Functionalised Benzocyclo-octenones: Synthesis and Chemistry

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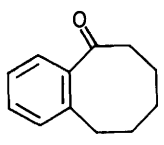
10,11-Dihydro-5-hydroxy-4-methoxycarbonylbenzo[5,6]cyclo-octa[1,2-*c*]furan-1,3-dione was selectively reduced and hydrolysed to 4,5-dihydrobenzo[5,6]cyclo-octa[1,2-*c*]furan-1,10(3*H*,11*H*)-dione whose structure was confirmed by *X*-ray analysis. Reduction and dehydration gave the lactone 10,11-dihydrobenzo[5,6]cyclo-octa[1,2-*c*]furan-1(3*H*)-one which was identical with one of two isomers obtained when the anhydride 10,11-dihydrobenzo[5,6]cyclo-octa[1,2-*c*]furan-1,3, 5(4*H*)-trione was reduced and dehydrated. Products of bromination of 10,11-dihydrobenzo[5,6]cyclo-octa[1,2-*c*]furan-1,3,5(4*H*)-trione and its methyl enol ether were identified: the enol ether was converted into several imides which could not be cleanly reduced. 4,5-Dihydrobenzo[5,6]cyclo-octa[1,2-*c*]furan-1,10(3*H*,11*H*)-dione was converted into the following lactones: 4,5,10,11-tetrahydro-10-hydroxybenzo[5,6]cyclo-octa[1,2-*c*]furan-1(3*H*)-one; 4,5-dihydrobenzo[5,6]cyclo-octa[1,2-*c*]furan-1(3*H*)-one; 3a,4,5,10,11,11a-hexahydro-10-hydroxybenzo[5,6]cyclo-octa[1,2-*c*]furan-1(3*H*)-one; 4,5,10,11-tetrahydro-10-hydroxybenzo[5,6]cyclo-octa[1,2-*c*]furan-1(3*H*)-one; 3a,4,5,11a-tetrahydrobenzo[5,6]cyclo-octa[1,2-*c*]furan-1,10(3*H*,11*H*)dione; 3a,4,5,11a-tetrahydrobenzo[5,6]cyclo-octa[1,2-*c*]furan-1(3*H*)-one. Reaction of appropriate lactones with benzylamine and benzylamine hydrochloride or with methylamine and hydrogen chloride gave lactams which were reduced to *N*-benzyl or *N*-methyl benzo[5,6]cyclo-octa[1,2-*c*]pyrrole derivatives. *N*-Benzyl analogues were debenzylated *via* carbamates. 4,5,10,11-Tetrahydro-10-hydroxybenzo[5,6]cyclo-octa[1,2-*c*]furan-1(3*H*)-one was arylated with anisole in the presence of acid to yield 4,5,10,11-tetrahydro-*p*-methoxyphenylbenzo[5,6]cyclo-octa[1,2-*c*]furan-1(3*H*)-one.

7,8,9,10-Tetrahydrobenzocyclo-octen-5(6*H*)-one (**1**) is available by high-dilution intramolecular cyclisation of 6-phenylhexanoic acid [1–4] or conveniently by reaction of benzyne with the sodium enolate of cyclohexanone.[5–7] Ring-expansion methods have been developed for synthesis of tetrahydrobenzocyclo-octen-6(5*H*)-one [8,9] and also for the 7-ketone.[10] However, not much is known about benzocyclo-octenones carrying substituents in the eight-membered ring. Some years ago we reported [11] a ring-expansion method which appeared to be capable of development for production of substituted benzocyclo-octenones. The present paper records progress in this direction.



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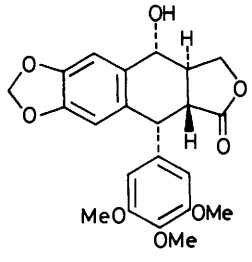

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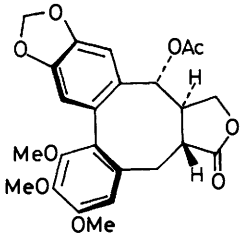

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It was of interest to obtain benzocyclo-octene derivatives bearing basic nitrogen substituents on or near the eight-membered ring since such an assembly would incorporate features associated with some CNS-acting drugs. Furthermore, it was desirable to establish whether fused-ring lactones were accessible: such materials would have structural features reminiscent of the natural lignan lactones such as podophyllotoxin [12] (**2**) and steganacin (**3**).[13]

Results and Discussion

As reported earlier,[11] the sodium enolate of the α-tetralone carboxylic ester (**4**) reacts with dimethyl acetylenedicarboxylate (DMAD) to yield, after neutralisation, the enolic triester (**5**; R = CO_2Me), whilst use of methyl propiolate in place of DMAD yielded the enolic diester (**5**; R = H). Mild alkaline hydrolysis of (**5**; R = CO_2Me) gave (after acidification) the ester anhydride (**6**; R = CO_2Me) whilst acid hydrolysis led to the keto anhydride (**7**; $R^1 = R^2 = H$).

In the present work, reduction of the keto anhydride (**7**; $R^1 = R^2 = H$) by catalytic hydrogenation or by the Clemmensen method yielded intractable material, but sodium borohydride reduction gave more promise, producing an inseparable pair of isomeric hydroxy lactones (**12a**, **b**; R = OH). The latter were dehydrated (PPA) to a pair of inseparable diene lactones in roughly equal proportions (g.l.c.): these are presumed to have structure (**8**; R = H) and (**9**; R = H). One of these lactones (**8**; R = H) was also obtained

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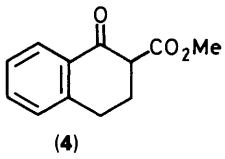

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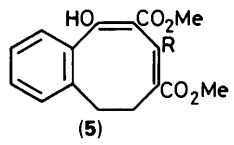

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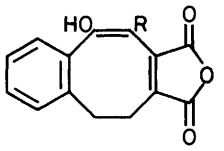

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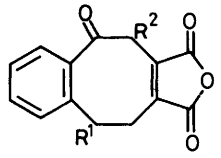

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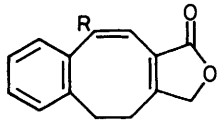

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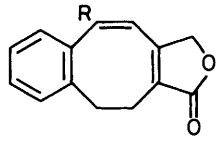

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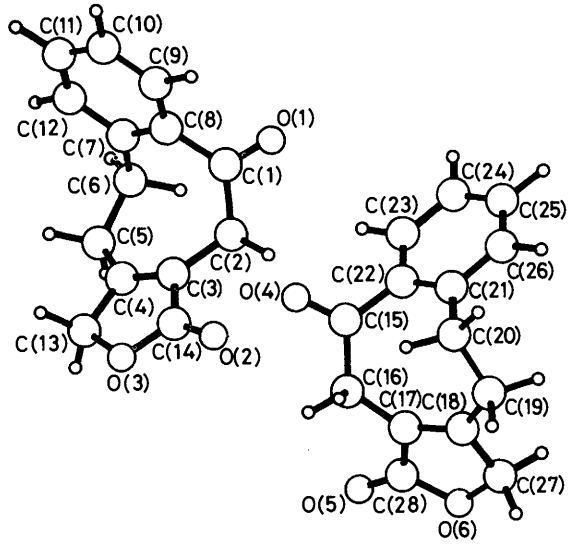
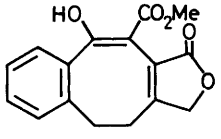


Figure 1. The crystal structure of the keto lactone (**11**) showing the contents of the asymmetric unit (PLUTO[31])



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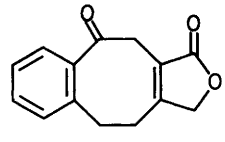


(11)

by an alternative unambiguous procedure (see below). Metal hydride reductions of anhydrides described in the literature[14–17] suggest that the predominant site for attack is the carbonyl group adjacent to the more highly substituted carbon atom. In this case, such a generalisation is not helpful and in regard to borohydride reduction of the ester anhydride (**6**; R = CO_2Me), the result was unexpected. In this example, a regiospecific reaction gave one lactonic ester (**10**) hydrolysis of which gave a keto lactone (**11**) whose structure was revealed by *X*-ray crystallography.

The *X*-ray crystallographic determination confirms unambiguously that the hydride reduction of the ester anhydride (**6**; R = CO_2Me) had taken place specifically at the distal, less sterically hindered carbonyl group to give ultimately the keto lactone (**11**).

Table 1. Derived geometrical parameters for keto lactone (**11**)

(a) Bond lengths (Å) with standard deviations

Molecule A		Molecule B	
O(1)–C(1)	1.212(5)	O(4)–C(15)	1.214(5)
O(2)–C(14)	1.215(6)	O(5)–C(28)	1.208(7)
O(3)–C(13)	1.442(5)	O(6)–C(27)	1.433(6)
O(3)–C(14)	1.348(5)	O(6)–C(28)	1.370(7)
C(1)–C(2)	1.521(6)	C(15)–C(16)	1.520(5)
C(1)–C(8)	1.494(5)	C(15)–C(22)	1.480(5)
C(2)–C(3)	1.507(5)	C(16)–C(17)	1.496(5)
C(3)–C(4)	1.329(5)	C(17)–C(18)	1.340(6)
C(3)–C(14)	1.468(6)	C(17)–C(28)	1.480(7)
C(4)–C(5)	1.480(5)	C(18)–C(19)	1.481(6)
C(4)–C(13)	1.495(5)	C(18)–C(27)	1.489(6)
C(5)–C(6)	1.538(6)	C(19)–C(20)	1.534(6)
C(6)–C(7)	1.505(6)	C(20)–C(21)	1.508(5)
C(7)–C(8)	1.403(5)	C(21)–C(22)	1.398(5)
C(7)–C(12)	1.400(6)	C(21)–C(26)	1.410(5)
C(8)–C(9)	1.398(6)	C(22)–C(23)	1.397(5)
C(9)–C(10)	1.361(7)	C(23)–C(24)	1.379(6)
C(10)–C(11)	1.380(7)	C(24)–C(25)	1.368(6)
C(11)–C(12)	1.391(7)	C(25)–C(26)	1.397(6)

(b) Bond angles (°) with standard deviations

Molecule A		Molecule B	
C(13)–O(3)–C(14)	108.5(3)	C(27)–O(6)–C(28)	109.3(4)
O(1)–C(1)–C(2)	117.6(4)	O(4)–C(15)–C(16)	117.3(3)
O(1)–C(1)–C(8)	119.2(3)	O(4)–C(15)–C(22)	119.4(3)
C(2)–C(1)–C(8)	123.2(3)	C(16)–C(15)–C(22)	123.3(3)
C(1)–C(2)–C(3)	118.0(3)	C(15)–C(16)–C(17)	118.5(3)
C(2)–C(3)–C(4)	132.4(3)	C(16)–C(17)–C(18)	132.7(4)
C(2)–C(3)–C(14)	119.4(3)	C(16)–C(17)–C(28)	119.0(4)
C(4)–C(3)–C(14)	107.9(3)	C(18)–C(17)–C(28)	108.1(4)
C(3)–C(4)–C(5)	130.9(3)	C(17)–C(18)–C(19)	131.4(4)
C(3)–C(4)–C(13)	108.9(3)	C(17)–C(18)–C(27)	109.1(4)
C(5)–C(4)–C(13)	120.2(3)	C(19)–C(18)–C(27)	119.4(4)
C(4)–C(5)–C(6)	115.1(3)	C(18)–C(19)–C(20)	115.0(3)
C(5)–C(6)–C(7)	112.0(3)	C(19)–C(20)–C(21)	111.0(3)
C(6)–C(7)–C(8)	124.4(3)	C(20)–C(21)–C(22)	124.5(3)
C(6)–C(7)–C(12)	118.3(3)	C(20)–C(21)–C(26)	117.7(3)
C(8)–C(7)–C(12)	117.2(3)	C(22)–C(21)–C(26)	117.7(3)
C(1)–C(8)–C(7)	124.3(3)	C(15)–C(22)–C(21)	124.4(3)
C(1)–C(8)–C(9)	115.4(3)	C(15)–C(22)–C(23)	115.5(3)
C(7)–C(8)–C(9)	120.3(3)	C(21)–C(22)–C(23)	120.1(3)
C(8)–C(9)–C(10)	121.2(4)	C(22)–C(23)–C(24)	121.2(4)
C(9)–C(10)–C(11)	119.8(5)	C(23)–C(24)–C(25)	119.7(4)
C(10)–C(11)–C(12)	119.8(5)	C(24)–C(25)–C(26)	120.2(4)
C(7)–C(12)–C(11)	121.6(4)	C(21)–C(26)–C(25)	121.0(4)
O(3)–C(13)–C(4)	105.0(3)	O(6)–C(27)–C(18)	105.3(4)
O(2)–C(14)–O(3)	121.5(4)	O(5)–C(28)–O(6)	122.8(5)
O(2)–C(14)–C(3)	128.9(4)	O(5)–C(28)–C(17)	129.0(5)
O(3)–C(14)–C(3)	109.6(3)	O(6)–C(28)–C(17)	108.2(4)

As depicted in Figure 1, the crystal structure actually consists of two independent molecules of the keto lactone (**11**) per asymmetric unit which exhibit only minor differences in their respective molecular geometries. Corresponding geometrical parameters between the two independent molecules A and B are generally in agreement to within two standard deviations. The independent and corresponding symmetry-related molecules of (**11**) are well separated in the crystal with no intermolecular contacts shorter than 3.2 Å between non-hydrogen atoms. The refined bond distances and angles for both molecules, and the fractional atomic co-ordinates for the non-hydrogen atoms are listed in Tables 1 and 2 respectively.

In the solid state, the central, eight-membered carbocyclic

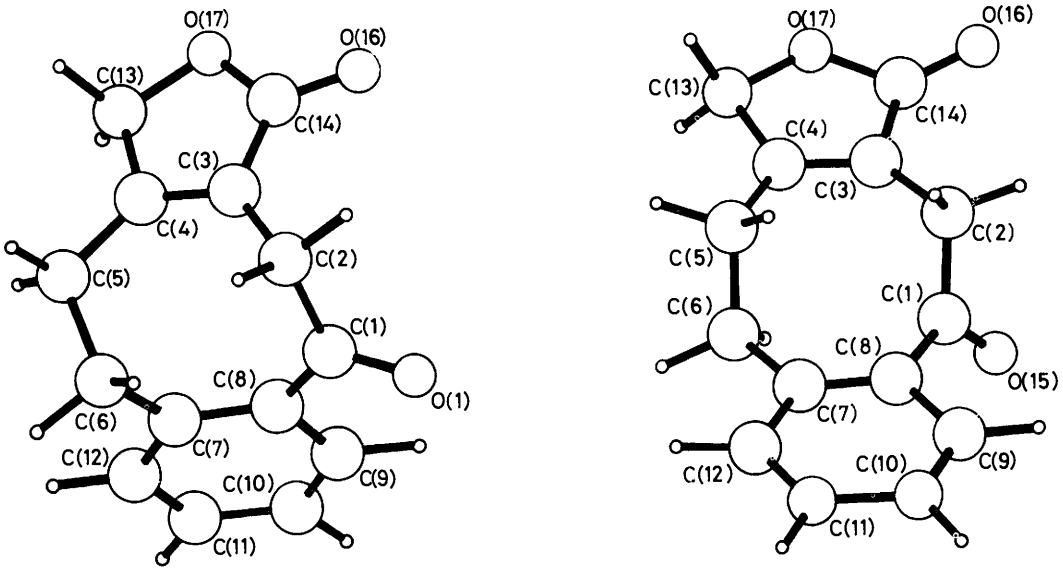


Figure 2. Minimised molecular geometries of (**11**) as calculated by MMP2[20] (a) in a distorted boat conformation with torsion angle C(7)–C(8)–C(1)–O(1) 150° and (b) in the chair conformation

Table 2. Fractional co-ordinates of atoms with standard deviations

	x	*y*	*z*
O(1)	0.389 92(24)	0.385 79(21)	0.462 77(22)
O(2)	0.255 7(3)	0.065 20(22)	0.463 91(23)
O(3)	0.113 58(23)	0.032 77(18)	0.307 04(22)
C(1)	0.318 3(3)	0.345 5(3)	0.385 2(3)
C(2)	0.333 4(3)	0.232 2(3)	0.367 0(3)
C(3)	0.229 6(3)	0.166 9(3)	0.312 8(3)
C(4)	0.152 4(3)	0.161 05(25)	0.214 0(3)
C(5)	0.138 5(3)	0.221 1(3)	0.121 1(3)
C(6)	0.203 4(3)	0.323 5(3)	0.144 6(3)
C(7)	0.166 2(3)	0.396 92(25)	0.204 5(3)
C(8)	0.219 5(3)	0.407 86(25)	0.313 4(3)
C(9)	0.182 5(3)	0.482 2(3)	0.361 6(3)
C(10)	0.091 8(4)	0.542 6(3)	0.305 0(4)
C(11)	0.035 4(4)	0.531 4(3)	0.198 0(4)
C(12)	0.073 5(3)	0.460 4(3)	0.148 3(3)
C(13)	0.072 1(3)	0.076 3(3)	0.203 8(3)
C(14)	0.205 3(3)	0.086 1(3)	0.371 7(3)
O(4)	0.586 72(24)	0.125 35(21)	0.053 45(22)
O(5)	0.725 0(3)	−0.191 77(24)	0.025 3(3)
O(6)	0.885 0(3)	−0.218 82(22)	0.173 6(3)
C(15)	0.667 9(3)	0.084 6(3)	0.122 7(3)
C(16)	0.661 1(3)	−0.030 72(25)	0.138 4(3)
C(17)	0.767 6(3)	−0.092 01(25)	0.182 1(3)
C(18)	0.854 8(3)	−0.096 93(25)	0.277 3(3)
C(19)	0.879 4(3)	−0.040 1(3)	0.374 8(3)
C(20)	0.810 3(3)	0.058 5(3)	0.360 5(3)
C(21)	0.833 4(3)	0.135 90(25)	0.293 9(3)
C(22)	0.768 1(3)	0.147 65(24)	0.186 4(3)
C(23)	0.793 2(3)	0.225 3(3)	0.132 7(3)
C(24)	0.884 8(3)	0.289 0(3)	0.183 0(3)
C(25)	0.951 7(3)	0.277 2(3)	0.287 6(4)
C(26)	0.925 8(3)	0.202 7(3)	0.344 0(3)
C(27)	0.935 1(4)	−0.176 8(3)	0.277 1(4)
C(28)	0.784 9(4)	−0.170 1(3)	0.115 4(4)

ring in molecule A (and similarly for molecule B) adopts a distorted boat conformation similar to that observed for other crystalline *cis,cis*-cyclo-octa-1,5-diene derivatives.[18,19] This conformation [torsion angles: C(4)–C(5)–C(6)–C(7) −61.7(4)° and C(8)–C(1)–C(2)–C(3)– −31.5(5)°] is presumably favoured in order to minimise eclipsing and transannular interactions between the respective ring hydrogen atoms. The carbonyl group at C(1) lies out of the plane with respect to the benzo group by some 35° indicating only partial conjugation between the two π-systems.

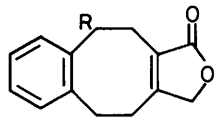
Although the bond lengths around the central ring lie within expected ranges, the bond angles at the sp^2 carbon atoms which constitute the ring junctions deviate significantly from the normal trigonal angle. The internal angles of the eight-membered ring [C(2)–C(3)–C(4) 132.4(3), C(3)–C(4)–C(5) 130.9(3), C(6)–C(7)–C(8) 124.4(3) and C(7)–C(8)–C(1) 124.3(3)°] are considerably widened whereas the angles within the five-membered furanone ring are necessarily compressed [C(3)–C(4)–C(13) 108.9(3) and C(4)–C(3)–C(14) 107.9(3)°]. As a consequence, the fused ring system possesses a high degree of angle strain, particularly at the ring junctions. The molecule is highly planar around the regions of the benzo and furanone rings; maximum deviations from least-squares planes through the ring atoms and the two adjacent carbon atoms are within ±0.3 Å in each case.

Further investigation of structure (**11**) using molecular mechanics calculations (MMP2[20]) reproduced many of the features observed in the solid state (Figure 2a). The distorted boat geometry appears to be reasonably flexible since a series of conformations, generated by varying the torsion angle C(7)–C(8)–C(1)–O(1) in the range +140– +170°, only differ in energy by *ca.* 3 kcal mol^{-1}. In addition, the alternative, more rigid chair conformation (Figure 2b) is disfavoured over the distorted boat forms by some 7—10 kcal mol^{-1}.

Apparently, steric hindrance in the ester anhydride (**6**; R = CO_2Me) has protected the carbonyl group which some previous experience[14–17] might have predicted to be selectively vulnerable. Borohydride reduction of the keto lactone (**11**) yielded an alcohol (**12a**; R = OH) which reacted with anisole in the presence of PPA to give the lactone (**12a**; R = *p*-C_6H_4OMe). The aforementioned sequence of reactions offers promise for syntheses of analogues of the natural lignan lactones mentioned previously.

Dehydration of the alcohol (**12a**; R = OH) gave a lactone (**8**; R = H) shown by n.m.r. spectroscopy and g.l.c. analysis to be one of the previously mentioned constituents (**8**) + (**9**) (R = H) obtained by reduction/dehydration of the keto anhydride (**7**; R^1 = R^2 = H).

Turning to the introduction of the nitrogen functionality into



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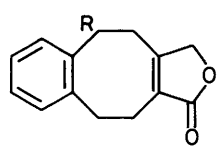

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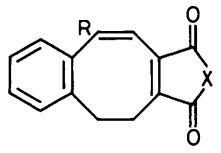

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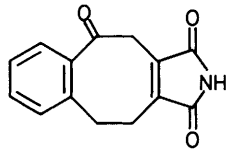
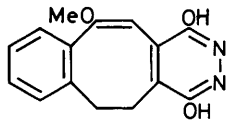


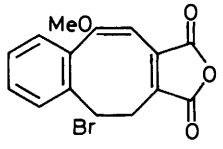
(13a)

these molecules, the keto anhydride (7; $R^1 = R^2 = H$) seemed a suitable candidate for reaction with amines. However, since, in practice, two molecules of benzylamine reacted with one of substrate we turned our attention to the enol ether (13; R = OMe, X = O). Although the latter reacted straightforwardly with bases to yield the imides (13; R = OMe, X = NMe, NNH_2, NH, and NCH_2Ph), no useful products could be obtained from these with $LiAlH_4$ or with borane–THF complex. The hydrazino product (13; R = OMe, X = NNH_2) reacted with aqueous sodium hydroxide to give the novel pyridazine compound (14); there are precedents for such behaviour.[21–24]

In order to explore the possibility of achieving indirect amination, halogenation was investigated. *N*-Bromosuccinimide (NBS) reaction of the keto anhydride (7; $R^1 = R^2 = H$) gave the bromo keto anhydride (7; $R^1 = H$, $R^2 = Br$), whilst the products from NBS reaction on the enol ether depended on the solvent. In tetrachloromethane, the bromo compound (15) was obtained but in methyl formate the unexpected bromo compound (16) resulted. Unfortunately, treatment of all these bromo compounds with amines gave intractable products.



(14)



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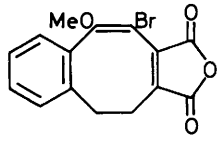

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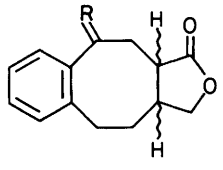

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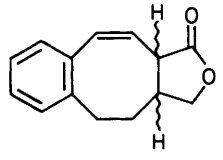

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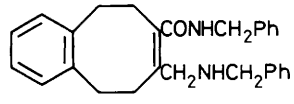
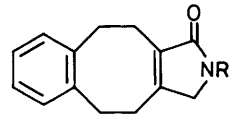


(19)

The lactone (11) has proved to be a versatile intermediate, allowing access to some of the basic materials that we had envisaged. Clemmensen reduction of the lactone (11) gave a mixture of lactones (8; R = H) and (12a; R = H) catalytic



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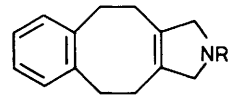

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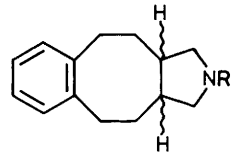

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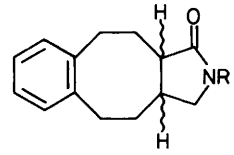

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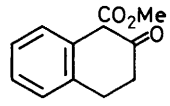

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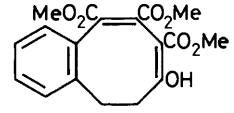

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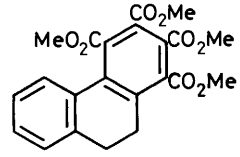
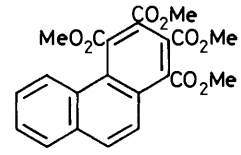


(26)



(27)

hydrogenation of which allowed conversion of the lactone (8; R = H) to (12a; R = H). Vigorous (80 °C) sodium borohydride treatment of lactone (11) yielded the hydroxy lactone (17; R = H, OH) which gave the keto lactone (17; R = O) on reoxidation with CrO_3–pyridine. Dehydration of the hydroxy lactone (17; R = H, OH) led to the olefinic lactone (18) which could be hydrogenated to give the lactone (17; R = H, H).

Several of these lactones have been converted in two steps into *N*-benzyl and *N*-methyl lactams. Thus, reaction with benzylamine and benzylamine hydrochloride (benzylamine alone was repeatedly ineffective) aminated the lactone (12a; R = H) to the amino amide (19) which was then converted into the lactam (20; R = $PhCH_2$) when heated *in vacuo* with alumina. $LiAlH_4$ (THF) treatment of the lactam (20; R = $PhCH_2$) at room temperature yielded a mixture of the amines (21; R = $PhCH_2$) and (22; R = $PhCH_2$), the latter predominating. When the reduction was conducted at −15 °C or better at room temperature in the presence of cerium chloride,[25] the amine (21; R = $PhCH_2$) was the major product. Similar amination of the lactone (17; R = H, H) followed by $LiAlH_4$ treatment of (23; R = $PhCH_2$) gave two bases ($C_{21}H_{25}N$), the major one of which could be obtained pure and was shown to be identical with (22; R = $PhCH_2$) described above. These bases are presumably the *cis*- and *trans*-fused versions of (22; R = $PhCH_2$), but spectroscopy could not distinguish which was which.

Debenzylation of the amines (21) and (22) (R = $PhCH_2$) was achieved with ethyl chloroformate[26] followed by hydrolysis. The *N*-methylamines (21) and (22) (R = Me) were also made by analogous reactions (see Experimental section): amination of the lactone (12; R = H) with methylamine proceeded quite readily in a sealed vessel at 70 °C over 4 days. *N*-Methylamine (22; R = Me) comprised two isomers (g.l.c. and h.p.l.c.) in the ratio 65 : 35. Repeated chromatography provided a pure sample of the major isomer, the *N*-methyl

quaternary iodide of which showed only one NMe peak in the n.m.r. spectrum. Accordingly we consider that the major isomer has the *trans*-ring junction.

When the β-tetralone ester (**24**) was treated with sodium hydride and DMAD, a very poor yield of the ring-expanded triester (**25**) was obtained. Lithium hydride brought about an increased yield (17%) but this did not provide enough material for further studies. β-Tetralone itself reacted with NaH and DMAD (α-tetralone fails) to give a dihydrophenanthrenetetracarboxylic ester (**26**) which could, with a little difficulty, be converted into the corresponding phenanthrene (**27**). DDQ or palladium on charcoal were not successful in this dehydrogenation which was achieved by bromination/dehydrobromination. This method of phenanthrene synthesis is worthy of further study.

In conclusion, it has been demonstrated that diverse functionalised benzocyclo-octenones are available by ring-expansion of tetralones with DMAD and that they are a fruitful source of tricyclic lactones, anhydrides, and amines.

Experimental

N.m.r. spectra were recorded at 90 MHz and silica was used for chromatography unless otherwise stated. All distillations were carried out in a Kugelrohr apparatus.

4,5,10,11-*Tetrahydro*-5-*hydroxybenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1(3H)-*one* (**12b**; R = OH) *and* 4,5,10,11-*Tetrahydro*-10-*hydroxybenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1(3H)-*one* (**12a**; R = OH).—Finely powdered sodium borohydride (2 g, 0.08 mol) was added slowly to a stirred solution of 10,11-dihydrobenzo[5,6]cyclo-octa[1,2-c]furan-1,3,5(4*H*)-trione[11] (**7**; R^1 = R^2 = H) (1.2 g, 4.9 mmol) in ethanol (500 cm^3) at room temperature. The reaction mixture was stirred for 2.5 h after which it was evaporated, diluted with water, acidified with 2M hydrochloric acid, and extracted with chloroform. The extract was dried and evaporated to give the *product* (1.09 g, 96%). Recrystallisation (ethyl acetate) of this gave colourless crystals, m.p. 173—176 °C (Found: C, 73.0; H, 6.2%; M^+, 230.0962. $C_{14}H_{14}O_3$ requires C, 73.05; H, 6.15%; *M*, 230.0943); $\nu_{max.}$ 3 600—3 200 (OH) and 1 715 cm^{-1} (CO, lactone).

10,11-*Dihydrobenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1(3H)-*one* (**9**; R = H) *and* 4,5-*Dihydrobenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1(3H)-*one* (**8**; R = H).—The mixture (**12a, b**; R = OH) (1.5 g, 6.52 mmol) was added to a stirred solution of polyphosphoric acid (PPA) (30 g) at 20 °C. After 16 h the reaction mixture was hydrolysed with water and extracted with chloroform. Work-up followed by chromatography (chloroform) gave separation of the major component (0.7 g, 50.6%) as a colourless solid, m.p. 109—111 °C (MeOH). G.l.c. analysis indicated two products in 1:1 ratio (Found: C, 79.4; H, 5.7%; *M*, 212.0831. $C_{14}H_{12}O_2$ requires C, 79.2; H, 5.7%; *M*, 212.0837); $\nu_{max.}$ 1 730 (CO, lactone) and 1 620 cm^{-1}, δ 7.25 (4 H, m, aryl), 7.0—6.6 (1 H, dd, vinylic), 6.5—5.9 (1 H, dd, vinylic), 4.56 (2 H, s, CH_2O), and 3.2—2.6 (4 H, m, CH_2).

4,5-*Dihydro*-10-*hydroxy*-11-*methoxycarbonylbenzo*[5,6]-*cyclo-octa*[1,2-c]*furan*-1(3H)-*one* (**10**).—To a stirred solution of compound (**6**; R = CO_2Me) in ethanol (60 cm^3) at 90 °C was added finely ground sodium borohydride (0.6 g, 15.7 mmol). After 4 h the reaction mixture was concentrated under reduced pressure, diluted with water, acidified, and extracted with chloroform. The extract was dried and evaporated to afford colourless crystals (0.72 g, 75.5%) m.p. 195—196 °C (methanol) (Found: C, 67.4; H, 5.05%; M^+, 286.0831. $C_{16}H_{14}O_5$ requires C, 67.5; H, 4.95%; *M*, 286.0841); $\nu_{max.}$ 1 745 (CO, lactone), 1 673 (CO ester), and 1 645 cm^{-1} (CO); δ 13.23 (1 H, s, exch. OH), 7.6—7.1 (4 H, m, aryl), 4.66 (1 H, d, *J* 17 Hz, C*H*HO), 4.14 (1 H, d, *J* 17 Hz, CH*H*O), 3.8 (3 H, s, OCH_3), and 3.5—2.5 (4 H, m, CH_2).

4,5-*Dihydrobenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1,10(3H,11H)-*dione* (**11**).—The benzocyclo-octafuran (**10**) (2 g, 7 mmol), acetic acid (60 cm^3), water (8 cm^3), and concentrated hydrochloric acid (8 cm^3) were heated under reflux for 48 h. The mixture was then evaporated under reduced pressure to leave a yellow solid which was dissolved in chloroform, and the solution washed with water and aqueous sodium hydrogen carbonate, dried, and evaporated to yield a powder. Recrystallisation of this from methanol yielded colourless crystals (1.33 g, 84%), m.p. 153—155 °C (Found: C, 73.75; H, 5.35%; M^+, 228.0785. $C_{14}H_{12}O_3$ requires C, 73.65; H, 5.3%; *M*, 228.0786] $\nu_{max.}$ 1 740 (CO lactone), 1 695 (CO aryl), and 1 595 cm^{-1} (C=C); δ 7.7—7.1 (4 H, m, aryl), 4.5 (2 H, s, $COCH_2$), 3.9 (2 H, s, CH_2O), 3.4—3.1 (2 H, m, CH_2), and 3.0—2.7 (2 H, m, CH_2).

10,11-*Dihydro*-5-*methoxybenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1,3-*dione* (**13**; R = OMe, X = O).—The benzocyclo-octafuran (**7**; R^1 = R^2 = H) (2 g, 8.26 mmol), trimethyl orthoformate (12 cm^3), and toluene-*p*-sulphonic acid (10 mg) were heated under reflux for 4 h in methanol (40 cm^3). The reaction mixture was worked up to yield a yellow crystalline product (1.95 g, 93%), m.p. 186—187 °C (MeOH) (Found: C, 70.25; H, 4.75%; M^+, 256.0908. $C_{15}H_{12}O_4$ requires C, 70.3; H, 4.7%; *M*, 256.0888); $\nu_{max.}$ 1 840, 1 760 (CO anhydride), and 1 610 cm^{-1}; δ 7.5—7.1 (4 H, m, aryl), 5.6 (1 H, s, vinylic), 3.91 (3 H, s, OCH_3), 3.7—3.4 (4 H, m, CH_2).

2-*Benzyl*-10,11-*dihydro*-5-*methoxybenzo*[5,6]*cyclo-octa*[1,2-c]*pyrrole*-1,3-*dione* (**13**; R = OMe, X = NCH_2Ph).—The benzocyclo-octafuran (**13**; R = OMe, X = O) (1 g, 3.9 mmol) and benzylamine (0.42 g, 3.9 mmol) were refluxed in toluene (40 cm^3) for 48 h. The reaction mixture was cooled, washed with aqueous sodium hydrogen carbonate, dried, and evaporated to yield a yellow product (1.2 g, 90%), m.p. 137—140 °C (EtOH) [Found: C, 76.35; H, 5.55; N, 4.0%; M^+, 345.1338. $C_{22}H_{19}NO_3$ requires C, 76.5; H, 5.5; N, 4.0%; *M*, 345.1365]; $\nu_{max.}$ 1 760, 1 700 (CO imide), and 1 615 cm^{-1} (C=C); δ 7.5—7.1 (9 H, m, aryl), 5.64 (1 H, s, vinylic), 4.57 (2 H, s, CH_2), 3.89 (3 H, s, OCH_3), and 3.3—2.7 (4 H, m, CH_2).

10,11-*Dihydro*-5-*methoxybenzo*[5,6]*cyclo-octa*[1,2-c]*pyrrole*-1,3-*dione* (**13**; R = OMe, X = NH).—The benzocyclo-octafuran (**13**; R = OMe, X = O) (5 g, 0.019 mol) concentrated ammonia solution (*d* 0.88), and ethanol (100 cm^3) were refluxed for 22 h. Work-up yielded a yellow crystalline product (4.6 g, 95%), m.p. 213 °C (Pr^iOH) [Found: C, 70.45; H, 5.15; N, 5.4%; M^+, 255.0896. $C_{15}H_{13}NO_3$ requires C, 70.6; H, 5.15; N, 5.5%; *M*, 255.0895] $\nu_{max.}$ 3 350—3 100 (NH), 1 765, and 1 710 cm^{-1} (CO, imide) δ 7.9—7.7 (1 H, s, exch.) 7.5—7.1 (4 H, m, aryl), 5.6 (1 H, s, vinylic), 3.9 (3 H, s, OCH_3), and 3.2—2.7 (4 H, m, CH_2).

10,11-*Dihydro*-5-*methoxy*-2-*methylbenzo*[5,6]*cyclo-octa*[1,2-c]*pyrrole*-1,3-*dione* (**13**; R = OMe, X = Me).—The benzocyclo-octa[1,2-*c*]furan (**13**; R = OMe, X = O) (0.5 g, 1.9 mmol), methylamine (33% in ethanol; excess) and ethanol (40 cm^3) were stirred at room temperature overnight to produce a yellow precipitate. Work-up afforded a yellow crystalline product (0.45 g, 85%), m.p. 179—181 °C (EtOH) (Found: C, 71.2; H, 5.55; N, 5.0%; M^+, 269.1054. $C_{16}H_{15}NO_3$ requires C, 71.35; H, 5.6; N, 5.2%; *M*, 269.1052); $\nu_{max.}$ 1 754 and 1 695 cm^{-1} (CO, imide); δ 7.5—7.1 (4 H, m, aryl), 5.63 (1 H, s, vinylic) 3.9 (3 H, s, OCH_3), 3.2—2.7 (4 H, m, CH_2), and 2.91 (3 H, s, NCH_3).

10,11-*Dihydrobenzo*[5,6]*cyclo-octa*[1,2-c]*pyrrole*-1,3,5-*trione* (**13a**).—The benzocyclo-octapyrrole (**13**; R = OMe, X = NH) (0.5 g, 1.96 mmol), aqueous tetrahydrofuran (4:1, v/v; 25 cm^3) and concentrated hydrochloric acid (0.5 cm^3) were refluxed overnight. Work-up gave a gum which crystallised from ether (0.39 g, 82%), m.p. 177—180 °C (MeOH) (Found: C, 69.45; H, 4.55; N, 5.5%; M^+, 241.0734. $C_{14}H_{11}NO_3$ requires C, 69.7; H, 4.6; N, 5.8%; *M*, 241.0739); $\nu_{max.}$ 1 760, 1 700 (CO imide), and 1 685 cm^{-1} (CO, aryl); δ 7.8—7.5 (1 H, m, exch.), 7.7—7.1 (4 H, m, aryl), 4.0 (2 H, s, $COCH_2$), and 3.5—2.7 (4 H, m, CH_2).

4-*Bromo*-10,11-*dihydrobenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1,3,5-*trione* (**7**; R^1 = H, R^2 = Br).—The benzocyclo-octafuran (**7**; R^1 = R^2 = H) (2 g, 8.26 mmol) and *N*-bromosuccinimide (1.47 g, 8.26 mmol) were refluxed in carbon tetrachloride (30 cm^3) for 2 h. The solvent was removed under reduced pressure, the residue dissolved in dichloromethane, and the solution washed with water (×2), dried, and evaporated to afford a yellow product which appeared as two spots on t.l.c. Chromatography (silica, dichloromethane as eluant) afforded the front running component as a yellow powder (1.95 g, 73.5%), m.p. 146—147 °C (Me_2CO–Et_2O) (Found: C, 52.55; H, 2.7; Br, 25.0%; M^+, 321.9660, 319.9680. $C_{14}H_9BrO_4$ requires C, 52.35; H, 2.8; Br, 24.9%; *M*, 321.9665, 319.9685); $\nu_{max.}$ 1 832 and 1 772 cm^{-1} (CO, anhydride); δ 7.6—7.1 (4 H, m, aryl), 5.65 (1 H, s, CHBr), and 3.6—2.8 (4 H, m, CH_2). The second component was negligible.

5-*Bromo*-4,5-*dihydro*-10-*methoxybenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1,3-*dione* (**15**).—The benzocyclo-octafuran (**13**; R = OMe), X = O) (4 g, 15.6 mmol) and *N*-bromosuccinimide (2.92 g, 16.4 mmol) were refluxed in carbon tetrachloride for 1 h. The solvent was removed under reduced pressure and the residue dissolved in dichloromethane and the solution washed with water (×2) dried, and evaporated to produce a yellow product (4.58 g, 87%) (Found: C, 53.65; H, 3.15; Br, 23.75%; M^+, 335.9832, 333.9830. $C_{15}H_{11}BrO_4$ requires C, 53.75; H, 3.3; Br, 23.85%; *M*, 335.9821, 333.9841); $\nu_{max.}$ 1 859 and 1 766 cm^{-1} (CO, anhydride); δ 7.6—7.2 (4 H, m, aryl), 5.71 (1 H, s, vinylic), 5.18 (1 H, dd, CHBr, J_{BX} 6.7 Hz, J_{AX} 11.3 Hz), 3.96 (3 H, s, OCH_3), 3.68 (1 H, dd, J_{AB} 13.3 Hz, J_{AX} 11.3 Hz), and 3.36 (1 H, dd, J_{AB} 13.3 Hz, J_{BX} 6.7 Hz).

4-*Bromo*-10,11-*dihydro*-5-*methoxybenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1,3-*dione* (**16**).—The benzocyclo-octafuran (**13**; R = OMe, X = O) (6 g, 23.4 mmol) and *N*-bromosuccinimide (4.38 g, 24 mmol) were refluxed in methyl formate (70 cm^3) for 1 h. After evaporation of solvent, work-up gave a yellow crystalline product (7.85 g, 100%), m.p. 137—138 °C (Et_2O–Me_2CO) (Found: C, 53.2; H, 3.3; Br, 23.85%; M^+, 335.9845, 333.9860. $C_{15}H_{11}BrO_4$ requires C, 53.75; H, 3.3; Br, 23.85%; *M*, 335.9821, 333.9841); $\nu_{max.}$ 1 854 and 1 771 cm^{-1} (CO, anhydride); δ 7.25 (4 H, m, aryl), 3.45—3.28 (1 H, m, CHH^1), and 3.1—2.7 (3 H, m, CH_2CHH^1).

2-*Amino*-10,11-*dihydro*-5-*methoxybenzo*[5,6]*cyclo-octa*[1,2-c]*pyrrole*-1,3-*dione* (**13**; R = OMe, X = NNH_2).—The benzocyclo-octafuran (**13**; R = OMe, X = O) (2 g, 7.8 mmol) and hydrazine hydrate (0.44 g, 8.8 mmol) were refluxed in methanol (50 cm^3) for 2.5 h. The methanol was removed under reduced pressure and the residual yellow product dissolved in chloroform and the solution washed (×2) with water, dried, and evaporated to afford an orange product (2.031 g, 96%), m.p. 193—195.5 °C (EtOH) (Found: C, 66.85; H, 5.3; N, 10.1%; M^+, 270.0986. $C_{15}H_{14}N_2O_3$ requires C, 66.65; H, 5.2; N, 10.35%; *M*, 270.1004); $\lambda_{max.}$ 3 360—3 200 (NH) and 1 755 and 1 695 cm^{-1} (CO, imide); δ 7.5—7.1 (4 H, m, aryl), 5.6 (1 H, s, vinylic), 3.9 (3 H, s, OCH_3), 3.8 (2 H, s, exch., NH_2), and 3.2—2.7 (4 H, m, CH_2).

11,12-*Dihydro*-6-*methoxybenzo*[5,6]*cyclo-octa*[1,2-d]*pyridazine*-1,4-*diol* (**14**).—The benzocyclo-octapyrrole (**13**; R = OMe, X = NNH_2) (0.5 g, 1.85 mmol) and 2M sodium hydroxide (20 cm^3) were refluxed overnight in ethanol (10 cm^3). The reaction mixture was cooled, excess of 2M hydrochloric acid was added to it and the whole stirred for 20 min. Filtration of mixture afforded a white powder (0.39 g, 78%), m.p. 290 °C (decomp.) (MeOH) (Found: C, 66.8; H, 5.2; N, 10.4%; M^+, 270.1003. $C_{15}H_{14}N_2O_3$ requires C, 66.65; H, 5.2; N, 10.35%; *M*, 270.1004); $\nu_{max.}$ 3 200—2 300br (OH) and 1 635 cm^{-1} (CO, amide); $\delta(CD_3)_2SO$ 11.6—10.7 (2 H, OH), 7.24 (4 H, s, aryl), 5.65 (1 H, s, vinylic), 3.8 (3 H, s, OCH_3), and 3.15—2.8 (4 H, m, CH_2).

Clemmensen Reduction of Compound (**11**).—The keto lactone (**11**) (2 g, 8.77 mmol), mossy zinc (4.8 g, 0.073 mol) [amalgamated by stirring with mercuric chloride (0.48 g, 1.75 mmol), concentrated hydrochloric acid (0.24 cm^3), and water (6 cm^3) for 5 min], water (3 cm^3), concentrated hydrochloric acid (6 cm^3), toluene (4 cm^3), and acetic acid (3 drops) were refluxed for 48 h, with addition of concentrated hydrochloric acid (2 cm^3) every 6 h. The mixture was cooled and the aqueous solution diluted with water and extracted with chloroform. The chloroform–toluene mixture was washed with water, dried, and evaporated to yield a yellow crystalline product (1.7 g, 90.5%). T.l.c. indicated that this product contained two components (**8**; R = H) and (**12 a**; R = H). Chromatography (chloroform as eluant) allowed the separation of the two components (**8**; R = H) (60%) and (**12a**; R = H) (30%). Compound (**8**; R = H) (30%) (Found: C, 79.35; H, 5.65%; M^+, 212.0832. $C_{14}H_{12}O_2$ requires C, 79.2; H, 5.7% *M*, 212.0837); $\nu_{max.}$(Nujol) 1 732 (CO lactone) and 1 650 cm^{-1} (C=C), δ 7.2 (4 H, s, aryl), 6.9—6.69 (1 H, dd, vinylic), 6.5—6.2 (1 H, dd, vinylic), 4.55 (2 H, s, CH_2O), 3.3—2.95 (2 H, m, CH_2), 2.95—2.65 (2 H, m, CH_2). Compound (**12a**; R = H) (Found: C, 78.45; H, 6.7%; M^+, 214.0985. $C_{14}H_{14}O_2$ requires C, 78.5; H, 6.6% *M*, 214.0993); $\nu_{max.}$(Nujol) 1 730 (CO lactone) and 1 670 cm^{-1} (C=C); δ 7.13 (4 H, s, aryl), 4.4 (2 H, s, CH_2O), 3.2—2.92 (4 H, m, CH_2CH_2), and 2.92—2.5 (4 H, m, CH_2CH_2).

3a,4,5,10,11-*Hexahydro*-10-*hydroxybenzo*[5,6]*cyclo-octa*-[1,2-c]*furan*-1(3H)-*one* (**17**; R = H, OH).—Finely powdered sodium borohydride (0.44 g, 0.011 mol) was added slowly to a stirred solution of the keto lactone (**11**) (2 g, 8.771 mmol) in ethanol (80 cm^3) at 90 °C. The mixture was stirred for 24 h after which ice–water (40 cm^3) and dilute hydrochloric acid (16 cm^3) were added. The organic layer was extracted with chloroform, dried, and evaporated under reduced pressure to afford a gum (1.9 g, 93.36%), t.l.c. of which indicated that it contained three components. Rapid chromatography (chloroform as eluant) permitted the separation of the major product, m.p. 154—156 °C (Et_2O–EtOAc) (Found: C, 72.1; H, 6.75%; M^+, 232.1102. $C_{14}H_{16}O_3$ requires C, 72.4; H, 6.95% *M*, 232.1099); $\nu_{max.}$(liquid film) 3 600—3 200 (OH alcohol) and 1 760 (CO saturated lactone); δ 7.7—6.9 (4 H, m, aryl), 5.3—4.9 (1 H, t, $CHOH$), 4.5—3.9 (1 H, m, CH), 3.9—3.4 (1 H, m, CH_2CHCO), 3.4—2.9 (1 H, s, exch., OH), 2.9—2.6 (2 H, t, CH_2O), and 2.6—1.0 (6 H, m, CH_2CH_2, CH_2).

4,5,10,11-*Tetrahydrobenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1(3H)-*one* (**12a**; R = H).—The mixture (**8**; R = H) and (**12a**; R = H) (0.5 g) obtained from the Clemmensen reduction, ethanol (20 cm^3), and 10% palladium on charcoal (50 mg) were stirred at room temperature under hydrogen (1 atm) for 7 h. The mixture was then filtered and evaporated under reduced pressure to

yield an off-white solid (0.38 g, 77.0%), which upon recrystallisation from methanol gave material, m.p. 110—112 °C, identical with that described above.

4,5,10,11-*Tetrahydro*-10-*hydroxybenzo*[5,6]*cyclo-octa*[1,2-c]-*furan*-1(3H)-*one* (**12a**; R = OH).—Finely powdered sodium borohydride (0.081 g, 2.1 mmol) was added slowly over 20 min to a stirred solution of the keto lactone (**11**) (0.5 g, 2.19 mmol) in ethanol (100 cm^3) and the mixture then kept at 60 °C overnight. Ice–water (10 cm^3) and hydrochloric acid (2M; 4 cm^3) were added and the organic layer was extracted with chloroform. The extract was dried and evaporated under reduced pressure to afford a solid. Recrystallisation of this from methanol gave the product (0.47 g, 93%), m.p. 194—196 °C (Found: C, 73.0; H, 6.2%; M^+, 230.0962. $C_{14}H_{14}O_3$ requires C, 73.05; H, 6.15% *M*, 230.0943); $\nu_{max.}$(Nujol) 3 560—3 200 (OH alcohol), 1 725 (CO lactone), and 1 670 cm^{-1} (C=C); δ[$(CD_3)_2SO$] 7.6—7.05 (4 H, m, aryl), 5.6—5.4 (1 H, exch.), 5.4—5.0 (1 H, m, C*H*OH), 4.5 (2 H, s, OCH_2), 3.2—2.95 (2 H, m, CH_2), and 2.95—2.3 (4 H, m, CH_2CH_2).

4,5,10,11-*Tetrahydro*-10-p-*methoxyphenylbenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1(3H)-*one*(**12a**;R = 4-$MeOC_6H_4$).—The benzocyclo-octafuran (**12a**; R = OH) (150 mg), anisole (1 cm^3), methanesulphonic acid (5 cm^3), and phosphorus pentoxide (1 g) were stirred at 18 °C for 27 h. The mixture was then poured into water, extracted with chloroform and the extract washed with aqueous sodium hydrogen carbonate and evaporated to give a gum which was chromatographed and distilled, b.p. 180 °C/0.01 mbar (125 mg) (Found: C, 78.25; H, 6.6%; M^+, 320.1407. $C_{21}H_{20}O_3$ requires C, 78.6; H, 6.3%; M^+, 320.1412); δ 7.3—6.75 (8 H, m, aryl), 4.78—4.3 (3 H, m, CH and CH_2O), 3.75 (3 H, s, OMe), and 3.6—2.5 (6 H, m, CH_2).

10,11-*Dihydrobenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1(3H)-*one*(**8**; R = H).—Compound (**12a**; R = H) (200 mg, 0.869 mmol), toluene (25 cm^3), toluene-*p*-sulphonic acid (0.1 g), and calcium chloride (200 mg) were refluxed overnight, and the mixture then cooled, washed with aqueous sodium hydrogen carbonate and water, and dried, and evaporated under reduced pressure to give a yellow solid (0.164 g, 89.3%), m.p. 130—132 °C (Et_2O), identical with material from the Clemmensen reduction.

3a,4,5,11a-*Tetrahydrobenzo*[5,6]*cyclo-octa*[2,1-c]*furan*-1,10(3H,11H)-*dione* (**17**; R = O).—Chromium trioxide (3.83 g, 38 mmol) and pyridine (4.0 g, 51.2 mmol) were added to dichloromethane (34 cm^3). After 30 min, the complex was formed and the alcohol (**17**; R = H, OH) (0.95 g, 4.09 mmol) in dichloromethane (28 cm^3) was added dropwise. After 1 h the solution was filtered and the residue was washed with dichloromethane. The filtrate was evaporated with toluene under reduced pressure to afford a brown solid which, dissolved in chloroform, was passed down a column of silica. Evaporation of the eluant and recrystallisation of the residue from methanol gave white crystals (0.6 g, 63.7%), m.p. 134—136 °C (Found: C, 73.3; H, 6.16%; M^+, 230.0954. $C_{14}H_{14}O_2$ requires C, 73.05; H, 6.1%; *M*, 230.0943); $\nu_{max.}$(Nujol) 1 775 (CO lactone), 1 690 (CO ketone), and 1 600 cm^{-1} (C=C aryl); δ 7.6—7.0 (4 H, aryl), 4.6—4.31 (1 H), 3.9—3.2 (2 H, CH_2O), 3.2—1.9 (6 H, CH_2CH_2, CCH_2), and 1.9—1.0 (1 H).

3a,4,5,11a-*Tetrahydrobenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1(3H)-*one* (**18**).—Compound (**17**; R = H, OH) (1 g, 4.3 mmol), toluene (100 cm^3), toluene-*p*-sulphonic acid hydrate (0.55), and calcium chloride (1 g) were heated at 130 °C overnight and the mixture then allowed to cool. It was then washed with aqueous sodium hydrogen carbonate and water, dried, and evaporated under reduced pressure to yield a brown gum which t.l.c. indicated contained more than one spot. Chromatography yielded white crystals, m.p. 114—116 °C [Found: C, 78.3; H, 6.5%; M^+, 214.0988. $C_{14}H_{14}O_2$ requires C, 78.45; H, 6.6%; *M*, 214.0994]; $\nu_{max.}$(Nujol) 1 735 (CO lactone) and 1 670 cm^{-1} (C=C); δ 7.16 (4 H, s, aryl), 4.3—4.0 (1 H, triplet, CHCO), 4.0—3.9 (1 H, dd, vinylic), 3.9—3.73 (1 H, dd, vinylic), 3.73—3.5 (1 H, dd, C*H*CH_2O), 3.1—2.5 (4 H, m, CH_2CH_2), and 2.2—1.5 (2 H, m, CH_2O).

7-*Benzylcarbamoyl*-8-*benzylaminomethyl*-5,6,9,10-*tetrahydrobenzocyclo-octene* (**19**).—A mixture of the lactone (**12a**; R = H) (3 g, 14.0 mmol) benzylamine hydrochloride (6 g), and benzylamine (20 cm^3) was stirred at 175 °C. After 7 h the reaction mixture was cooled, poured into dichloromethane (100 cm^3), and filtered. The filtrate was washed with hydrochloric acid (excess, 2M) (× 3) and water (× 3), dried, and evaporated under reduced pressure to afford a red oil (5.4 g, 96%) which t.l.c. indicated was a mixture of three components. Crystallisation of this from ether yielded off-white crystals, m.p. 93—94 °C (Found: C, 81.75; H, 74.; N, 6.7%; M^+, 410.2379. $C_{28}H_{30}N_2O$ requires C, 81.95; H, 7.3; N, 6.8%; *M*, 410.2358]; $\nu_{max.}$(Nujol) 3 630—3 230 (NH amide and NH amine), 3 100—3 000 (CH aryl), 2 960—2 850 (CH, aliphatic), and 1 680 cm^{-1} (CO amide); δ 7.4—6.9 (14 H, m, aryl), 5.1—4.7 (2 H, dd, CH_2NH), 4.2—3.8 (2 H, m, NHCH_2Ph), 3.7—3.5 (2 H, dd, NHCH_2Ph), 3.0—1.8 (8 H, m, $CH_2CH_2CH_2CH_2$), and 1.6—1.3 (2 H, exch.).

2-*Benzyl*-4,5,10,11-*tetrahydrobenzo*[5,6]*cyclo-octa*[2,1-c]*pyrrol*-1(3H)-*one* (**20**; R = $PhCH_2$).—(*a*) A mixture of the lactone (**12a**; R = H) (0.6 g, 2.8 mmol), benzylamine hydrochloride (1.2 g), and benzylamine (8 cm^3) was stirred at 170 °C. After 7 h the reaction mixture was cooled, poured into dichloromethane (60 cm^3), and filtered. The filtrate was washed with hydrochloric acid (2M; excess) (× 3) and water (× 3), dried, and evaporated under reduced pressure to afford a red oil (0.8 g, 95%) which t.l.c. indicated was a mixture of two components. Short-path column chromatography [light petroleum (b.p. 60—80 °C) + 20% ethyl acetate] permitted the separation of the major compound as a gum. Crystallisation (Et_2O–EtOAc) of this gave off-white crystals, m.p. 80—82 °C (Found: C, 83.0; H, 6.8; N, 4.65%; M^+, 303.1574. $C_{21}H_{21}NO$ requires C, 83.15; H, 6.9; N, 4.6%; *M*, 303.1623); $\nu_{max.}$(Nujol) 3 100—3 000 (CH aryl), 2 980—2 800 (CH aliphatic), and 1 670 cm^{-1} (CO lactam); δ 7.4—6.9 (9 H, m, aryl), 4.7 (2 H, s, CH_2), 3.4 (2 H, s, CH_2), and 3.2—2.5 (8 H, m, $CH_2CH_2CH_2CH_2$).

(*b*) Compound (**19**) (2.07 g, 5.04 mmol) and acid-washed alumina (6 g) were mixed and heated (Kugelrohr) at 200 °C/0.02 mbar for 2 h. The alumina was washed several times with dichloromethane and the extract evaporated to yield a gummy product. Crystallisation of this from ether gave off-white crystals (1.53 g, 91.5%), m.p. 79—81 °C, identical with material in (*a*).

2-*Benzyl*-1,3,3a,4,5,10,11,11a-*octahydrobenzo*[5,6]*cyclo-octa*[2,1-c]*pyrrole* (**22**; R = $PhCH_2$).—(*a*) To a stirred suspension of lithium aluminium hydride (0.05 g, 1.26 mmol) in dry THF (20 cm^3) under nitrogen was added dropwise over 20 min at 10 °C the lactam (**20**; R = $PhCH_2$) (0.153 g, 0.5 mmol) in dry THF (20 cm^3). Stirring was continued at 18 °C for 16 h after which water (5.9 cm^3), aqueous sodium hydroxide (20%; 4.4 cm^3), and water (20 cm^3) were cautiously added in that order. After 20 min the suspension was filtered, washed with dichloromethane (× 2), and worked-up to give an oil (0.4 g, 85%) containing two components (t.l.c.). Flash chromatography permitted separation of the major product (0.25 g), b.p. 170 °C/0.01 mbar (Found: C, 86.15; H, 8.45; N, 4.7%; M^+, 291.1981. $C_{21}H_{25}N$ requires C, 86.6; H, 8.6; N, 4.8%; *M*, 291.1987); $\nu_{max.}$ 3 100—3 000 (CH aromatic) and 2 900—2 800

cm^{-1} (CH aliphatic); no carbonyl absorption; δ(250 MHz) 7.4—7.2 (5 H, m, aryl), 7.2—7.0 (4 H, m, aryl), 3.6—3.26 (2 H, dd, CH_2Ph), 3.0—2.65 (4 H, m, aryl CH_2), 2.65—2.0 (4 H, m, CH_2-*N*-benzyl), and 2.0—1.0 (6 H, m, 2 × CH_2CH).

(*b*) To a stirred suspension of lithium aluminium hydride (74 mg, 2 mmol) in dry THF (40 cm^3) under nitrogen was added the lactam (**23**; R = $PhCH_2$) (0.246 g, 0.8 mmol) in dry THF (20 cm^3) dropwise over 20 min. The mixture was stirred for 5 h after which it was worked up to give a yellow oil (215 mg, 91.8%), identical with that in (*a*). The *hydrochloride* had m.p. 225—226 °C (EtOAc) (Found: C, 76.45; H, 7.45; Cl, 11.1; N, 4.15%. $C_{21}H_{26}ClN$ requires C, 76.7; H, 7.9; N, 4.25; Cl, 11.1%).

2-*Benzyl*-1,3,4,5,10,11-*hexahydrobenzo*[5,6]*cyclo-octa*[1,2-c]*pyrrole* (**21**; R = $PhCH_2$).—(*a*) Compound (**20**; R = $PhCH_2$) (100 mg, 0.34 mmol), cerium chloride (212.5 mg, 0.85 mmol), and dry THF were stirred for 15 min under nitrogen and then lithium aluminium hydride (37 mg, 1 mmol) was added over 15 min at 18 °C and the mixture stirred for 20 h. Work-up as in previous paragraph gave a yellow oil (95%), b.p. 170 °C (0.1 mbar); $\nu_{max.}$ 3 100—3 000 (CH aromatic), and 3 000—2 850 cm^{-1} (CH aliphatic); no carbonyl absorption; δ 7.3—7.0 (9 H, m, aryl), 3.63 (2 H, s, CH_2Ph), 3.3 (4 H, s, CHN benzyl), 3.1—2.6 (4 H, m, CH_2 aryl), and 2.6—2.2 (4 H, m, CH_2).

(*b*) To a stirred suspension of lithium aluminium hydride (74 mg, 2.0 mmol) in dry benzene (10 cm^3) under nitrogen was added the lactam (**20**; R = $PhCH_2$) (100 mg, 0.34 mmol) in dry benzene (10 cm^3) over 15 min. Stirring at 60 °C for 24 h was followed by work-up which yielded the base (39 mg, 41%) as in (*a*). The *fumarate* had m.p. 183 °C (Found: C, 74.0; H, 6.75; N, 3.2. $C_{25}H_{27}NO_4$ requires C, 74.05; H, 6.7; N, 3.45%).

3a,4,5,10,11,11a-*Hexahydrobenzo*[5,6]*cyclo-octa*[1,2-c]*furan*-1(3H)-*one* (**17**; R = H, H).—Compound (**18**) (500 mg, 2.33 mmol) was hydrogenated in ethanol (50 cm^3) over 10% palladium on charcoal (100 mg) to give a white solid (492 mg, 97%), m.p. 68—70 °C (Et_2O) (Found: C, 77.65; H, 7.5%; M^+, 216.113. $C_{14}H_{16}O_2$ requires C, 77.75; H, 7.4%; *M*, 216.115); $\nu_{max.}$(Nujol) 1 750 cm^{-1} (5-ring lactone); no C=C absorptions; δ 7.3—7.0 (4 H, s, aryl), 4.35 (1 H, t, CHO), 3.65 (1 H, t, CHO), 3.1—2.7 (4 H, m, CH_2 aryl), 2.7—1.8 (4 H, m, CH_2), and 1.8—1.2 (2 H, m, CH).

2-*Benzyl*-3a,4,5,10,11,11a-*hexahydrobenzo*[5,6]*cyclo-octa*[1,2-c]*pyrrol*-1(3H)-*one* (**23**; R = $PhCH_2$).—The lactone (**17**; R = H, H) (0.43 g, 1.99 mmol), benzylamine hydrochloride (1 g), and benzylamine (6 cm^3) was stirred at 180 °C for 3 days. After cooling, the reaction mixture was poured into dichloromethane, filtered, and the filtrate washed with dilute hydrochloric acid and water, dried, and evaporated. Flash chromatography [20% ethyl acetate/light petroleum (b.p. 60—80 °C)] allowed separation of the product as an oil (0.246 g, 40.5%), b.p. 190 °C/0.03 mbar (Found: C, 82.5; H, 7.55; N, 4.45%; M^+, 305.176. $C_{21}H_{23}NO$ requires C, 82.6; H, 7.55; N, 4.6%; *M*, 305.178); $\nu_{max.}$ 1 680 cm^{-1} (CO); δ 7.5—7.0 (9 H, aryl) 4.5 and 4.3 (2 H, 2d, *J* 15 Hz, $PhCH_2N$), 3.4—3.0 (2 H, m, CH_2N), 3.0—2.7 (4 H, m, CH_2 aryl), 2.3—1.7 (4 H, m, CH_2), and 1.7—1.2 (2 H, m, CH).

2-*Methyl*-4,5,10,11-*tetrahydrobenzo*[5,6]*cyclo-octa*[1,2-c]*pyrrol*-1(3H)-*one* (**20**; R = Me).—The lactone (**12a**; R = H) (0.6 g, 2.8 mmol), 40% methylamine in water (50 cm^3), and concentrated hydrochloric acid (2.5 cm^3) were stirred at 70 °C for 4 days, cooled, and extracted with dichloromethane. After three distillations (160 °C/0.05 mbar), flash chromatography [dichloromethane/ethanol/ammonia (300:8:1)] gave the *product* as colourless crystals (75%), m.p. 90—91 °C (Et_2O) (75%) (Found: C, 79.0; H, 7.2; N, 6.05%; M^+, 227.301. $C_{15}H_{17}NO$ requires C, 79.3; H, 7.5; N, 6.15%; *M*, 227.304); $\nu_{max.}$(Nujol) 1 640 cm^{-1} (lactam); δ 7.08 (4 H, s, aryl), 3.5 (2 H, s, CH_2N), 3.2—2.9 (4 H, m, CH_2-aryl), and 2.86 (3 H, s, NCH_3), and 2.8—2.5 (4 H, m, CH_2).

2-*Methyl*-1,3,4,5,10,11-*hexahydrobenzo*[5,6]*cyclo-octa*[1,2-c]*pyrrole* (**21**; R = Me).—Compound (**20**; R = Me) (200 mg, 0.88 mmol), cerium trichloride (543 mg, 2.2 mmol), and dry THF (25 cm^3) were stirred under nitrogen and lithium aluminium hydride (74 mg, 2 mmol) was added over 15 min at room temperature. The mixture was stirred for 24 h after which work-up gave a yellow oil (180 mg) purified by flash chromatography [dichloromethane/ethanol/ammonia (150:8:1)] and distillation at 120 °C/0.4 mbar; δ 7.3—7.0 (4 H, br, s, aryl), 3.25 (4 H, s, CH_2N), 3.1—2.8 (4 H, m, CH_2 aryl), 2.6—2.2 (4 H, m, CH_2), and 2.3 (3 H, s, NMe); [M^+, 213.1524. $C_{15}H_{19}N$ require 213.1517). The *hydrochloride* had m.p. 175—176 °C (EtOAc) (Found: C, 71.9; H, 8.4; Cl, 13.9; N, 5.55%. $C_{15}H_{20}ClN$ requires C, 72.15; H, 8.0; Cl, 14.2; N, 5.6%).

The *fumarate* had m.p. 198—9 °C (from ethanol) (Found: C, 75.9; H, 8.1; N, 5.05. $C_{34}H_{42}N_2O_4$ requires C, 75.3; H, 7.75; N, 5.15%).

cis- *and* trans-2-*Methyl*-1,3,3a,4,5,10,11,11a-*octahydrobenzo*-[5,6]*cyclo-octa*[1,2-c]*pyrrole* (**22**; R = Me).—(*a*) The above experiment was repeated on compound (**20**; R = Me) (2.4 g) cerium trichloride being omitted. The mixture thus obtained (2.1 g, 9.8 mmol) was hydrogenated in acetic acid (20 cm^3) over palladised charcoal (10%; 300 mg) at 4.5 bar for 72 h. This gave an oil, b.p. 100 °C/0.1 mbar; δ 7.2—7.0 (4 H, br s, aryl), 3.0—2.7 (4 H, m, $ArCH_2$), 2.7—2.0 (4 H, m, CH_2N), 2.22 (3 H, s, NMe), and 2.0—2.1 (6 H, m, CH_2CH). By g.l.c. and h.p.l.c. this product was shown to be a 65:35 mixture of isomers.

The *fumarate* had m.p. 143 °C (EtOH) (Found: C, 69.0; H, 7.6; N, 4.2. $C_{19}H_{25}NO_4$ requires C, 68.85; H, 7.6; N, 4.25%). Repeated chromatography [dichloromethane/ethanol/ammonia (200:8:1)] allowed separation of some of the major isomer. The *N*-methyl quaternary iodide was hygroscopic (Found: C, 53.45; H, 6.65; I, 35.2; N, 3.8%. $C_{16}H_{24}IN$ requires C, 53.8; H, 6.7; I, 33.55; N, 3.9%]; δ 7.15 (4 H, m, aryl), 4.25—3.9 (2 H, m, CH_2N), 3.75—3.45 (2 H, m, CH_2N), 3.42 (6 H, s, NMe), 3.15—2.7 (4 H, m, CH_2, aryl), and 2.5—1.5 (6 H, m, CH_2 + CH).

(*b*) Catalytic hydrogenation of compound (**21**; R = Me) (Pd/C/EtOH/$MeCO_2H$) gave the same products in the ratio *ca.* 80:20 (g.l.c.).

Ethyl 1,3,4,5,10,11-*Hexahydrobenzo*[5,6]*cyclo-octa*[1,2-c]-*pyrrole*-2-*carboxylate* (**21**; R = CO_2Et).—The amine (**21**; R = $PhCH_2$) (1.94 g, 4.13 mmol), benzene (50 cm^3), and ethyl chloroformate (27 cm^3) were refluxed for 48 h after which the mixture was cooled, washed with water, dried, and evaporated. The residue was flash chromatographed (10% ethyl acetate–light petroleum) and recrystallised (pentane) to give colourless material (1.07 g, 59%), m.p. 89—90 °C (Found: C, 74.95; H, 7.85; N, 5.1. $C_{17}H_{21}NO_2$ requires C, 75.25; H, 7.75; N, 5.15%); $\nu_{max.}$(Nujol) 1 700 cm^{-1} (CO_2Et); δ 7.1 (4 H, s, aryl), 4.1 (2 H, q, OCH_2CH_3), 3.95 (4 H, s, CH_2NCH_2, 3.2—2.8 (4 H, m, aryl CH_2), 2.6—2.3 (4 H, m, CH_2CH_2 aryl), 1.2 (3 H, t, CH_3CH_2).

Ethyl 1,3,3a,4,5,10,11,11a-*Octahydrobenzo*[5,6]*cyclo-octa*-[1,2-c]*pyrrole*-2-*carboxylate* (**22**; R = CO_2Et).—The amine (**22**; R = $PhCH_2$) (1.5 g, 5.15 mmol) was subjected to the same conditions and purification as in the previous paragraph. This gave a colourless oil (0.86 g, 61%), b.p. 120 °C/0.2 mbar (Found: C, 74.6; H, 8.2; N, 5.45%. $C_{17}H_{23}NO_2$ requires C, 74.7; H, 8.4; N, 5.1%); $\nu_{max.}$(film) 1 690 cm^{-1} (CO_2Et); δ 7.1 (4 H, s, aryl), 4.05 (2 H, q, CH_2CH_3), 3.7—3.5 (2 H, m, CH_2N), 3.1—2.85 (2 H, m, CH_2N), 2.85—2.7 (4 H, m, CH_2 aryl), 2.3—1.7 (4 H, m, CH_2), 1.6—1.3 (2 H, m, CH), and 1.2 (3 H, t, CH_3CH_2).

1,3,4,5,10,11-*Hexahydrobenzo*[5,6]*cyclo-octa*[1,2-c]*pyrrole* (**21**; R = H).—The carbamate (**21**; R = CO_2Et) (3.346 g, 12.35 mmol), ethanol (100 cm^3), and aqueous potassium hydroxide (50%; 250 cm^3) were refluxed for 24 h, and then cooled, acidified with concentrated hydrochloric acid, concentrated under reduced pressure, and extracted with ether. Basification of the aqueous layer allowed recovery of oil (1.2 g), b.p. 100 °C/mbar; $\nu_{max.}$ 3 550—3 120 (NH) and 1 640 cm^{-1} (C=O); δ 7.1 (4 H, s, aryl), 3.5 (4 H, s, CH_2NCH_2), 3.1—2.86 (4 H, m, aryl CH_2), 2.86—2.7 (1 H, br s, exch.), and 2.6—2.2 (4 H, m, CH_2).

The *fumarate* had m.p. 205—206 °C (MeOH) (Found: C, 68.6; H, 6.7; N, 4.35. $C_{18}H_{20}NO_4$ requires C, 68.75; H, 6.4; N, 4.45%).

1,3,3a,4,5,10,11,11a-*Octahydrobenzo*[5,6]*cyclo-octa*[1,2-c]-*pyrrole* (**22**; R = H).—The carbamate (**22**; R = CO_2Et) (4.92 g, 0.018 mmol) was treated as in the preceding experiment to give an oil which solidified (m.p. 45—46 °C) with time (2.15 g, 59%); $\nu_{max.}$(Nujol) 3 600—3 100 cm^{-1} (NH); δ 7.1 (4 H, s, aryl), 3.2—2.6 (6 H, m, CH_2 aryl + CH_2N), 2.6—2.3 (2 H, m, CH_2N), 1.9 (1 H, br s, exch. NH), 2.1—1.7 (2 H, m, CH), and 1.7—1.1 (4 H, m, CH_2). T.l.c. indicated presence of a minor isomer (< 5%), unresolved by g.l.c.

The *fumarate* had m.p. 187—189 °C (MeOH) (Found: C, 67.75; H, 7.3; N, 4.25%. $C_{18}H_{23}NO_4$ requires C, 68.15; H, 7.25; N, 4.4%).

Methyl 1,2,3,4-*Tetrahydro*-2-*oxonaphthalene*-1-*carboxylate* (**24**).—To a stirred suspension of sodium hydride (50% in oil; 0.806 g, 17 mmol) in freshly distilled dimethyl carbonate at 0 °C, under nitrogen was added 3,4-dihydronaphthalen-2(1*H*)-one (1.46 g, 0.01 mmol) in dimethyl carbonate (25 cm^3). After 15 min the temperature was allowed to rise to 20 °C and stirring was continued for 48 h. Ice–water and 2M hydrochloric acid was added cautiously, and the organic layer separated and worked up to give an oil (b.p. 130 °C/0.04 mbar). Chromatography (chloroform) allowed the separation of the major component as a colourless oil (0.34 g) (Found: C, 70.2; H, 5.9%; M^+, 204.0793. $C_{12}H_{12}O_3$ requires C, 70.55; H, 5.9%; *M*, 204.0786); $\nu_{max.}$(film) 1 740 (CO, ester), 1 715 (CO), and 1 635 cm^{-1}; δ 13.3 (1 H, s, exch.), 7.8—7.0 (4 H, m, aryl), 3.88 (3 H, s, OCH_3), and 2.9—2.4 (4 H, m, CH_2).

Trimethyl 9,10-*Dihydro*-8-*hydroxybenzocyclo-octene*-5,6,7-*tricarboxylate* (**25**).—The naphthalene ester (**24**) (1.44 g, 7 mmol) in dimethoxyethane was added dropwise to a suspension of lithium hydride (55 mg, 7.8 mmol) in dry dimethoxyethane (10 cm^3) at ice temperature under nitrogen. Dimethyl acetylenedicarboxylate (0.995 g, 7.6 mmol) was added slowly and the temperature allowed to rise to 20 °C after 15 min. After 6 h, glacial acetic acid was added cautiously followed by 2M hydrochloric acid. The mixture was extracted with toluene, and the extract dried and evaporated to afford a dark gum. Trituration of this with methanol yielded colourless crystals (0.44 g, 17%), m.p. 164—166 °C (MeOH) (Found: C, 62.25; H, 5.3%; M^+, 346.1051. $C_{18}H_{18}O_7$ requires C, 62.4; H, 5.2%; *M*, 346.1052); $\nu_{max.}$ 1 725 (CO ester), 1 650 (CO), and 1 585 cm^{-1} (C=C); δ 12.75 (1 H, s, exch., OH), 7.5—7.1 (4 H, m, aryl), 3.8 (3 H, s, OCH_3), 3.78 (3 H, s, OCH_3), 3.65 (3 H, s, OCH_3), and 3.5—2.5 (4 H, m, CH_2).

Tetramethyl 9,10-*Dihydrophenanthrene*-1,2,3,4-*tetracarboxylate* (**26**).—To a stirred solution of 3,4-dihydronaphthalene-2(1*H*)-one (1.46 g, 0.01 mol) and dimethyl acetylenedicarboxylate (1.96 g, 0.014 mol) in anhydrous toluene at 0 °C under nitrogen was added sodium hydride (60% oil dispersion; 0.4 g, 10 mmol) in one portion. After 10 min the reaction mixture was allowed to rise to room temperature and was then stirred overnight. Work-up gave a dark gum, trituration of which with methanol afforded a white crystalline product (0.95 g, 23%), m.p. 166—167 °C (MeOH) (Found: C, 64.25; H, 5.0%; M^+, 412.1142. $C_{22}H_{20}O_8$ requires C, 64.1; H, 4.9%; *M*, 412.1158); $\nu_{max.}$ 1 720 cm^{-1} (CO, ester); δ 7.4—7.2 (4 H, m, aryl), 3.92 (3 H, s, OCH_3), 3.87 (6 H, s, OCH_3^{-2}), 3.77 (3 H, s, OCH_3), and 2.79 (4 H, s, CH_2).

Tetramethyl Phenanthrene-1,2,3,4-*tetracarboxylate* (**27**).—The phenanthrene ester (**26**) (0.2 g, 0.48 mol) and *N*-bromosuccinimide (87 mg, 0.49 mmol) were refluxed in carbon tetrachloride for 1 h. The solvent was removed under reduced pressure and the resultant gum dissolved in chloroform and the solution washed with water. It was then dried and evaporated to yield a gum (0.25 g) which was stirred with triethylamine (1 cm^3) and ether (15 cm^3) at 18 °C for 0.5 h. Work-up yielded an off-white solid, recrystallisation of which methanol yielded a white crystalline product (0.16 g, 80%), m.p. 166.5—168 °C (Found: C, 64.3; H, 4.3%; M^+, 410.1011. $C_{22}H_{18}O_8$ requires C, 64.4; H, 4.4%; *M*, 410.1002); $\nu_{max.}$ 1 720 cm^{-1} (CO, ester); δ 8.35—7.6 (6 H, m, aryl), 4.05 (3 H, s, OCH_3), 4.00 (3 H, s, OCH_3) 3.95 (3 H, s, OCH_3), and 3.93 (3 H, s, OCH_3).

X-*Ray Structure Determination of the Keto Lactone* (**11**).—*Crystal data.* $C_{14}H_{12}O_3$, *M* = 228.23, colourless prisms, monoclinic, space group $P2_1/n$ (non-standard setting of No. 14), *a* = 13.313(5), *b* = 12.964(4), *c* = 14.328(3) Å, β = 116.57(2)°, *U* = 2 211.65 $Å^3$, *Z* = 8, D_c = 1.371 g cm^{-3}, *F*(000) = 960, μ(Mo-K_α) = 0.90 cm^{-1}, crystal dimensions *ca* 0.2 × 0.2 × 0.4 mm.

Data collection. The intensity data were collected over the quadrant (*h*, −15—+15; *k*, 0—+15; *l*, 0—+17; 2.0 < θ < 25.0°) using ω—2θ scanning and graphite monochromated Mo-K_α *X*-radiation (λ = 0.710 693 Å). Of 3 874 unique data measured, 2 039 had $I > 2\sigma(I)$ and were subsequently used in structure solution and refinement. The data were corrected for Lorentz and polarisation effects, but not for absorption or crystal decay (< 1%).

Structure Solution and Refinement.—The positions of the non-hydrogen atoms of the two independent molecules of the keto lactone (**11**) were determined by application of 'direct methods' (SHELX86[27]). The hydrogen atoms were subsequently located on a series of different Fourier maps and included in the refinement process on calculated positions (C–H 1.08 Å). Full-matrix least-squares refinement of the structure SHELX76[28]) using anisotropic temperature factors for the non-hydrogen atoms reduced the discrepancy factors *R* and R_w at convergence to 0.053 and 0.063 respectively. The weighting scheme $w^{-1} = [\sigma^2(F) + 0.000\,524(F^2)]$ gave satisfactory analyses of variance. The final difference Fourier map contained no features greater than ±0.28 $e^-Å^{-3}$ with a general noise level *ca.* ±0.15 $e^-Å^{-3}$. The program CALC[29] was used to undertake all incidental crystallographic calculations. The thermal parameters and the fractional co-ordinates for hydrogen atoms are available from the C.C.D.C.*

Conformational Studies of the Keto Lactone (**11**).—Molecular mechanics calculations were carried out using the program MMP2(85)[20] as supplied by QCPE. Starting molecular geometries were calculated using the program STRUCTURE.[30]

* For details of the crystallographic deposition system see Instructions for Authors (1989), *J. Chem. Soc., Perkin Trans. 1*, 1989, Issue 1.

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