evaporated to a thick oil, $CDCl_3$ was added, and the *N,N'*-di-*n*-butylurea was determined by nmr (δ 5.55, NH), using 1,4-dioxane (δ 3.69) as an internal standard. Although the urea peak employed appears to be distinctive in comparison to those of the other amides, it is possible that a mixture of all three amides would have a common NH peak due to hydrogen exchange, thereby causing the urea value to be high. Molecular oxygen analyses were carried out by standard procedures already referenced.

In a few instances the amine was ozonized in chloroform at −60° with an excess (2–3 molar equiv) of ozone, resulting in the reaction of 1.6–1.9 molar equiv of ozone. The major products were the nitrobutane and the *tert*-butylammonium chloride. Small amounts of *n*-butyric acid, *N-n*-butyl-*n*-butyramide, and *n*-butyl isocyanate (column 2, 90°) were detected by glpc. Quantitative determinations were made, however, only in the case of the *n*-butylammonium chloride (36% yield).

Ozonation of *n*-butylamine (20 mmol) in pentane at −60° with 1 molar equiv of ozone resulted in the formation of a white solid which melted and settled to the bottom as a small yellow aqueous layer when the reaction mixture was allowed to warm to room temperature. The two layers were separated and analyzed independently. The *pentane layer* was analyzed for 1-nitrobutane, *N-n*-butyl-*n*-butyramide, and *N-n*-butylformamide by glpc in the same manner as described for ozonations in chlorinated solvents. Glpc determinations were also employed for unreacted butylamine and *N-n*-butylidene-*n*-butylamine (column 1, 75° for 4 min and 75–175° at 6°/min, propylbenzene as internal standard), and the pentanones and pentanols (column 3, 90°, ethylbenzene as internal standard); the 2- and 3-pentanones were not separable from each other and are reported together in Table II. A trace of *C-n*-propyl-*N-n*-butylnitrone was shown to be present by nmr (see details under chlorinated solvent experiments).

A portion of the *aqueous phase* was dissolved in acetone and traces of pentanones and pentanols were determined by glpc using the procedure already described. The aqueous phase was concentrated at room temperature under reduced pressure (6 mm) for 40 min and the volatile material was trapped at −70° and weighed. This was shown to be composed of water and unreacted amine; the amounts were obtained by integration. The residue from the aqueous phase was extracted with chloroform and analyzed by glpc for *N-n*-butyl-*n*-butyramide and *N-n*-butylformamide, using the procedure already described. The *n*-butylammonium cation was determined by nmr ($BuNH_3^+$ peak at δ 7.09) on a portion of the original residue, using the butyramide as an internal standard ($EtCH_2CONHBu$ at δ 2.17). Since the residue gave a positive nitrate anion test,[34] the salt is reported in Table II as the nitrate. In a separate experiment, a trace of butyric acid was identified in the aqueous phase by acidification, extraction with ether, and glpc analysis of the ether extract, using the procedure already described. The values for unreacted amine, the butyramide, and the formamide reported in Table II are the sums of the determinations in the pentane and aqueous phases.

Ozonation of *n*-butylamine in pentane at −100° gave a colorless solution which, however, gave a strong epr signal for the ozonate anion radical.

Registry No.—Isopropylamine, 75-31-0; isopropylhydroxylamine, 5080-22-8; *n*-butylamine, 109-73-9.

Acknowledgment.—This work was supported by grants from the Robert A. Welch Foundation (F-042) and the National Science Foundation (GP-7351), for which the authors are grateful. Acknowledgment is also made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial support of the research.

Addition of Pseudohalogens to 1,5-Cyclooctadiene[1]

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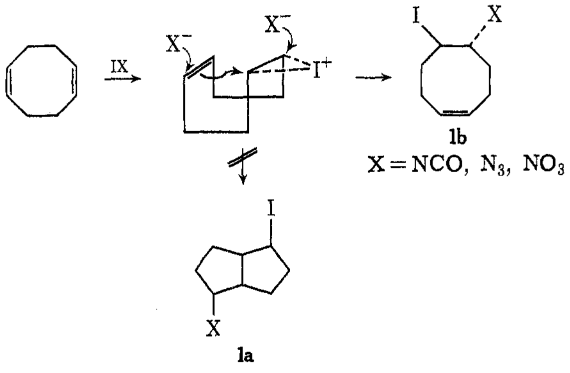
The addition of pseudohalogens IX, where X = NCO, N_3, NO_3, to 1,5-cyclooctadiene (mole ratio 1:1) yields 1,2-monocyclic adducts. In contrast, addition of iodine in methanol activates the second double bond, resulting in the direct formation of *endo,endo*-2,6-diiodo-9-oxabicyclo[3.3.1]nonane (**2**). The complete analysis of the nmr spectrum of **2** with the help of chemical shift reagents confirms the chair conformation for this fused ring system Similarly, the reaction of 5-methoxycyclooctene (**5**) with iodine in methanol gives *endo*-2-iodo 9-oxabicyclo[3.3.1]-nonane (**7**), whereas cyclooct-1-en-5-ol (**6**) gives only *endo*-2-iodo-9-oxabicyclo[4.2.1]nonane (**8**).

The addition of various reagents to 1,5-cyclooctadiene (COD) can lead to either monocyclic or bicyclic products. The monocyclic products arise by simple addition of the reagent to one of the double bonds, while the formation of bicyclic products involves transannular π participation, a well-documented pathway.[2] Recently, a detailed study of ionic additions to COD outlined some of the requirements for formation of bicyclic *vs.* monocyclic products and also presented information on the stereochemistry of the substituents on the bicyclic ring skeleton.[3]

SCHEME I



We were interested in the preparation of 2-amino-6-iodobicyclo[3.3.0]octanes (**1a**) (Scheme I) and felt that these could be obtained by the addition of pseudohalogens of type IX to COD.[4] It was visualized that the initial formation of an iodonium ion might be followed by transannular π participation to form a bicyclo[3.3.0]octane. However in all cases, where X^- =

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[1] (a) This work was supported in part by U. S. Public Health Service Grants CA-05222, 07803, and 07174 of the National Cancer Institute. Pseudohalogens. XVIII. Paper XVII: *Amer. Chem. Soc., Div. Petrol. Chem., Prepr.*, **15**, E39 (1970). (b) Presented at the 162nd National Meeting of the American Chemical Society, Washington, D. C., Sept 1971, Paper 169, Organic Chemistry Division.

[2] R. Dowbenko, *Tetrahedron*, **20**, 1843 (1964); L. Friedman, *J. Amer. Chem. Soc.*, **86**, 1885 (1964); G. Pregaglia and G. Gregorio, *Chim. Ind. (Milan)*, **45**, 1065 (1963); M. Julia and E. Colomer, *An. Quim.*, **67**, 199 (1971); T. Cantrell and B. L. Strasser, *J. Org. Chem.*, **36**, 670 (1971).

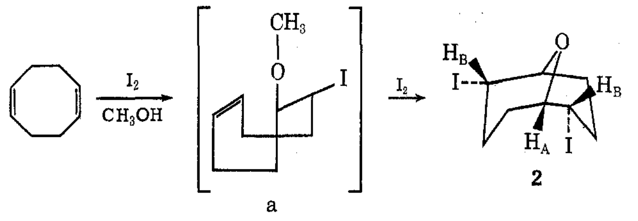
[3] I. Tabushi, K. Fujita, and R. Oda, *J. Org. Chem.*, **35**, 2376 (1970).

[4] (a) S. Rosen and D. Swern, *Anal. Chem.*, **38**, 1392 (1966); (b) F. W. Fowler, A. Hassner, and L. A. Levy, *J. Amer. Chem. Soc.*, **89**, 2077 (1967).

NCO^-, N_3^-, or NO_3^-, only 1,2-addition products (**1b**) are observed. This is believed due in part to the "closed nature" of the iodonium ion where so little positive charge resides on the carbon atoms of the iodonium ring that the remaining double bond cannot compete with the anion.[5] We have observed similar 1,2-adduct formation in the addition of *N*,*N*-dichlorourethane to COD.[6]

In contrast, the reaction of COD with I_2 in methanol (Scheme II) gives a single crystalline product characterized as *endo*,*endo*-2,6-diiodo-9-oxabicyclo[3.3.1]nonane (**2**) by analysis, its infrared spectrum with peaks at 1490 cm^{-1} characteristic of 9-oxabicyclo[3.3.1]nonanes[7] and at 1030 cm^{-1} for an ether, its nmr spectrum [δ 4.6 (2, p), 3.95 (2, t), 2.8–2.0 (8)],[8] and its reduction with LiAlH$_4$ to 9-oxabicyclo[3.3.1]nonane (**3**). The nmr coupling pattern, $J_{H_AH_B}$ = 5 cps, is compatible with the conclusion that H_B is in the exo position.

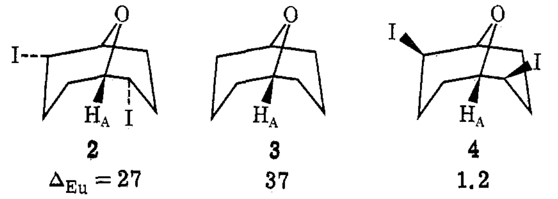
SCHEME II



An isomeric compound, formed from the reaction of mercuric acetate, potassium iodide, and iodine with COD, has $J_{H_AH_B} < 1$ cps and is thus *exo*,*exo*-2,6-diiodo-9-oxabicyclo[3.3.1]nonane (**4**).[9,10]

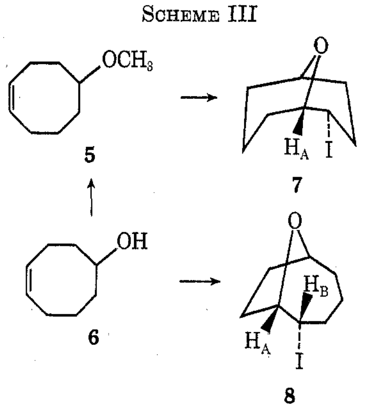
In order to distinguish clearly between structures **2** and **4**, we examined their nmr spectra with the help of chemical shift reagents.[11] Chart I shows the chemical shift gradient (Δ_{Eu}) of H_A in three 9-oxabicyclononanes with Eu(thd)$_3$. The values of the α hydrogens H_A in **2** and **3** show that these ethers are complexed about three and four times stronger, respectively, than alicyclic ethers ($\Delta_{Eu} \sim 10$). Also, the weakness of complexation with **4** confirms that it has the exo,exo configuration, since the iodines in this configuration could readily interfere with complexation. Further, the use of Eu(thd)$_3$ allowed a first-order analysis of the six different hydrogens in **2**. The coupling constants thus determined confirmed the chair cyclohexane geometry for this ring system.[12]

CHART I



The mechanism of formation of **2** (Scheme II) can be visualized as proceeding through an intermediate iodine–methoxy adduct a in which the ether oxygen activates the remaining π bond, which adds a second iodine atom followed by loss of methyl iodide. This result is similar to that with sulfenyl halide additions to COD where diadducts are formed almost exclusively unless high dilution techniques are employed.[13] To test this mechanism, 5-methoxycyclooctene (**5**) was treated with iodine in methanol (Scheme III). A new product was formed which was characterized as *endo*-2-iodo-9-oxabicyclo[3.3.1]nonane (**7**) on the basis of spectral data and its reduction with LiAlH$_4$ to give 9-oxabicyclo[3.3.1]nonane (**3**).[14]

SCHEME III



In contrast with this result, under the same conditions **6** gives *endo*-2-iodo-9-oxabicyclo[4.2.1]nonane (**8**).[14] The infrared spectrum of **8** has an ether peak at 1064 cm^{-1} while its nmr pattern shows δ 4.5 (2, m), 4.15 (1, m) (splitting identical with that of **2** and **7** suggesting the endo configuration), and 2.3–1.2 (10). The α hydrogens H_A in the [4.2.1] ring system are deshielded by ~0.5 ppm compared with those in the [3.3.1] ring system; thus in **8** H_A gives a signal at lower field than H_B.[15] This feature of sizable differences in the chemical shifts of bridgehead protons between ring systems has also been found in the 9-thiabicyclonanes and has been attributed to differences in ring strain.[16]

These results support the mechanism for formation of **2**. Reaction of iodine with **6** is faster than with **5** and this may explain in part the difference in the products formed. Thus, before the methyl group is lost (Scheme IV), a second-order reaction, the more stable bridged structure b may be formed, whereas in the formation of **8** simple proton loss is required from a species like a and this reaction may be under kinetic control. This in-

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[5] For a discussion of iodonium ions as intermediates see A. Hassner, *Accounts Chem. Res.*, **4**, 9 (1971), and references cited therein.

[6] T. A. Foglia and D. Swern, *J. Org. Chem.*, **31**, 3625 (1966).

[7] (a) E. D. Weil, K. J. Smith, and R. J. Gruber, *ibid.*, **31**, 1669 (1966); (b) F. G. Bordwell and M. L. Douglass, *J. Amer. Chem. Soc.*, **88**, 993 (1966).

[8] This isomer of diiodo-9-oxabicyclononane is identical with one of the six isomers formed in the iododemercuration of the mercuric acetate adduct of COD.[9]

[9] C. Ganter, K. Wicker, W. Zwahlen, and K. Schaffner-Sabba, *Helv. Chim. Acta*, **53**, 1618 (1970).

[10] H. Stetter, H. J. Meissner, and W. D. Last, *Chem. Ber.*, **101**, 2889 (1968).

[11] J. K. M. Sanders and D. K. Williams, *J. Amer. Chem. Soc.*, **93**, 641 (1971).

[12] E. J. Corey and E. Block, *J. Org. Chem.*, **31**, 1663 (1966).

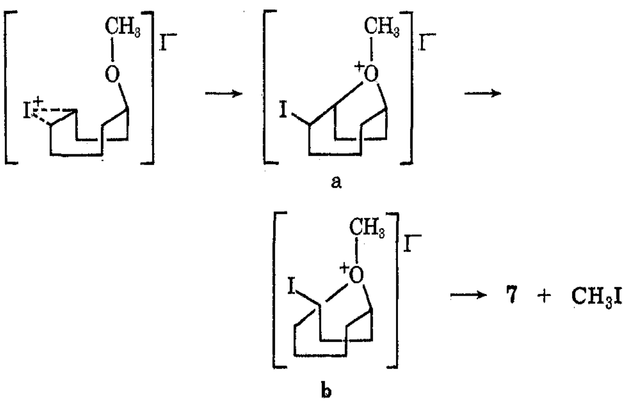
[13] W. H. Mueller, *J. Amer. Chem. Soc.*, **91**, 1223 (1969).

[14] C. Ganter, R. O. Duthaler, and W. Zwahlen, *Helv. Chim. Acta*, **54**, 578 (1971).

[15] The δ values for the parent systems are 3.9 for **3** and 4.4 for 9-oxabicyclo[4.2.1]nonane.[16]

[16] H. J. Franz, W. Höbold, R. Höhn, G. Müller-Hagen, R. Müller, W. Pritzkow, and H. Schmidt, *J. Prakt. Chem.*, **3**, 622 (1970).

SCHEME IV



terpretation is supported by results on the addition of mercuric acetate to **6** where, under buffered conditions, a [4.2.1] ring system is formed, while under acidic conditions the [3.3.1] ring system is formed since added acid inhibits proton loss, thus leading to the thermodynamic product.[7b]

Experimental Section

Nmr spectra were obtained on a Varian XL-100 spectrometer. Infrared spectra were recorded on a Perkin-Elmer Model 137. 1,5-Cyclooctadiene was obtained from Aldrich Chemical Co.

Addition of Pseudohalogens to 1,5-COD.—Literature procedures were followed for the preparation of INCO,[4a] IN$_3$,[4b] INO$_3$ (solvent acetonitrile), and *N*,*N*-dichlorourethane,[6] and their addition to COD. A 1:1 molar ratio of reagent to COD was used. After removal of unreacted COD, the products were analyzed by nmr for the presence of olefinic hydrogens. In all cases proton ratios indicated one remaining double bond.

Methyl (5-iodo-6-cyclooctenyl)carbamate, mp 114°, was prepared from the INCO adduct by reaction with methanol, nmr δ 5.7 (2), 5.1 (1), 4.6 (1), 4.0 (1), 3.5 (3, s), 2.7–1.8 (8).

Anal. Calcd for C$_{10}$H$_{16}$NIO$_2$: C, 38.6; H, 5.17; N, 4.52; I, 41.3. Found: C, 38.6; H, 5.15; N, 4.27; I, 41.3.

5-Iodo-6-azidocyclooctene had nmr δ 5.7 (2), 4.6 (1), 4.0 (1), 3.0–2.0 (8); **5-iodo-6-nitratocyclooctene** had mp 110°, nmr δ 5.6 (2), 5.3 (1), 4.5 (1), 2.5–2.0 (8) (compare -CH$_2$ONO, δ 4.8); **ethyl (5-chloro-6-cyclooctenyl)carbamate**[6] had bp 105° (0.02 mm), nmr δ 5.8–5.5 (2), 4.5–3.8 (4), 2.7–1.8 (8), 1.2 (3, t).

***endo,endo*-2,6-Diiodobicyclo[3.3.1]nonane (2).**—A solution of 1,5-COD (5 g, 0.05 mol) and iodine (22 g, 0.09 mol) in methanol was refluxed for 3–4 hr. On cooling a precipitate formed, which was filtered and washed with a solution of sodium thiosulfate. Recrystallization from ether or hexane gave crystals (5 g, 30%): mp 124°; ir 2980, 1490, 1150, 1030, 905, 860, 790 cm^{-1}; nmr δ 4.6 (2, p), 4.0 (2, t), 2.8–2.0 (8, b).

Anal. Calcd for C$_8$H$_{12}$I$_2$O: C, 25.5; H, 3.19; I, 67.0. Found: C, 25.5; H, 3.15; I, 66.9.

The same yield was obtained in methanol–water (80:20). **2** gave an immediate precipitate with AgNO$_3$ and a quantitative yield of AgI. Reaction of **2** (1 g) with LiAlH$_4$ (0.4 g) in ether gave a residue which after work-up was identical with 9-oxabicyclo[3.3.1]nonane (**3**) by ir and nmr [δ 3.8 (2), 7.9–8.6 (12)]. Further purification by sublimation gave crystals, mp 50–52° (lit. mp 52–52.5°).[7b]

***endo*-2-Iodo-9-oxabicyclo[4.2.1]nonane (8).**—Cyclooct-1-en-5-ol (**6**) (1 g) was dissolved in methanol (25 ml), and iodine (2.5 g excess) was added; the reaction mixture was stirred at 25° for 4 days. Sodium thiosulfate solution was added to destroy excess iodine and the mixture was extracted with hexane, washed, and dried. On evaporation of hexane a residue (1.5 g) was formed: bp 56° (0.03 mm); ir 2980, 1475, 1458, 1060, 960, 920 cm^{-1}; nmr δ 4.5 (2, m), 4.15 (1, m) (six peaks), 2.3–1.2 (10).

Anal. Calcd for C$_8$H$_{13}$IO: C, 38.1; H, 5.16. Found: C, 38.26; H, 5.17.

5-Methoxycyclooctene (5).[16]—**6** was treated with NaH and methyl iodide. The product after work-up and distillation [43° (1.5 mm)] showed ir 2980, 1100, 995, 879 cm^{-1} and nmr δ 5.6 (2), 3.8 (1), 3.2 (3), 2.4–1.2 (10).

Anal. Calcd for C$_9$H$_{16}$O: C, 77.3; H, 11.4. Found: C, 77.2; H, 11.4.

***endo*-2-Iodo-9-oxabicyclo[3.3.1]nonane (7).**—**5** was treated with iodine in methanol for 1 week and worked up as previously described. The product showed ir 1490 and 1028 cm^{-1} and nmr δ 4.55 (1, p), 3.93 (2, q), 2.7–1.7 (10), with a pattern identical with that reported.[14] The ether **5** reacts slower than the alcohol **6** with iodine, as determined from a competition reaction. When a 70:30 mixture of ether–alcohol was treated with excess iodine for 24 hr, unreacted ether **5** was still present. Distillation [56° (0.03 mm)] afforded a mixture of the iodo ethers **7** and **8** as determined from nmr. A sample of **7** was treated with LiAlH$_4$ in ether to give 9-oxabicyclo[3.3.1]nonane (**3**) identical with an authentic sample.[7b]

Registry No.—**2**, 29417-22-9; **5**, 32160-45-5; **8**, 35048-89-6; 1,5-COD, 111-78-4; methyl (5-iodo-6-cyclooctenyl)carbamate, 35048-90-9.

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