compound, cyclohexyltrimethylammonium chloride (III) was prepared by a similar route. The chlorides rather than the iodides were employed because of their greater solubility in *t*-butyl alcohol.



TRANS-I



CIS-I

The reagent chosen for the study of the competitive bimolecular elimination and displacement reactions of cyclohexyltrimethylammonium ion (II and III) was potassium *t*-butoxide in *t*-butyl alcohol. This reagent provides a combination of a relatively poor solvolyzing solvent and a strong base. These features were desired in order to minimize the possibility of a competing solvolysis (S_N1 or E_1) reaction.

---

[1] (a) Taken in part from the Ph.D. Thesis submitted by Robert David Stolow to the University of Illinois, 1956. Presented in preliminary form at the 132nd Meeting of the American Chemical Society, New York, N. Y., September, 1957. (b) N.S.F. Fellow, 1953–1955. (c) Pfizer postdoctoral fellow, 1957–1958.

[2] N. L. McNiven and J. Read, *J. Chem. Soc.*, 153, 159 (1952).

[3] D. Y. Curtin, *Rec. Chem. Prog. Kresge–Hooker Sci. Lib.*, **15**, 122 (1954); see also A. C. Cope and E. M. Acton, THIS JOURNAL, **80**, 355 (1958).

[4] S. Schmukler, Ph.D. Dissertation, Columbia University, 1955.

[5] R. D. Haworth, J. McKenna and R. G. Powell, *J. Chem. Soc.*, 1110 (1953).

[6] B. B. Gent and J. McKenna, *ibid.*, 573 (1956).

[7] D. V. Nightingale, J. D. Kerr, J. H. Gallagher and M. Maienthal, *J. Org. Chem.*, **17**, 1017 (1952).

[8] For references see D. H. R. Barton and R. C. Cookson, *Quart. Rev.* (*London*), **10**, 44 (1956); R. C. Cookson, *Ann. Repts. on Progr. Chem.* (*Chem. Soc. London*), **54**, 185 (1957).

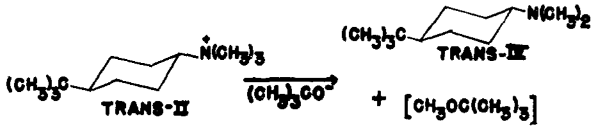
[9] A. Skita, *Ber.*, **56**, 1014 (1923).

[10] D. H. R. Barton, *J. Chem. Soc.*, 1027 (1953).

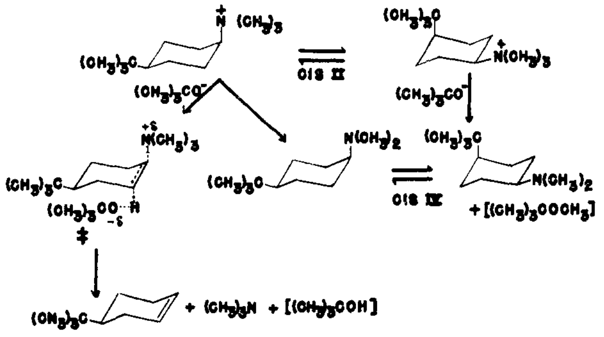
[11] See W. Klyne, "Progress in Stereochemistry," Vol. 1, Academic Press, Inc., New York, N. Y., 1954, p. 196, for references.

The reactions at 75° were carried out in sealed tubes to prevent the loss of products. The sealed tubes were opened at −80°, hydrochloric acid was added immediately to convert the amines to their hydrochlorides and then the solutions were evaporated to dryness and the hydrochloride mixture in chloroform solution was analyzed by infrared spectroscopy. The reactions were carried to completion in most cases and the weight of amine hydrochloride in general corresponded to 100 ± 3% of the calculated amount. For the isolation and identification of the resulting 4-*t*-butyl-N,N-dimethylcyclohexylamines (*cis*- and *trans*-IV) and olefin, the reactions were also carried out on a larger scale, in an open system, under an atmosphere of nitrogen.

The *trans* isomer (*trans*-II) reacted to give products which showed no visible sign of the separation of an olefin layer when added to aqueous acid. The absence of elimination of trimethylamine to yield olefin was confirmed by infrared analysis of a chloroform solution of the hydrochloride salts of the tertiary amine products, which showed no evidence of trimethylamine hydrochloride. Therefore, less than about 2% of trimethylamine could have been formed. The 4-*t*-butyl-N,N-dimethylcyclohexylamine formed was the *trans* isomer (*trans*-IV), as shown by comparison of the infrared spectrum with that of an authentic sample prepared by reductive methylation of the *trans* primary amine (*trans*-I). The only detectable course of the reaction is thus one in which the *t*-butoxide ion attacks one of the N-methyl groups to displace the tertiary amine (*trans*-IV).



The *cis* isomer (*cis*-II) gave an olefin fraction (carbon–carbon double bond stretching frequency 1657 cm.$^{-1}$) together with a mixture of amine hydrochlorides shown by infrared analysis to consist largely of trimethylamine hydrochloride. The 4-*t*-butyl-N,N-dimethylcyclohexylamine hydrochloride was isolated, and shown to be the *cis* isomer (*cis*-IV) by comparison of the infrared spectrum with that of an authentic sample prepared as in the case of *trans*-IV. The major course of the reaction then appears to have been the normal Hofmann elimination. The small amount of *cis*-4-*t*-butyl-N,N-dimethylcyclohexylamine presumably was formed from a displacement reaction of the *t*-butoxide ion on one of the N-methyl groups, the other product being *t*-butyl methyl ether.



Cyclohexyltrimethylammonium chloride (III) gave a mixture of tertiary amine hydrochlorides shown by comparison of the infrared spectrum with spectra of authentic samples to consist largely of N,N-dimethylcyclohexylamine. In agreement with this result, no cyclohexene fraction was observed. The major course of this reaction was apparently a displacement reaction of *t*-butoxide ion on one of the methyl groups.

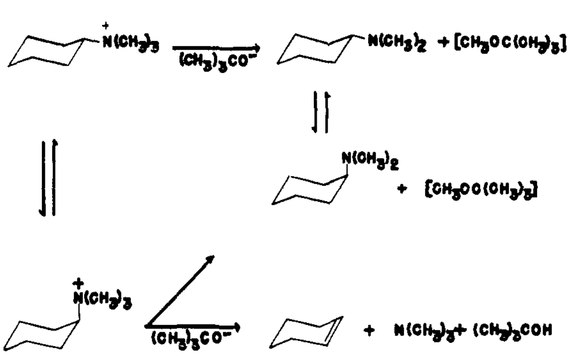


TABLE I

PRODUCTS OF THE REACTION OF CYCLOHEXYLTRIMETHYLAMMONIUM SALTS WITH POTASSIUM *t*-BUTOXIDE IN *t*-BUTYL ALCOHOL (75°)

Substituted trimethylammonium chloride	Trimethylamine (Hofmann elimination), %	Dimethylcyclohexylamine (displacement), %	[Elimination / Displacement (*R*)]
trans-4-*t*-Butylcyclohexyl (*trans*-II)	0	100	0.00
cis-4-*t*-Butylcyclohexyl (*cis*-II)	90	10	9
Cyclohexyl (III)	7	93	0.07

The results are in agreement with an analysis in terms of two competing reactions. The one, the Hofmann elimination, is favored by a *trans* coplanar arrangement in the transition state of the hydrogen atom, trimethylamine group and two carbon atoms undergoing covalency change.[12] In such a transition state, the leaving hydrogen and trimethylamine group, in a chair conformation, are axial. The second reaction, displacement on a methyl group by *t*-butoxide ion, would be expected to have a much smaller dependence of rate on the steric orientation of the trimethylammonium group.[13]

The behavior of the *cis* isomer (*cis*-II) can serve as a reference point for interpretation since in its transition states either a *t*-butyl group or a trimethylammonium group is necessarily in an equatorial position while the remaining group must be

---

[12] See D. J. Cram, Chapter 6, in "Steric Effects in Organic Chemistry," John Wiley and Sons, Inc., New York, N. Y., 1956, pp. 304 ff.

[13] Displacement at a cyclohexyl carbon atom to give *t*-butyl cyclohexyl ether would not be expected since, not only is there a statistical factor of 3 in favor of methyl attack but the SN2 displacement is generally much slower at a cyclohexyl carbon atom [see A. Streitwieser, Jr., *Chem. Revs.*, **56**, 668 (1956)].

axial when in a chair conformation.[14] It is thus a sterically balanced molecule and its behavior could be considered to be dictated primarily by factors other than conformational effects. Under such circumstances the preferred reaction is found to be the Hofmann elimination with the experimental conditions here employed. The behavior of the unsubstituted salt III may now be interpreted. Replacement of the 4-*t*-butyl group of the *cis* isomer (*cis*-II) by a hydrogen atom gives a molecule which is some 5.4 kcal. more stable when the trimethylammonium group is equatorial than when it is axial. Thus, the transition state for the elimination reaction (which requires an axial trimethylammonium group if the preferred *trans* coplanar geometry is to be achieved) is destabilized by that amount. The transition state for the displacement on an N-methyl group should be relatively indifferent to a change of the trimethylammonium group from an axial to an equatorial position. The anticipated result is that, as observed, the ratio of elimination to displacement in the reaction of the unsubstituted compound III should be considerably smaller. Finally, the *trans*-4-*t*-butyl salt (*trans*-II), which would have to place both the *t*-butyl and the trimethylammonium groups in axial positions in order to adopt the *trans* coplanar geometry for the elimination reaction through a chair transition state, gives an amount of elimination too small to be detected by infrared spectroscopy.

The results here obtained should be compared with previous results of Hofmann elimination reactions carried out by heating cyclohexyltrimethylammonium hydroxide. The principal products of this reaction were reported by Skita and Rolfes[15] to be cyclohexene and trimethylamine. Menzies and Robinson,[16] on the other hand, found 25–26% cyclohexene with cyclohexyldimethylamine as the principal product. The exact reaction conditions were not specified by these investigators, however, and it is not possible to explain the difference in their results. Cyclohexyltrimethylammonium hydroxide, when heated without a solvent at 145–160° at 11 mm. pressure, is converted to cyclohexene (62%) with the formation of only 15% of N,N-dimethylcyclohexylamine.[17] It seems likely, therefore, that the thermal decomposition of the quaternary ammonium hydroxide favors the elimination reaction in contrast to the behavior of potassium *t*-butoxide in *t*-butyl alcohol employed in the present work. Such a conclusion is also supported by the results of Haworth, McKenna and Powell[5] and Gent and McKenna.[6]

Neither elimination nor displacement was observed with hydroxide ion in aqueous solution. After treatment of cyclohexyltrimethylammonium chloride with 1 *N* aqueous potassium hydroxide at 75° for 3.5 hr., 97% of starting material was recovered. Even after treatment with 4.5 *N* aqueous potassium hydroxide at 100° for 16 hr., no trimethylamine hydrochloride nor N,N-dimethylcyclohexylamine hydrochloride could be detected by infrared examination of the salts isolated from the acidified reaction mixture. Changes of relative amounts of elimination and displacement with a change in the structure of the base employed have been previously observed.[18] Such changes are no doubt due to a combination of factors including the geometry[19] and degree of solvation of the base and its relative nucleophilic character with respect to attack on hydrogen and carbon.

Other possible paths should be considered for the formation of the elimination products in the reaction with potassium *t*-butoxide in *t*-butyl alcohol with the quaternary salts *cis*-II and III. The commonly made assumption that cyclohexane derivatives react essentially exclusively in chair conformations[20] is probably valid here. Inspection of molecular models indicates that a *trans* coplanar elimination reaction *via* a boat or other "flexible" conformation in the transition state should involve a more highly strained transition state than a reaction with a quaternary ammonium group axial in a chair conformation. A third possibility is that in the face of steric retardation of the *trans* coplanar (E2) elimination, a non-*trans* elimination may account for the olefin formed from the parent compound III. Trimethyl-(*trans*-2-phenylcyclohexyl)-ammonium hydroxide has been shown to behave in this way.[21] On heating it is converted to a mixture of 1-phenylcyclohexene and 3-phenylcyclohexene.[22] The 1-phenyl product has been shown to be formed directly and not by isomerization of the 3-phenylcyclohexene since the 3-isomer has been shown to be stable under simulated reaction conditions.[21] In this case, with the axial effects of the phenyl and trimethylammonium groups combining to retard the "normal" *trans*-elimination (which would necessarily lead to 3-phenylcyclohexene), the competing reaction which becomes important has been postulated to be a non-*trans* elimination involving removal of a proton alpha to the phenyl group. Such a process would be accelerated by the phenyl ring[23] and is therefore less probable in the examples with which we are dealing. The observation that no detectable elimination (and therefore no *cis* elimination) occurred in the reaction with *t*-butoxide when a 4-*t*-butyl group was placed in a *trans* position of the parent compound III leads us tentatively to favor the suggestion that the olefin formed from III came from a *trans* elimination with the trimethyl-

---

[14] It has been estimated by S. Winstein and N. J. Holness [THIS JOURNAL, **77**, 5562 (1955)] that the *t*-butyl group is at least 5.4 kcal. less stable in an axial position than in an equatorial one. It will be noted that the molecular dimensions of an unsolvated trimethylammonium group are nearly the same as those of a *t*-butyl group.

[15] A. Skita and H. Rolfes, *Ber.*, **53**, 1250 (1920).

[16] R. C. Menzies and R. Robinson, *J. Chem. Soc.*, **125**, 2165 (1924).

[17] A. C. Cope, R. A. Pike and C. F. Spencer, THIS JOURNAL, **75**, 3212 (1953).

[18] C. K. Ingold and C. S. Patel, *J. Chem. Soc.*, 68 (1933).

[19] H. C. Brown, I. Moritani and Y. Okamoto, THIS JOURNAL, **78** 2193 (1956).

[20] The boat form of cyclohexane has been estimated to be more than 6 kcal. less stable than the chair form (see W. G. Dauben and K. S. Pitzer, Chapter 1, p. 14, in ref. 12).

[21] J. Weinstock and F. G. Bordwell, THIS JOURNAL, **77**, 6706 (1955).

[22] R. T. Arnold and P. N. Richardson, *ibid.*, **76**, 3619 (1954).

[23] See J. Weinstock, R. G. Pearson and F. G. Bordwell, *ibid.*, **78**, 3468 (1956).

ammonium group forced into an axial position in a chair transition state.

A more quantitative discussion of these results is of some interest since it illustrates a general method and provides a check on the reasonableness of our data. Following the analysis employed by Winstein and Holness,[14] and Eliel, Ro and Lukach,[24] the rate constant for displacement by both an axial and an equatorial path

$$\begin{tikzcd} \text{olefin} & \text{a} \arrow[l, "k_a^E"'] \arrow[r, "k_a^S"] \arrow[d, shift right] & \text{displacement products} \\ & \text{e} \arrow[u, shift right] \arrow[ur, "k_e^S"'] & \end{tikzcd}$$

is given[14] by

$$k^S = k_e^S N_e + k_a^S N_a$$

and that for elimination (elimination by way of an equatorial path is assumed to be negligible) by

$$k^E = k_a^E N_a$$

Here the symbols have the following significance.

a = conformation of any of the quaternary salts with the trimethylammonium group axial

e = conformation of the same salt with the same group equatorial

k^S = total rate constant for displacement

k^E = total rate constant for elimination

k_a^S = specific rate constant for displacement on conformation a (through an axial transition state)

k_e^S = specific rate constant for displacement on conformation e (through an equatorial transition state)

k_a^E = specific rate constant for elimination of conformation a (through an axial *trans*-coplanar transition state)

N_a = mole fraction of a

N_e = mole fraction of e

If it be assumed that the rate constants k_e^S, k_a^S and k_a^E are independent of the presence, absence or steric orientation of a *t*-butyl group in the 4-position of the cyclohexane ring and further that all displacements and eliminations are of the same kinetic order (presumably first order in *t*-butoxide and first order in trimethylammonium ion or else first order in trimethylammonium *t*-butoxide ion pairs), then the ratios of elimination product (trimethylamine) to displacement product (an N,N-dimethylcyclohexylamine) are given for the *cis*-4-*t*-butyl and unsubstituted quaternary ions as

$$\left[\frac{\text{elimination}}{\text{displacement}}\right]_{cis} = R_{\text{cis}} = \frac{k_a^E N_a^{\text{cis}}}{k_e^S N_e^{\text{cis}} + k_a^S N_a^{\text{cis}}}$$

$$\left[\frac{\text{elimination}}{\text{displacement}}\right]_{\text{unsub}} = R_{\text{uns}} = \frac{k_a^E N_a^{\text{uns}}}{k_e^S N_e^{\text{uns}} + k_a^S N_a^{\text{uns}}}$$

R_{cis} and R_{uns} are the ratios defined in these equations. Solution of these two simultaneous equations gives the relative rates of displacement by *t*-butoxide ion on the equatorial and axial trimethylammonium groups in terms of the observed ratios of elimination and displacement products.

$$\frac{k_e^S}{k_a^S} = \frac{R_{\text{uns}} - R_{\text{cis}}}{R_{\text{cis}}K_{\text{cis}} - R_{\text{uns}}K_{\text{uns}}} \text{ where } K_{\text{cis}} = \frac{N_e^{\text{cis}}}{N_a^{\text{cis}}};\ K_{\text{uns}} = \frac{N_e^{\text{uns}}}{N_a^{\text{uns}}}$$

Using values of $R_{\text{uns}} = 0.07$ and $R_{\text{cis}} = 9$ (from Table I) and taking $K_{\text{cis}} = 1$ and $K_{\text{uns}} = 2{,}500$ (calculated for 75° from the Winstein and Holness estimate of a 5.4 kcal. difference in energy between *t*-butyl axial and equatorial[14]) the calculated value of k_e^S/k_a^S is $^1/_{20}$. That is, displacement is a factor of about 20 faster when the trimethylammonium group is axial than when it is equatorial. Since this value is rather sensitive to the choice of the experimentally as yet undetermined conformational equilibrium constants, K_{cis} and K_{uns}, it can be considered only a rough approximation, but at least it is reasonable since it might be expected that a trimethylammonium group is crowded in its axial position and that a certain amount of strain should be relieved in going to the transition state leading to the less crowded tertiary amine. Since the equatorial trimethylammonium group is less crowded, its conversion to tertiary amine (and correspondingly to the transition state) might have less relief of strain. An argument in terms of solvation differences leads to the same result.

Information bearing on this point has been obtained[6] from a study of the rates of displacement on methyl iodide of axial and equatorial tertiary amines, reactions which are similar to the reverse of the displacement reactions involved in the present work. It would be expected that the rate of formation of the more crowded axial trimethylammonium group would be slower than the rate of formation of the equatorial trimethylammonium group. The rate of methylation of the equatorial 3-dimethylaminocholestane with methyl iodide in nitrobenzene-benzene was greater than that of the axial isomer by a factor of 150 at 0°, and 72 at 25°,[6] in agreement with expectation.

It should be pointed out that a calculation of the ratio of elimination to displacement for the *trans*-4-*t*-butyl compound (*trans*-II) by the method above gives $R_{\text{trans}} = 10^{-5}$ in agreement with the value of 0.00 found (Table I), assuming that the axial effects of the *t*-butyl and trimethylammonium groups are additive (*i.e.*, $K = 10^7$) and assuming an axial *trans* coplanar transition state for elimination.

From the equation for R_{cis} above and the value of $^1/_{20}$ for k_e^S/k_a^S it is found that the ratio of axial elimination to axial substitution (k_a^E/k_a^S) is 9, that is, the preferred reaction of the axial conformation is elimination, but by a relatively small margin. Thus the relative values of the specific rate constants are estimated to be $k_e^S = 1$, $k_a^S = 20$ and $k_a^E = 180$.

Experimental[25]

trans-4-*t*-**Butylcyclohexylamine**[7] (*trans*-I).—4-*t*-Butylcyclohexanone oxime (28.2 g., 0.167 mole) was hydrogenated in ethanol over 6 g. of Raney nickel at 70–80° and 2000 p.s.i. After filtration of the catalyst the solvent was distilled and replaced by 250 ml. of reagent grade toluene. The amine hydrochloride, formed by bubbling in anhydrous hydrogen chloride, was collected by filtration, washed with toluene and dried to give 6.8 g. of *trans*-I hydrochloride, m.p. (uncor.) 330°. A second crop of 1.4 g. was obtained by cooling the filtrate to −10° for 2 hr. Comparison of the infrared spectrum of the first crop with that of authentic *cis*-I hydrochloride described below showed no contamina-

---

(24) E. L. Eliel and R. S. Ro, *Chemistry & Industry*, 251 (1956); E. L. Eliel, and C. A. Lukach, THIS JOURNAL, **79**, 5986 (1957).

(25) All melting points are corrected, unless labeled otherwise. All boiling points are uncorrected. Many of the infrared spectra are reproduced in the Ph.D. Thesis of R.D.S., available from University Microfilms, Ann Arbor, Mich.; see *Dissertation Abstracts*, **17**, 751 (1957). The microanalyses were performed by Mr. Jozsef Nemeth, Mrs. R. Maria Benassi, Mrs. Ruby Ju and Miss Claire Higham of the University of Illinois Microanalytical Laboratory.

tion of the product by the *cis* isomer. The total yield of hydrochloride was thus 8.2 g. (26%). Although the hydrochloride is appreciably water-soluble (*ca.* 13 g./100 ml.) it was purified by recrystallization from carefully limited amounts of water.

Anal. Calcd. for $C_{10}H_{22}ClN$: C, 62.6; H, 11.6; N, 7.3. Found: C, 62.7; H, 11.5; N, 7.2.

Concentration of the toluene filtrate from which the hydrochloride fractions above had been crystallized gave a paste which was extracted with successive portions of hot water. The aqueous solution of amine hydrochloride, freed from toluene by extraction, was treated with 8 g. of sodium hydroxide in 11 ml. of water added through a layer of hexane. After extraction of the liberated amine with hexane it was distilled through a four-foot spiral wire column[26] in a nitrogen atmosphere. The large column was desirable because of a tendency of the charge to foam at the beginning of the distillation. The distillate was a mixture (b.p. 107° (32.5 mm.), $n^{25}D$ 1.464) of *cis*- and *trans*-4-*t*-butylcyclohexylamine (31%) which was not separated by distillation but from which derivatives of each component could be isolated. The sample analyzed was exposed to the air briefly. The analysis is consistent with pure 4-*t*-butylcyclohexylamine plus 1% of carbon dioxide.

Anal. Calcd. for $C_{10}H_{21}N$: C, 77.4; H, 13.6; N, 9.0. Calcd. for $C_{10}H_{21}N + 1\%\ CO_2$: C, 76.9; H, 13.5; N, 8.9. Found: C, 76.6; H, 13.6; N, 8.9.

The amine mixture rapidly formed a white solid, m.p. 67–76.5° (Fisher–Johns apparatus), probably a carbonate mixture, on exposure to air, but remained a colorless liquid for over a year when stored in a sealed glass tube. The *trans*-amine is reported to be a solid, m.p. 81–83°, b.p. 142–145° (19 mm.).[7]

N-(*trans*-4-*t*-Butylcyclohexyl)-benzamide (0.48 g., 70%, m.p. 179.5–180°) was obtained from 0.5 g. of the original hydrochloride fraction and after recrystallization from cyclohexane had m.p. 179–179.5°. The reported[7] m.p. is 178–179°.

N-Salicyliden-*trans*-4-*t*-butylcyclohexylamine was prepared from the *trans*-hydrochloride (4.10 g., 0.0214 mole) which was first converted to the free amine with 4.3 g. of sodium hydroxide in 10 ml. of water under 100 ml. of pentane. The pentane extract was added to 2.26 g. (0.0216 mole) of salicylaldehyde and the solution heated on a steam-bath for 20 min. After the addition of 20 ml. of methanol the solution was concentrated and cooled to 0° to give the crystalline, yellow salicylidene derivative which after washing with 40 ml. of 97% methanol amounted to 5.08 g. (92%) and had m.p. 130–133°. The infrared spectrum of a 9% solution in carbon tetrachloride showed no N–H stretching characteristic of the amine but had diffuse O–H stretching from 2200 to 3000 cm.$^{-1}$.

Anal. Calcd. for $C_{17}H_{25}NO$: C, 78.7; H, 9.7. Found: C, 78.7; H, 9.7.

***trans*-4-*t*-Butylcyclohexanecarboxylic Acid.**—Crude *cis*-4-*t*-butylcyclohexanecarboxylic acid[27] (36.0 g., 0.196 mole) was converted to the methyl ester by way of the acid chloride. The ester was dissolved in a solution of sodium methoxide prepared from 250 ml. of absolute methanol and 9.2 g. (0.40 mole) of sodium, and allowed to reflux for 12 hr., protected from moisture. The ester was hydrolyzed by the addition of excess water. The crude acid, 34.9 g., which the infrared spectrum showed to be almost pure *trans*, was recrystallized from hexane, yielding 24.9 g. (70%) of *trans*-acid, m.p. 173–176°, infrared spectrum identical with that of an authentic sample.[27]

Rearrangement of *trans*-4-*t*-Butylcyclohexanecarboxylic Acid.—*trans*-4-*t*-Butylcyclohexanecarboxylic acid (9.2 g., 0.050 mole) in 50 ml. of chloroform with 25 ml. of sulfuric acid (0.5 mole) in 50°, was treated with sodium azide (10 g., 0.15 mole) added in small portions through a side arm over a period of 45 min., while the solution was stirred. The reaction mixture was left at room temperature with stirring for 12 hr., refluxed on a steam-bath for 4 hr., and then slowly poured into 1 l. of water and heated for 1 hr. more, to ensure decomposition of the isocyanate. The mixture was made basic with an excess of sodium hydroxide, and the amine taken up in pentane. The extract, after drying with potassium hydroxide, was distilled from the pentane, and the residue vacuum transferred. There was obtained 7.6 g. (98%) of *trans*-I, $n^{20}D$ 1.4630.

***cis*-4-*t*-Butylcyclohexylamine (*cis*-I). (A) Reduction of 4-*t*-Butylcyclohexanone Oxime.**—The oxime (15.4 g., 0.091 mole) was reduced in glacial acetic acid (170 ml.) with hydrogen over platinum oxide at room temperature. After 17 min., 97% of the theoretical amount of hydrogen had been absorbed. Evaporation of the acetic acid solution to dryness after conversion of the amines to the hydrochlorides with 7.8 ml. (0.091 mole) of concentrated hydrochloric acid in 2 ml. of water was followed by the addition of 45 ml. of 0.44 *N* aqueous hydrochloric acid and a second evaporation to dryness. The residue was heated for 0.5 hr. with 250 ml. of water containing 5 ml. of 2 *N* hydrochloric acid and allowed to stand for 8 hr. after which it was filtered. Water-insoluble material, 2.4 g., probably a mixture of secondary amine hydrochlorides, remained on the filter. A sample, recrystallized from methanol–acetone, had m.p. 360°. Evaporation of the aqueous filtrate gave 14.0 g. (80%) of amine hydrochlorides, m.p. 240–257°. The amine hydrochlorides were dissolved in 120 ml. of water and converted to the free amines by the addition of 5.1 g. of sodium hydroxide in 25 ml. of water through a layer of 100 ml. of hexane. The amines were extracted with hexane, and after drying, were chromatographed on a column of Merck aluminum oxide (4.0 × 72 cm.). After elution with hexane-benzene-ether mixtures, which gave only small amounts of material from the column, ethanol was used as the eluent to give two fractions (260 ml.) which upon addition of hydrogen chloride, followed by evaporation to dryness, gave 2.1 g. of solid amine hydrochloride. Recrystallization from 40 ml. of a 2-propanol–acetone mixture gave 1.08 g. of *cis*-amine hydrochloride, m.p. 283°. A second crop of 0.39 g. was also obtained to give a total of 1.47 g. (10.5%).

The first crop of the hydrochloride of *cis*-I (1.08 g., 0.0057 mole) was converted to **N-salicylidene-*cis*-4-*t*-butylcyclohexylamine** (1.0 g., 68%, m.p. 65.5–67°, yellow crystals from methanol) by the procedure described for *trans*-I above. The infrared spectra of the *cis*- and *trans*-salicylidene derivatives have maxima at the same positions in the region of 1500–4000 cm.$^{-1}$.

Anal. Calcd. for $C_{17}H_{25}NO$: C, 78.7; H, 9.7; N, 5.4. Found: C, 79.1; H, 9.8; N, 5.4.

The N-salicylidene derivative (0.34 g., 1.3 mmoles) was readily hydrolyzed to the *cis*-amine (*cis*-II) by treatment with 5.8 *N* hydrochloric acid for 40 min. on a steam-bath. **The amine hydrochloride** crystallized directly from the acid solution on cooling and after precipitation from methanol with acetone and washing with acetone and ether amounted to 0.17 g. (68%), m.p. 282° (Fisher–Johns apparatus).

Anal. Calcd. for $C_{10}H_{22}NCl$: C, 62.6; H, 11.6; N, 7.3. Found: C, 62.3; H, 11.4; N, 7.2.

(B) Rearrangement of *cis*-4-*t*-Butylcyclohexanecarboxylic Acid Azide.—*cis*-4-*t*-Butylcyclohexanecarboxylic acid[27] (8.03 g., 0.0435 mole, m.p. 117.5–118.5°) in 75 ml. of chloroform with 22 ml. (0.83 equivalent) of sulfuric acid was treated with 31.5 ml. of a solution of hydrazoic acid in chloroform (1.58 *N*, 0.0498 mole) added with stirring over a period of 2.2 hr. at 37–38°.[28] After 2 hr. at 40–50° the solution was slowly poured into 500 g. of ice-water, non-ionic products (only a very small amount of solid residue) extracted with chloroform and the free amine (*cis*-I) was liberated by the addition of 70 g. (1.7 moles) of sodium hydroxide in 80 ml. of water through a layer of 270 ml. of hexane in a nitrogen atmosphere. After the hexane extracts were dried (under nitrogen) and the solvent evaporated the amine was distilled through a four-foot spiral-wire column.[26] A total of 6.8 g. (90%) of *cis*-I, b.p. 90° (15 mm.), $n^{25}D$ 1.4659, was obtained.

N-(*cis*-4-*t*-Butylcyclohexyl)-benzamide, prepared from the above sample of amine (*cis*-I), had m.p. 156–157° without purification and after recrystallization from aqueous methanol had m.p. 158.5–158.7°.

Anal. Calcd. for $C_{17}H_{25}NO$: C, 78.7; H, 9.7; N, 5.4. Found: C, 78.9; H, 9.6; N, 5.5.

N,N-Dimethylcyclohexylamine.—Cyclohexylamine, b.p.

---

[26] J. Cason and H. Rapoport, "Laboratory Text in Organic Chemistry," Prentice-Hall, Inc., New York, N. Y., 1950, p. 237.

[27] R. D. Stolow, THIS JOURNAL, in press.

[28] H. Wolff, in "Organic Reactions," Vol. 3, edited by R. Adams, John Wiley and Sons, Inc., New York, N. Y., 1946, pp. 327 ff.; F. R. Hewgill, P. R. Jefferies and A. K. Macbeth, *J. Chem. Soc.*, 699 (1954).

132–133°, $n^{20}\mathrm{D}$ 1.4585 (25.0 ml.), was added slowly with cooling to 53.0 g. (45 ml.) of formic acid (88–90%, reagent grade) and 50 ml. of 40% formaldehyde was then added. The procedure is based on that employed for the preparation of N,N-dimethyl-2-phenylethylamine.[29]

The product (25 ml., b.p. 151–155.5°) was isolated by distillation. A part of the product was fractionated from 0.5 g. of sodium metal in a nitrogen atmosphere. The center fraction, b.p. 80.4(52.8 mm.)–80.8° (53.0 mm.) had $n^{25}\mathrm{D}$ 1.4519 (reported[30] $n^{25}\mathrm{D}$ 1.4517, b.p. 75° (47 mm.)).

N,N-Dimethylcyclohexylamine hydrochloride was prepared by bubbling anhydrous hydrogen chloride into a solution of 520 mg. of N,N-dimethylcyclohexylamine ($n^{25}\mathrm{D}$ 1.4518) in 15 ml. of anhydrous ether. The product had m.p. 224–226° when taken in a capillary tube heated from 25° (reported[31] 226–227°).

The 4-*t*-butyl-N,N-dimethylcyclohexylamines (*cis*- and *trans*-IV) were prepared by the same procedure used for N,N-dimethylcyclohexylamine, employing the respective primary amines (*cis*- and *trans*-I). The tertiary amines were obtained in 42% yield; *cis*-IV, $n^{20}\mathrm{D}$ 1.4642; *trans*-IV, $n^{20}\mathrm{D}$ 1.4638.

The hydrochlorides were prepared by the same procedure as for the parent compound. **The *cis*-IV hydrochloride** had m.p. 285° dec.

Anal. Calcd. for $C_{12}H_{26}ClN$: C, 65.6; H, 11.9. Found: C, 65.6; H, 11.8.

The *trans*-IV hydrochloride had m.p. 300° dec.

Anal. Calcd. for $C_{12}H_{26}ClN$: C, 65.6; H, 11.9. Found: C, 65.7; H, 11.9.

Cyclohexyltrimethylammonium Iodide (3.7 g., 94%, m.p. 278–278.2° dec., after recrystallization from ethanol) was prepared from dimethylcyclohexylamine[16] (1.87 g., 0.0147 mole) and methyl iodide (1.1 ml., 0.018 mole) in absolute ether (40 ml.). A second method adapted from that of Willstätter[32] which consisted of treating cyclohexylamine (28 ml., 0.24 mole) in 120 ml. of ethanol with a total of 61 ml. (0.98 mole) of methyl iodide added in portions with 20.6 g. (0.51 mole) of sodium hydroxide under reflux for 4 hr. gave 52% of material, m.p. 274–278° dec., after recrystallization from ethanol. Literature values for the m.p. are 277°,[15] 271.5–271.8° dec.,[33a] 292° and 285–286°.[33b] Titration[34] of a 0.4558-g. sample with 0.1 *N* perchloric acid in glacial acetic acid in the presence of mercuric acetate gave an equivalent weight of 271.4 (calcd. for $C_9H_{20}NI$, 269.2).

Cyclohexyltrimethylammonium chloride (III) was prepared from the quaternary iodide by an adaptation of procedure of Ford-Moore[35] by treatment with silver chloride. The chloride, unlike the iodide, was quite hygroscopic, and had m.p. *ca.* 310° dec.

***trans*-4-*t*-Butylcyclohexyltrimethylammonium Iodide.**—The amine (*trans*-I) was regenerated from its hydrochloride (1.00 g., 0.0052 mole) with aqueous sodium hydroxide and was simultaneously extracted with 17 ml. of pentane. The pentane solution and a second pentane extract (10 ml.) were added directly to a solution of 2 ml. of methyl iodide in 4 ml. of methanol. The solution was concentrated to about 5 ml. Methanol (1.4 ml.) was added. During 3.3 hr., an additional 4 ml. (0.064 mole) of methyl iodide and a total of 0.48 g. (0.012 mole) of sodium hydroxide pellets were added alternately, in portions, to the refluxing solution. After 1 hr. under reflux, the solution was evaporated to dryness. The ether-insoluble salts obtained were extracted with 40 ml. of hot chloroform in seven portions. The extract was concentrated, the chloroform was replaced by 1:1 2-propanol–*t*-butyl alcohol, and the trimethylammonium iodide crystallized to yield 1.60 g. (94%) of white platelets, m.p. 308° dec. (sample inserted into bath at 307°). Recrystallization from 10 ml. of 2-propanol yielded 1.33 g. of the desired iodide. The analytical sample was recrystallized from a diethyl ether–methanol mixture.

Anal. Calcd. for $C_{13}H_{28}NI$: C, 48.0; H, 8.7; N, 4.3. Found: C, 47.9; H, 8.7; N, 4.4.

***cis*-4-*t*-Butylcyclohexyltrimethylammonium Iodide.**—A procedure similar to that described above for the *trans* isomer was employed to convert the amine (*cis*-I) to the corresponding trimethylammonium iodide in 97% yield. The iodide was recrystallized from 2-propanol. The infrared spectra of the *cis*- and *trans*-trimethylammonium iodides (10.0% solutions in chloroform) were essentially identical in the region 1400–4000 cm.$^{-1}$, but in the region 800–1400 cm.$^{-1}$, distinct differences appear in the spectra.[15]

Anal. Calcd. for $C_{13}H_{28}NI$: C, 48.0; H, 8.7; N, 4.3; I, 39.0. Found: C, 47.9; H, 9.0; N, 4.2; I, 39.1.

***cis*- and *trans*-4-*t*-Butylcyclohexyltrimethylammonium chloride** (*cis*- and *trans*-II) were prepared from the trimethylammonium iodides by the method described above for the parent compound III. The hygroscopic white salts were dried in a vacuum desiccator over phosphorus pentoxide before use.

Reactions of the Trimethylammonium Chlorides (*cis*-II, *trans*-II, and III) **with Potassium *t*-Butoxide in *t*-Butyl Alcohol.**—In a dry-box a sample of the trimethylammonium chloride (about 1 millimole weighed to one part in one thousand) which had previously been dried at 20 mm. over phosphorus pentoxide was placed in a 16 × 150 mm. Pyrex test-tube sealed at one end and constricted to about 4 mm. at the other. The tube was then further constricted to about 1 mm., evacuated to 0.3 mm. and filled with dry nitrogen. Then a measured volume (4–6 ml.) of standard potassium *t*-butoxide[36] solution (0.78–0.94 *N*) was added from a syringe. The tube was sealed, placed in a bath at 75.0° and shaken by hand for 3 min. until all of the starting material had dissolved, after which it was allowed to stand for the specified time. The tube was then cooled to −80° and opened. Excess standard aqueous hydrochloric acid (about 1 *N*) was added with a syringe and the tube was then immediately inverted into 20 ml. of water. Great care was taken to prevent the escape of trimethylamine (b.p. 3°). As the frozen reaction mixture melted the solution appeared homogeneous in the mixtures from the parent salt (III) and the *trans*-salt (*trans*-II), but there was a visible second layer (of olefin) in the reaction mixture from the *cis* isomer (*cis*-II). In the latter case the olefin was extracted with carbon tetrachloride and the infrared spectrum of the carbon tetrachloride solution determined. In all cases the aqueous solution so obtained was evaporated to dryness and the mixture of tertiary amine hydrochlorides was dissolved in chloroform and submitted to infrared analysis.

Methods of Determination of the Composition of Tertiary Amine Product Mixtures from the Reactions with Potassium *t*-Butoxide at 75°. (A) Cyclohexyltrimethylammonium Chloride (III).—The compositions of amine hydrochloride mixtures from two reactions, run 3 carried out for 3 hr., and run 4, for 36 min., were determined from pairs of simultaneous equations describing the absorbancies at two wave lengths[37] of chloroform solutions in sodium chloride cells using a Perkin–Elmer model 21 infrared spectrophotometer. Trimethylamine hydrochloride has a strong absorption maximum at 993 cm.$^{-1}$ which is absent in N,N-dimethylcyclohexylamine hydrochloride while the latter compound has strong absorption maxima at 1005, 995 and 900 cm.$^{-1}$ which are absent in trimethylamine hydrochloride. Because of the difficulty of determining accurately the absorbancy of the authentic sample of trimethylamine hydrochloride at 1005 cm.$^{-1}$ (this frequency occurs on the steep side of the 993 cm.$^{-1}$ band) the spectrum of a known mixture of trimethylamine hydrochloride (7.3%) and N,N-dimethylcyclohexylamine hydrochloride (92.7% by weight) were employed for the calculations, using this frequency together with the spectra of a known 10% solution of N,N-dimethylcyclohexylamine hydrochloride and the

---

[29] R. N. Icke, B. B. Wisegarver and G. A. Alles, "Organic Syntheses," Coll. Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1955, p. 723.

[30] J. D. Roberts and V. C. Chambers, THIS JOURNAL, **73**, 5030 (1951).

[31] T. D. Perrine, *J. Org. Chem.*, **16**, 1303 (1951).

[32] R. Willstätter, *Ann.*, **317**, 220 (1909).

[33] (a) D. R. Howton, THIS JOURNAL, **69**, 2556 (1947); (b) M. Matayer, *Bull. soc. chim. France Mem.*, [5] **17**, 1050 (1950).

[34] S. Siggia, "Quantitative Organic Analysis via Functional Groups," 2nd ed., John Wiley and Sons, Inc., New York, N. Y., 1954, p. 118.

[35] A. H. Ford-Moore, *Org. Syntheses*, **30**, 12 (1950).

[36] R. H. Hunt, L. J. Chinn and W. S. Johnson, *ibid.*, **34**, 55 (1954); W. S. Johnson and W. P. Schneider, *ibid.*, **30**, 18 (1950).

[37] H. H. Willard, L. L. Merritt and J. A. Dean, "Instrumental Methods of Analysis," D. Van Nostrand Co., Inc., New York, N. Y., 1948, pp. 2 and 7.

spectra of the reaction products to be analyzed. The results are

	Frequencies employed, cm.$^{-1}$	N,N-Dimethylcyclohexylamine hydrochloride, mole, %	Trimethylamine hydrochloride, mole %
Run 3 (3 hr.)	993, 1005	93.8	6.2
	900, 993	93.2	6.8
Run 4 (36 min.) (expanded scale)	993.7, 1003.8	92.9	7.1
	Average	93.3	6.7

The yields of mixed hydrochlorides amounted to 98 and 105% of theoretical.

(B) ***trans*-4-*t*-Butylcyclohexyltrimethylammonium Chloride** (*trans*-II).—The reaction, carried out at 75° for 150 min., gave an infrared spectrum (10% chloroform solution) which showed no detectable amount of starting material. The absorption intensity at 993.7 cm.$^{-1}$ (expanded scale) showed that no more than 2% (by weight) of trimethylamine hydrochloride could be present. Comparison of the spectrum with that of the product from a reaction of *trans*-4-*t*-butylcyclohexyltrimethylammonium iodide isolated in such a way that all trimethylamine should have been removed by aqueous extraction and evaporation indicated that the percentage of trimethylamine hydrochloride was 0. The weight of hydrochloride isolated corresponded to 100.2% of the theoretical amount of *trans*-4-*t*-butyl-N,N-dimethylcyclohexylamine hydrochloride. For the characterization of the tertiary amine formed, another run was made in a large scale (fourfold), carried out under a nitrogen atmosphere, using a reflux condenser. The tertiary amine was isolated as before, and purified by freeing the amine, and reforming the hydrochloride. *trans*-4-*t*-Butyl-N,N-dimethylcyclohexylamine (*trans*-IV) hydrochloride was isolated in 90% yield, and its infrared spectrum was identical to that of the *trans*-IV hydrochloride prepared above.

(C) ***cis*-4-*t*-Butylcyclohexyltrimethylammonium Chloride** (*cis*-II).—Since the presence of starting material in the product would interfere with the method of analysis, it was first shown by examination of the 890 cm.$^{-1}$ region of the infrared spectrum (where the starting material has strong absorption) that there was less than 2% of the quaternary chloride (*cis*-II) in the product. Since there was a decision as to the choice of the base-line to be made, each calculation was made twice, once using each of two extreme base-lines. The results were again calculated employing pairs of simultaneous equations at two frequencies (993.7 and 1375 cm.$^{-1}$), the data for the 993.7 band being obtained from an expanded scale spectrum of that region. The values used were the average of those presented here.

	4-*t*-Butyl-N,N-dimethylcyclohexylamine hydrochloride, %	Trimethylamine hydrochloride, %
Run 10	8.8	91.2
(180 min.)	10.4	89.6
Run 12	9.0	91.0
(150 min.)	10.4	89.6

The weight of hydrochloride isolated from run 12 corresponds to 97.4% of that calculated for a mixture of the composition indicated by the data above.

To characterize the tertiary amine and olefin formed, another run was made in a larger scale (fourfold), carried out as in the case of the *trans*-quaternary ammonium salt. The olefin fraction was extracted with methylene chloride, and after evaporation of the solvent, vacuum transfer and drying with magnesium sulfate, 41% of the olefin was isolated, $n^{25}\text{D}$ 1.4565 (reported[14] for 4-*t*-butylcyclohexene $n^{20}\text{D}$ 1.4583). There was good agreement of the spectrum of this olefin with that of 4-*t*-butylcyclohexene obtained with a Baird instrument.[38] *cis*-4-*t*-Butyl-N,N-dimethylcyclohexylamine (*cis*-IV) was isolated in 3.5% yield by a procedure identical to that employed in the case of *trans*-amine. The infrared spectrum of this sample was identical with that of the *cis*-IV prepared above.

Attempted Reaction of Cyclohexyltrimethylammonium Chloride (III) with Aqueous Potassium Hydroxide.—When 156 mg. (0.882 mmole) of III was heated for 3.5 hr. with 5.00 ml. of 0.97 *N* potassium hydroxide at 75°, extraction from chloroform gave 151 mg. (97%) of hygroscopic residue with an infrared spectrum essentially identical with that of the starting material. When a similar reaction was carried out by treating 159 mg. of III with 1.00 ml. of 4.54 *N* potassium hydroxide in a sealed tube in a steam-bath for 16 hr. the residue from chloroform of 177 mg. (111%) had an infrared spectrum which contained all the bands of the starting material and, in addition, broad absorption in the ranges of 3040–3500 and 1035–1200 cm.$^{-1}$.

Dissociation Constants of *cis*- and *trans*-I Hydrochlorides.—The apparent dissociation constants, determined in 66% dimethylformamide–34% water, did not differ sufficiently to provide a method of conformational analysis. The pK_a of *cis*-4-*t*-butylcyclohexylamine hydrochloride was 10.27 and that for *trans*-4-*t*-butylcyclohexylamine hydrochloride 10.35.[39]

---

(38) This spectrum was provided for Prof. E. Eliel by Prof. S. Winstein to both of whom we are indebted for its use.

(39) We are indebted to Dr. H. Boaz, Eli Lilly and Co., Indianapolis, Ind., for these determinations. The reported relative error is ±0.05.

URBANA, ILL.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY AND CHEMICAL ENGINEERING, STANFORD UNIVERSITY]

The Stereochemical Course of the Raney Nickel-catalyzed Cleavage of 2-Arylethanols[1,2]

BY WILLIAM A. BONNER AND THOMAS W. GREENLEE

RECEIVED NOVEMBER 17, 1958

The stereochemical course of the Raney nickel-catalyzed C1–C2 cleavage of optically active (−)-2-methyl-2-phenyl-1-butanol (B) to 2-phenylbutane has been investigated, with the observation that B yielded (+)-2-phenylbutane ((+)-F) of 68–70% optical purity. Comparative optical rotatory data are presented which strongly suggest that the conversion of B to (+)-F proceeded with predominant *inversion* of configuration. These conclusions are in accord with a mechanism involving concerted S$_\text{N}$2 attack by surface-adsorbed hydrogen at the C2 of those 2-arylethanols undergoing Raney nickel-catalyzed C1–C2 fission. (−)-2-Phenylbutane (F) has been found to undergo slow racemization when heated with Raney nickel in refluxing ethanol. Duplication of such experiments using deuterated Raney nickel in deuterioethanol led to the exchange of 1–8 D atoms/molecule in the F substrate. Racemization and exchange rate data are presented which argue that the H–D exchange at C2 in F is a stereospecific process occurring with *retention* of configuration at a rate up to 30 times as great as the racemization rate of F.

In a previous communication we have reported the Raney nickel-catalyzed cleavage of 2-aryl-

---

(1) This constitutes Communication XII in the series "The Stereochemistry of Raney Nickel Action." For XI see THIS JOURNAL, **81**, 2122 (1959).

(2) This research was supported by a grant from the Petroleum Research Fund administered by the American Chemical Society. Grateful acknowledgment is hereby made to the donors of said fund.