

lized after several days. After recrystallizations from water, it melted at 102–104°. This was ethyl triacetylxyloside, known¹⁸ to melt at 106°.

(18) L. Asp and B. Lindberg, *Acta Chem. Scand.*, **4**, 1446 (1950).

The behavior of ketene toward the arabinosyl chloride was similar. Also, other catalysts, as boron fluoride etherate, gave no evidence of promoting a reaction between ketene and the glycosyl halide.

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The Effects of Deuterium Substitution on the Rates of Organic Reactions. VI. Secondary Isotope Effects on the Solvolysis Rates of γ -Methyl Substituted *t*-Alkyl Chlorides¹

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Deuterium substitution β to the chlorine of tertiary alkyl chlorides has previously been observed to have a marked decelerating influence on the rate of solvolysis of the alkyl chloride. This paper continues the study of these secondary isotope rate effects with particular reference to the influence of alkyl substitution on them. The 3,3-dideuterio analogs of all and the 1,1,1-trideuterio analogs of all but the second member of the following series of compounds have been synthesized and their solvolysis rates in "80%" aqueous alcohol at 25° measured: 2-chloro-2-methylbutane, 2-chloro-2-methylpentane, 2-chloro-2,4-dimethylpentane and 2-chloro-2,4,4-trimethylpentane. The secondary isotope rate effects of the 1-deuterio substitution do not show large variations in the series while the effects of 3-deuterio substitution are about the same for all but the last member of the series where only a small effect is evident. This result is thought to be due to steric inhibition of hyperconjugation in the neopentyl group of the last compound. The rate constants have been calculated by a statistical method programmed for an electronic computer.

The substitution of deuterium for β -situated hydrogen has been shown to have a marked retarding effect on the rates of solvolysis of certain derivatives of secondary and tertiary aliphatic alcohols.^{3,4,5} The effect has been shown to be cumulative as the degree of deuterium substitution increases and, per deuterium atom, is larger in a tertiary position than a secondary and is smallest in a primary position.^{3,4} It has also been observed to operate only slightly more effectively from a fixed *cis* than from a fixed *trans* position in the acetolysis of deuterated cyclopentyl tosylates.⁶ Further, the effect can be transmitted across a molecule through unsaturated linkages^{7,8} and has been shown to be solvent dependent.^{5,8} In a preliminary communication¹ it has been reported that deuterium substitution in the 3-position of 2-chloro-2,4,4-trimethylpentane had an abnormally *small* effect on the solvolysis rate. The present paper reports the details of that work and extends the observations to include secondary isotope rate effects of methylene deuteration through a complete series of compounds with increasing γ -methyl substitution. Some additional effects of methyl group deuteration are included for purposes of comparison. The series then gives the effects of deuterium substitution on the rates of solvolysis of 2-chloro-2-methylbutane,³ 2-chloro-2-methylpentane, 2-chloro-2,4-dimethylpentane and 2-chloro-2,4,4-trimethylpentane in 80% aqueous ethanol. Effects of complete deuteration of the 3-position are now available for each member of the

series and of the complete deuteration of the 1-position of all save the second member.

The starting point in the synthesis of the 3,3-dideuterioalkyl chlorides in each case was the reduction of the appropriate ethyl ester with lithium aluminum deuteride to give an α,α -dideuterio alcohol. The alcohols were converted to alkyl halides with phosphorus tribromide or with a triphenyl phosphite adduct⁹ and finally through the Grignard reagents to the alkyl- α -*d*₂-dimethylcarbinols.

The 1,1,1-trideuterio alkyl chlorides were made *via* the tertiary alcohols from the Grignard reagents starting with the methyl alkyl ketone and methyl-*d*₃ iodide. Methyl-*d*₃ iodide was made *via* the alcohol from lithium aluminum deuteride and diethyl carbonate. Deuterium analyses on a number of the compounds used are given in Table I.

TABLE I
DEUTERIUM ANALYSES

Compound	Av. atoms D/molecule
2-Methylpentane-3,3- <i>d</i> ₂ -2-ol	1.76
2-Chloro-2-methylpentane-3,3- <i>d</i> ₂	1.72
2,4-Dimethylpentane-3,3- <i>d</i> ₂ -2-ol	1.76
2-Chloro-2,4-dimethylpentane-3,3- <i>d</i> ₂	1.82
2,4-Dimethylpentane-1,1,1- <i>d</i> ₃ -2-ol	2.61
2-Chloro-2,4-dimethylpentane-1,1,1- <i>d</i> ₃	2.62
2,4,4-Trimethylpentane-3-3- <i>d</i> ₂ -2-ol	1.70
2-Chloro-2,4,4-trimethylpentane-3,3- <i>d</i> ₂	1.79
2,4,4-Trimethylpentane-1,1,1- <i>d</i> ₃ -2-ol	2.58
2-Chloro-2,4,4-trimethylpentane-1,1,1- <i>d</i> ₃	2.70, 2.69

Nuclear magnetic resonance (n.m.r.) spectral measurements at 60 mc. have been used to establish that the deuterium substitution is essentially complete at the sites indicated in the last four compounds listed in Table I. The 2,4,4-trimethylpentyl residue shows three unsplit bands. In order of increasing field these are: (1) a band of relative

(1) A preliminary communication on part of this work appeared in *THIS JOURNAL*, **73**, 2653 (1956). Presented in part at the XVth International Congress of Pure and Applied Chemistry, Paris, 1957.

(2) Alfred P. Sloan Research Fellow.

(3) V. J. Shiner, Jr., *THIS JOURNAL*, **75**, 2925 (1953).

(4) V. J. Shiner, Jr., *ibid.*, **76**, 1603 (1954).

(5) E. S. Lewis and C. E. Boozer, *ibid.*, **76**, 791 (1954).

(6) A. Streitwieser, Jr., R. H. Jagow and S. Suzuki, *ibid.*, **77**, 6713 (1955).

(7) E. S. Lewis and G. M. Copinger, *ibid.*, **76**, 4495 (1954).

(8) V. J. Shiner, Jr., and C. J. Verbanic, *ibid.*, **79**, 373 (1957).

(9) D. G. Coe, S. R. Landauer and H. N. Rydon, *J. Chem. Soc.*, 2281 (1954).

area 2 for the two equivalent hydrogens of the 3-position, (2) a band of relative area 6, for the six equivalent hydrogen of the 1 position and (3) a band of relative area 9 for the 9 equivalent hydrogens of the 5-position. In the 3,3-dideuterio compound the first band is absent while in the 1,1,1-trideuterio compound the second band has a relative area of only 3.

The solvolysis rates were measured conductimetrically in "80%" aqueous ethanol by a method previously described.³ The rate constants were calculated by the statistical method for the first-order reactions reported by DeTar except that the points were weighted for a proportional error (constant percentage error) by using a weighting factor w equal to the square of the reciprocal of the conductivity reading.¹⁰ Thirty-five to seventy points were used in each run for the calculation which was programmed for an IBM 650 magnetic drum data processing machine. The program yielded the rate constants, the terms a and b ¹⁰ and the standard errors for each. Table II summarizes the results obtained.

TABLE II
SOLVOLYSIS RATE CONSTANTS IN "80%" AQUEOUS ETHANOL AT 25°

Compound	$k \cdot 10^{-5} \text{ sec.}^{-1}$	Std. error
2-Chloro-2-methylbutane (I) ^a	1.57	0.02
I-1,1,1- d_3 ^a	1.17	.01
I-3,3- d_2 ^a	1.12	.01
2-Chloro-2-methylpentane (II)	1.533	.004
II-3,3- d_2	1.146	.004
2-Chloro-2,4-dimethylpentane (III)	4.12	.02
III-1,1,1- d_3	3.07	.02
III-3,3- d_2	2.81	.02
2-Chloro-2,4,4-trimethylpentane (IV)	22.4	.1
IV-1,1,1- d_3	16.0	.1
IV-3,3- d_2	20.6	.1

^a From ref. 3.

It is important to note that the statistical method used successfully overcomes difficulties in reproducing the rate constants which are due to errors in the zero and infinity readings. These quantities are included in the disposable parameters and are eliminated along with the rate constant to give the best fit of the data to the first-order rate law according to the least square criterion. As a result the reproducibilities between duplicate runs are about the same size as the standard errors in the individual runs. Calculations of this type for the numbers of points in the runs done in this work are not practical without the use of electronic computing machines. However, once the calculation has been programmed for the computer, it is easier to get the results by this method than by using the traditional, simple, often unsatisfactory point to point method and a calculator. The isotope rate effects are further summarized in Table III.

The standard errors in the constants quoted run as high as 1-2%. The reproducibility is about $\pm 2\%$. Thus each ratio given in Table III might be in error by as much as 4%. Therefore the following two important points can be made from the data: first, the rate effect for deuteration of the 1-

(10) D. F. DeTar, *THIS JOURNAL*, **73**, 3911 (1956).

TABLE III
EFFECT OF DEUTERIUM SUBSTITUTION ON SOLVOLYSIS RATES IN 80% AQUEOUS ALCOHOL AT 25°

Compound, 2-chloro	Deuteration of 1-position		Deuteration of 3-position	
	k_H/k_D^a	$\Delta F_{a,b}$	k_H/k_D^a	$\Delta F_{a,b}$
2-Methylbutane	1.34	177	1.40	204
2-Methylpentane			1.34	202
2,4-Dimethylpentane	1.34	199	1.47	250
2,4,4-Trimethylpentane	1.40	221	1.08	53

^a Observed ratio for approximately 90% deuteration; see Table I for analyses. ^b Corrected to represent the effect of complete deuteration.

position does not show a significant variation from compound to compound; second, the rate effect of deuteration of the 3-position is nearly the same for each of the first three compounds but is markedly lower for the fourth, highly branched compound. In view of these facts it seems difficult to attribute the abnormally low isotope rate effect observed for 2-chloro-2,4,4-trimethylpentane to anything but a steric effect. Any inductive effect of the γ -methyl group would build up gradually as the branching increases, as would a steric inhibition of solvation effect. The sudden reduction of the isotope rate effect at the most highly branched compound is characteristic of a steric prevention of a certain important conformation. Thus it is believed that a preferred orientation of the C-D bond in the 3-position is important for the exhibition of the maximum isotope rate effect and that this conformation is prevented by complete branching at the γ -carbon atom. This fits in well with the previously expressed idea that hyperconjugative transfer of electron density, from the C-H or C-D bond to help satisfy the developing electron deficiency in the adjacent orbital, is necessary for the exhibition of a large secondary isotope effect.^{3,5} This would require a nearly parallel arrangement of the CH_2 bonds with respect to the developing vacant adjacent orbital.

These results seem to be a rather striking confirmation of the existence of steric inhibition of hyperconjugation originally suggested by Arnold and Truett¹¹ and by Baddeley and Gordon.¹² Whether this factor alone will suffice to explain the characteristic apparent decrease in electron-releasing ability that has been observed in all or part of the series of groups ethyl, *n*-propyl, isobutyl and neopentyl in the bromination of alkylbenzenes,¹³ the solvolysis of alkylbenzhydryl chlorides,⁸ the bromination of olefins¹⁴ and the bimolecular eliminations of alkyl bromides¹⁵ or whether other effects such as steric inhibition of solvation are also important.^{16,17}

Experimental

Neopentyl- α - d_3 Alcohol.—A sample of 26 g. (0.20 mole) of ethyl pivalate in dry ether was slowly added to a slurry

(11) R. T. Arnold and W. L. Truett, *ibid.*, **73**, 5508 (1951).

(12) G. Baddeley and M. Gordon, *J. Chem. Soc.*, 2190 (1952).

(13) E. Berliner and F. Berliner, *THIS JOURNAL*, **72**, 222 (1950).

(14) P. W. Robertson, J. K. Heyes and B. E. Swedlund, *J. Chem. Soc.*, 1014 (1952).

(15) V. J. Shiner, Jr., M. J. Boskin and M. L. Smith, *THIS JOURNAL*, **77**, 5525 (1955).

(16) C. C. Price and W. J. Belanger, *ibid.*, **76**, 2682 (1954).

(17) (a) W. M. Schubert and W. A. Sweeney, *J. Org. Chem.*, **21**, 119 (1956); (b) W. M. Schubert and J. Robins, *THIS JOURNAL*, **80**, 559 (1958).

of 4 g. (0.095 mole) of lithium aluminum deuteride in dry ether. After the addition was completed the mixture was refluxed overnight and then decomposed with 4 *N* aqueous hydrogen chloride. The combined ether layer and ether extracts of the water layer were distilled through a spinning band column and yielded 14.5 g. (0.165 mole) of neopentyl alcohol, b.p. 110.0–11.5° (745 mm.), yield 82%.

Neopentyl- α - d_2 Iodide.—The method of Coe, Landauer and Rydon⁹ was used. A sample of 14.5 g. (0.165 mole) of neopentyl- α - d_2 alcohol was refluxed slowly for 17 hr. with 38 g. (0.268 mole) of freshly distilled methyl iodide and 93.0 g. (0.300 mole) of triphenyl phosphite. The volatile products were removed at reduced pressure, dissolved in *n*-pentane, extracted with 10% aqueous sodium carbonate, dried over anhydrous potassium carbonate, passed through a small silica gel column and vacuum distilled. Neopentyl- α - d_2 iodide, 19 g. (0.096 mole), b.p. 55° (50 mm.), yield 58%, was obtained.

***t*-Butylacetic- α - d_2 Acid.**—The 19-g. (0.096 mole) sample of neopentyl- α - d_2 iodide was converted to neopentylmagnesium iodide using the standard Grignard reaction technique, carbonated at 0° and poured on a mixture of ice and sulfuric acid. The combined ether layer and ether extracts of the water layer were dried over calcium chloride and the ether removed by distillation through a packed column.

Ethyl *t*-Butylacetate- α - d_2 .—The residue from the *t*-butylacetic- α - d_2 acid preparation described above was mixed with 35 ml. of chloroform, 30 ml. of 95% ethanol and 3 g. of a sulfonic acid resin and refluxed under a phase-separating head overnight. The reaction mixture was decanted from the resin and the excess alcohol and chloroform were removed through a glass-helix packed column and the residue distilled through a spinning band column. A fraction of 3.1 g. (0.021 mole) of ethyl *t*-butylacetate- α - d_2 was collected at 142° (740 mm.); yield, based on neopentyl iodide, 23%.

2,4,4-Trimethylpentane-3,3- d_2 -2-ol.—Methylmagnesium iodide made from 0.1 mole of methyl iodide was treated with 3.1 g. (0.021 mole) of ethyl *t*-butylacetate- α - d_2 and worked up in the usual way after hydrolysis with aqueous ammonium chloride. The ether layer on distillation yielded 2.4 g. (0.185 mole) of 2,4,4-trimethylpentane-3,3- d_2 -2-ol, b.p. 142–145° (740 mm.).

2,4,4-Trimethylpentane-2-ol was made in the manner described above from ordinary ethyl *t*-butylacetate and methylmagnesium iodide and distilled through a spinning band column; b.p. 142–145° (743 mm.).

Methyl- d_3 Iodide.—To a slurry of 3 g. (0.071 mole) of lithium aluminum deuteride in 100 ml. of freshly distilled diethyl carbitol was added slowly 15 g. (0.127 mole) of diethyl carbonate dissolved in diethyl carbitol. The reaction was vigorous and it was necessary to cool the reaction vessel with ice-water. After the addition was complete the mixture was heated on the steam-bath overnight and then hydrolyzed with 30 ml. of water. The methyl- d_3 alcohol was distilled from the reaction mixture through a small glass helix packed column. A 2.0-g. (0.057 mole) sample, b.p. 65–75°, was obtained; yield 64%. This sample of methyl- d_3 alcohol was mixed with 50 ml. of concd. aqueous hydrogen iodide and slowly distilled. Methyl- d_3 iodide with some azeotroped water, b.p. 38–45°, was collected and dried over anhydrous calcium chloride; yield 4.8 g. (0.034 mole), 59%.

2,4,4-Trimethylpentane-1,1,1- d_3 -2-ol was prepared from the above sample of methyl- d_3 iodide and methyl neopentyl ketone using the conventional Grignard reaction procedure and was distilled through the spinning band column, b.p. 142–144° (741 mm.).

2,4-Dimethylpentane-3,3- d_2 -2-ol was prepared starting with the reduction of ethyl isobutyrate by lithium aluminum deuteride using the procedure described above for neopentyl- α - d_2 alcohol. A sample of 35 g. (0.21 mole) of benzyl bromide was mixed with 70 g. (0.23 mole) of freshly distilled triphenyl phosphite. The mixture was heated at 100–110° for 24 hours, cooled and washed with petroleum ether. The last traces of petroleum ether were removed at reduced pressure and then 11.7 g. (0.15 mole) of isobutyl- α - d_2 alcohol was added. The sirupy triphenyl phosphite-benzyl bromide adduct dissolved slowly in the added alcohol as the reaction mixture warmed. After standing for 1 hour the product was removed and trapped at reduced pressure. Distillation yielded 16 g. (0.12 mole) of isobutyl-

α - d_2 bromide; yield 80%. This isobutyl- α - d_2 bromide was converted to the Grignard reagent, treated with acetone and worked up following the conventional procedure. The material was distilled through the spinning band column and 5.0 g. (0.043 mole) of 2,4-dimethylpentane-3,3- d_2 -ol was obtained, b.p. 79–82° (107 mm.), yield 36%.

2,4-Dimethylpentane-1,1,1- d_3 -2-ol was obtained by reaction of methyl- d_3 -magnesium iodide with a carefully purified sample of commercial methyl isobutyl ketone. The product was distilled through the spinning band column and the desired compound was collected, b.p. 83–85° (118 mm.).

***n*-Propyl- α - d_2 Alcohol.**—A sample of 20 g. (0.20 mole) of ethyl propionate dissolved in freshly distilled diethyl carbitol was added dropwise to a slurry of 3.8 g. (0.09 mole) of lithium aluminum deuteride in 250 ml. of diethyl carbitol while the reaction mixture was kept cool with ice-water. After the addition was complete the mixture was allowed to stand at room temperature overnight. Then 50 ml. of freshly distilled 1-hexanol was added and the mixture was fractionally distilled. *n*-Propyl- α - d_2 alcohol was collected, b.p. 93–100° (745 mm.), 7.5 g. (0.125 mole), yield 69%.

***n*-Propyl- α - d_2 Bromide.**—The sample of *n*-propyl- α - d_2 alcohol obtained as described above was converted to the bromide with phosphorus tribromide using the conventional procedure. The product was finally purified by distillation and 5.5 g. (0.045 mole), b.p. 68–71°, was obtained, yield 36%.

2-Methylpentane-3,3- d_2 -2-ol was prepared using the conventional Grignard reaction procedure with *n*-propyl- α - d_2 bromide and acetone. The product was collected at 75° (145 mm.).

2-Methylpentane-2-ol was prepared using the conventional Grignard procedure with *n*-propyl bromide and acetone.

***t*-Alkyl Chlorides.**—The *t*-alkyl chlorides were made by bubbling dry hydrogen chloride through a small sample of the tertiary carbinol at room temperature in a centrifuge tube. The water layer formed was removed with a capillary pipet and the alkyl chloride dried over anhydrous potassium carbonate. These materials gave good first-order rate constants without purifications.

"80%" aqueous alcohol was prepared in the manner previously described.³

The kinetic apparatus and procedure was the same as that previously described.⁵

Deuterium Analysis.—Combustion analyses for deuterium using the gradient density tube method were done as described in an earlier paper.¹⁸ The analyses are generally reproducible to within $\pm 2\%$ or 0.01 atom of D per molecule, whichever is greater.

N.m.r. spectra.—were done using a Varian Associates DP-60 Nuclear Magnetic Resonance Spectrometer.

Calculation of Rate Constants.—The statistical method was essentially that described by DeTar.¹⁰ The first-order rate law in the form

$$l = 1/R = a + be^{-kt}$$

applies; where $a = l_\infty$ and $b = l_0 - l_\infty$, R is the resistance observed at time t , l is its reciprocal the conductivity, l_∞ is the conductivity after the reaction is completed and l_0 is the conductivity at the start of the reaction.

Since the probable absolute errors in R are proportional to R (constant percentage error) the same holds true for l and the statistical treatment was therefore weighted with a weighting factor w equal to $(1/l)^2$ or R^2 . The entire calculation was programmed for the IBM 650 Magnetic Drum Data Processing Machine using the Bell Laboratories interpretive system. As finally set up, the kinetic data consisting of a series of readings R from the conductivity bridge each associated with a reading t of a direct reading second clock were entered directly onto a sheet used to punch the information on the IBM cards. An estimate of the infinity resistance reading was also entered. The program uses the first reading entered as the zero time and trial zero resistance value and calculates from this, the values for the fifteenth point and the estimated infinity entered, a trial rate constant k_0 . Then corrections for each of the constants a , b and k are calculated according to the least squares method. The corrections are applied and tested for size. If they are larger than 0.1% of the corrected value the machine cycles through the calculation of another cor-

(18) V. J. Shiner, Jr., THIS JOURNAL, 74, 5285 (1952).

rection. When the corrections are small enough the standard errors are calculated and the constants a , b and k and their standard errors are punched on the output cards. The machine then takes in data from the cards for the next run and continues calculating. The program for a 70-point run usually takes 5 to 10 minutes machine time depending on the number of successive corrections (usually two to four) it must calculate. This compares with DeTar's estimate of 4 hours used by an experienced operator to calculate a single set of corrections and the standard errors for a 10 point run using a desk calculator. With the program used here *no* calculations are made by the operator. The method described by DeTar seemed to overcome almost all of the difficulties traditionally associated with the

exact calculation of first-order rate constants. Its only drawback was the excessive time required. By the application of electronic computing machines this last difficulty is overcome.

Acknowledgment.—The author would like to thank Professor L. L. Merritt for his assistance in developing the computer program, and Professor Riley Schaeffer for his help in obtaining the n.m.r. data. The computations were done using the facilities of the Indiana University Research Computing Center. This work was supported in part by a Grant from the National Science Foundation.

[CONTRIBUTION FROM THE BAKER LABORATORY OF CHEMISTRY, CORNELL UNIVERSITY, ITHACA, N. Y.]

The Stereochemistry of 1,1,5,5-Tetramethylcyclononane Derivatives^{1,2}

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The purpose of this investigation was to discern the intrinsic molecular dissymmetry of a preferred conformation in a nine-membered carbon ring. To this end an azeloin was synthesized which possessed two *gem*-dimethyl groups attached to annular atoms, 4,4,8,8-tetramethylcyclononan-2-one. Two different approaches were examined in an effort to resolve suitable derivatives of the highly substituted azeloin. The first of these studies was the attempted resolution of the quinoxaline derivative produced by reaction of 4,4,8,8-tetramethyl-1,2-cyclononanedione with 3,4-diaminobenzoic acid; the second study comprised chromic acid oxidation, at 0°, of pure optical antipodes of 3,3,7,7-tetramethylcyclononan-2-one. Neither path led to a successful demonstration of our original purpose. Synthesis of the cyclic acyloin aforementioned and the several related tetramethylcyclononane derivatives, required for the study, was straightforward and involved only procedures described earlier by ourselves and others.

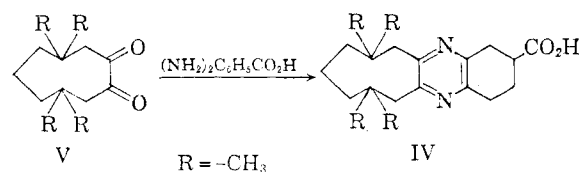
Molecular dissymmetry in certain derivatives of nine-membered carbon rings has been discussed in earlier reports.^{3,4} Up to the present time there has been no success in efforts to construct cyclononane derivatives which possess sufficient restriction in single bond rotation to allow, at room temperature, their resolution into optical antipodes.

The present article describes efforts to discern hindered rotation about single carbon-carbon bonds in certain cyclononane derivatives which have two *gem*-dimethyl groups attached to annular atoms. The particular nine-membered ring compound selected as the starting point for the investigation is the substituted azeloin 4,4,8,8-tetramethylcyclononan-2-one (I).

The intermediate δ -keto- $\beta,\beta,\beta',\beta'$ -tetramethylazelaic acid (II) was prepared by basic hydrolysis⁵ of the ketene-dimer obtained upon dehydrochlorination⁶ of γ -carbomethoxy- β,β -dimethylbutyryl chloride.⁷ The keto-acid II was easily reduced (70%) to $\beta,\beta,\beta',\beta'$ -tetramethylazelaic acid (III) by the standard Hwang-Minlon⁸ modification of the Wolff-Kishner method.^{9,10} Acyloin cyclization of the

dimethyl ester of III by a standard procedure,¹² using solvent toluene, produced the cyclic acyloin I in excellent yield (84%).¹³

With the purpose of demonstrating dissymmetry in appropriate unsymmetrical derivatives of 1,1,5,5-tetramethylcyclononane, a study was made of the resolution of the quinoxaline derivative IV obtained by the condensation of 3,4-diaminobenzoic acid and 4,4,8,8-tetramethyl-1,2-cyclononanedione (V). In the 6-carboxyquinoxaline derivative IV the rigidity of the 2,3-heptamethylene part of the molecule is



enhanced both by the two bulky *gem*-dimethyl groups and by fusion to the quinoxaline system.²

Cupric acetate oxidation of the acyloin I gave the α -diketone V in nearly quantitative yield; the latter afforded the quinoxaline IV smoothly (75%). Salts of the 6-carboxyquinoxaline IV with the active bases cinchonidine, strychnine, (+)- α -phenyl-

(1) This is the 22nd report in a series of articles on investigations of many-membered carbon rings. For the preceding paper in the series see A. T. Blomquist and B. H. Smith, *J. Am. Chem. Soc.*, **82**, 2073 (1960).

(2) For closely related papers see (a) A. T. Blomquist, E. S. Wheeler and Y. Chu, *ibid.*, **77**, 6307 (1955); and (b) A. T. Blomquist and Y. C. Meinwald, *J. Org. Chem.*, **23**, 6 (1958).

(3) Supported by funds from du Pont Grant-in-Aid, Summer, 1958; Procter and Gamble Fellow, Summer, 1959; American Viscose Fellow, Summer, 1960; Procter and Gamble Fellow, 1960-1961.

(4) A. T. Blomquist, L. H. Liu and J. C. Bohrer, *J. Am. Chem. Soc.*, **74**, 3463 (1952).

(5) J. C. Sauer, *ibid.*, **69**, 2444 (1947).

(6) A. T. Blomquist, *et al.*, *ibid.*, **74**, 4203 (1952).

(7) J. Cason, G. Sumrell and R. S. Mitchell, *J. Org. Chem.*, **15**, 850 (1950).

(8) Hwang-Minlon, *J. Am. Chem. Soc.*, **68**, 2487 (1946).

(9) "Organic Reactions," Vol. 4, John Wiley and Sons, Inc., New York, N. Y., 1948, p. 378.

(10) Application of the Barton modification for sterically hindered ketones proved to be hazardous. A violent explosion occurred when anhydrous hydrazine was distilled into the reaction vessel.¹¹

(11) D. H. Barton, D. A. J. Ives and B. R. Thomas, *J. Chem. Soc.*, 2056 (1955).

(12) A. T. Blomquist, R. E. Burge and A. C. Sucsy, *J. Am. Chem. Soc.*, **74**, 3636 (1952).

(13) It is interesting to note here the effect of the presence of the two *gem*-dimethyl groups. Azelaic ester and 5,5-dimethylazelaic ester afford their respective acyloins in yields of 35-40% and 66-70%; see refs. 2a and 4.