Bridged Polycyclic Compounds. XXXVIII. Stereochemistry of Cyclopropane Ring Formation from γ-Chlorosulfones in the Dibenzobicyclo[3.2.1]octadiene System[1]

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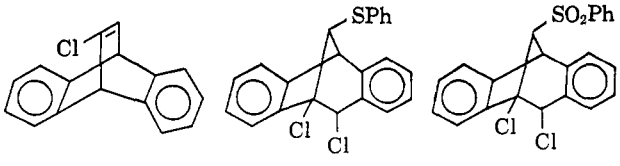
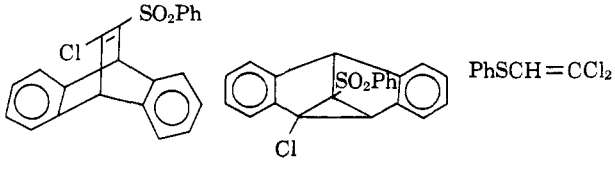
Abstract: The stereochemistry of base-promoted 1,3 elimination to give cyclopropanes has been scrutinized in the reaction of isomeric 4-chloro-8-phenylsulfonyldibenzobicyclo[3.2.1]octadienes to give 8-phenylsulfonyldibenzotricyclo[3.2.1.$0^{2,8}$]octadienes. The reaction involves carbanionic intermediates, and, as anticipated, there appears to be a very large preference for the ring closure to involve inversion at the carbon atom undergoing displacement of chloride ion by the carbanionic carbon atom. A number of stereospecific Wagner–Meerwein rearrangements have been observed in conversions of bicyclo[2.2.2]octadienes to bicyclo[3.2.1]octadienes. The stereochemistry observed in the rearrangements was in accord with expectations from previous observations.

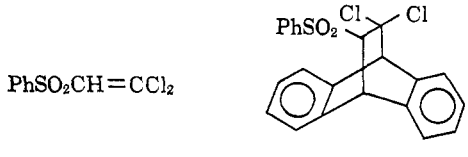
In the previous paper[1] it was shown that the addition of benzenesulfenyl chloride to the chloro olefin I gave the dichloro thioether II, and the subsequent oxidation of II gave the sulfone III. Although II was recovered from treatment with strong bases, treatment of III with sodium ethoxide gave a new sulfone, which differed in analysis from III by loss of hydrogen chloride, and whose proton magnetic resonance and ultraviolet spectra were consistent with those expected for the olefin IV or the tricyclooctane V. At the time this experiment was conducted,[1] the structures of II and III had not been established, and both IV and V were therefore reasonable possibilities. In addition, one can write plausible mechanisms for the formation of each of these from III (the β-elimination product would violate Bredt's rule and was therefore not considered).



I II III



IV V VI

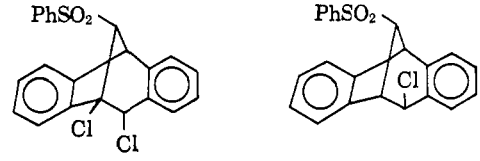


VII VIII

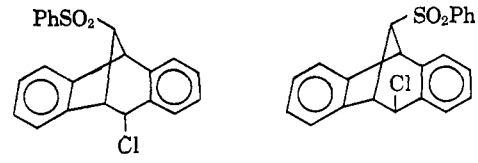
In order to resolve this problem, we devised an alternative sysnthesis of IV *via* VI, VII, and VIII. Treatment of trichloroethylene with thiophenol in the presence of benzoyl peroxide gave 2,2-dichlorovinyl phenyl thioether (VI) in excellent yield. (*Caution: this material is a powerful vesicant.*) Presumably, phenylmercapto radical adds to trichloroethylene to yield the more stable radical (stabilized by two chlorine atoms rather than one[2]), which then ejects a chlorine atom[3-5] to give VI.

Oxidation of VI gave the related sulfone VII. The isomeric *cis*- and *trans*-1,2-dichlorovinyl phenyl sulfones are both known,[6] and VII melts lower than either of these. When the Diels–Alder reaction between VII and anthracene was attempted, VIII was not isolated, but it presumably was formed and eliminated hydrogen chloride to give IV. Compound IV was different from the product from III and the latter was therefore assigned structure V.

In view of our previous experience with epimerization of γ-chloro sulfones prior to γ elimination,[7] it seemed reasonable that a similar carbanion-intermediate process might occur here. In fact, when the dichloro sulfone III was treated with sodium ethoxide at room temperature, an equilibrium mixture of III and the *anti*-8 epimer IX was formed prior to dehydrochlorination to V.



IX X

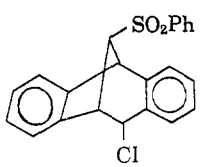


XI XII

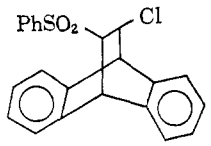
(1) Previous paper in series: S. J. Cristol and B. B. Jarvis, *J. Am. Chem. Soc.*, **88**, 3091 (1966).

(2) P. D. Bartlett, L. K. Montgomery, and B. Seidel, *ibid.*, **86**, 616 (1964).
(3) L. Schmerling and J. P. West, *ibid.*, **71**, 2015 (1949).
(4) E. I. Heiba and L. C. Anderson, *ibid.*, **79**, 4940 (1957).
(5) W. O. Haag and E. I. Heiba, *Tetrahedron Letters*, 3683 (1965).
(6) G. Modena and F. Montanari, *Gazz. Chim. Ital.*, **86**, 432 (1956).
(7) S. J. Cristol, J. K. Harrington, and M. S. Singer, *J. Am. Chem. Soc.*, **88**, 1529 (1966).

In view of our interests in the stereochemistry of cyclopropane ring formation in γ eliminations,[7] we decided to scrutinize ring closure reactions of this type more closely. The bridgehead chlorine atom in III was not useful to us, and in fact caused stereochemical complications in synthetic procedures.[1] To consider stereochemical requirements for γ eliminations, we undertook the preparation of the four isomeric γ-chloro sulfones X, XI, XII, and XIII. Of these, the *endo* chlorides XI and XIII may form the cyclopropane ring with inversion at the carbon atom bearing the chlorine atom, while the *exo* chlorides X and XII would have to react with over-all retention at C-4.



XIII



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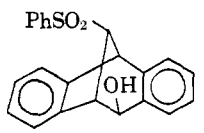
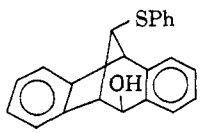


XV

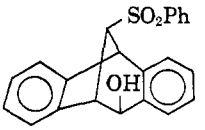


XVI

Addition of benzenesulfenyl chloride to dibenzobicyclo[2.2.2]octatriene in carbon tetrachloride[1,8] followed by oxidation gave the chloro sulfone XIV. Silver acetate assisted acetolysis of XIV gave the acetate of XV with the anticipated stereochemistry.[9] (Stereochemical assignments in these bicyclo[3.2.1]-octadienes may be made with confidence from pmr spectral data.[8,10]) Transesterification of this acetate gave the alcohol XV. Treatment of the *exo* alcohol XV with thionyl chloride in either dioxane or pyridine gave the *exo*-4-chloro *anti*-8-sulfone X. The formation of the *exo* chloride is consistent with the generally observed[11] preference for *exo* (axial) coordination with nucleophiles by cations at C-4 in these systems, and apparently displacement with inversion does not compete.

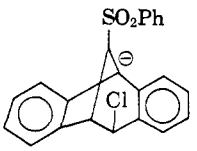
Addition of benzenesulfenyl chloride to dibenzobicyclo[2.2.2]octatriene in acetic acid proceeded with rearrangement to give the acetate of XVI,[8] which was then converted by moist alumina into the alcohol XVI. Oxidation of XVI gave the sulfone XVII. Treatment of XVII with thionyl chloride in pyridine gave exclusively the *endo* chloride XIII, while the same reagent in dioxane gave a mixture of XIII and *exo* isomer XII. The fourth isomer, the *endo*-chloro *anti*-sulfone XI was produced by base-catalyzed epimerization of the *syn* sulfone XIII.

As mentioned above, the reaction between *exo*-hydroxy *anti*-sulfone XV and thionyl chloride gave *exo*-chloro sulfone X, with retention of configuration,

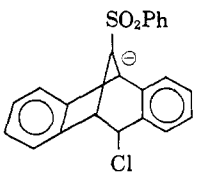


XVII

XVIII



XIX



XX

no matter whether the solvent used was one which ordinarily gives retention (dioxane)[12,13] or one which ordinarily gives inversion (pyridine).[12,13] On the other hand, the *exo*-hydroxy *syn*-sulfone XVII with thionyl chloride in pyridine gave complete inversion of configuration (product was XIII) while the reaction in dioxane gave approximately equal amounts of inversion (XIII) along with the ordinarily anticipated product of retention (XII). It would appear that the bulky *syn*-8-phenylsulfonyl group hinders the normal attack from the *exo* side of the cationic intermediate[12,13] in this reaction.

In a solution with sodium ethoxide, *endo*-chloro sulfones XI and XIII readily proceed to an equilibrium mixture, slightly favoring the *anti*-sulfone XI. However, the *exo*-chloro *syn*-sulfone XII is transformed completely (within the limits of pmr analysis) to the *exo*-chloro *anti*-sulfone X. The strong preference for X undoubtedly reflects the steric interference between the *exo*-chlorine at C-4 and the *syn*-sulfone group at C-8 in XII.

The *endo*-chloro sulfones XI and XIII eliminated hydrogen chloride quantitatively with 0.44 *M* sodium ethoxide in a refluxing solution of 50% absolute ethanol in dioxane within 30 min to form the dibenzotricyclooctyl sulfone XVIII. With Raney nickel in diethyl ether, V was dechlorinated to XVIII, demonstrating the relationship between these two compounds.

Related 1,3 eliminations in acyclic[14,15] and bicyclic[7] sulfones are known to occur. In part, the ease of elimination from XX is due to the rigidity of system since, as models show, very little movement of the atoms is required in going from the dibenzobicyclo-[3.2.1]octadiene to the dibenzotricyclo[3.2.1.$0^{2,8}$]-3,6-octadiene system.

When *exo*-chloro sulfones X and XII were treated under the same conditions as XI and XIII, only X resulted. Even when the *exo* chlorides were heated for 5 days with 1 *M* sodium ethoxide in ethanol–dioxane, no elimination occurred and X was the sole product.

The results can be readily rationalized by considering the carbanion intermediates in the epimerization and ring-closure reactions. It would appear that the formation of the cyclopropane ring from the *endo*-chloro carbanion XX has the normally expected[7,16]

(8) S. J. Cristol, R. Caple, R. M. Sequeira, and L. O. Smith, Jr., *J. Am. Chem. Soc.*, **87**, 5679 (1965).

(9) (a) S. J. Cristol, F. P. Parungo, and D. E. Plorde, *ibid.*, **87**, 2870 (1965); (b) S. J. Cristol, F. P. Parungo, D. E. Plorde, and K. Schwarzenbach, *ibid.*, **87**, 2879 (1965).

(10) S. J. Cristol, J. R. Mohrig, and D. E. Plorde, *J. Org. Chem.*, **30**, 1956 (1965).

(11) For a summary of such reactions, see ref 9.

(12) E. S. Lewis and C. E. Boozer, *J. Am. Chem. Soc.*, **74**, 308 (1952).

(13) E. S. Lewis and C. E. Boozer, *ibid.*, **75**, 3182 (1953).

(14) H. E. Zimmerman and B. S. Thyagarajan, *ibid.*, **82**, 2505 (1960).

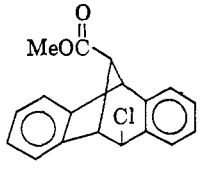
(15) W. E. Truce and L. B. Lindy, *J. Org. Chem.*, **26**, 1463 (1961).

(16) H. M. Walborsky and C. G. Pitt, *J. Am. Chem. Soc.*, **84**, 4831 (1962).

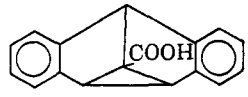
requirement for inversion, in the nucleophilic attack of the carbanion carbon on the C-4 carbon in the formation of the 4,8 bridge. This is not possible with the epimeric *exo*-4-chloro-8-carbanion XIX.

However, in dimethyl sulfoxide solvent, and with potassium *t*-butoxide as base, *exo*-chloro sulfone X was converted to the tricyclooctane XVIII. Although it is conceivable that this reaction is a frontside displacement,[17] it seems more reasonable to assume that the strong base removes the benzylic proton[19] reversibly at C-4 enabling epimerization of the *exo* chloride X to the *endo* chloride XI to occur. XI would of course be rapidly dehydrochlorinated to XVIII.[20]

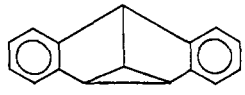
This type of 1,3 elimination is not limited to the sulfones. The ester chloride XXI with potassium *t*-butoxide in dimethyl sulfoxide at room temperature gave the acid XXII. The carboxylic acid was not unexpected, as normal esters are known to be converted to acids rapidly under these conditions.[22]



XXI



XXII



XXIII

Several examples of this tricyclo[3.2.1.$0^{2,8}$]octane system (without the benzene rings) have been recently reported.[23-25] Their syntheses included a carbene reaction[23] and photochemical isomerizations.[24,25] Recently, the parent hydrocarbon, dibenzotricyclo-[3.2.1.$0^{2,8}$]-3,6-octadiene (XXIII), was reported to be formed in the dimerization of benzocyclobutadiene.[26] We have since prepared XXIII by several routes[21] and have confirmed the structure assigned by Pettit.

Experimental Section

Spectra. The ultraviolet spectra were determined in spectral grade carbon tetrachloride on a Cary 14 instrument; pmr spectra were determined as saturated solutions in either carbon tetrachloride or deuteriochloroform on a Varian A-60 instrument, and results are expressed in τ units, where τ = 10.00 for the internal standard tetramethylsilane. J values reported are "observed" ones.

Epimerization of *endo*-4,5-Dichloro-*syn*-8-phenylsulfonyldibenzobicyclo[3.2.1]octadiene (III). In 25 ml of dry dioxane and 10 ml of absolute ethanol, 509 mg (1.23 mmoles) of III[1] (ultraviolet spectrum: shoulder λ_{max} 252 mμ (ε 870), λ_{max} 259 mμ (ε 1250), λ_{min} 262 mμ (ε 1230), λ_{max} 266 mμ (ε 1760), λ_{min} 270 mμ (ε 1220), and λ_{max} 273 mμ (ε 1480)) was dissolved. To this solution was added 15 ml of absolute ethanol in which 64 mg (2.8 mg-atoms) of sodium metal had been dissolved. This mixture was allowed to stand for 2 hr at room temperature and was then poured into 100 ml of water. The mixture was extracted with 100 ml of ether and the ethereal solution was then washed with water and dried over anhydrous magnesium sulfate. The ether was removed by rotary evaporation, and a pmr spectrum of the resulting solid showed an approximately 60:40 mixture of IX and III. The resulting solid was recrystallized from chloroform–carbon tetrachloride solution, yielding 300 mg (59%) of *endo*-4,5-dichloro-*anti*-8-phenylsulfonyldibenzobicyclo-[3.2.1]octadiene (IX), mp 236–237°.

The pmr spectrum of a deuteriochloroform solution of IX showed one sharp and two broader singlets (1 H each) at τ 4.39, 5.20, and 5.75 ($J_{1s} \sim 0$ cps),[10] respectively, and two distinct sets of aromatic protons (2 H and 11 H) at 2.1–2.3 and 2.5–2.9.

Anal. Calcd for $C_{22}H_{16}Cl_2O_2S$: C, 63.62; H, 3.88. Found: C, 63.46; H, 3.92.

Preparation of 1-Chloro-8-phenylsulfonyldibenzotricyclo-[3.2.1.$0^{2,8}$]-3,6-octadiene (V). To a solution containing 2.00 g (4.82 mmoles) of III, 25 ml of dry dioxane, and 10 ml of absolute ethanol was added 15 ml of absolute ethanol in which 500 mg (22 mg-atoms) of sodium metal had been dissolved. This solution was heated at reflux for 30 min and was then poured into 100 ml of water. The mixture was extracted with 100 ml of ether; the ethereal solution was then washed with water, dried over anhydrous magnesium sulfate, and decolorized with activated charcoal. The ether was removed by rotary evaporation, and the resulting solid was recrystallized from carbon tetrachloride, yielding 1.52 g (83%) of V, mp 180–182° dec. A pmr spectrum of the mother liquor showed that only V was present.

The ultraviolet spectrum showed λ_{max} 256 mμ (ε 2560), λ_{min} 262 mμ (ε 2000), λ_{max} 265 mμ (δ 2380), λ_{min} 268 mμ (ε 1790), λ_{max} 273 mμ (ε 2300), λ_{min} 278 mμ (ε 1090), and λ_{max} 281 mμ (ε 1250).

The pmr spectrum of V in deuteriochloroform showed two sharp singlets (1 H each) at τ 5.05 and 5.65 and two distinct sets of aromatic protons (2 H and 11 H) at 2.0–2.2 and 2.5–3.1.

Anal. Calcd for $C_{22}H_{15}ClO_2S$: C, 69.74; H, 3.99. Found: C, 70.01; H, 4.04.

Preparation of 2,2-Dichlorovinyl Phenyl Thioether (VI). To a refluxing solution of 80 ml of trichloroethylene containing 0.2 g of benzoyl peroxide, 30 g (0.27 mole) of thiophenol was added dropwise over a period of 1 hr. This mixture was heated at reflux for and additional 12 hr. The volatile materials were removed by rotary evaporation. The resulting oil was distilled under vacuum to give 51 g (92%) of VI, bp 119–121° (2.5 mm). (*Caution: this material is a powerful vesicant.*)

The pmr spectrum of a carbon tetrachloride solution of VI showed one sharp singlet (1 H) at τ 3.62 and a symmetrical multiplet for the aromatic protons (5 H) at 2.89.

Preparation of 2,2-Dichlorovinyl Phenyl Sulfone (VII). Sixty milliliters of 30% hydrogen peroxide was added slowly to a solution of 15.0 g (73.1 mmoles) of VI in 200 ml of glacial acetic acid. This mixture was allowed to stand for 2 hr on a steam bath and was then poured into 400 ml of water. The aqueous solution was extracted with two 150-ml portions of water. The aqueous solution was extracted with two 150-ml portions of ether. The ether fractions were combined, washed with 10% sodium carbonate until basic, and then dried over anhydrous magnesium sulfate. After the ether was removed by rotary evaporation, the resulting oil was crystallized from 95% ethanol, yielding 16.5 g (95%) of VII, mp 51.5–52.0°.

The pmr spectrum of a carbon tetrachloride solution showed one sharp singlet (1 H) at τ 3.11 and two distinct sets of aromatic protons (2 H and 3 H), at 2.0–2.3 and 2.4–2.6.

Anal. Calcd for $C_8H_6Cl_2O_2S$: C, 40.50; H, 2.55. Found: C, 40.54; H, 2.66.

Reaction between Anthracene and the Sulfone VII. Ten grams (42 mmoles) of VII, 10 g (56 mmoles) of anthracene, and 50 ml of xylene were sealed in a tube. The tube was heated at 210–220° for 2 days. The tube was cooled and opened and the xylene was

(17) It has been reported[18] that a cyclopropane ring was formed *with retention* in the formation of tricyclo[2.1.1.$0^{5,6}$]hexane-5-*t*-butylcarboxamide from *exo*-5-chlorotricyclo[2.1.1]hexane-*exo*-6-*t*-butylcarboxamide by dehydrohalogenation with excess *n*-butyllithium. It was further reported that the *endo*-6-*t*-butylcarboxamide, which, in our opinion, should give the same carbanion, did not react. Details of these experiments have not yet appeared.

(18) J. Meinwald, C. Swithenbank, and A. Lewis, *J. Am. Chem. Soc.*, **85**, 1880 (1963).

(19) J. E. Hofmann, R. J. Muller, and A. Schriescheim, *ibid.*, **85**, 3000, 3002 (1963).

(20) This suggested reaction path, involving removal of the benzylic proton at C-4 by strong base, gains considerable support from an observation we have recently made[21] that *exo*-4-*anti*-8-dichlorodibenzobicyclo[3.2.1]octadiene is readily transformed by potassium *t*-butoxide in dimethyl sulfoxide to 1-chlorodibenzotricyclo[3.2.1.$0^{2,8}$]-3,6-octadiene.

(21) S. J. Cristol and B. B. Jarvis, unpublished work.

(22) F. C. Chang and N. F. Wood, *Tetrahedron Letters*, 2969 (1964).

(23) M. Schwarz, A. Besold, and E. R. Nelson, *J. Org. Chem.*, **30**, 2425 (1965).

(24) J. Zirner and S. Winstein, *Proc. Chem. Soc.*, 235 (1964).

(25) W. R. Roth and B. Peltzer, *Angew. Chem., Intern. Ed. Engl.*, **3**, 440 (1964).

(26) G. F. Emerson, L. Watts, and R. Pettit, *J. Am. Chem. Soc.*, **87**, 131 (1965).

removed by rotary evaporation. The resulting brown solid was partially dissolved in 150 ml of hot absolute methanol. The undissolved, unreacted anthracene was removed by filtration and the filtrate decolorized with activated charcoal and concentrated to a volume of 40 ml. The resulting precipitate was recrystallized from carbon tetrachloride, yielding 5.2 g (33%) of 7-chloro-8-phenylsulfonyldibenzobicyclo[2.2.2]octatriene (IV), mp 177–178°.

The ultraviolet spectrum showed λ_{max} 256 mμ (ε 2730), λ_{min} 258–265 mμ (ε 2690), λ_{max} 268 mμ (shoulder) (ε 3030), λ_{max} 274 mμ (ε 3300), λ_{min} 277 mμ (ε 3220), and λ_{max} 280 mμ (ε 3450).

The pmr spectrum of a deuteriochloroform solution showed two sharp singlets (1 H each) at τ 4.35 and 4.91 and two sets of aromatic protons (2 H and 11 H) at 2.1–2.4 and 2.5–3.2.

Anal. Calcd for $C_{22}H_{15}ClO_2S$: C, 69.74; H, 3.99. Found: C, 69.85; H, 4.07.

Preparation of *anti*-8-Phenylsulfonyldibenzobicyclo[3.2.1]octadien-*exo*-4-ol Acetate (XV Acetate). To a solution of 4.0 g (14.7 mmoles) of *trans*-7-chloro-8-thiophenoxydibenzobicyclo[2.2.2]octadiene[8] in 95 ml of glacial acetic acid was added slowly 30 ml of 30% hydrogen peroxide. This mixture was allowed to stand on a steam bath for 2 hr. The solution was then poured into 200 ml of 30% hydrogen peroxide. This mixture was allowed to stand on a steam bath for 2 hr. The solution was then poured into 200 ml of water and the resulting mixture was extracted with two 150-ml portions of ether. The ether extracts were combined, washed with 10% sodium carbonate, and dried over anhydrous magnesium sulfate. The ether was removed by rotary evaporation; an infrared spectrum of the crude reaction mixture showed no starting material or intermediate sulfoxide present.

The crude reaction mixture was dissolved in 150 ml of glacial acetic acid containing 2.5 g (15 mmoles) of silver acetate. This mixture was then heated at reflux and stirred for 75 hr. The mixture was filtered while hot, and the filtrate was poured into 300 ml of water. The aqueous acetic acid was extracted with two 150-ml portions of ether. The ether portions were combined, washed with 10% sodium carbonate, and dried over anhydrous magnesium sulfate. The solution was decolorized with activated charcoal, and the ether was removed by rotary evaporation. The resulting solid was recrystallized from carbon tetrachloride, yielding 4.1 g (69%) of XV acetate, mp 173–174°.

The pmr spectrum of a deuteriochloroform solution showed a sharp singlet (3 H) at τ 8.02, a sharp doublet (1 H) at 4.09 (J_{45} = 2.5 cps),[10] an unresolved multiplet (1 H) at 6.07, a broad singlet (1 H) at 5.47, a sharper singlet (1 H) at 5.75, and two distinct sets of aromatic protons (2 H and 11H) at 2.3–2.5 and 2.6–3.2.

Anal. Calcd for $C_{24}H_{20}O_4S$: C, 71.26; H, 4.98. Found: C, 71.14; H, 4.93.

Preparation of *anti*-8-Phenylsulfonyldibenzobicyclo[3.2.1]octadien-*exo*-4-ol (XV). To a solution containing 3.00 g (7.42 mmoles) of the *exo* acetate of XV dissolved in 150 ml of absolute methanol was added 20 ml of concentrated hydrochloric acid. This mixture was heated at reflux for 3 hr and was then poured into 200 ml of water. This was extracted with two 100-ml portions of ether. The ether portions were combined, washed with water, and dried over anhydrous magnesium sulfate. The ether was removed by rotary evaporation, and the resulting solid was recrystallized from carbon tetrachloride, yielding 2.3 g (86%) of XV, mp 163.5–164.5°.

The pmr spectrum of a deuteriochloroform solution showed a sharp doublet (1 H) at τ 5.23 (J_{45} = 2.5 cps),[10] an unresolved multiplet (1 H) at 6.08, a sharp singlet (1 H) at 5.68, an unresolved multiplet (1 H) at 5.59 ($J_{18} \sim J_{58} \sim 0$ cps),[10] and two distinct sets of aromatic protons (2 H and 11 H) at 2.2–2.4 and 2.5–3.2.

Anal. Calcd for $C_{22}H_{18}O_3S$: C, 72.90; H, 5.01. Found: C, 72.76; H, 4.80.

Preparation of *exo*-4-Chloro-*anti*-8-phenylsulfonyldibenzobicyclo-[3.2.1]octadiene (X). To a solution of 1.50 g (4.14 mmoles) of *exo*-alcohol XV dissolved in 25 ml of dry dioxane was added 3 ml of thionyl chloride. This mixture was allowed to stand at room temperature for 15 hr. Water was slowly added until the excess thionyl chloride was destroyed, and then an additional 100 ml of water was added. The mixture was extracted with 100 ml of ether; the ethereal solution was washed with water and dried over anhydrous magnesium sulfate. The ether was concentrated to a volume of 25 ml, and the solid complex of ether–X was filtered. This solid was recrystallized from 95% ethanol, yielding 1.20 g (76%) of X, mp 150–151°. No *endo* epimer (XXI) was observed in either the crude reaction mixture or the mother liquor of crystallization. This same reaction carried out in pyridine gave essentially identical results.

The pmr spectrum in deuteriochloroform showed a sharp doublet (1 H) at τ 4.82 (J_{45} = 2.5 cps),[10] a broad doublet (1 H) at 5.91, a sharp singlet (1 H) at 5.58, a broader singlet (1 H) at 5.51 ($J_{18} \sim J_{58} \sim 0$ cps),[10] and two distinct sets of aromatic protons (2 H and 11 H) at 2.2–2.4 and 2.5–3.1.

Anal. Calcd for $C_{22}H_{17}ClO_2S$: C, 69.37; H, 4.50. Found: C, 69.31; H, 4.56.

Hydrolysis of *syn*-8-Thiophenoxydibenzobicyclo[3.2.1]octadien-*exo*-4-ol Acetate (XVI). When XVI acetate[8] was passed over Merck 71707 neutral alumina using carbon tetrachloride–chloroform as the eluent, it was hydrolyzed in varying yields to *syn*-8-thiophenoxydibenzobicyclo[3.2.1]octadien-*exo*-4-ol (XVI). Unreacted *exo*-acetate of XVI, epimerized *endo*-acetate, and the *endo*-alcohol epimeric with XVI also came off the column as minor products. Hydrolysis was favored by slightly moist alumina; no hydrolysis or epimerization was observed if the alumina was carefully dried.

Preparation of *syn*-8-Phenylsulfonyldibenzobicyclo[3.2.1]octadien-*exo*-4-ol (XVII). To a solution containing 5.0 g (15.2 mmoles) of XVI in 75 ml of benzene was added 8.8 g (45.7 mmoles) of *m*-chloroperbenzoic acid (85% min assay, FMC Corp.). The solution became warm as the reaction took place. The solution stood for 15 min and then additional 150 ml of benzene was added. The benzene solution was washed with acidic 10% ferrous sulfate, with 10% sodium carbonate until basic, with saturated salt solution and was then dried over anhydrous magnesium sulfate. The solution was decolorized with activated charcoal and the benzene was removed by rotary evaporation. The resulting oil was crystallized from carbon tetrachloride yielding 3.9 g (71%) of XVII, mp 186–187°.

The pmr spectrum in deuteriochloroform showed a sharp doublet (1 H) at τ 4.45 (J_{45} = 2.5 cps),[10] a series of complex overlapping multiplets (3 H) from 5.8 to 6.2, and two distinct sets of aromatic protons (2 H and 11 H) at 2.1–2.4 and 2.6–3.1.

Anal. Calcd for $C_{22}H_{18}O_3S$: C, 72.90; H, 5.01. Found: C, 72.70; H, 4.89.

Reaction between *exo* Alcohol XVII and Thionyl Chloride. One gram (2.76 mmoles) of XVII and 2.0 ml of thionyl chloride were dissolved in 25 ml of dry dioxane. This mixture stood for 15 hr at room temperature and was then poured into 100 ml of water, after the excess thionyl chloride had been destroyed by dropwise addition of water. The mixture was extracted twice with 75-ml portions of ether. The ether portions were combined, washed with water, and dried over anhydrous magnesium sulfate. The ether was removed by rotary evaporation, and a pmr spectrum of the crude reaction mixture showed an approximately 55% XIII and 45% XII mixture. Fractional crystallization of this mixture from chloroform–carbon tetrachloride gave 510 mg (49%) of *endo*-4-chloro-*syn*-8-phenylsulfonyldibenzobicyclo[3.2.1]octadiene (XIII), mp 224.5–225.5°.

Anal. Calcd for $C_{22}H_{17}ClO_2S$: C, 69.37; H, 4.50. Found: C, 69.36; H, 4.54.

Successive crystallizations gave 320 mg (30%) of *exo*-4-chloro-*syn*-8-phenylsulfonyldibenzobicyclo[3.2.1]octadiene (XII), mp 209–210°.

Anal. Calcd for $C_{22}H_{17}ClO_2S$: C, 69.37; H, 4.50. Found: C, 69.20; H, 4.45.

XII showed a pmr spectrum in deuteriochloroform solution with a sharp doublet (1 H) at τ 4.82 (J_{45} = 2.0 cps),[10] a series of complex overlapping multiplets (3 H) between 5.6 and 6.1, and two distinct sets of aromatic protons (2 H and 11 H) at 2.0–2.3 and 2.4–3.0.

XIII showed a pmr spectrum in deuteriochloroform solution having a sharp doublet (1 H) at 3.90 (J_{45} = 4.5 cps),[10] a series of complex overlapping multiplets (3 H) between 5.8 and 6.7, and two distinct sets of aromatic protons (2 H and 11 H) at 2.0–2.3 and 2.4–3.0.

One gram (2.76 mmoles) of XVII and 2.0 ml of thionyl chloride were dissolved in 25 ml of dry pyridine. This mixture stood for 10 hr at room temperature and was poured into 100 ml of 5% hydrochloric acid, after the excess thionyl chloride had been destroyed by dropwise addition of water. The mixture was extracted with 100 ml of ether. The ether was washed with water and dried over anhydrous magnesium sulfate. The ether was removed by rotary evaporation, and a pmr spectrum of the crude reaction mixture showed only *endo* chloride XIII present. Crystallization from chloroform–carbon tetrachloride gave 820 mg (80%) of XIII, mp 224.5–225.5°.

Epimerization of the *endo*-Chloro *syn*-Sulfone XIII to Its *anti* Epimer XI. To a solution containing 1.01 g (2.65 mmoles) of the *syn* sulfone XIII dissolved in 20 ml of dry dioxane and 15 ml of absolute ethanol was added 170 mg (7.4 mg-atoms) of sodium metal

which had been dissolved in 5 ml of absolute ethanol. The solution was allowed to remain at room temperature for 5 hr. The precipitate which had formed was filtered and recrystallized from 95% ethanol, yielding 360 mg (36%) of *endo*-4-chloro-*anti*-8-phenylsulfonyldibenzobicyclo[3.2.1]octadiene (XI), mp 244–245°.

The pmr spectrum in deuteriochloroform showed a sharp doublet (1 H) at τ 4.51 (J_{45} = 4.5 cps),[10] a series of complex overlapping multiplets (3 H) between 5.6 and 6.2, and two distinct sets of aromatic protons (2 H and 11 H) at 2.1–2.4 and 2.5–3.1.

Anal. Calcd for $C_{22}H_{17}ClO_2S$: C, 69.37; H, 4.50. Found: C, 69.17; H, 4.49.

Preparation of 8-Phenylsulfonyldibenzotricyclo[3.2.1.0^{2,8}]-3,6-octadiene (XVIII). The preparation of XVIII was performed in exactly the same manner as V was prepared from III, starting either with XIII or XI. The product XVIII was obtained essentially quantitatively and was recrystallized from carbon tetrachloride, mp 179–180°.

The pmr spectrum of a deuteriochloroform solution showed two sharp singlets (2 H:1 H) at τ 6.00 and 5.20, respectively, and two distinct sets of aromatic protons (2 H and 11 H) at 2.1–2.3 and 2.6–3.1.

Anal. Calcd for $C_{22}H_{16}O_2S$: C, 76.71; H, 4.68. Found: C, 76.70; H, 4.59.

Hydrogenolysis of V with Raney Nickel to Give XVIII. About 5 g of Raney nickel W-2[27] was added to a solution of 1.05 g (2.53 mmoles) of V in 75 ml of ethyl ether. The mixture was stirred for 2 hr at room temperature. The Raney nickel was removed by filtration, and the ether was removed by rotary evaporation. A comparison of the pmr spectrum of the crude reaction mixture with that for XVIII showed them to be identical with no observable amount of V left. Crystallization from carbon tetrachloride gave 810 mg (80%) of XVIII, mp and mmp 179–180°

Attempted Elimination from the *exo*-Chloro Sulfones in Ethanol–Dioxane. To a solution containing 1.30 g (3.41 mmoles) of *exo*-chloro sulfones X or XII in 25 ml of dry dioxane and 10 ml of absolute ethanol was added 15 ml of absolute ethanol in which 1.20 g (52 mg-atoms) of sodium metal had been dissolved. This mixture was held at reflux for 5 days and worked up in the usual manner. A pmr spectrum of the crude reaction mixture showed only X present. Crystallization from carbon tetrachloride gave 1.20 g (92%) of X, mp and mmp 150–151°.

Elimination of Hydrogen Chloride from *exo*-Chloro Sulfones X and XII in Dimethyl Sulfoxide with Potassium *t*-Butoxide. To a solution containing 500 mg (1.31 mmoles) of either of the *exo*-chloro sulfones X and XII dissolved in 25 ml of dry dimethyl sulfoxide was added 700 mg (6.25 mmoles) of potassium *t*-butoxide. The mixture was allowed to stand at room temperature for 10 min. The mixture was poured into 150 ml of water which was extracted with 100 ml of ether. The ethereal solution was washed with water, dried over anhydrous magnesium sulfate, and decolorized with activated charcoal. The ether was removed by rotary evaporation. A pmr spectrum of the crude reaction mixture showed XVIII as the only compound present. Recrystallization from carbon tetrachloride gave 375 mg (83%) of XVIII.

Preparation of Dibenzotricyclo[3.2.1.0^{2,8}]-3,6-octadiene-8-carboxylic Acid (XXII). To a solution containing 1.20 g (4.28 mmoles) of *anti*-8-carbomethoxydibenzobicyclo[3.2.1]octadien-*exo*-4-ol[28] in 30 ml of anhydrous ether was added 2 ml of thionyl chloride. This mixture stood for 15 hr at room temperature and was then poured into 100 ml of water, after the excess thionyl chloride had been carefully destroyed by dropwise addition of water. The mixture was extracted with 100 ml of ether; the ethereal solution was washed with water and dried over magnesium sulfate and the ether removed by rotary evaporation. A pmr spectrum of the resulting yellow oil showed that oil to be nearly all *exo*-4-chloro-*anti*-8-carbomethoxydibenzobicyclo[3.2.1]octadiene (XXI). A small portion of the oil (*ca.* 100 mg) was crystallized from absolute methanol giving colorless needles of XXI, mp 108–109°. (*Anal.* Calcd for $C_{18}H_{15}ClO_2$: C, 72.36: H, 5.06. Found: C, 72.29; H, 5.11.) The remainder of the oil was dried under vacuum and used without further purification. The dried oil was dissolved in 30 ml of dry dimethyl sulfoxide, and 4.0 (36 mmoles) of potassium *t*-butoxide was added. This mixture stood for 10 min at room temperature and was then poured into a 5% sodium hydroxide solution. The sodium hydroxide solution was washed with 100 ml of ether and was then acidified with 5% hydrochloric acid. This was extracted with 100 ml of ether. The ether extract was washed with water, dried over anhydrous magnesium sulfate, and decolorized with activated charcoal, and the ether was removed by rotary evaporation. The oil was crystallized from carbon tetrachloride, yielding 750 mg (70%) of acid XXII, mp 230–231° (sublimes).

The pmr spectrum in deuteriochloroform showed two sharp singlets (2 H:1 H) at τ 6.29 and 5.20, respectively, and aromatic protons (8 H) centered at 2.99.

Anal. Calcd for $C_{17}H_{12}O_2$: C, 82.24; H, 4.87; neut equiv, 248. Found: C, 82.05; H, 4.66; neut equiv, 248.

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The Total Synthesis of Iboga Alkaloids[1]

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Abstract: The two alkaloids, ibogamine and ibogaine, have been prepared in the form of their racemates from nicotinamide by a 13-step sequence.

Through common usage the term "iboga alkaloids" has come to include all of the bases from diverse *Apocyanaceae*[5] species having the ibogamine (**1**) skeleton, or simple variations of it as catharanthine[6] (**3**), iboluteine[7] (**4**), and kisantine[8] (**5**).

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