13132-84-8; **14**, 13132-85-9; **16**, 13132-86-0; **17**, 13132-87-1; **18**, 13132-88-2; **19**, 1694-67-3; **20**, 13132-90-6; **21**, 13132-91-7; **22**, 5958-08-7; 2-amino-5-chloro-4′-hydroxybenzophenone *syn*-oxime, 13132-93-9.

Acknowledgment.—The authors are indebted to Dr. F. Vane, Dr. T. Williams, and Mr. S. Traiman for the spectral data and many helfpul discussions and to Dr. Al Steyermark and his staff for the microanalyses.

3,7-Disubstituted Octahydro-1,5-diazocines. Their Conversion into Tetrahydro-1,5-diazocines and into Ring-Contracted Products

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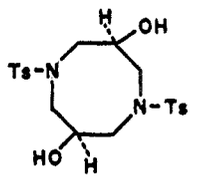
The *cis* and *trans* isomers of 1,5-bis(*p*-toluenesulfonyl)-3,7-dihydroxyoctahydro- (**1** and **2**) and of 1,5-bis-(*p*-toluenesulfonyl)-3,7-dihydroxy-3,7-dimethyloctahydro-1,5-diazocines (**5** and **6**) have been identified by spectral and chemical means. The *trans* isomer **6** readily affords the anhydro compound **7** upon treatment with acetic anhydride, while the *cis* isomer **5** is converted into the diacetyl derivative **8**. The dichloro compound **9** affords the dienes **11** and **12** when treated with sodium ethoxide. The diene **12** is the sole product when **9** is treated with potassium carbonate in dimethylformamide. The tetratosyl compounds **15** and **16** afford, in addition to the dienes **11** and **12**, the monoene-monool **14**. Treatment of the diols **1** and **2** with thionyl chloride affords the piperazine **17** and the diazepine **18**. The structures of the various compounds are established by chemical and spectral means.

We have recently described[1] the synthesis of the *cis*- and *trans*-1,5-bis(*p*-toluenesulfonyl)-3,7-dihydroxyoctahydro-1,5-diazocines. While the nuclear magnetic resonance (nmr) spectra of the two compounds strongly imply their stereochemistry (the low melting isomer corresponding to the *cis* isomer **1** and the high melting isomer corresponding to the *trans* isomer **2**), it is still necessary to confirm these tentative assignments by additional studies.



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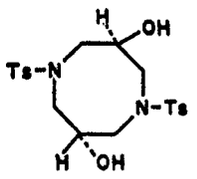


2

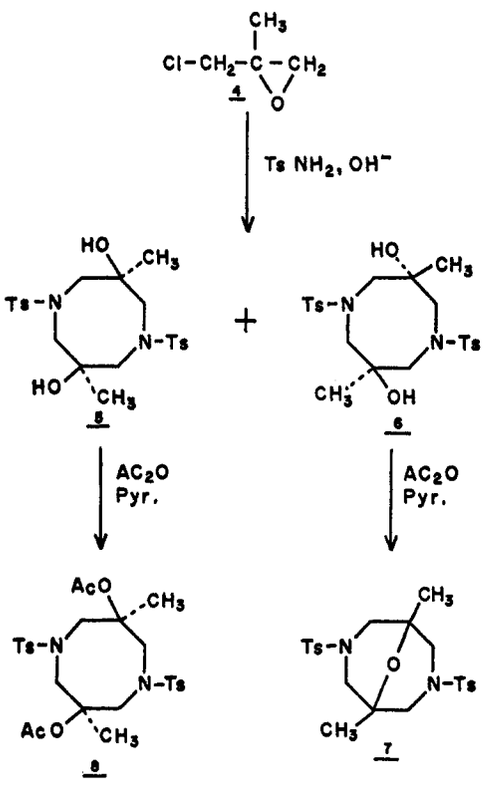
The treatment of the epoxide **4** with *p*-toluenesulfonamide in base, under conditions similar to those described for the preparation of the diols **1** and **2**, afforded the two isomeric diols **5** and **6** (Scheme I).

The methylene protons (H_A and H_B, J_{AB} = 15 cps) of the high melting diol **5** resonate at τ 5.93 and 7.09, while the corresponding protons (H_A and H_B, J_{AB} = 16 cps) of the low melting diol **6** resonate at τ 6.20 and 6.60, respectively. An examination of Dreiding models of the two isomers clearly shows that the methylene protons in the *trans* isomer are more nearly magnetically equivalent than those in the *cis* isomer. Consequently, the high melting diol should be the *cis* isomer **5**, and the low melting diol should be the *trans* isomer **6**.

The structural assignment is further confirmed by the results of acetylation studies on the two isomers. The *trans* isomer **6** forms the anhydro derivative **7** exclusively, while the *cis* isomer **5** forms the 3,7-diacetyl compound **8** only.

This analysis can now be used to further confirm the stereochemical assignment of the diols **1** and **2**. The chemical shift difference between the methylene protons

SCHEME I



of the low melting diol **1** is 0.89 ppm while it is essentially nil[1] in the high melting diol **2**. This is in agreement with the assignment deduced from both nmr and chemical evidence for the tertiary diols **5** and **6**, and consequently proves the structures of the diols **1** and **2**. The differences in the melting points of the two series (the *cis* compound **1** is the low melting isomer, while the *cis* compound **5** is the high melting one in the dimethyl series) is of some interest. These melting point differences are no longer present in any of the derivatives of the two different diol series. The relative positions on thin layer chromatographic plates are the same for the two series of diols (the *trans* isomer being the one with a higher R_f value in both cases).

(1) W. A. Paudler, G. R. Gapski, and J. M. Barton, *J. Org. Chem.*, **31**, 277 (1966).

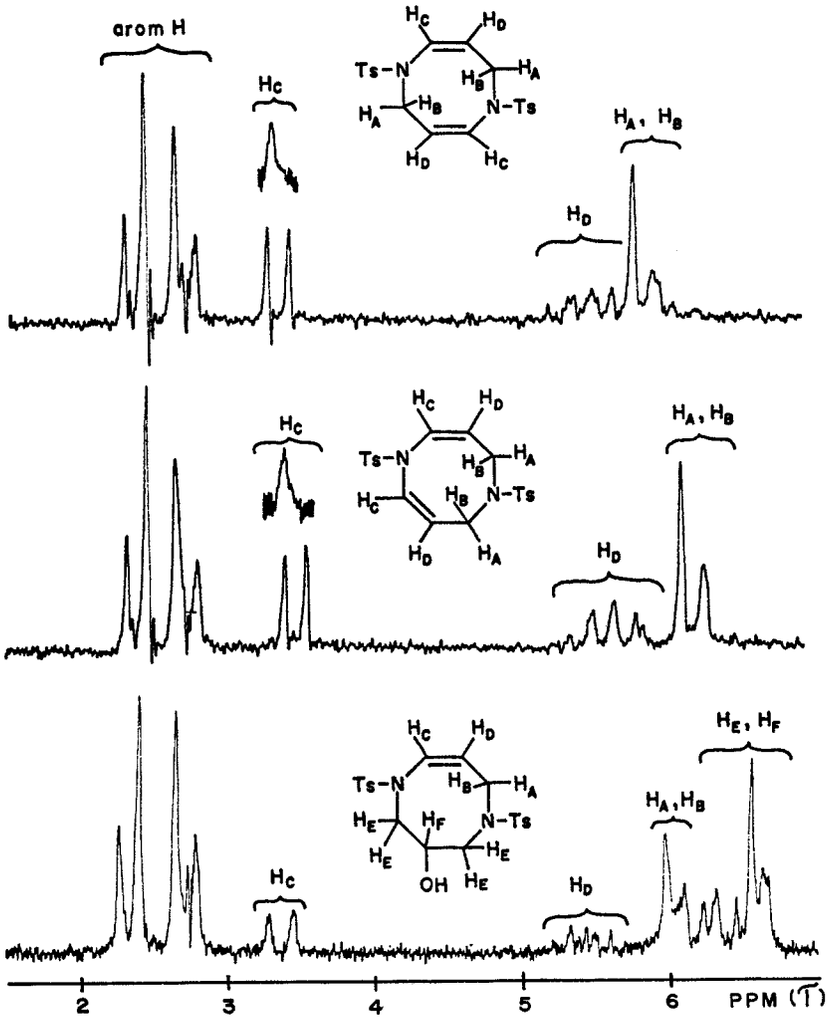


Figure 1.—Nuclear magnetic resonance spectra.

The literature does not describe the synthesis of any simple tetrahydrodiazocines, compounds which would be reasonable precursors to the synthesis of 1,5-diazocine itself.[2] The diols **1** and **2** present reasonable starting materials for the synthesis of tetrahydrodiazocines. Since the separation of these diols involves a considerable amount of effort, we elected to use the diol mixture for the various transformations to be described.

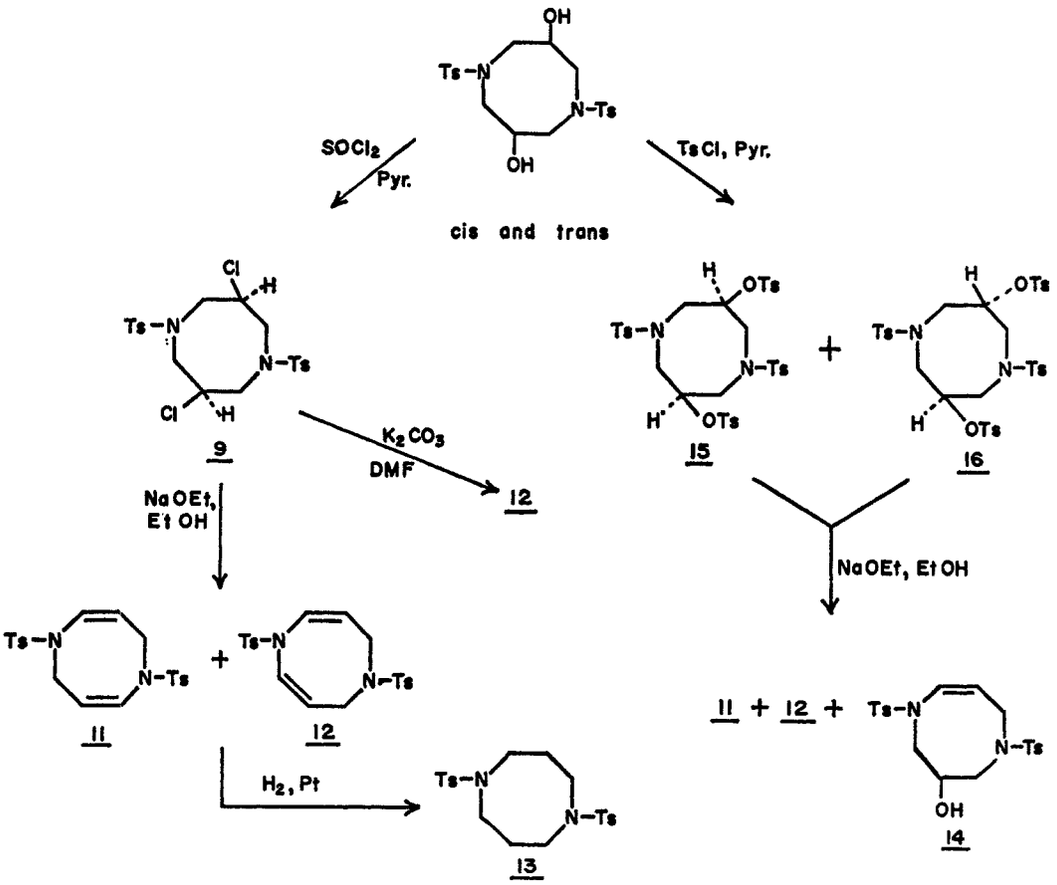
Treatment of the diols with thionyl chloride in pyridine affords compound $C_{20}H_{24}Cl_2N_2O_4S_2$. This molecular formula corresponds to a 1,5-bis(*p*-toluenesulfonyl)-3,7-dichlorooctahydro-1,5-diazocine. The nmr spectrum of this dichloro compound is very similar to the spectrum of the *cis*-diol **1** and we tentatively suggest that it is the *cis*-3,7-dichloro compound **9**. In addition to this compound, a mixture of two isomers was also isolated in this reaction. These isomers are the preponderant product when the diols (**1** and **2**) are treated with thionyl chloride in the absence of pyridine.

Dehydrohalogenation of the dichloro compound **9** with sodium ethoxide in ethanol yields, as the major product, compound $C_{20}H_{22}N_2O_4S_2$ (**11**). In addition to this substance, a small amount of an isomeric material **12** is also formed during this reaction. The dehydrohalogenation of the dichloro compound **9** with potassium carbonate in dimethylformamide affords compound **12** as the sole reaction product. Both of these substances fragment identically under electron impact. From the molecular formulas of the two compounds it is clear that we are dealing with two isomeric dienes. This was substantiated by the fact that catalytic reduction of both of the materials afforded the 1,5-bis(*p*-toluenesulfonyl)octahydro-1,5-diazocine (**13**). The nmr spectra of the two dienes (Figure 1) show the presence of two rather deshielded olefinic protons (H_C's) in both of the substances. The spacing of the doublet in both instances is due to spin–spin coupling of 9 cps, well within the established limit for a *cis*-olefinic proton system. These protons can be spin decoupled from the other olefinic protons (H_D's) (Figure 1) and, thus, the interpretation is verified. The assignment of the various multiplets can now be made as is indicated in Figure 1. The allylic protons in both isomers are magnetically nonequivalent, as is shown by the presence of the "lopsided" AB system. Two of the allylic protons, either H_A or H_B, are coupled to two of the olefinic protons (H_D's), while the other two allylic

(2) The question of the existence of the following interesting equilibrium

has recently been raised [S. Trofimenko, *J. Am. Chem. Soc.*, **88**, 5588 (1966)]. It is hoped that our study will aid in the elucidation of this problem.

SCHEME II



protons, either H_B or H_A, are not coupled to olefinic hydrogens to any large extent.

This analysis does not differentiate structure **11** from structure **12**. In order to do so, the nmr spectrum of compound **14** must be utilized. The preparation of compound **14** will be described first.

An alternate way of preparing the dienes from the diols **1** and **2** is by elimination of *p*-toluenesulfonic acid from the tetratosyl compounds **15** and **16**. These compounds are readily available from the diol mixture and can be separated by fractional crystallization. Treatment of either one of these tetratosyl compounds with sodium ethoxide in ethanol affords a mixture of the two dienes (**11** and **12**), along with a substance which analyzes for the monoene-ol **14**. The structure of this compound is substantiated by the formation of an acetyl derivative and the presence of hydroxyl absorption in its infrared spectrum. The nmr spectrum (Figure 1) further proves the assigned structure and can be used to identify the structures of the two isomeric dienes. The chemical shifts of the allylic protons (H_A and H_B) of the monoene-ol **14** should be the same as those of the unsymmetrical diene, since these protons are adjacent to a nitrogen atom bonded to an sp^3 carbon atom. In the symmetrical diene **11** these protons (H_A and H_B) are adjacent to a nitrogen atom bonded to an sp^2 carbon atom and should resonate at a more deshielded position. The olefinic proton H_D adjacent to the allylic protons would be expected to resonate at similar positions in both of the dienes and in the monoene-ol **14**. The remaining olefinic proton (H_C) should resonate at the same position in the monoene-monool (**14**), as it does in the symmetrical diene because of the essentially identical magnetic environment. Unfortunately, these dienes are chemically too labile to permit any degradative attempts at proving their structures by chemical means. We believe, however, that the spectroscopic evidence is sufficient to allow the structure assignments as outlined in Scheme II.

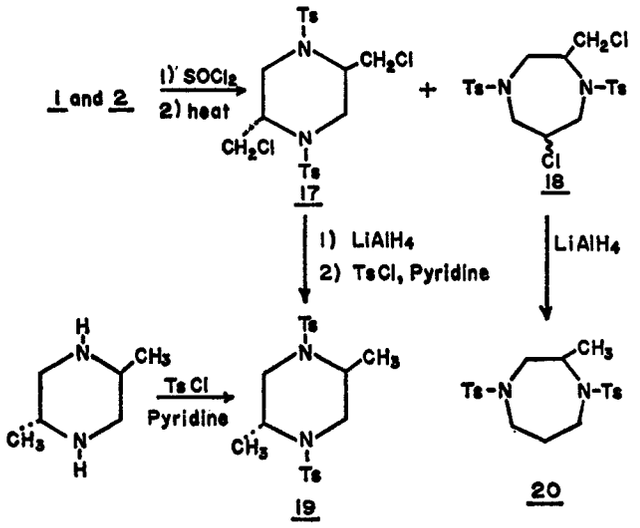
It now remains to identify the isomers obtained from the diols **1** and **2** as the main product upon treatment with thionyl chloride in the absence of pyridine. Although the product appeared homogeneous by tlc under a variety of conditions, the melting point (195–203°) suggested a mixture, and separation into two components (**17** and **18**) was achieved by fractional recrystallization from dioxane.

The mass spectrometric molecular weight (*m/e* 490) and the elemental analyses of the two compounds (**17** and **18**) confirm their molecular formulas as $C_{20}H_{24}N_2O_4S_2Cl_2$ (*cf.* Scheme III).

The nmr spectrum of compound **17** shows the pattern expected for the presence of two *identical* *p*-toluenesulfonyl groups (*cf.* Experimental Section). In addition to this pattern there are two sets of complex multiplets (centered at τ 6.65 and at 5.9) with a relative area ratio of 3:2, corresponding to six and four protons, respectively. Thus, the nmr spectrum is of little aid in establishing the structure of this compound, other than indicating its symmetry by the identity of the respective protons of the two tosyl groups.

The first clue to the structure of this compound was obtained from an inspection of its mass spectrum which shows a prominent loss of a CH_2Cl fragment, suggesting ring contraction of the octahydro-1,5-diazocine carbon

SCHEME III



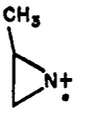
skeleton. A possible structure of the product is represented by formula **17**. Reduction of this compound with lithium aluminum hydride affords a basic material, which upon treatment with *p*-toluenesulfonyl chloride in pyridine yields a white crystalline solid, $C_{20}H_{26}N_2O_4S_2$. The nmr spectrum of this compound, in addition to the tosyl group protons, shows a six-proton doublet at τ 9.08 (J = 7 cps), a complex two-proton multiplet centered at 5.88, and another four-proton multiplet centered at 6.60. Thus, the substance contains two equivalent methyl groups on a carbon atom bearing a single proton. This is consistent with structure **19**. Finally, the structure of compound **19** was proven by an unequivocal synthesis from *trans*-2,5-dimethylpiperazine by converting the latter into its N,N-di(*p*-toluenesulfonyl) derivative and by demonstrating identity of the compounds prepared by the two different methods.

The structure of the higher melting dichloro compound is consequently correctly represented by formula **17**.

The mass spectrum of the low melting dichloro compound **18** is quite similar to that of compound **17** in that it loses a CH_2Cl fragment, though to a much lesser extent, upon electron impact. Another difference between the two mass spectra is found in the significant loss of HCl from the low melting isomer and the very much lower relative intensity of the parent ion. Thus, it appears that the lower melting isomer **18** also contains a CH_2Cl grouping, as well as a chlorine substituent that is readily lost, upon electron bombardment, as HCl. These data are consistent with structure **18**. This is strongly confirmed by the nonequivalence of the corresponding protons in the two tosyl groups (*cf.* Experimental Section). The remaining protons cannot be identified in the nmr spectrum of this compound since the multiplicity is too complex.

Reduction with lithium aluminum hydride affords a compound of formula $C_{20}H_{26}N_2O_4S_2$. The nmr spectrum of this compound (**20**) shows the presence of one methyl group (in addition to the two methyl groups of the tosyl functions) at τ 8.96 (J = 7 cps). The remaining ring protons are multiplets which cannot clearly be resolved. The reduction product **20** is a known compound[3] and the physical properties of the reduction product are in agreement with those listed for the compound of structure **20**.

The mass spectra of compounds **19** and **20** are dominated by the species formed from the loss of one tosyl group. In addition to this, two significant fragmentations take place in the perhydrodiazepine **18**, which affords fragment ions at m/e 56 and 70, consistent with structures **21** and **22**.[4] Fragment **22** is the base peak



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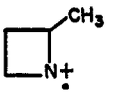
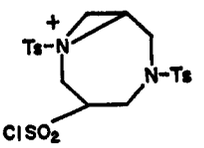


22

in the mass spectrum of compound **17**, while fragment **21** is more abundant in the spectrum of the piperazine **19** than in the diazepine **20**. The mass spectra of the compounds are, consequently, consistent with the assigned structures.

In the absence of detailed mechanistic studies, we can only suggest that the ring contraction occurs with the involvement of a bicyclic intermediate such as **23**.



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A detailed study of these ring contractions from both a synthetic and a mechanistic point of view is in progress.

Experimental Section[5]

***cis*- and *trans*-1,5-Bis(*p*-toluenesulfonyl)-3,7-dihydroxy-3,7-dimethyloctahydro-1,5-diazocine (5 and 6).**—To a stirred, refluxing solution of 52 g (0.3 mole) of *p*-toluenesulfonamide and 27 g (0.25 mole) of α-methylepichlorohydrin in 90 ml of ethanol was added, over a period of 2 hr, a solution of 12 g (0.3 mole) of sodium hydroxide in 45 ml of water; refluxing was continued for an additional 12 hr. The hot reaction mixture was filtered and the precipitate was washed with ethanol to give 13.4 g (23.7%) of a mixture of compounds **5** and **6** (mp 227–235°).

***cis*-1,5-Bis(*p*-toluenesulfonyl)-3,7-dihydroxy-3,7-dimethyloctahydro-1,5-diazocine (5).**—The mixture of diols (13 g) was stirred with 150 ml of refluxing acetone for 12 hr and the insoluble material was collected. Recrystallization of this compound from N,N-dimethylformamide–water (4:1) afforded 8.3 g of pure **5**: mp 272–273°; nmr (CF_3CO_2D), methylene protons H_A at τ 7.09, and H_B at 5.93 (J_{AB} = 15 cps), methyl (aliphatic) at 8.65.

Anal. Calcd for $C_{22}H_{30}N_2O_6S_2$: C, 54.75; H, 6.27; N, 5.80. Found: C, 54.70; H, 6.22; N, 5.59.

***trans*-1,5-Bis(*p*-toluenesulfonyl)-3,7-dihydroxy-3,7-dimethyloctahydro-1,5-diazocine (6).**—Evaporation to dryness of the acetone extract from the isolation procedure for compound **5** afforded 3.2 g of a white solid. A portion (1 g) of this substance was chromatographed on 100 g of neutral, grade III alumina. Elution with ether gave 426 mg of pure **6**: mp 232–232.5°; nmr ($CDCl_3$), methylene protons H_A at τ 6.60 and H_B at 6.20 (J_{AB} = 16 cps), methyl (aliphatic) at 8.70, hydroxyl at 6.14.

(3) T. Ishigura and M. Matsumura, *Yakugaku Zasshi*, **79**, 302 (1959); *Chem. Abstr.*, **53**, 16147*g* (1959).

(4) The corresponding linear olefinic ion radicals are, of course, also possible.

(5) Nmr spectra were obtained with a Varian A-60 spectrometer. Mass spectra were obtained with a Hitaschi-Perkin Elmer RMU-6E instrument equipped with a solid sample injector. The ionizing voltage employed was 80 v. Elemental analyses were done by Mrs. S. De Boer of this department.

Anal. Calcd for $C_{22}H_{30}N_2O_6S_2$: C, 54.75; H, 6.27; N, 5.80. Found: C, 54.66; H, 6.64; N, 5.70.

***cis*-1,5-Bis(*p*-toluenesulfonyl)-3,7-diacetoxy-3,7-dimethyloctahydro-1,5-diazocine (8).**—A solution of 2.5 g (5.2 mmoles) of *cis*-diol **5** in 5 ml of pyridine and 15 ml of acetic anhydride was refluxed for 2 hr. The reaction mixture was poured into 100 ml of water and the resulting suspension was extracted with ether. The ether extract was dried over magnesium sulfate and decolorized with charcoal. Removal of the solvent yielded a tan solid which, on recrystallization from ethanol, gave 1.12 g (38%) of **8**: mp 209.5–211°; nmr ($CDCl_3$), methylene protons H_A at τ 6.64 and H_B at 6.22 (J_{AB} = 15 cps), methyl (aliphatic) at 8.33, methyl (acetyl) at 8.02.

Anal. Calcd for $C_{28}H_{34}N_2O_8S_2$: C, 55.10; H, 6.05; N, 4.94. Found: C, 55.23; H, 5.97; N, 4.78.

3,7-Bis(*p*-toluenesulfonyl)-3,7-diaza-1,5-dimethyl-9-oxabicyclo[3.3.1]nonane.—A solution of 0.53 g (1.1 mmoles) of *trans*-diol **6** in 5 ml of pyridine and 5 ml of acetic anhydride was refluxed for 24 hr. The reaction mixture was poured into 50 ml of water and extracted with ether. The ether extract was dried over magnesium sulfate and the solvent was removed leaving a white solid. Recrystallization from benzene–ligroin gave 0.36 g (70%) of white needles: mp 274–276°; nmr (CF_3CO_2D), methylene protons H_A at τ 7.28 and H_B at 6.05 (J_{AB} = 12 cps), methyl (aliphatic) at 8.71; mass spectrum [*m/e* (% of P)], 464 (100), 465 (P + 1, 29), 466 (P + 2, 22).

Anal. Calcd for $C_{22}H_{28}N_2O_5S_2$: C, 56.87; H, 6.07; N, 6.03. Found: C, 56.80; H, 6.21; N, 6.02.

***cis*- and *trans*-1,5-Bis(*p*-toluenesulfonyl)-3,7-dihydroxyoctahydro-1,5-diazocine (1 and 2).**—The previously described[1] mixture of diols **1** and **2** was prepared by an improved procedure. In a typical experiment, 512 g (3 moles) of *p*-toluenesulfonamide was dissolved in a solution of 120 g (3 moles) of sodium hydroxide in 500 ml of water and 1800 ml of thanol. To this stirred solution w s added, in one portion, 266 g (2.9 moles) of epichlorohydrin. The exothermic reaction subsided after about 2 hr and the product began to crystallize. After 24 hr the product was collected and washed, first with 500 ml of ethanol, followed by 1000 ml of water. The dried product weighed 178 g (27%), melted at 200–202°, and was identical in every respect (tlc, nmr, and infrared) with the diol mixture which was prepared earlier.[1]

***cis*-1,5-Bis(*p*-toluenesulfonyl)-3,7-dichlorooctahydro-1,5-diazocine (9).**—To a solution of 10 g (0.022 mole) of a mixture of diols **1** and **2** in 100 ml of pyridine was added, during 1 hr, 8.3 g (0.07 mole) of thionyl chloride in 50 ml of pyridine. The reaction mixture became warm and darkened during the addition. After the addition was complete, the mixture was refluxed for 15 min. The reaction mixture was then poured into 1 l. of water and the dark brown residue was collected and dried. This material was stirred with 500 ml of boiling chloroform and the black residue was removed by filtration. The chloroform extract was then decolorized with charcoal and evaporated *in vacuo* to yield a rose-colored oil. Crystallization of this substance from acetone gave 1.64 g (15%) of **9**: mp 286.5°; mass spectrometric mol wt, 490.

Anal. Calcd for $C_{20}H_{24}Cl_2N_2O_4S_2$: C, 48.88; H, 4.92; N, 5.70. Found: C, 48.98; H, 4.79; N, 5.95.

Evaporation of the mother liquor from the preparation of **9** afforded an oily solid which on recrystallization from methanol–chloroform gave 2.1 g of a white solid (**17** and **18**). An analytical sample was obtained by recrystallization from dioxane: mp 230–235°; mass spectrometric mol wt 490.

Anal. Calcd for $C_{20}H_{24}Cl_2N_2O_4S_2$: C, 48.88; H, 4.92; H, 5.70. Found: C, 48.98; H, 5.10; N, 5.96.

N,N-Di(*p*-toluenesulfonyl)-2,5-di(chloromethyl)piperazine (17) and 1,4-Bis(*p*-toluenesulfonyl)-6-chloro-2-chloromethylhexahydro-1,4-diazepine (18).—To 10 g (0.022 mole) of a mixture of **1** and **2** in a Carius tube was added 15 ml of thionyl chloride; the mixture was warmed until reaction ceased and all of the solid had dissolved. The tube was then sealed and heated to 120° for 4 hr. The reaction mixture was transferred to a 250-ml flask and 150 ml of methanol was slowly added. The mixture darkened and a crystalline solid precipitated. This solid was filtered and washed with methanol to yield 6.8 g of a white solid (mp 195–203°). Recrystallization of this material from dioxane gave 1.3 g of a white solid. A second crop (0.5 g) was obtained by evaporation of the mother liquor to about half of its original volume. Recrystallization of this material from dioxane gave 1.2 g (11%) of pure **17**: mp 251.5–252°; nmr (CF_3CO_2D), eight aromatic protons H_A at τ 2.22 and H_B at 2.58 (J_{AB} = 8.5 cps), four-proton multiplet at 5.9, six-proton multiplet at 6.65, six methyl protons (aromatic) at 7.54; mass spectrum [*m/e* (%)], 490 (P, 1), 454 (3), 441 (16), 335 (28), 286, 155 (28), 91 (100).

Anal. Calcd for $C_{20}H_{24}N_2S_2O_4Cl_2$: C, 48.87; H, 4.92; N, 5.70. Found: C, 48.91; H, 5.02; N, 5.81.

The mother liquor from the separation of **17** was treated with 100 cc of hot methanol and cooled in an ice bath to give 4.7 g (44%) of pure **17** as white needles: mp 201–203°; nmr ($CDCl_3$), eight aromatic protons (two AB patterns) H_{1A} at τ 2.25, H_{1B} at 2.70, H_{2A} at 2.40, and H_{2B} at 2.73, six-proton singlet 7.59, ten-proton multiplet from 5.2 to 7.2; mass spectrum [*m/e* (%)], 490 (0.3), 454 (3), 441 (4), 334 (26.5), 299 (4), 286 (10), 155 (28), 145 (10.5), 131 (10), 91 (100).

Anal. Calcd for $C_{20}H_{24}S_2O_4Cl_2$: C, 48.87; H, 4.92; N, 5.70; Cl, 14.42; S, 13.04. Found: C, 48.98; H, 5.10; N, 5.96; Cl, 14.69; S, 13.32.

***cis*- and *trans*-1,5-Bis(*p*-toluenesulfonyl)-3,7-bis(*p*-toluenesulfonoxy)octahydro-1,5-diazocine (15 and 16).**—To a solution of 20 g (0.044 mole) of the mixture of diols **1** and **2** in 150 ml of pyridine was added 20 g (0.1 mole) of *p*-toluenesulfonyl chloride. The reaction was stirred and heated at 80° for 18 hr. Water (400 ml) was then added and the resulting suspension was sitrred for 1 hr. The white solid was filtered and washed with 400 ml of water and recrystallized from chloroform to yield 16.1 g (46%) of pure *cis* isomer **15**: mp 211.5–212°.

Anal. Calcd for $C_{34}H_{38}N_2O_{10}S_4$: C, 53.52; H, 5.02; N, 3.67 Found: C, 53.44; H, 5.34; N, 3.52.

Evaporation of the mother liquor afforded a second crop of compound **15**, weighing 3.45 g. The remaining solution was evaporated to dryness and the resulting solid was recrystallized twice from acetone to yield 1.9 g (5.6%) of pure **16**: mp 202.5–203°.

Anal. Found: 53.20; H, 5.18; N, 3.52.

1,5-Bis(*p*-toluenesulfonyl)-1,2,5,8-tetrahydro-1,5-diazocine (12).—A mixture of 4.4 g (9 mmoles) of dichloro compound **9**, 2 g (14 mmoles) of anhydrous potassium carbonate, and 50 ml of N,N-dimethylformamide was refluxed for 8 hr. The reaction mixture was poured into 400 ml of water and the resulting suspension was extracted with chloroform. The chloroform extract was washed twice with water, dried over magnesium sulfate, and evaporated *in vacuo* to leave a brown oil. This material was recrystallized from ethanol giving 2.56 g (65%) of diene **12**. An analytical sample was prepared by an additional recrystallization from ethanol: mp 128–129.5°; mass spectrum [*m/e* (% of P)], 418 (100), 419 (P + 1, 21.1), 420 (P + 2, 11.5).

Anal. Calcd for $C_{20}H_{22}N_2O_4S_2$: C, 57.39; H, 5.30; N, 6.69. Found: C, 57.18; H, 5.11; N, 6.81.

1,5-Bis(*p*-toluenesulfonyl)-1,2,5,6-tetrahydro-1,5-diazocine (11).—The dichloro compound **9** (2.5 g, 5 mmoles) was refluxed for 8 hr with an excess of sodium ethoxide in 50 ml of absolute ethanol. The product was precipitated by the addition of 100 ml of water. Recrystallization of the precipitated solid from ethanol–chloroform gave 1.3 g (62%) of white crystals melting at 228–233°. Repeated recrystallizations from ethanol–chloroform afforded 0.91 g of pure **11**: mp 157–158.5°; mass spectrum [*m/e* (% of P)], 418 (100), 419 (P + 1, 24), 420 (P + 2, 12.3).

Anal. Found: C, 57.52; H, 5.37; N, 6.91.

An examination of the nmr spectrum of the crude reaction product indicated that it contained approximately 15% of diene **12**.

Catalytic Reduction of Dienes 11 and 12.—A solution of 104 mg (0.25 mmoles) of diene **12** in 50 ml of acetic acid–ethanol (1:1) was hydrogenated with 0.2 g of prereduced platinum oxide at atmospheric pressure. The sample required 12.6 ml of hydrogen (calcd 14.6). The catalyst was removed and the solvent was evaporated to give a white solid. Recrystallization of this solid from ethanol gave 63 mg of the known 1,5-bis(*p*-toluenesulfonyl)octahydro-1,5-diazocine (**13**): mp 214–216°; mixture melting point undepressed. The nmr spectrum was identical with that of an authentic sample.[1]

By the same procedure, 106 mg of diene **11** gave 43 mg of **13**.

Dienes 11 and 12 from Tetratosyl Compounds 15 and 16 and Isolation of 1,5-Bis(*p*-toluenesulfonyl)-7-hydroxy-1,2,5,6,7,8-hexahydro-1,5-diazocine (14).—When either of the tetratosyl compounds **15** or **16** is treated with sodium ethoxide in ethanol, the same product composition is observed. In a typical experiment 2.5 g (3.3 mmoles) of **15** was refluxed for 4 hr with an excess of sodium ethoxide in 50 ml of ethanol. The reaction mixture was diluted with 200 ml of water and extracted with chloroform.

The chloroform extract was dried over magnesium sulfate and evaporated to yield a white solid. The solid was dissolved in a few milliliters of chloroform and 50 ml of ethanol was added. After a few seconds, crystallization occurred giving 0.95 g (69%) of dienes **11** and **12** (about 2:1 by nmr). Evaporation of the mother liquor gave an oily solid. This solid was dissolved in a few drops of chloroform and 10 ml of ether was added. After standing several hours, a white crystalline solid was obtained. Recrystallization from chloroform–ether gave 0.18 g of pure **14**: mp 131–132.5°; mass spectrometric mol wt 436; infrared ($CHCl_3$), hydroxyl absorbance at 2.88 μ; acetate (mass spectrometric mol wt 478).

Anal. Calcd for $C_{20}H_{24}N_2O_5S_2$: C, 55.02; H, 5.54; N, 6.41. Found: C, 54.90; H, 5.62; N, 6.70.

Reduction of 17 with Lithium Aluminum Hydride.—A solution of 416 mg of **3** in 25 ml of 1,2-dimethoxyethane was treated with an excess of lithium aluminum hydride and the mixture was heated at reflux overnight. The excess reagent was decomposed by the careful addition of a 10:1 mixture of tetrahydrofuran and water. The mixture was then diluted with 200 ml of water and extracted with chloroform. The chloroform extract was dried over magnesium sulfate. Removal of the solvent gave a colorless oily solid. This material was treated with a solution of 1 g of *p*-toluenesulfonyl chloride in 20 ml of pyridine and the mixture was heated at reflux for 10 min. The reaction mixture was diluted with 20 ml of water and 50 ml of concentrated hydrochloric acid was added. The resulting suspension was extracted with chloroform, the chloroform extract was dried over magnesium sulfate, and the filtrate was evaporated to dryness to leave a brown solid. Recrystallization of this solid from methanol–chloroform gave 236 mg of **19**: mp 227–228°; nmr ($CDCl_3$), eight aromatic protons H_A at τ 2.34 and H_B at 2.73 (J_{AB} = 8.5 cps), two-proton multiplet at 5.58, four-proton multiplet at 6.60, six-proton singlet at 7.58, six-proton doublet at 9.08 (J = 7 cps); mass spectrum [*m/e* (%)], 422 (P, 6.2), 407 (0.4), 267 (100), 252 (3.8), 212 (4), 155 (15), 91 (47), 84 (24), 70 (11.5), 56 (37).

Anal. Calcd for $C_{20}H_{26}N_2S_2O_4$: C, 56.84; H, 6.20; N, 6.63. Found: C, 56.61; H, 5.81; N, 6.68.

The nmr and infrared spectra of **19** were identical with those of an authentic sample which was prepared from *trans*-2,5-dimethylpiperazine.

Reduction of 18 with Lithium Aluminum Hydride.—A solution of 1.5 g of **18** in 50 ml of tetrahydrofuran was treated with an excess of lithium aluminum hydride and refluxed for 2 hr. Excess reagent was decomposed by addition of a 10:1 mixture of tetrahydrofuran and water. The mixture was acidified with concentrated hydrochloric acid and extracted with chloroform. The chloroform extract was dried over magnesium sulfate and filtered, and the filtrate was evaporated *in vacuo* to yield a white solid. A 400-mg portion of this material was chromatographed on 150 g of grade III neutral alumina. Elution with a mixture of benzene and ethyl acetate (20:1) yielded two compounds.

The first compound was recrystallized from chloroform–methanol to give 1,5-bis(*p*-toluenesulfonyl)-6-chloro-2-methyl-1,4-diazepine: mp 190–191.5°; nmr ($CDCl_3$), eight-proton multiplet at τ 2.25, eight-proton multiplet from 5.5 to 7.5, six-proton singlet at 7.61, three-proton doublet at 8.98 (J = 7 cps); mass spectrum [*m/e* (%)], 456 (P, 0.5), 420 (6), 301 (100), 265 (11), 198 (19), 155 (32), 91 (79).

Anal. Calcd for $C_{20}H_{25}N_2S_2O_4Cl$: C, 52.56; H, 5.51; N, 6.13. Found: C, 52.57; H, 5.47; N, 6.28.

The second compound was recrystallized from methanol–chloroform to give 84 mg of pure **20**: mp 150–151°; nmr ($CDCl_3$), eight-proton multiplet at τ 2.6, one-proton multiplet at 5.8, six-proton multiplet at 6.7, six-proton singlet at 7.6, two-proton multiplet at 8.2, three-proton doublet at 8.96 (J = 7 cps); mass spectrum [*m/e* (%)], 422 (P, 0.1), 267 (93), 252 (1), 212 (2), 155 (22), 91 (91), 84 (15), 70 (100), 56 (23.5).

Anal. Calcd for $C_{20}H_{26}N_2S_2O_4$: C, 56.84; H, 6.20; N, 6.63. Found: C, 56.30; H, 5.88; N, 6.66.

Registry No.—**1**, 6204-13-3; **2**, 5997-54-6; **5**, 13116-96-6; **6**, 13116-97-7; **8**, 13116-98-8; **9**, 13116-99-9; **11**, 13117-00-5; **12**, 13117-01-6; **14**, 13117-02-7; **15**, 13199-99-0; **16**, 13143-65-2; **17**, 13117-03-8; **18**, 13117-04-9; **19**, 13117-05-0; **20**, 13117-06-1; 3,7-bis(*p*-toluenesulfonyl)-3,7-diaza-1,5-dimethyl-1,9-oxabicyclo[3.3.1]nonane, 13117-07-2; 1,5-bis(*p*-toluenesulfonyl)-6-chloro-2-methyl-1,4-diazepine, 13117-08-3.

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The Conversion of Imidazo[1,5-*a*]pyridines into 3-(2-Pyridyl)-1,2,4-oxadiazoles

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Imidazo[1,5-*a*]pyridine (**2**) and its 3-methyl and 3-phenyl derivatives rearrange, upon treatment with nitrous acid, to 3-(2-pyridyl)-1,2,4-oxadiazole (**4**) and its 5-methyl (**5**) and 5-phenyl (**6**) derivatives, respectively. Pyrolysis, alkaline hydrolysis, as well as mass, ultraviolet, and nuclear magnetic resonance spectral studies were used to establish the structures of the rearrangement products. Compounds **4** and **5** were prepared by unequivocal syntheses.

Electrophilic substitution reactions in polyazaindenes (**1**) have been the subject of several recent publications from different laboratories.[1-8]

These studies have shown that, generally, electrophilic substitution occurs in either the 3, or in the 1 position, or both depending upon the location of the nonbridge nitrogen atom or atoms.

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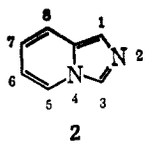
Imidazo[1,5-*a*]pyridine (**2**) has been acetylated,[5] for example, at position 1 and brominated to form a 1,3-



2

dibromo derivative exclusively.[6] Imidazo[1,2-*a*]pyridine (**3**), on the other hand, forms 3-bromo,[7] 3-nitro, as well as 3-nitroso[8] derivatives.

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