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DIAZAPOLYCYCLIC COMPOUNDS—XIV[1]

EPOXIDES FROM DIAZAQUINONE ADDUCTS: SYNTHESIS AND STEREOCHEMICAL CHARACTERIZATION

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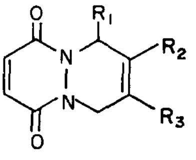
Abstract—Epoxidation by *m*-chloroperbenzoic acid of adducts obtained by Diels–Alder reaction of pyridazine-1,4-dione, phthalazine-1,4-dione and benzo(g)phthalazine-1,4-dione with substituted 1,3-butadienes is reported. Although the epoxidation takes place in most of the cases in good yields, no reaction is observed in adducts which lack electron-donating groups attached to the double bond, and their epoxides must be obtained from the corresponding bromohydrines. The reaction affords either a single product or a mixture of *cis* and *trans* isomers, according to the location of the substituents in the piperidazine ring. The stereochemistry of these compounds is studied from their ^{1}H NMR spectra and by X-rays diffraction methods.

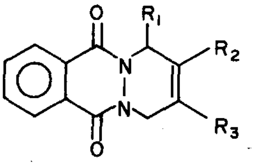
Diazaquinones have been shown to be excellent dienophiles in Diels–Alder reactions when produced by oxidation of the corresponding hydrazides in the presence of dienes. In previous papers[2–4] we reported the use of this characteristic in the synthesis of diverse heterocyclic systems, which could exhibit biological activity. In the course of these investigations, diazapolycyclic adducts **1–13** have been synthesized, among many others, by 1,4-cycloaddition of pyridazine-1,4-dione (**1–4**), phthalazine-1,4-dione (**5–9**) or benzo(g)phthalazine-1,4-dione (**10–13**) with Me-substituted 1,3-butadienes.[5,6] Three of them (**1, 2 and 11**) are described for the first time in this work.

We are now interested in the introduction at the new ring formed in the cycloaddition, of any substituents capable of modifying the biological properties of these compounds. In the preceeding communication[1] the action of N-bromosuccinimide on these adducts was studied, and different addition and/or allylic substitution products were obtained, depending on the reaction conditions employed. Then, it was thought desirable to prepare new derivatives by epoxidation of the double bond and further electrofilic cleavage of the oxirane ring with different reactives. The present paper deals with the preparation and stereochemical study of these epoxides.

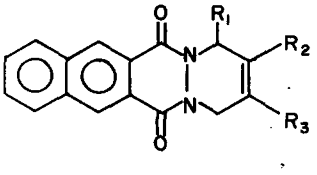
Treatment of the diazapolycyclic adducts **1–6, 8, 9, 12** and **13** with *m*-chloroperbenzoic acid in chloroform solution[7,8] affords the epoxides **14–23** in good yields. As could be expected, in the epoxidation of the 4a,8a-diazabicyclic adducts only the less desactivated double bond (in which the withdrawing effect of the CO group is



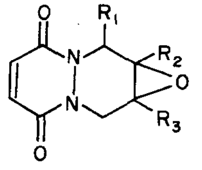
1: R_1 = Me, R_2 = H, R_3 = Me
2: R_1 = R_2 = Me, R_3 = H
3: R_1 = H, R_2 = Me, R_3 = H
4: R_1 = H, R_2 = R_3 = Me



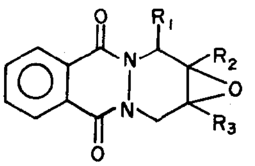
5: R_1 = Me, R_2 = H, R_3 = Me
6: R_1 = R_2 = Me, R_3 = H
7: R_1 = R_2 = R_3 = H
8: R_1 = H, R_2 = Me, R_3 = H
9: R_1 = H, R_2 = R_3 = Me



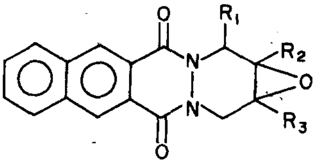
10: R_1 = R_2 = R_3 = H
11: R_1 = Me, R_2 = R_3 = H
12: R_1 = H, R_2 = Me, R_3 = H
13: R_1 = H, R_2 = R_3 = Me



14: $R_1 = Me, R_2 = H, R_3 = Me$
15: $R_1 = R_2 = Me, R_3 = H$
16: $R_1 = H, R_2 = Me, R_3 = H$
17: $R_1 = H, R_2 = R_3 = Me$



18: $R_1 = Me, R_2 = H, R_3 = Me$
19: $R_1 = R_2 = Me, R_3 = H$
20: $R_1 = H, R_2 = Me, R_3 = H$
21: $R_1 = H, R_2 = R_3 = Me$



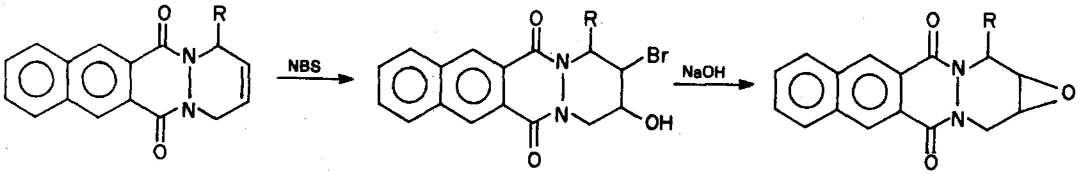
22: $R_1 = H, R_2 = Me, R_3 = H$
23: $R_1 = H, R_2 = R_3 = Me$

diminished) results affected, in accordance with the great selectivity usually shown by reactions performed with this epoxidizing agent.

Moreover, it is interesting to note that epoxidation takes place only in adducts double bond of which is directly activated by electron-donating Me groups. Adducts **7** and **10**, in which the piperidazine ring lacks any substituent, failed to give the corresponding epoxides by this procedure, even under stronger reaction conditions. The same absence of epoxidation is found for compound **11**, in spite of the fact that a Me group is here attached to the piperidazine ring (but not to the double bond). It seems that the desactivating action of the two withdrawing amide groups is so strong that the presence of donating substituents attached to C-2 and/or C-3 is required in order that the epoxidation can be achieved. As a matter of fact, adducts **4**, **9** and **13**, in which the double bond is activated by two Me groups, are epoxidized in better yields than those having only one Me group, when reactions are carried out under the same conditions.

On the other hand, the non-substituted epoxides can be indirectly obtained by treatment of the respective adducts with N-bromosuccinimide in aqueous acid medium to give the corresponding bromohydrines,[1] followed by deshydrobromination in the presence of aqueous NaOH (Scheme 1). By this procedure the epoxides **24** and **25** are formed in respectively 75% and 72% yields. However, care must be taken in the second step of this process by maintaining carefully the reaction conditions according to the experimental, as the amide groups are readily hydrolysed in the aqueous basic medium, to give the corresponding open products.

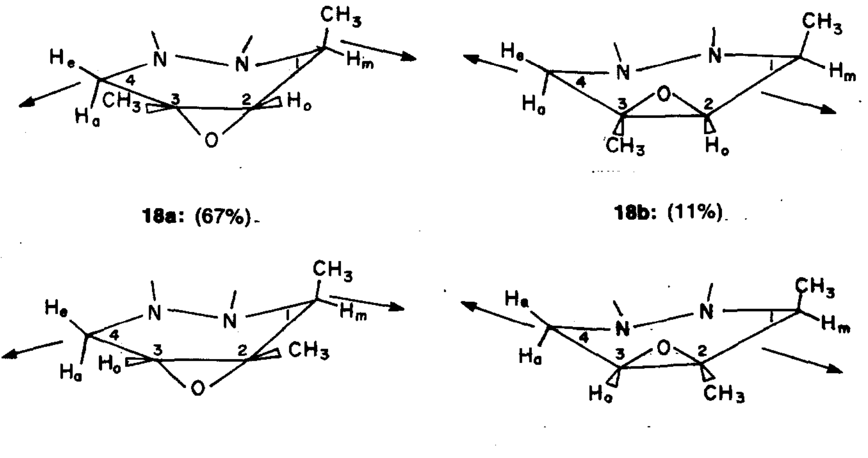
All the epoxidated adducts afforded exclusively one single reaction product, with exception of those containing a substituent at C-1. Thus, by epoxidation of **5** and further separation of the reaction mixture by thin layer preparative chromatography, the two stereoisomers **18a** and **18b** were obtained in respective yields of 67% and 11%, the main difference between both isomers being that of the relative orientation of the Me group at C-1



26: R = H
27: R = Me

24: R = H
25: R = Me

Scheme 1.



18a: (67%). **18b:** (11%).

19a: (52%). **19b:** (20%).

(Direction of the C=O groups with respect to the substituents at C-1 and C-4 is shown by the arrows in every case)

Fig. 1.

with respect to the oxirane ring. Similarly, oxidation of **6** led to isomers **19a** and **19b** in yields of 52 and 20%. The configurations of these two pairs of diastereomers (Fig. 1) have been unambiguously established both by X-ray diffraction and NMR techniques.

Before the discussion concerning these assignments may be developed, real geometry at the two bridgehead N atoms in the epoxides must be resolved. If a planar arrangement with sp^2 hibridization is supposed, as usually happens in amides, the piperidazine ring must be close to a like-boat conformation. On the other hand, if the stereochemistry at the N atom approaches the pyramidal configuration, the structure must be explained in terms of a half-chair form. Many reports can be found in the literature[9–12] about the geometry at the N atoms in similar tetrahydropiridazine and piperidazine systems, and contradictory results are often obtained.

X-ray diffraction analysis of isomer **18a**[13] shows that the two N atoms are closer to a sp^2 hibridization. Thus, the C–N–C bond angles are of 119.3 and 119.7°, clearly corresponding to a quasi-planar geometry for both of them. Moreover, the values measured for the torsion angles of the piperidazine ring at **18a** (Table 1) are consistent with a quasi 1,3-diplanar conformation, intermediate between sofa and boat, and characterized by the existence of two zero dihedral angles at 1,3, according to the classification established by Bucourt and Haitnant.[14,15] In this form, the methine at C-1 is consistently more deviated from the plane of the benzo and central rings than the opposite methylene. The two Me groups are found to be *cis* to one another (*trans* situation of the epoxide ring and the Me group at C-1).

With respect to the **18b** isomer, X-ray analysis (Table 1) indicates a conformation which, being also intermediate between sofa and boat, has been identified as 1,2-diplanar (two zero dihedral angles at 1,2). The C–N–C angles are of 118.9 and 117.3°. In this isomer both Me groups are in a *trans* relation. Owing to the conformational variations found between **18a** and **18b**, the relative positions of the CO groups regarding the substituents at C-1 and C-4 are somewhat different from those observed for the **18a** isomer, as can be deduced by studying the deviations of the atoms from the planes of the benzo and central rings.[13] These differences, as will be seen later, are reflected in their NMR spectra. Direction of the C=O groups in both compounds is schematically shown in Fig. 1.

Table 1. Selected torsion angles in the **18a** and **18b** isomers

Atoms	Angles (**18a**)	Angles (**18b**)
C_1–C_2	−34.6	2.1
C_2–C_3	0.8	−0.6
C_3–C_4	19.6	24.6
C_4–N	−4.1	−53.8
N–N	32.3	58.2
N–C_1	50.7	−30.3

Although the geometry of a molecule obtained by X-ray diffraction in the solid state does not necessarily reflect its conformation in solution, the ^1H NMR spectra of these epoxides can be perfectly explained on the basis of the structures reported, hence we will assume that these conformations are also valid for the NMR study of both isomers. Chemical shifts and coupling constants of protons attached to the piperidazine ring are shown in Table 2. The assignment of the different signals in the spectra has been confirmed by double resonance experiments.

The oxirane proton, H_0, appears in the **18a** spectrum as a doublet centered at 3.35 ppm, its coupling constant with the vicinal methinic proton H_m being of $J_{H_0H_m} = 3.5$ Hz. The same coupling in the **18b** isomer gives the larger value of 4.5 Hz. This difference is in accordance with the structures assigned to both isomers, as the dihedral angle $H_mC_1C_2H_0$ is larger in **18a** than in **18b** (62 and 45° for the *cis* and *trans* forms,† respectively).

On the other hand, the difference in the chemical shifts of the two protons at the methylene group is 1.45 ppm in the **18b** isomer whereas in **18a** a difference of only

Table 2. NMR data of the piperidazine ring in the epoxides

	Chemical shifts (δ scale)							Coupling constants (Hz)				
Comp.	H_0	H_m	H_a	H_e	C_1–CH_3	C_2–CH_3	C_3–CH_3	$J_{H_0H_m}$	$J_{H_0H_a}$	$J_{H_0H_e}$	$J_{H_mCH_3}$	$J_{H_aH_e}$
14a	3.35(m)	5.45(o)	3.80(d)	4.90(d)	1.45(d)		1.57(s)	3.0			7.0	16.0
15a	3.50(m)	5.45(q)	4.00(q)	4.90(q)	1.45(d)	1.58(s)			1.5	2.5	7.0	17.0
16	3.45(m)		3.95(q)	4.95(m)		1.53(s)			1.5	—		15.5
			3.75(d)	4.95(m)								15.0
17			3.70(d)	4.90(d)		1.50(s)	1.50(s)					15.5
18a	3.35(m)	5.65(o)	4.00(d)	4.95(d)	1.45(d)		1.58(s)	3.5			7.0	15.0
18b	3.38(d)	5.30(o)	3.58(d)	5.05(d)	1.35(d)		1.56(s)	4.5			7.0	15.0
19a	3.52(m)	5.65(q)	4.20(q)	4.95(q)	1.45(d)	1.58(s)			1.5	2.3	6.5	15.6
19b	3.45(t)	5.05(q)	3.80(q)	5.00(q)	1.30(d)	1.58(s)			1.9	1.7	6.5	14.8
20	3.50(m)		3.85(d)	5.05(d)		1.57(s)			1.3	2.8		15.0
			4.15(q)	4.95(q)								15.0
21			3.85(d)	5.05(d)		1.50(s)	1.50(s)					16.0
22	3.50(m)		3.92(d)	5.08(d)		1.58(s)			1.5	2.0		15.0
			4.18(q)	5.00(q)								14.0
23			3.92(d)	5.10(d)		1.54(s)	1.54(s)					15.0
24	3.62(m)		4.15(t)	4.96(t)					1.6	2.4		14.0
25	3.58(m) 3.62(m)	5.30(m)	3.68(q)	5.18(q)	1.32(d)			—	1.0	1.0	6.5	14.5

Spectra measured in chloroform solution at room temperature. s = singlet, d = doublet, t = triplet, q = quartet, o = octet, m = unresolved multiplet.

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†In the nomenclature we have employed, the terms *cis* and *trans* are referred to the relative positions of the two Me groups.

0.95 ppm is found. The H_m signal appears at 5.65 ppm in **18a** and at 5.30 ppm in **18b**. All these facts are easily explained on the basis of the different orientation of these protons with respect to the neighbouring C=O groups, as it can be seen from the respective molecular models. In the *trans* isomer, the plane of the C=O group is closer to the pseudoequatorial proton H_e than to the pseudoaxial one H_a and, consequently, H_e is more deshielded by anisotropic effect. In the *cis* form, however, both protons are nearly equidistant from the C=O plane, and their chemical shift difference must be diminished. Similarly, the methinic H_m is more deshielded in **18a**, because it is practically coplanar with respect to the C=O group, whereas in the other isomer this coplanarity does not exist.

Another difference between the NMR spectra of both isomers is the downfield shift found for the Me attached at C-1 in compound **18a** with respect to the same group in **18b**. These variations are again in accordance with the respective structures obtained by X-ray analysis, as the C-1 Me is closer to the C=O group in **18a** than in **18b**, and the deshielding effect must be increased in the former of both compounds (Fig. 1).

According to these assignments, the major isomer is that showing a *cis* configuration (6:1 relation). This result is in good agreement with the high stereoselectivity found usually in epoxidation reactions, since the peracid attack takes place primarily at the less hindered side of the double bond, to give as the main product the epoxide with the less steric hindrance, in our case, **18a**.[16] This effect is probably increased by the solvent employed, as the steric hindrance is somewhat greater in relatively polar solvents, such as chloroform.[17]

These same arguments can be employed in the structural assignment of the two compounds obtained by epoxidation of the 1,2-dimethyl substituted adduct. The methinic proton H_m of the major isomer **19a** is more deshielded than that of the **19b** isomer. This fact agrees with a *cis* disposition of both Me groups in **19a**, as H_m must be closer to the plane of the C=O group in the *cis* isomer than in the *trans* one. The chemical shifts difference between the two methylenic protons is larger in **19b**, this fact being justified, as discussed above for **18**, according to the relative orientations of these protons with respect to the C=O group. The C-1 Me is deshielded to a greater extent in **19a** than in **19b** by the anisotropic effect of the nearly coplanar C=O, as has been shown for the isomers previously studied. The stereoselectivity of this epoxidation is again observed, the major isomer showing a *cis* relation between the C-1 and C-2 Me's, as could be expected.

With respect to the 4a,8a-diazabicyclic epoxides **14** and **15**, it must be said that, although the formation of two isomers was detected by chromatographic essays performed on the crude products of both epoxidation reactions, only the major isomers, **14a** and **15a**, were isolated in the preparative tlc, in respective yields of 43% and 30%. The NMR spectra of these compounds are very similar to those found for **18a** and **19a**, and agree with the stereochemistry assigned to them. $J_{H_0H_m}$ is only 3 Hz in **14**, in accordance with the value obtained for the dihedral angle $H_0C_2C_1H_m$ in the **a** form of **18**. Difference between the chemical shifts of H_a and H_e is similar in both compounds to that observed for **18a** and **19a**, and clearly smaller than that found for the respective *trans* isomers. In addition, the C-1 Me groups are deshielded by the anisotropic effect of the neighbouring C=O (1.45 ppm), as it happens in the previously studied *cis* compounds. The stereoselectivity observed in the synthesis of the analogous diazatricyclic epoxides is then confirmed in both cases.

In the preparation of the 1-Me substituted epoxide **25**, only one isomer was formed, in a 72% yield. By comparing its spectral data with those of the 1,2 and 1,3-dimethyl substituted isomers, a stereochemistry of the **b** type can be assigned to this new compound, being in this case both the Me group and the epoxidic oxygen on the same side of the piperidazine ring. The high field position obtained for the C-1 Me group (1.32 ppm) and the methinic proton H_m (5.30 ppm), so as the great difference found between the chemical shifts of the methylenic H_a and H_e (1.5 ppm), are the main facts which support this assignment, on the basis of the arguments exposed above. Owing to the different preparative procedure employed in the synthesis of **25** with respect to the other epoxides studied, nothing can be discussed about the stereospecifical formation of this compound, as the stereochemistry of the starting bromohydrine has not yet been resolved.

Epoxides **16**, **17** and **20**–**24**, which lack the possibility of the geometrical isomerism described, show chemical shifts and proton couplings of the same order as those found for **18** and **19** (Table 2). Therefore, similar conformational arrangements should be assumed.

Finally, we should regard the small values observed for the coupling constants between H_0 and the neighbouring protons, which are in most of the cases less than what could be expected from the modification of the Karplus equation proposed by Tori and Komeno[18] for these couplings in steroidal epoxides:

$$J_{H_0H_x} = 5.1 \cos^2 \alpha.$$

However, it must be noted that, in compounds studied by us, the epoxide group is attached to a piperidazine ring, in which the electronegativity of both N atoms is a new factor reducing the magnitude of the coupling constant, specially, when these electronegative substituents are *trans*-coplanar to the coupling protons.[19,20]

EXPERIMENTAL

M.ps are uncorrected and were determined on capillary tubes. IR spectra were recorded on a Perkin-Elmer 257 spectrophotometer. ^1H NMR spectra were obtained with Perkin–Elmer R-12 and Varian XL-100 spectrophotometers, using TMS as internal standard. Chemical shifts are given in ppm (δ scale). X-ray diffraction analysis was performed on a Philips PW 1100 four-circle diffractometer operating in the $\omega/2\theta$ scan mode, and the structures were solved by the use of the direct method computer program Multan. Tlc plates were prepared with silica gel G (Merck).

Adducts **3**–**10**, **12** and **13**, were obtained by methods previously described.[1,5,6] The bromohydrines **26** and **27** have been prepared as reported.[1]

5,7 - *Dimethyl* - 4a,8a - *diaza* - 1,4,4a,5,8,8a - *hexahydronaphtalen* - 1,4 - *dione* **1**. To a cooled (−10°) methylene chloride suspension of maleic hydrazide (5.6 g or 0.05 mole in 250 ml), 4.1 g (0.05 mole) of 2-methyl-1,3-pentadiene and 5 ml glacial AcOH were added whilst stirring. Then, 22.2 g (0.05 mole) lead tetraacetate were added over a period of 60 min, and the mixture stirred at 0° for 3 hr. The white ppt formed was filtered off (lead acetate), and the filtrate washed successively with 5% $NaHCO_3$ aq and water, and dried over $MgSO_4$. The solvent was removed by rotary evaporation, and crude **1** recrystallised from cyclohexane to give 3.8 g of the pure compound (39% yield). M.p.

79–81°. IR (KBr) ν_{max} 3060, 2980, 1630 (C=O), 1580, 1325, 1220, 1140, 850, 765 cm^{-1}; NMR (CCl$_3$D) δ 1.30 (d, 3, C$_1$–CH$_3$) 1.85 (s, 3, C$_3$–CH$_3$) 4.40 (m, 2, CH$_2$) 5.30 (c, 1, CH–) 5.75 (m, 1, C=C–H) 7.20 (d, 2, CH=CH–C=O) ppm. (Found: C, 62.62; H, 6.26; N, 14.67. $C_{10}H_{12}N_2O_2$ requires: C, 62.48; H, 6.29; N, 14.57%).

5,6 - *Dimethyl* - 4a,8a - *diaza* - 1,4,4a,5,8,8a - *hexahydronaphtalen* - 1,4 - *dione* **2**. This compound was prepared as described for **1**, from 5.6 g (0.05 mole) of maleic hydrazide, 4.1 g (0.05 mole) of 3-methyl-1,3-pentadiene and 22.2 g (0.05 mole) of lead tetraacetate to give a yellow solid. Recrystallisation from cyclohexane afforded 7 g (73% yield) of pure **2**, m.p. 96–100°. IR (KBr) ν_{max} 3080, 2970, 1630 (C=O), 1590, 1415, 1230, 1140, 1070, 850, 760 cm^{-1}; NMR (CCl$_3$D) δ 1.35 (d, 3, C$_1$–CH$_3$) 1.90 (m, 3, C$_2$–CH$_3$) 4.50 (m, 2, CH$_2$) 5.20 (c, 1, CH–) 5.70 (m, 1, CH=) 6.95 (m, 2, CH=CH–C=O) ppm. (Found: C, 62.57; H, 6.25; N, 14.64. $C_{10}H_{12}O_2N_2$ requires: C, 62.48; H, 6.29; N, 14.57%).

1 - *Methyl* - 4a,12a - *diaza* - 1,4,4a,5,12,12a - *hexahydronaphtacen* - 5,12 - *dione* **11**. This compound was prepared as described for **1**, from 8.4 g (0.04 mole) of the cyclic hydrazide of 2,3-naphtalendicarboxilic acid, 2.7 g (0.04 mole) of 1,3-pentadiene and 17.8 g (0.04 mole) of lead tetraacetate. The reaction product crystallised from benzene to give 6.2 g of pure **11** (57% yield). M.p. 131–2°. IR (KBr) ν_{max} 3040, 2970, 1640 (C=O), 1625 (C=C), 1450, 1380, 1245, 1210, 1135, 980, 915, 765, 725, 715 cm^{-1}; NMR (CCl$_3$D) δ 1.35 (d, 3, CH$_3$) 4.30 (m, 1, CH$_2$ pseudoaxial proton) 5.08 (m, 1, CH$_2$ pseudoequatorial proton) 5.60 (m, 1, CH–C=C) 6.08 (m, 2, CH=CH) 7.75 (m, 2, aromat. ring A) 8.12 (m, 2, aromat. ring A) 8.85 (s, 2, aromat. ring B) ppm. (Found: C, 73.65; H, 4.79; N, 9.83. $C_{17}H_{14}N_2O_2$ requires: C, 73.40; H, 5.03; N, 10.07%).

General procedure for epoxidation. To a cooled (0°) chloroform soln of the adduct (0.01 mole in 20 ml), 0.0108 mole of *m*-chloroperbenzoic acid in 15 ml CHCl$_3$ were added dropwise. The mixture was stirred for 1 hr at room temp., and then refluxed from 1–4 hr. The soln was cooled at room temp. and treated with 10% Na$_2$SO$_3$ aq for destroying the excess peracid. The organic layer was successively washed with 5% NaHCO$_3$ aq and water, and dried over MgSO$_4$. The solvent was removed by rotary evaporation, and the residue purified either by recrystallisation or preparative tlc.

6,7 - *Epoxi* - 5,7 - *dimethyl* - 4a,8a - *diaza* - 1,4,4a,5,6,7,8,8a - *octahydronaphtalen* - 1,4 - *dione* **14**. A CHCl$_3$ soln of **1** and *m*-chloroperbenzoic acid was refluxed for 3 hr. Tlc of the resulting solid, developed in 1/1/1 mixture of EtOAc, CHCl$_3$ and petroleum ether afforded two products, one of them (m.p. 55–57°), obtained in very small quantities, could not be analyzed, the other was crystallised from MeOH to give 0.9 g (43% yield) of **14**. M.p. 195–7°. IR (KBr) ν_{max} 3080, 1640 (C=O), 1590, 1440, 1260, 1225 (C–O epoxide), 1150, 870 (C–O epoxide), 770, 720 cm^{-1}. (Found: C, 57.38; H, 5.69; N, 13.21. $C_{10}H_{12}N_2O_3$ requires: C, 57.68; H, 5.80; N, 13.45%).

6,7 - *Epoxi* - 5,6 - *dimethyl* - 4a,8a - *diaza* - 1,4,4a,5,6,7,8,8a - *octahydronaphtalen* - 1,4 - *dione* **15**. A CHCl$_3$ soln of **2** and *m*-chloroperbenzoic acid was refluxed for 3 hr. The resulting product was crystallised from MeOH, affording 0.6 g (30% yield) of an unique compound, which was identified as **15**. M.p. 164–6°. IR (KBr) ν_{max} 3060, 2970, 1630 (C=O), 1450, 1380, 1230, 1200 (C–O), 1150, 860 (C–O epoxide), 760, 700 cm^{-1}. (Found: C, 57.46; H, 5.53; N, 13.20. $C_{10}H_{12}N_2O_3$ requires: C, 57.68; H, 5.86; N, 13.45%).

6,7 - *Epoxi* - 6,7 - *dimethyl* - 4a,8a - *diaza* - 1,4,4a,5,6,7,8,8a - *octahydronaphtalen* - 1,4 - *dione* **16** A CHCl$_3$ soln of **3** and *m*-chloroperbenzoic acid was refluxed for 3 hr. The solid obtained was recrystallised from EtOAc, to give 0.8 g (42% yield) of the title compound. M.p. 183–5°. IR (KBr) ν_{max} 3060, 2990, 1635 (C=O), 1450, 1330, 1260 (C–O epoxide), 1140, 1050, 850 (C–O epoxide), 770 cm^{-1}. (Found: C, 55.89; H, 5.34; N, 14.60. $C_9H_{10}N_2O_3$ requires: C, 55.65; H, 5.15; N, 14.42%).

6,7 - *Epoxi* - *dimethyl* - 4a,8a - *diaza* - 1,4,4a,5,6,7,8,8a - *octahydronaphtalen* - 1,4 - *dione* **17**. A CHCl$_3$ soln of **4** and *m*-chloroperbenzoic acid was refluxed for 3 hr. The solid obtained was recrystallised from EtOAc, affording 2.0 g of **17** (96% yield). M.p. 172–4°. IR (KBr) ν_{max} 2980, 2920, 1640 (C=O), 1625, 1280 (C–O epoxide), 1120, 840 (C–O epoxide) cm^{-1}. (Found: C, 57.47; H, 5.87; N, 13.58. $C_{10}H_{12}N_2O_3$ requires: C, 57.68; H, 5.87; N, 13.45%).

2,3 - *Epoxi* - cis - 1,3 - *dimethyl* - 4a,9a - *diaza* - 1,2,3,4,4a,9,9a,10 - *octahydroantracen* - 9,10 - *dione* **18a**. A CHCl$_3$ soln of **5** and *m*-chloroperbenzoic acid was refluxed for 3 hr. Tlc of the resulting oil, developed in 2 : 1 mixture of benzene and EtOAc afforded **18a** as the more retained product. Crystallisation from MeOH yielded 1.73 g (67%) of the pure compound. M.p. 181–2°. IR (KBr) ν_{max} 3080, 2980, 1630 (C=O), 1605, 1360, 1210 (C–O epoxide), 1170, 1085, 865 (C–O epoxide), 790 cm^{-1}. (Found: C, 64.98; H, 5.25; N, 10.90. $C_{14}H_{14}N_2O_3$ requires: C, 65.10; H, 5.46; N, 10.84%).

2,3 - *Epoxi* - trans - 1,3 - *dimethyl* - 4a,9a - *diaza* - 1,2,3,4,4a,9,9a,10 - *octahydroantracen* - 9,10 - *dione* **18b**. This compound was obtained in the same reaction which produced **18a**, as the less retained product of the preparative tlc described above. Crystallisation from MeOH gave 0.28 g (11%) of **18b**. M.p. 149–50°. IR (KBr) ν_{max} 3060, 2970, 1635 (C=O), 1600, 1360, 1250 (C–O epoxide), 1140, 860 (C–O epoxide), 790, 725 cm^{-1}. (Found: C, 64.93; H, 5.36; N, 10.81. $C_{14}H_{14}N_2O_3$ requires: C, 65.10; H, 5.46; N, 10.84%).

2,3 - *Epoxi* - cis - 1,2 - *dimethyl* - 4a,9a - *diaza* - 1,2,3,4,4a,9,9a, 10 - *octahydroantracen* - 9,10 - *dione* **19a**. A CHCl$_3$ soln of **6** and *m*-chloroperbenzoic acid was refluxed for 3 hr. The resulting oil was purified by preparative tlc developed in 2 : 1 mixture of benzene and EtOAc, leading to the isolation of the title compound as the more retained product. Crystallisation from water afforded 1.35 g (52%) of pure **19a** m.p. 151–2°. IR (KBr) ν_{max} 3070, 2980, 1635 (C=O), 1610, 1360, 1215 (C–O epoxide), 1175, 870 (C–O epoxide), 790, 700 cm^{-1}. (Found: C, 65.13; H, 5.37; N, 11.02. $C_{14}H_{14}N_2O_3$ requires: C, 65.10; H, 5.46; N, 10.84%).

2,3 - *Epoxi* - trans - 1,2 - *dimethyl* - 4a,9a - *diaza* - 1,2,3,4,4a,9,9a,10 - *octahydroantracen* - 9,10 - *dione* **19b**. This compound was obtained in the same reaction which produced **19a**, as the less retained product of the preparative tlc described above. Crystallisation from MeOH gave 0.53 g (20%) of **19b**. M.p. 179–80°. IR (KBr) ν_{max} 3070, 2980, 1650 (C=O), 1600, 1365, 1245 (C–O epoxide), 1090, 850 (C–O epoxide), 780, 730 cm^{-1}. (Found: C, 65.21; H, 5.64; N, 11.04. $C_{14}H_{14}N_2O_3$ requires: C, 65.10; H, 5.46; N, 10.84%).

2,3 - *Epoxi* - 2 - *methyl* - 4a,9a - *diaza* - 1,2,3,4,4a,9,9a,10 - *octahydroantracen* - 9,10 - *dione* **20**. A CHCl$_3$ soln of **8** and *m*-chloroperbenzoic acid was refluxed for 3 hr. The resulting white solid was crystallised from MeOH, affording 2.1 g (85%) of pure **20**. M.p. 119–20°. IR (KBr) ν_{max} 3060, 2980, 1640 (C=O), 1600, 1360, 1265 (C–O epoxide), 1190, 850 (C–O epoxide), 790, 700 cm^{-1}. (Found: C, 64.12; H, 4.95; N, 11.33. $C_{13}H_{12}N_2O_3$ requires: C, 63.92; H, 4.95; N, 11.47%).

2,3 - *Epoxi* - 2,3 - *dimethyl* - 4a,9a - *diaza* - 1,2,3,4,4a,9,9a,10 - *octahydroantracen* - 9,10 - *dione* **21**. A CHCl$_3$ soln of **9** and *m*-chloroperbenzoic acid was refluxed for 1 hr. The product obtained was crystallised from MeOH, to give 2.35 g (90%) of the title compound. M.p. 201°. IR (KBr) ν_{max} 3060, 2980, 1640 (C=O), 1600, 1365, 1275 (C–O epoxide), 1135, 840 (C–O epoxide), 785, 700 cm^{-1}. (Found: C, 64.85; H, 5.26; N, 10.91. $C_{14}H_{14}N_2O_3$ requires: C, 65.10; H, 5.46; N, 10.84%).

2,3 - *Epoxi* - 2 - *methyl* - 4a,12a - *diaza* - 1,2,3,4,4a,5,12,12a - *octahydronaphtacen* - 5,12 - *dione* **22**. A CHCl$_3$ soln of **12** and *m*-chloroperbenzoic acid was refluxed for 6 hr. The pale yellow solid isolated was crystallised from MeOH to give 2.2 g (74%) of pure **22**. M.p. 200–1°. IR (KBr) ν_{max} 3070, 2890, 1645 (C=O), 1625, 1370, 1265 (C–O epoxide), 920, 870 (C–O epoxide), 765, 725 cm^{-1}. (Found: C, 69.68; H, 4.88; N, 9.73. $C_{17}H_{14}N_2O_3$ requires: C, 69.41; H, 4.77; N, 9.53%).

2,3 - *Epoxi* - 2,3 - *dimethyl* - 4a,12a - *diaza* - 1,2,3,4,4a,5,12,12a - *octahydronaphtacen* - 5,12 - *dione* **23**. A CHCl$_3$ soln of **13** and *m*-chloroperbenzoic acid was refluxed for 2 hr. The yellow solid isolated was crystallised from MeOH to give 2.8 g (90%) of the title compound. M.p. 262–3°. IR (KBr) ν_{max} 3070, 2940, 1650 (C=O), 1630, 1385, 1280 (C–O epoxide), 1180, 970, 855 (C–O epoxide), 760 cm^{-1}. (found: C, 70.11; H, 5.43; N, 9.34. $C_{18}H_{16}N_2O_3$ requires: C, 70.11; H, 5.23; N, 9.08%).

2,3 - *Epoxi* - 4a,12a - *diaza* - 1,2,3,4,4a,5,12,12a - *octahydronaphtacen* - 5,12 - *dione* **24**. To a stirred suspension of **26** in

MeOH (1 g or 0.0028 mole in 20 ml), 0.12 g (0.0030 mole) of NaOH in 20 ml water were slowly added. The pH of the suspension increased by 10 units. The mixture was then heated to 40°, and stirred until a neutral pH was obtained (50 min). After cooling at room temp. the ppt was filtered off, washed with water and crystallised from, MeOH, to give 0.6 g (78%) of pure **24**. M.p. 223°. IR (KBr) ν_{max} 3070, 2940, 1645 (C=O), 1625, 1380, 1265 (C–O epoxide), 975, 870 (C–O epoxide), 765, 720 cm^{-1}. (Found: C, 68.46; H, 4.33; N, 9.90. $C_{16}H_{12}N_2O_3$ requires: C, 68.57; H, 4.29; N, 10.00%).

2,3 - *Epoxi* - 1 - *methyl* - 4a,12a - *diaza* - 1,2,3,4,4a,5,12,12a - *octahydronaphtacen* - 5,12 - *dione* **25**. This compound was prepared as described for **24**, from 1 g (0.026 mole) of **27** and 0.12 g (0.0030 mole) NaOH. The solid obtained recrystallised from MeOH to give 0.5 g (65% yield) of the title compound. M.p. 161–2°. IR (KBr) ν_{max} 3030, 2980, 1645 (C=O), 1620, 1385, 1360, 1345, 1260 (C–O epoxide), 1195, 880 (C–O epoxide), 780, 760 cm^{-1}. (found: C, 69.51; H, 4.84; N, 9.30. $C_{17}H_{14}N_2O_3$ requires: C, 69.41; H, 4.77; N, 9.53%).

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