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CONFORMATIONAL ANALYSIS—LXI

ABSENCE OF TRANSANNULAR HYDROGEN-BONDING IN CYCLO/OCTANONE[1]*

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Abstract—5,5-Dideuterocyclooctanone and 4,5-dideuterocyclooctanone have been prepared and their IR spectra were examined in the C–D stretching region. The C–D frequencies are the same in these ketones as in the corresponding hydrocarbons. Thus the earlier suggestion, that the low CO stretching frequencies shown by the medium-ring ketones are due to transannular hydrogen bonding, is incorrect.

INTRODUCTION

IT has long been recognized[2] that a ketone group in an open chain or 6-membered ring shows CO stretching absorption in the range of 1709–1714 cm^{-1} in non-polar solvents, whereas cyclopentanones and cyclobutanones absorb respectively near 1745 and 1775 cm^{-1}. When the IR spectra of the medium ring ketones were first examined many years ago, it was noted that they all showed CO stretching at rather low frequencies,[3] in particular, cyclooctanone was found to absorb at 1692 cm^{-1}. The suggestion was made by Prelog[3] that the low stretching frequencies of the medium-ring ketones might be due to transannular hydrogen bonding, since it was already well known that hydrogen bonding of the usual sort produced a lowering of the CO frequency.[4] Such transannular hydrogen bonding would also be required to lower the C—H stretching frequency. Unfortunately, the C—H stretching regions of the medium ring ketones contained too many absorption frequencies too close together to settle this question. However, from a study of the C—H overtone region, it was concluded that such hydrogen bonding did occur.[5]

A few years later, Halford[6] deduced that there should exist an inverse relationship between the CO stretching frequency and the C—C—C bond angle at the CO carbon. It was later suggested[7] that the low stretching frequencies for the medium ring ketones were in fact due to bond angle expansion in these compounds, rather than to transannular hydrogen bonding. That the C—C—C bond angles in the medium rings are expanded beyond the values found for 6-membered rings and open chains has subsequently been amply verified by crystallographic studies,[8] but the question of the existence of transannular hydrogen-bonding suggested by Prelog has never been further discussed.

The present work is concerned with a determination of the significance of transannular hydrogen bonding in cyclooctanone. While it is still not possible to resolve the C—H stretching region adequately so as to determine whether or not lower

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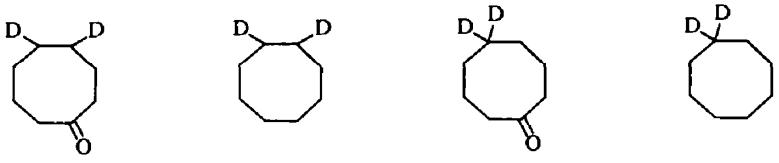
frequency absorption is present, there existed the alternative of replacing the suspected transannular hydrogens with deuterium, in which case the C—D stretching absorption would be well removed from the remainder of absorption in the molecule. It should then be easily possible to determine whether or not a shift of this band to lower frequency has occurred. If transannular hydrogen bonding to the CO oxygen did occur, it would most likely involve a hydrogen on C-5, although the possibility of a C-4 hydrogen being involved could not be ignored. The compounds chosen for study are I–IV, as they permit the examination of each of these possibilities; the shift of the C—D stretching frequency in I relative to II, and in III relative to IV being the quantities sought.



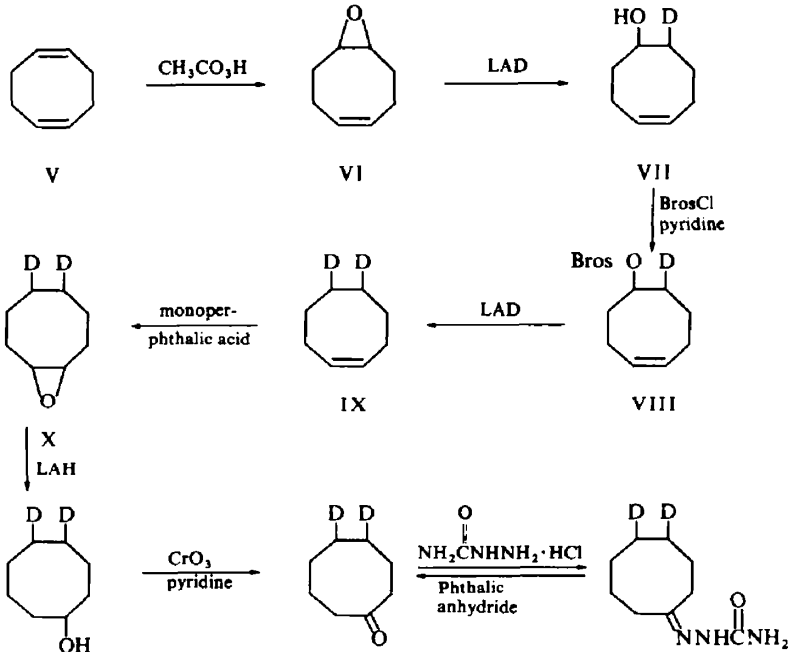
I II III IV

THE SYNTHETIC METHOD

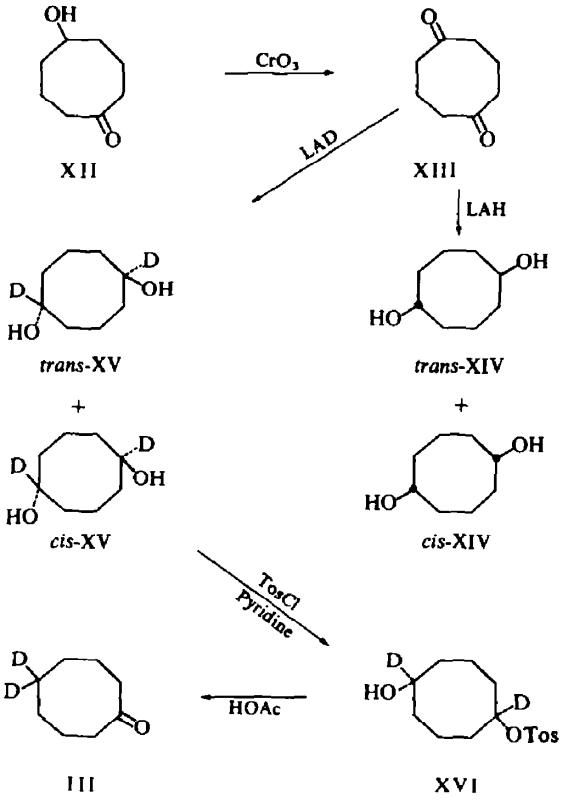
The syntheses of the deuterium labeled cyclooctanone molecules, I and III were undertaken via the pathways outlined on the flowsheets.

Route A was previously employed by Cope[9] to obtain compound (X).

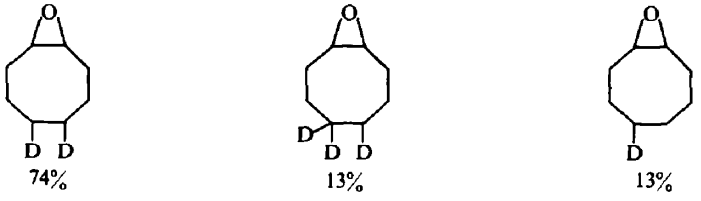
Route A:



Route B was simultaneously explored in view of the well documented 1,5-transannular hydride shift in the solvolysis of tosylates[10] and brosylates.[11]
Route B:



The commercially available 1,5-cyclooctadiene (V) was converted to X via route A as described in the experimental part. These procedures generally follow those of Cope *et al.*[9] They showed by mass spectrometric analysis that the H atoms of the epoxide ring in VI undergo some exchange prior to ring cleavage, and X is actually composed of the species as indicated:



The epoxide ring in (X) was then opened with LAH using tetrahydrofuran as solvent. Unlike the monoepoxide VI, which was cleaved at room temperature with LAD in tetrahydrofuran, the isotopically labeled *cis*-cyclooctene oxide (X) required that the reaction be carried out at reflux temperatures in order to effect the epoxide opening. When X was treated with LAH at room temperature no reaction occurred.

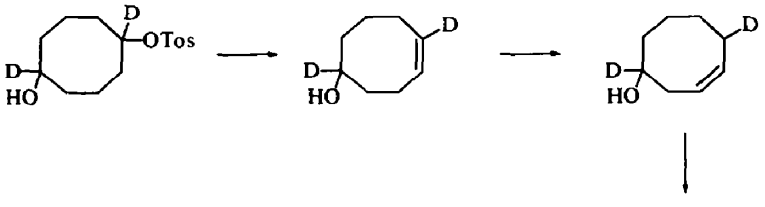
The deuterated alcohol (XI) was then oxidized with chromic anhydride in pyridine to give the desired 4,5-dideuterocyclooctanone (I). This ketone was purified via its semicarbazone, the m.p. of which corresponded to that of cyclooctanone semicarbazone. The 4,5-dideuterocyclooctanone (I) was then regenerated from its semicarbazone derivative with phthalic anhydride and water. Mass spectrometric analysis indicated that I consisted of 13% monodeuterated, 74% dideuterated and 13% trideuterated species, in agreement with the findings of Cope *et al.*[9] for the synthetic precursers VII to X.

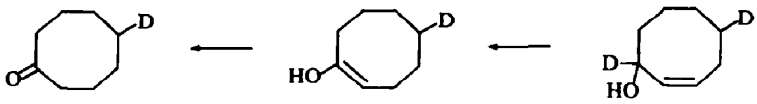
Route B was utilized for the synthesis of 5,5-dideuterocyclooctanone. The starting material for this sequence is 5-hydroxycyclooctanone (XII). From its IR spectrum this molecule can be seen to exist as a hemi-ketal. It showed one peak when analyzed via gas chromatography.[12] It was converted to 1,5-cyclooctanedione (XIII) by treatment with Jones Reagent[13] according to the procedure of Rapoport,[12] and this diketone (XIII) was purified by recrystallization from ether–pentane. The purified XIII was then reduced to a stereoisomeric mixture of *cis*- and *trans*-1,5-dideutero-1,5-cyclooctanediols (XV). By careful column chromatography and subsequent repeated recrystallizations from ether–pentane, pure *cis*-XV was obtained.

The configuration of this isotopically labeled dialcohol was demonstrated in the following way. A mixed m.p. of the isotopically labeled diol with the non-deuterated diol (*cis*-XIV prepared in a similar manner from cyclooctanedione and LAH) did not depress. The configuration of *cis* XIV was established by the fact that the IR spectrum of its bis-*p*-nitrobenzoate is identical with the IR spectrum of an authentic sample prepared by a stereospecific route.[14] The IR spectrum of the *cis*-1,5-cyclooctanediol bis-*p*-nitrobenzoate differed significantly from that of the *trans* compound, which is also known.[14]

The *cis*-1,5-dideutero-1,5-cyclooctanediol was treated with an equimolar amount of *p*-toluenesulfonyl chloride to produce a mixture which contained the monotosylate of the deuterium labeled *cis*-XV. After drying, this derivative was immediately solvolyzed at room temperature in a solution of anhydrous sodium acetate and glacial acetic acid. The subsequent workup yielded a mixture, the IR spectrum of which showed it to contain the deuterated ketone in addition to unreacted tosylate. Part of the tosylate was removed by precipitation from an etheral solution of the mixture with pentane. The ketone was isolated as its 2,4-dinitrophenylhydrazone derivative, which was purified by recrystallization from aqueous ethanol. The m.p. (173–176°) of the 5,5-dideuterocyclooctanone-2,4-dinitrophenylhydrazone thus obtained did not depress the m.p. of an authentic sample of cyclooctanone-2,4-dinitrophenylhydrazone. The desired ketone (III) was regenerated from its pure 2,4-dinitrophenylhydrazone with acidic chromous chloride.[15] A mass spectrometric analysis of this compound showed that it was pure 5,5-dideuterocyclooctanone.

It is important to note that the mass spectral evidence eliminates the possibility of a deuterated cyclooctanone forming by a process similar to that outlined:

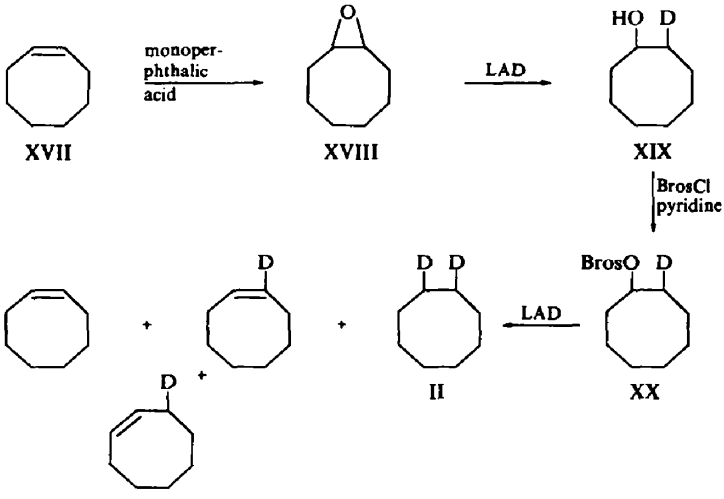




Such a mechanism would require that a deuterium atom be lost in the formation of the enol.

Use of chromous chloride to effect the regeneration of the ketone from the dinitrophenylhydrazone is a convenient procedure as it allows the use of the nicely crystalline 2,4-dinitrophenylhydrazone derivative as a means of purification.

1,2-Dideuterocyclooctane (II) and 1,1-dideuterocyclooctane (IV) were utilized as reference compounds for the determination of the C—D stretching frequencies to be expected from the ketones if no hydrogen-bonding is taking place. In order to obtain a reference compound with a deuterium distribution similar to that present in 4,5-dideuterocyclooctanone (I), 1,2-dideuterocyclooctane (II) was synthesized via the route outlined:

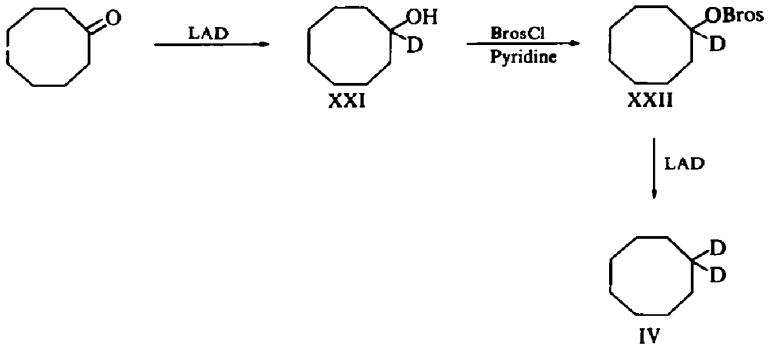


The methods of incorporating deuterium into the molecule are similar to those employed for route A.

Commercially available *cis*-cyclooctene (XVII) was converted to its epoxide (XVIII) using monoperphthalic acid as the oxidizing agent.[9] The epoxide ring was opened as before to yield 2-deuterocyclooctanol (XIX). This alcohol was converted to its brosylate derivative (XX),[16] which was immediately reduced with LAD[11] to obtain a mixture which was shown by gas chromatography to contain both cyclooctane and cyclooctene. The cyclooctene was removed from the mixture by employing Kharash's reagent,[17] (benzenesulfenyl chloride) according to the procedure of Cram.[18] This method had been shown not to cause isomerizations and rearrangements. The product thus obtained was found to be free of olefins, as it gave a negative tetranitromethane test.

In obtaining an IR reference compound for the 5,5-dideuterocyclooctanone (III) the sequence outlined was followed to prepare 1,1-dideuterocyclooctane (IV).

Commercially available cyclooctanone was reduced with LAD to yield 1-deutero-cyclooctanol (XXI). The brosylate (XXII) of this deutero-alcohol[16] was immediately reduced with LAD[11] to give a mixture containing both deuterated cyclooctane (IV) and deuterated cyclooctene. The cyclooctene impurities were removed with Kharasch reagent.[17, 18]



CONCLUSIONS

The IR spectra were run in CCl_4 solution. The 1,2-dideuterocyclooctane (0·17 M) showed a single slightly broad absorption peak at 2145 ± 5 cm^{-1}, while 4,5-dideutero-cyclooctanone showed the same peak at 2148 ± 5 cm^{-1} (0·86 M) and at 2150 ± 5 cm^{-1} (0·12 M). Thus no shift (beyond experimental error) is detectable. 1,1-Dideuterocyclooctane (0·20 M) in CCl_4 showed three peaks, which decreased in intensity with frequency, at 2085 ± 5, 2130 ± 10 and 2170 ± 5 cm^{-1}. 5,5-Dideutero-cyclooctanone, at either 0·13 or 0·5 M, showed 3 similar peaks at 2100 ± 10, 2140 ± 5, and 2185 ± 5 cm^{-1}. The first and last of these peaks appear shifted very slightly relative to those of the hydrocarbon. However, the shift is to higher frequency for the ketone, the opposite of which would be required by hydrogen-bonding. The conclusion is therefore unambiguous: There is no evidence for transannular hydrogen-bonding in the present study. We therefore conclude that the unusually low CO frequencies observed for cyclooctanone (and the other medium rings) are simply a result of bond angle expansion, and transannular hydrogen-bonding, at least in cyclooctanone, is of negligible importance.

EXPERIMENTAL

cis-cis-1,5-*Cyclooctadiene monoepoxide* (VI).[19] A soln of 494 g of 40% peracetic acid,* 100 g of sodium acetate trihydrate and 100 ml of reagent grade AcOH was added dropwise with stirring during 1 hr to 200 g of 1,5-cyclooctadiene while maintaining the temp at 24–30° with an ice bath. The soln, which did not become homogenous as reported, was cooled to about 0° and neutralized with 40% NaOH aq and water. Enough distilled water was then added to dissolve the ppt and the soln was extracted with ether. The dried etheral soln was combined with that of a similar run. The ether was removed and the residual liquid was distilled through a spinning band column to yield 106 g (24%) of product, b.p. 69·5–71° (9·3–10·5 mm), n_D^{26} 1·4921; lit.[19] b.p. 114–115° (73 mm), n_D^{25} 1·4930.

Reaction of 1-deutero-5-cycloocten-2-yl brosylate with LAD. Epoxide VI was converted through alcohol VII to the brosylate VIII, following the method of Cope.[9, 16] A soln of 54·75 g of VIII in 750 ml dry ether was stirred under N_2 at −6 to −10° while a slurry of 5 g of LAD in 115 ml ether was added during 1 hr.

* Obtained from Inorganic Chemicals Division, F.M.C. Corporation, New York, New York.

After the mixture had been stirred at 0 to −9° for 7 hr and at room temp for 36·5 hr, 100 ml ether saturated with water was added with external cooling. This mixture was carefully poured into 515 ml 10% H_2SO_4aq, shaken, and the ether layer was removed. The aqueous layer was further extracted with ether, and the combined ether solns were washed and dried. The soln was filtered and the ether was distilled through a Podbielniak column.

While the distillation of the residual oil through the Podbielniak column was yielding a clear liquid b.p. 84–85° (102 mm), a sudden decomposition with concurrent bumping occurred in the distillation pot. All of the liquid other than the decomposed tar in the pot was taken up in ether, dried and distilled to yield 11 g of hydrocarbon mixture, b.p. 79–85° (97·5 mm), lit.[9] b.p. 73–76° (92 mm).

In carrying out this reaction Cope *et al.*[9] reported that the mixture which they obtained contained not only *cis*-cyclooctene, but also *cis*-bicyclo[3.3.0]octane, cyclooctane and *cis-cis*-cyclooctadiene. Therefore IX was not separated from the impurities at this point, since the purification of its epoxide is a more convenient method.

5,6-*Dideuterocyclooctene oxide* X.[9] A sample of crude IX (which weighed 10·3 g) was dissolved in 175 ml dry ether and added during 1 hr to a stirred, 280 ml ethereal soln containing 25·79 g monoperphthalic acid. The reaction vessel was protected from light with Al foil throughout the process. The etheral mixture was stirred at room temp for 45 hr, filtered from the precipitated phthalic acid, washed with 5% NaOHaq, then water and finally dried over Na_2SO_4. This soln was filtered, the ether was distilled through a Podbielniak column, and the residual oil was thrice distilled through the above column to yield 1·5 g 5,6-dideuterocyclooctene oxide, b.p. 97·5–98° (31–32 mm), lit.[20] *cis*-cycloctene oxide, b.p. 90–93° (37 mm).

4,5-*Dideuterocyclooctanol* (XI). To a mixture of 1 g LAH in 35 ml dry THF stirred at room temp was added a soln of 0·93 g of X in 6 ml dry THF. The mixture was stirred at reflux for 20 hr and then cooled in an ice-bath while the excess reducing agent was decomposed by the cautious dropwise addition of 20 ml of 50% aqueous THF. After standing overnight this mixture was poured into 10% H_2SO_4aq and extracted with ether. Distillation of the washed and dried extracts gave 631 mg (67%) of the dideuterated alcohol, b.p. 112–116 (21 mm), $n_D^{24\cdot7}$ 1·4832, lit.,[21] cyclooctanol, b.p. 99 (16 mm).

4,5-*Dideuterocyclooctanone* (I). To a stirred preformed complex of 600 mg CrO_3 in 15 ml dry pyridine was added 248 mg 4,5-dideuterocyclooctanol dissolved in 2 ml of dry pyridine. The mixture was stirred for 24 hr at room temp, water was added and the dark mixture was extracted with pentane. The combined pentane extracts were washed with 10% HClaq, $KHCO_3$aq and water. After drying the soln, the pentane was evaporated. The yield was 113 mg (46%) crude ketone, which exhibited CO absorption at 1690 cm^{-1} (reported CO absorption of cyclooctanone 1688 cm^{-1} or 1692 cm^{-1}).[3,22]

4,5-*Dideuterocyclooctanone semicarbazone*. The crude I obtained above was dissolved in 95% EtOH and then excess semicarbazide hydrochloride and anhyd AcONa were added. The mixture was heated on the steambath, filtered, then allowed to cool. The crystals were collected, wt. 78 mg, m.p. 165–167° (lit.,[23] cyclooctanone semicarbazone, m.p. 167–168°).

4,5-*Dideuterocyclooctanone* (I). 4,5-Dideuterocyclooctanone semicarbazone (189 mg), phthalic anhydride (0·7 g) and water (8 ml) were placed in a short path still and distilled with the further addition of water as necessary until no more ketone was evident (odor) in the distillate. The distillate was extracted with pentane, and the pentane soln was washed with water, dried, filtered and concentrated. The residual oil was distilled to yield 50 mg of 4,5-dideuterocyclooctanone, b.p. 85–90° (22 mm), lit.,[23] cyclooctanone, b.p. 74° (12 mm).

A mass spectrum of this compound indicate that it consisted of 13% monodeuterated, 74% dideuterated and 13% trideuterated species.

1,5-*Cyclooctanedione* (XIII). The procedure followed was essentially that of Glover *et al.*[12] which is the chromic acid oxidation[13] of 5-hydroxycyclooctanone.[24] Crystallization of the compound from ether–pentane yielded cyclooctanedione, m.p. 69·5–72°, lit.[12] m.p. 71–72°.

cis-1,5-*Dideutero*-cis-1,5-*cyclooctanediol* (XV). A mixture of 0·6 g LAD in 130 ml dry ether was stirred at reflux and to this was added during 30 min an ethereal soln of 2·05 g 1,5-cyclooctanedione. This mixture was then stirred at reflux for 20 hr. The excess LAD was decomposed by the cautious portionwise addition of Rochelle salt soln with cooling.

The mixture was extracted with ether, and the ether was evaporated to yield a viscous oil. This was combined with the product from a similar reduction of 5·22 g 1,5-cyclooctanedione and chromatographed on 300 g activity II alumina. The ether fractions yielded an oil which crystallized on standing. An oil which did not crystallize was also obtained from the 0·5% MeOH–ether and 1% MeOH–ether fractions. Crystals were obtained from these later fractions and were recrystallized from ether–pentane. The total yield of

crystals was 2·11 g. They were recrystallized twice from ether–pentane to yield 823 mg (11·3%) of pure *cis*-1,5-dideutero-*cis*-1,5-cyclooctanediol, m.p. 74·8–75·5°, lit.,[14] *cis*-1,5-cyclooctanediol, m.p. 73·8–74·8°.

A mixed m.p. of this isotopically labeled diol with an identically prepared non-labeled diol (from 1,5-cyclooctanedione and LAH) did not depress. The configuration of the nondeuterated compound was demonstrated by the fact that the IR spectrum of its di-*p*-nitrobenzoate derivative was identical with the spectrum of the di-*p*-nitrobenzoate derivative of authentic *cis*-1,5-cyclooctanediol[14] and different from that of *trans*-1,5-cyclooctanediol di-*p*-nitrobenzoate.[14]

5,5-*Dideuterocyclooctanone* 2,4-*dinitrophenylhydrazone*. To a cold soln of 338 mg *cis*-1,5-dideutero-1,5-cyclooctanediol in 6 ml pyridine was added a soln of 453 mg *p*-toluenesulfonyl chrloride dissolved in 4 ml cold pyridine. After the mixture was allowed to stand at −20° for 51 hr it was poured over crushed ice, and the resulting aqueous mixture was extracted with ether. The combined ethereal extracts were washed repeatedly with cool 6N HCl and then several times with sat $NaHCO_3$aq. After drying ($MgSO_4$) in the refrigerator for 4 hr, the soln was filtered and the ether was removed at reduced press without heating. The resulting oil was immediately solvolyzed at room temp for 70 hr in a soln of 89 mg of anhyd AcONa in 50 ml glacial AcOH. The acid soln was poured over ice and extracted with pentane. The pentane extracts were washed with cold water, cold sat $NaHCO_3$aq and again with water. The soln was dried over $MgSO_4$ and filtered. The solvent was evaporated and the residual liquid was treated with 2,4-dinitrophenylhydrazine reagent to yield a 2,4-dinitrophenylhydrazone derivative. This was recrystallized once from aqueous EtOH to yield 10 mg of compound, m.p. 173–176°, undepressed in mixed m.p. with an authentic sample of cyclooctanone 2,4-dinitrophenylhydrazone.

Because of the low yield the aqueous AcOH mother liquor was further extracted with ethyl ether. The ethereal extracts were washed with cold water, cold sat $NaHCO_3$aq and again with cold water. The soln was dried over $MgSO_4$, filtered and the solvent was evaporated to give an oil whose IR spectrum indicated the presence of tosylate in addition to ketone. The oil was dissolved in a small amount of ether and the major portion of the tosylate was precipitated by the addition of pentane. After filtration and evaporation of the solvent the remaining oil yielded the same 2,4-dinitrophenylhydrazone derivative as the pentane extracts (10 mg), m.p. 173–176°, and undepressed in mixed m.p.

Chromous chloride.[15] In a 500 ml separatory funnel fitted with a condenser was placed 57·3 g $CrCl_3 \cdot 6H_2O$, 400 ml water and 90 ml conc HCl. Dry-ice chips were added to flush out air and then 50 g of grannular Zn was added over a period of a few min. A few chips of dry-ice were periodically added to exclude air. After several hr another 10 ml of conc HCl was added and the reaction was protected under N_2. When the evolution of H_2 had ceased (after about one day), the product was ready for use. It was stored under N_2 but was vented as small amounts of gas continued to be evolved.

Regeneration of 5,5-*dideuterocyclooctanone from the* 2,4-*dinitrophenylhydrazone*. A 100 ml separatory funnel was charged with a soln of 19 mg of 5,5-dideuterocyclooctanone 2,4-dinitrophenylhydrazone in 20 ml CH_2Cl_2. To this was added a soln of 5 ml conc HCl in 5 ml water. Small pieces of dry-ice were added to expel the O_2 and 50 ml chromous chloride solution (prepared above) was added. After shaking for a few min the characteristic yellow color of the 2,4-dinitrophenylhydrazone derivative disappeared. The mixture was allowed to stand (occasional shaking) for an additional 20 min and then the CH_2Cl_2 layer was run into water. The aqueous layer was extracted with fresh portions of CH_2Cl_2. The combined organic layers were washed twice with water and dried over $MgSO_4$. The soln was filtered and the solvent was evaporated to yield 6 mg (76%) of III.

This ketone exhibited an IR carbonyl absorption at 1690 cm^{-1}. The mass spectrometric analysis of this compound showed that it was essentially isotopically pure 5,5-dideuterocyclooctanone.

2-*Deuterocyclooctanol* (XIX). A soln of 5·5 g of *cis*-cyclooctene oxide[9] dissolved in 30 ml dry THF was added to a mixture of 0·85 g LAD in 40 ml dry THF. After 4 days of stirring and heating at reflux, the excess LAD was decomposed by the cautious addition of aqueous THF with cooling. The reaction mixture was poured into dilute H_2SO_4 and the mixture was extracted with ether. The combined ethereal solns were washed, dried, and filtered, and the solvent was evaporated. The residual oil was twice distilled through a Podbielniak column to yield 4·0 g of product, b.p. 109–111° (17 mm), lit.[21,25] b.p. 99 (16 mm).

1,2-*Dideuterocyclooctane* (II). A cold soln of 380 mg 2-deuterocyclooctanol in 3 ml pyridine was added to a soln prepared by dissolving 1·54 g *p*-bromobenzenesulfonyl chloride in 7 ml cold pyridine. After standing 1·5 day at 0 to −5° the excess *p*-bromobenzenesulfonyl chloride was decomposed by the dropwise addition of water while the reaction temp was kept below 5° in an ice-bath. Finally excess water was added and the mixture was extracted with ether. The ethereal soln was washed with 6N HCl, 5% Na_2CO_3aq, and then dried over $MgSO_4$ in the refrigerator. The soln was allowed to warm to room temp, filtered, and

the ether was removed at reduced press without heating. The residual oil was taken up in dry ether and this soln was added dropwise to a cold stirred mixture of 250 mg LAD in 15 ml dry ether. The mixture was then stirred at room temp for 1 day. After the excess LAD had been decomposed with water and 15% NaOH aq, the mixture was stirred for 2 hr. $MgSO_4$ was added and the mixture was filtered. The ether was removed at reduced press (no heat). A gas liquid chromatographic analysis (30% SE 30 on chromasorb W support) of the residue indicated that both cyclooctene and cyclooctane were present. Therefore the residual liquid was heated for 30 min with a mixture of 3·5 g of 2,4-dinitrobenzenesulfenyl chloride in 20 ml of glacial AcOH.[17,18] The mixture was cooled, olefin-free pentane was added and the soln was washed with water, dried, and then passed through a column of 6 g of Woelm (neutral) alumina using pentane as eluant. The pentane was evaporated and the residual liquid was distilled through a short path still to yield 30 mg of product, b.p. 135–145°, lit.[26] cyclooctane, b.p. 148–149° (749 mm). This liquid now showed a negative tetranitromethane test.

1-*Deuterocyclooctanol* (XXI). Cyclooctanone (3 g) dissolved in 20 ml dry ether was added dropwise to a stirred mixture of 480 mg LAD in 120 ml dry ether. When the addition was complete the mixture was heated at reflux for 5 hr. The usual work up gave a residual oil which was distilled to yield 1·68 g (54%) of 1-deuterocyclooctanol, b.p. 106–109° (15 mm). $n_D^{25\cdot2}$ 1·4829, lit.,[21,25] cyclooctanol b.p. 100–101° (15 mm); 99° (16 mm).

1,1-*Dideuterocyclooctane* (IV). 1-Deuterocyclooctanol, 1·36 g, was converted to XXII as described for the synthesis of II. It was taken up in ether and added to a cold stirred mixture of 0·5 g LAD in 20 ml dry ether. After stirring in an ice-bath for 2 hr and at room temp for 1 day, the reaction mixture was decomposed by the cautious addition of a few drops water then a few ml 15% NaOH aq. After stirring for 1 hr $MgSO_4$ was added, the soln was filtered and most of the ether was evaporated. The liquid was heated for 30 min with a mixture of 3·5 g of 2,4-ditrobenzenesulfenyl chloride in 20 ml of glacial AcOH.[17,18] The mixture was cooled, olefin-free pentane was added and the mixture was washed 6 times with water. The pentane soln was dried over $MgSO_4$ and then passed through a column of 6 g of Woelm (neutral) alumina using olefin-free pentane as eluent. The pentane was evaporated and the residual liquid was distilled to yield 164 mg of product, b.p. 135–145°, lit.[26] cyclooctane, b.p. 148–149° (749 mm). The liquid showed a negative tetranitromethane test.

IR spectra. The IR instrument used was a Perkin–Elmer No. 273 B grating type instrument. In order to accurately compare the C–D stretching frequencies, the spectrum of each deuterated ketone (at two concentrations) and of its similarly labelled reference compound were obtained on the same chart paper in order to eliminate the possibility of calibration errors and the erroneous interpretation of any band shift caused by intermolecular hydrogen-bonding.

*Mass spectra.** The mass spectra of cyclooctanone 1,2-dideuterocyclooctanone and 1,1-dideuterocyclooctanone were determined with an Atlas CH 4 mass spectrometer. The pertinent data are discussed in the text.

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