2-Arylperimidine derivatives. Part 1. Synthesis, NMR spectroscopy, X-ray crystal and molecular structures

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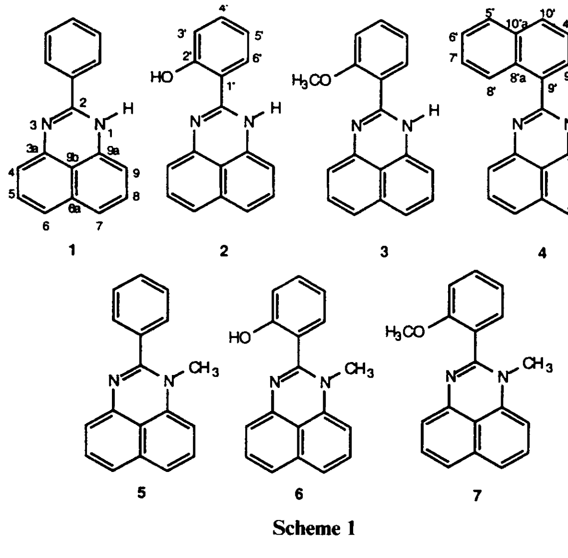
The synthesis and NMR spectroscopy of seven 2-phenyl-, 2-(2-hydroxyphenyl)- and 2-(2-methoxyphenyl)-perimidines **1**–**7** are described. The X-ray structural characterization of four perimidine derivatives: 2-(2-hydroxyphenyl)perimidine (**2**), 2-(9-anthryl)perimidine (**4**), 1-methyl-2-phenylperimidine (**5**) and 1-methyl-2-(2-methoxyphenyl)perimidine (**7**) is reported. The conformation of the molecules in the crystal has been compared with the results of a quantum chemical analysis at the AM1 level. The agreement between the predicted and the experimental conformations depends on the presence of strong intramolecular hydrogen bonds.

Following our research work in the field of the photophysics and photostability studies of new derivatives related to 9,9′-bianthryl and 2-(2-hydroxy-5-methylphenyl)benzotriazole or Tinuvin P,[1,2] we describe here the synthesis and molecular structures, both in solution and in the solid state, of seven derivatives of the perimidine system, namely 2-phenylperimidine (**1**), 2-(2-hydroxyphenyl)perimidine (**2**), 2-(2-methoxyphenyl)-perimidine (**3**), 2-(9-anthryl)perimidine (**4**), 1-methyl-2-phenylperimidine (**5**), 1-methyl-2-(2-hydroxyphenyl)perimidine (**6**) and 1-methyl-2-(2-methoxyphenyl)perimidine (**7**). Their photophysical behaviour constitutes Part 2 of the work and will be published elsewhere.

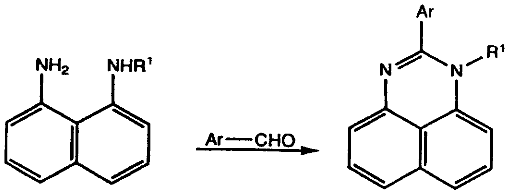


Scheme 1

Results and discussion

Chemistry

The synthetic procedure of Paragamian *et al.*[3a] was used to prepare the title compounds **1**–**7**. 1,8-Diaminonaphthalene and 1-amino-8-methylaminonaphthalene[4a] were treated with the corresponding aldehydes in xylene and in the presence of palladium–charcoal (10%) to afford with quantitative yields the 2-arylperimidine derivatives as shown in Scheme 2.



Compound	Ar	R¹
1	Phenyl	H
2	2′-Hydroxyphenyl	H
3	2′-Methoxyphenyl	H
4	9′-Anthryl	H
5	Phenyl	CH_3
6	2′-Hydroxyphenyl	CH_3
7	2′-Methoxyphenyl	CH_3

Scheme 2

Even though the compounds can also be prepared from the corresponding acyl chlorides,[3] the work-up of such a process is tedious and gives poorer yields.

NMR spectroscopy

The ^1H and ^{13}C chemical shifts of compounds **1**–**7** are given in Tables 1, 2 and 3. In solution, the analysis of the chemical shifts has been performed when necessary by means of homonuclear (^1H–^1H) COSY and heteronuclear (^1H–^{13}C) correlations.[5] The NH-derivatives **1**–**4** presented blocked prototropy (Table 2) and to obtain the averaged spectra corresponding to rapid proton exchange, a catalytic amount of water or acid must be present in the NMR solution (Table 3). This behaviour clearly differentiates perimidines and benzimidazoles regarding annular tautomerism: in the former compounds the proton exchange rate is much lower than in the latter compounds, a result which is related to the difference in aromaticity and in the acid–basic character of the NH and N centres.

Concerning the aryl group in derivatives **1**–**3** and **5**–**7**, the influence of hydroxy and methoxy substituents[6,7] had been

Table 1 ^1H NMR parameters (δ and J) of 2-arylperimidines at 200 MHz

Compd.	H_4	H_5	H_6	H_7	H_8	H_9	$H_{2'}$	$H_{3'}$	$H_{4'}$	$H_{5'}$	$H_{6'}$	NH	OH	N–CH_3	O–CH_3	Solvent
1	6.70	7.17	7.06	7.05	7.14	6.54	8.07	7.51	7.53	7.51	8.07	10.64				[$^2H_6$]DMSO
2	6.69	7.19	7.11	7.11	7.19	6.69		6.92	7.40	6.94	7.97	10.8	14.7			[$^2H_6$]DMSO
	$J_{4.5} = J_{7.8} = 7.0; J_{5.6} = J_{8,9} = 8.3$							$J_{3'.4'} = 8.3; J_{4'.5'} = 7.4; J_{5'.6'} = 8.3$								
	$J_{4.6} = J_{7.9} = 1.3$							$J_{4'.6'} = 1.6; J_{3'.5'} = 1.2$								
3	6.57	7.14	7.03	6.95	7.07	6.34		7.14	7.48	7.03	7.59	10.47			3.86	[$^2H_6$]DMSO
	$J_{4.5} = 7.2$					$J_{8.9} = 7.1$		$J_{3',4'} = 8.8; J_{4'.5'} = 7.5; J_{5'.6'} = 7.5$								
	$J_{4.6} = 0.9$					$J_{7.9} = 1.1$		$J_{4'.6'} = 1.8$								
3[a]	6.85	7.23	7.02	7.03	7.08	6.20		7.02	7.46	7.12	8.35	9.28			4.01	$CDCl_3$
	$J_{4.5} = 7.2; J_{5.6} = 8.3$			$J_{7.8} = 9.5; J_{8.9} = 6.9$				$J_{3'.4'} = 8.4; J_{4'.5'} = 7.3; J_{5'.6'} = 7.9$								
								$J_{3'.5'} = 1.0; J_{4'.6'} = 1.9$								
4	6.64			← 7.06–7.26 →		6.30		*b*				11.14				[$^2H_6$]DMSO
	$J_{4.5} = 6.9$					$J_{8.9} = 6.0$										
	$J_{4.6} = 1.4$					$J_{7.9} = 2.3$										
4	6.58			← 7.21–7.26 →		6.58		*c*				n.o.				$CDCl_3$
5	6.72			← 7.15–7.30 →		6.41			← 7.49–7.61 →					3.05		[$^2H_6$]DMSO
	$J_{4.5} = 6.9$					$J_{8.9} = 7.2$										
	$J_{4.6} = 1.5$					$J_{7.9} = 1.2$										
6	6.68	7.25	7.16	7.14	7.23	6.36		6.95	7.32	6.92	7.31		10.06	2.99		[$^2H_6$]DMSO
	$J_{4.5} = 7.0; J_{5.6} = 8.3$			$J_{7.8} = 8.2; J_{8.9} = 7.2$				$J_{3'.4'} = 7.4; J_{4'.5'} = 7.2; J_{5'.6'} = 7.4$								
	$J_{4.6} = 1.4$			$J_{7.9} = 1.3$				$J_{4',6'} = 1.5$								
6	6.85			← 7.15–7.22 →		6.35		7.01	7.31	6.90	7.40		n.o.	3.36		$CDCl_3$
	$J_{4.5} = 6.8$					$J_{8.9} = 6.3$		$J_{3'.4'} = 8.3; J_{4'.5'} = 7.3; J_{5'.6'} = 7.8$								
	$J_{4.6} = 1.6$					$J_{7.9} = 2.1$		$J_{3'.5'} = 1.2; J_{4'.6'} = 1.7$								
7	6.68	7.25	7.17	7.15	7.23	6.35		7.16	7.49	7.08	7.38			2.92	3.83	[$^2H_6$]DMSO
	$J_{4.5} = 7.0; J_{5.6} = 8.3$			$J_{7.8} = 8.4; J_{8.9} = 7.1$				$J_{3'.4'} = 8.4; J_{4'.5'} = 7.4; J_{5'.6'} = 7.4$								
	$J_{4.6} = 1.5$			$J_{7.9} = 1.3$				$J_{3'.5'} = 0.9; J_{4'.6'} = 1.8$								

[a] At 600 MHz. [b] 8.78: ($H_{10'}$); 8.14–8.24: ($H_{1'}$, $H_{8'}$, $H_{4'}$, $H_{5'}$); 7.53–7.66: ($H_{2'}$, $H_{7'}$,$H_{3'}$, $H_{6'}$). [c] 8.53: ($H_{10'}$); 8.30–8.34: ($H_{1'}$, $H_{8'}$); 8.00–8.05: ($H_{4'}$, $H_{5'}$); 7.50–7.57: ($H_{2'}$, $H_{7'}$, $H_{3'}$, $H_{6'}$).

Table 2 ^{13}C NMR parameters (δ and J) of 2-arylperimidines

Compd.	C_2	C_{3a}	C_4	C_5	C_6	C_{6a}	C_7	C_8	C_9	C_{9a}	C_{9b}	$C_{1'}$	$C_{2'}$	$C_{3'}$	$C_{4'}$	$C_{5'}$	$C_{6'}$	N–CH$_3$	O–CH$_3$
1^a	152.7	145.1	114.0	128.9	119.3	135.1	117.8	128.0	102.8	138.6	121.7	133.5	126.8	128.4	131.0	128.4	126.8		
1^b	156.5	144.9	113.2	127.6	120.0	133.8	120.0	127.6	102.6	138.7	122.4	133.8	127.6	127.6	131.3	127.6	127.6		
2^b	153.6	140.3	111.1	129.2	120.1	135.5	120.1	129.2	103.1	140.3	123.5	111.1	160.8	116.7	135.5	118.0	129.2		
3^a	152.8	145.4	113.4	128.8	118.8	135.0	117.3	127.9	102.0	138.2	121.5	123.6	156.7	111.6	131.4	120.3	129.7		55.6
3^b	150.8	144.9	113.1	129.1	117.1	136.6	117.1	129.1	102.8	136.6	120.3	121.2	158.0	109.2	132.0	118.5	129.1		58.6
4^a	153.4	145.4	113.9	129.0	119.6	135.3	118.0	128.0	102.3	138.7	121.9	*c*							
			^1J 160.3	^1J 156.4	^1J 162.0		^1J 158.0	^1J 158.7	^1J 160.0										
5^a	156.7	143.3	114.3	128.7	119.5	135.8	118.6	128.0	102.0	140.2	121.7	134.6	128.1	128.5	129.6	128.5	128.1	36.8	
		^3J 8.4	^1J 161.1	^1J 158.2	^1J 157.2		^1J 161.7	^1J 159.4	^1J 162.8		^3J 5.6		^1J 158.2	^1J 161.8	^1J 161.3	^1J 161.8	^1J 158.2	^1J 140.0	
											^3J 5.6								
5^b	156.7	144.4	115.2	127.5	117.8	137.0	117.8	127.5	103.2	139.9	122.5	134.4	129.2	129.2	129.2	129.2	129.2	35.4	
6^a	154.6*	142.0	113.3	128.7	119.7	134.6	119.1	128.1	102.3	139.2	121.5	122.1	155.7*	115.8	131.3	119.3	129.7	35.1	
			^1J 160.2	^1J 158.6	^1J 161.4		^1J 164.5	^1J 159.7	^1J 161.7					^1J 161.5	^1J 163.2	^1J 164.5	^1J 161.6	^1J 140.5	
			^3J 8.2											^3J 7.6	^3J 9.3		^3J 8.8		
6^b	155.5	142.7	110.8	129.5	121.3	137.1	118.7	129.5	102.4	142.7	121.3	127.5	155.5	116.0	135.7	116.0	129.5	33.2	
6^d	156.9	140.6*	114.2	128.7	120.7	134.7	119.9	128.6	103.1	140.5*	121.7	126.0	158.2	118.7	132.0	118.7	127.4	39.0	
7^a	154.8	143.5	114.2	128.7	119.4	134.7	118.5	128.0	101.3	139.7	121.7	124.8	156.0	111.2	131.1	120.8	129.5	34.6	55.6
			^1J 160.3	^1J 157.8	^1J 162.3		^1J 160.5	^1J 159.4	^1J 160.5					^1J 162.6	^1J 162.8	^1J 160.3	^1J 162.2	^1J 139.9	^1J 145.2
7^b	154.0	143.7	115.7	128.2	120.1	134.5	117.2	128.2	100.0	139.6	122.6	125.4	156.2	108.7	130.7	120.1	130.7	34.2	55.1

[a] In [$^2H_6$]DMSO. [b] CP-MAS. [c] 125.1, ^1J 160.2 ($C_{1'}/C_{8'}$); 125.7, ^1J 161.3, ^3J 8.5 ($C_{2'}/C_{7'}$); 127.0, ^1J 161.5, ^3J 8.5 ($C_{3'}/C_{6'}$); 128.6, ^1J 160.5 ($C_{4'}/C_{5'}$); 129.4 ($C_{9'}$); 128.2, ^1J 162.0 ($C_{10'}$); 130.8 ($C_{4'a}/C_{10'a}$); 128.5 ($C_{8'a}/C_{9'a}$). [d] In $CDCl_3$.

Table 3 ^{13}C NMR parameters (δ and J) of 2-arylperimidines (rapid prototropy)

Compd.	C_2	C_{3a}/C_{9a}	C_4/C_9	C_5/C_8	C_6/C_7	C_{6a}	C_{9b}	$C_{1'}$	$C_{2'}$	$C_{3'}$	$C_{4'}$	$C_{5'}$	$C_{6'}$	O–CH$_3$
1^a	153.0	141.7	108.5	128.5	118.7	135.2	121.7	133.5	127.0	128.5	131.2	128.5	127.0	
	^3J 3.6		^1J 159.6	^1J 158.5	^1J 163.2		^3J 6.2	^3J 5.6	^1J 158.6	^1J 159.5	^1J 161.6	^1J 159.5	^1J 158.6	
	^3J 3.6						^3J 6.2							
2^a	154.7	139.0vbr	107.9vbr	128.4	119.3br	134.8	121.1	112.8	161.3	117.9	133.2	118.0	126.2	
			^1J *b*	^1J 158.6	^1J *b*					^1J 161.9	^1J 158.9	^1J 161.9	^1J 158.2	
										^3J 7.2	^3J 7.6	^3J 7.2	^3J 7.1	
3^a	153.3	141.8	107.7	128.7	118.5	135.4	121.8	123.7	157.1	111.9	131.8	120.6	130.0	55.9
	^3J 3.6		^1J *b*	^1J 158.2	^1J 163.6	^3J 8.5		^3J 6.7	^3J 8.6	^1J 162.5	^1J 160.3	^1J 162.3	^1J 161.0	^1J 145.2
						^3J 8.5		^3J 6.7	^3J 8.6	^3J 8.0	^2J 2.6	^3J 8.0	^3J 8.5	
									^3J(OMe) 4.3				^2J 2.1	
3^c	151.8	*b*	*b*	128.4br	119.0br	135.5	120.8	122.2	157.5	111.6	132.3	121.7	131.0	56.1
4^c	152.9	140.7	108.9	128.3	120.1	135.4	121.9	*d*						
			^1J *b*	^1J 159.0	^1J 156.0		^1J 156							

[a] In [$^2H_6$]DMSO. [b] Not measurable. [c] In $CDCl_3$. [d] 124.9, ^1J 162.9 ($C_{1'}/C_{8'}$); 125.5, ^1J 160.3, ^3J 8.6 ($C_{2'}/C_{7'}$); 126.9, ^1J 160.4, ^3J 8.9 ($C_{3'}/C_{6'}$); 128.6, ^1J 161.1 ($C_{4'}/C_{5'}$); 129.0 ($C_{9'}$); 129.1, ^1J 159.9 ($C_{10'}$), 131.1 ($C_{4'a}/C_{10'a}$); 128.1 ($C_{8'a}/C_{9'a}$). br = broad, vbr = very broad.

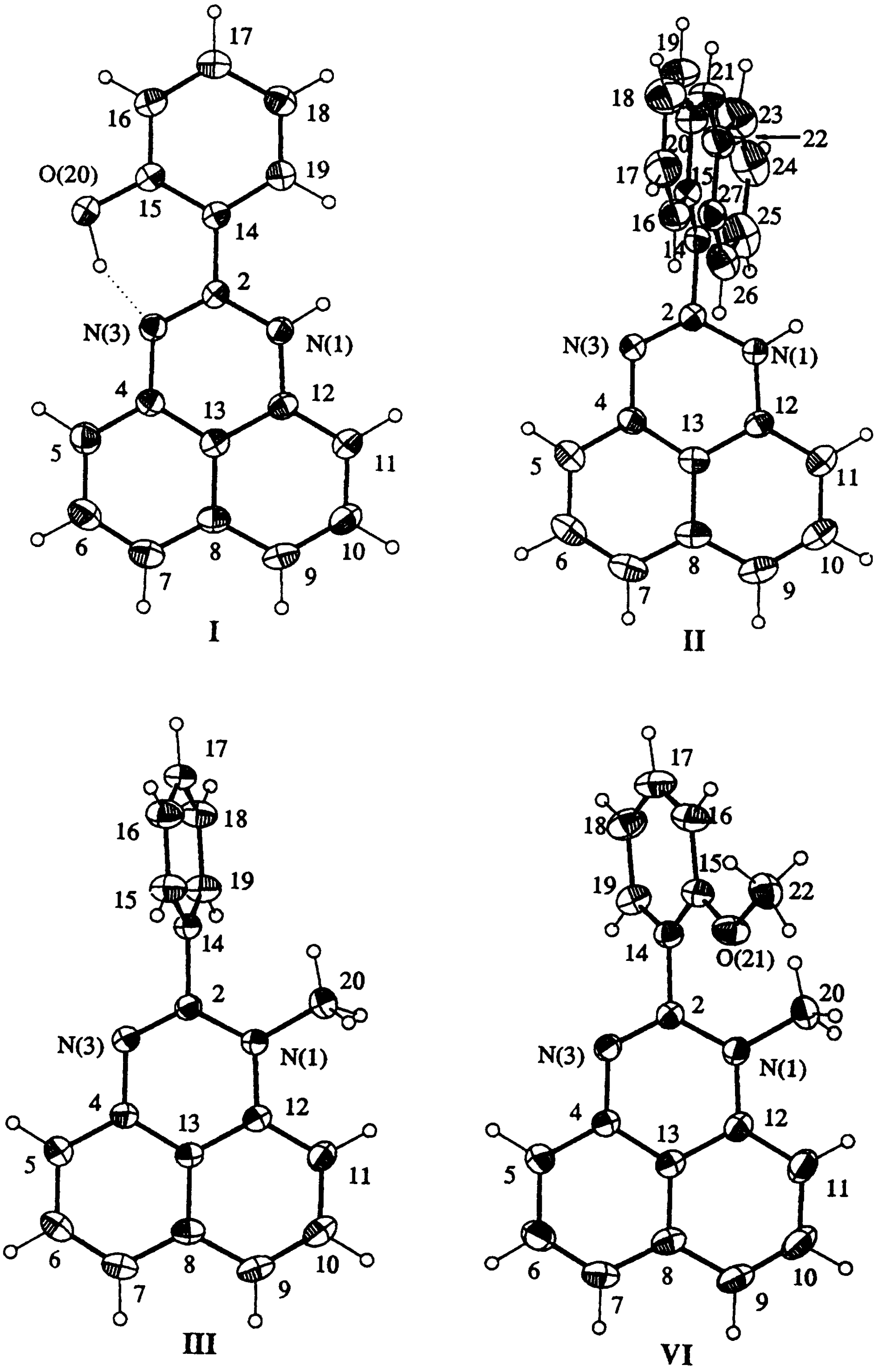


Fig. 1 Molecular structure[11] of compounds **2**, **4**, **5** and **7**. Thermal ellipsoids scaled to 30% probability and the H atoms are denoted by spheres of 0.1 Å in radius. Dotted lines indicate hydrogen bonds.

used for the assignment of the protons and carbons, together with the multiplicity of the signals and the coupling constant values. The planarity criteria discussed in refs. 2 and 8 have also been applied to our derivatives with the following conclusions: in compounds **2** and **3** the aryl groups and the perimidine rings are nearly coplanar due to hydrogen bonding, in the first derivative, between the phenolic OH group and the pyridinic nitrogen at the 3-position (δ_{OH} appears at 14.7 ppm), and in the second one, between the methoxy and the NH as indicated previously in ref. 9.

The signals of the anthryl substituent were assigned on the basis of our previous work where the chemical shift values of the 9,9′-bianthryl are discussed.[1]

NMR data for the perimidine system had been scarcely reported in the literature;[9,10] in ^1H NMR spectroscopy of the 2-arylperimidines **1**–**7**, the most striking feature is the chemical shift difference between the pairs of signals $\Delta\delta = \delta_{H_4} - \delta_{H_9}$ of *ca.* 0.28 ppm in [$^2H_6$]DMSO and 0.57 in $CDCl_3$ (Table 1), the remaining ones, H_5/H_8 and H_6/H_7, having closer values.

Similarly, in the ^{13}C NMR spectra, δ_{C_4} is larger than δ_{C_9} by *ca.* 11.7 ppm and C_{3a} appears downfield by *ca.* 5.0 ppm with respect to C_{9a} (Table 2). When comparing the reported ^{13}C

Table 4 Selected experimental bond distances and angles and semiempirical averaged values for compounds **2**, **4**, **5** and **7** and perimidine (Å, °). For compounds **2**: R1 = H, X1 = O(20), X2 = H; **4**: R1 = H, X1 = C(16), X3 = C(27); **5**: R1 = C(20), X1 = X3 = H and **7**: R1 = C(20), X1 = O(21), X2 = C(22), see Fig. 1

	2	**4**	**5**	**7**	AM1
N(1)–C(2)	1.361(4)	1.352(2)	1.375(2)	1.377(2)	1.404,[a] 1.411,[b] 1.393[c]
N(1)–C(12)	1.399(3)	1.398(2)	1.407(3)	1.400(2)	1.399,[a] 1.409,[b] 1.400[c]
N(1)–R1	0.93(4)	0.92(3)	1.458(3)	1.459(2)	0.992,[a] 1.436,[b] 0.990[c]
C(2)–N(3)	1.312(4)	1.301(2)	1.293(2)	1.297(2)	1.309
C(2)–C(14)	1.464(3)	1.493(2)	1.493(3)	1.493(2)	1.488,[d] 1.493,[e] 1.111[c]
N(3)–C(4)	1.396(3)	1.408(2)	1.403(3)	1.396(2)	1.407
C(4)–C(5)	1.373(5)	1.378(3)	1.380(3)	1.383(2)	1.393
C(4)–C(13)	1.411(4)	1.416(2)	1.414(3)	1.415(2)	1.439
C(5)–C(6)	1.413(4)	1.404(3)	1.400(3)	1.402(2)	1.408
C(6)–C(7)	1.361(5)	1.358(4)	1.373(3)	1.363(3)	1.377
C(7)–C(8)	1.404(6)	1.416(3)	1.413(3)	1.411(3)	1.419
C(8)–C(9)	1.409(5)	1.412(3)	1.414(3)	1.412(3)	1.422
C(8)–C(13)	1.420(3)	1.420(2)	1.423(3)	1.419(2)	1.412
C(9)–C(10)	1.363(6)	1.355(3)	1.360(3)	1.353(3)	1.373
C(10)–C(11)	1.405(4)	1.408(3)	1.405(3)	1.404(3)	1.411
C(11)–C(12)	1.371(4)	1.374(3)	1.380(3)	1.382(3)	1.392
C(12)–C(13)	1.419(5)	1.412(2)	1.413(3)	1.416(2)	1.442
C(14)–C(15)	1.417(4)	1.402(3)	1.379(3)	1.402(2)	—
C(14)–C(19)/C(27)	1.402(5)	1.406(3)	1.384(3)	1.384(2)	—
C(15)–X1	1.352(4)	1.416(3)	—	1.354(2)	—
X1–X2	1.05(4)	—	—	1.432(2)	—
C(19)–X3	—	1.426(3)	—	—	—
C(12)–N(1)–R1	120(2)	119(1)	117.7(2)	117.5(1)	120.0,[a] 118.7,[b] 119.8[c]
C(2)–N(1)–R1	118(2)	119(1)	122.5(2)	122.3(1)	120.3,[a] 122.6,[b] 121.3[c]
C(2)–N(1)–C(12)	122.2(2)	121.9(1)	119.6(2)	120.2(1)	119.7,[a] 118.5,[b] 118.9[c]
N(1)–C(2)–N(3)	122.0(2)	124.4(2)	125.1(2)	124.5(1)	125.1,[f] 126.6[c]
C(2)–N(3)–C(4)	120.2(2)	117.5(1)	118.3(2)	118.5(1)	118.3
N(3)–C(4)–C(13)	119.7(3)	120.8(1)	120.2(2)	120.5(1)	120.0
N(3)–C(4)–C(5)	120.8(2)	120.1(2)	119.9(2)	119.8(1)	121.1
N(1)–C(12)–C(11)	122.8(3)	123.0(2)	122.6(2)	123.3(2)	122.9
N(1)–C(12)–C(13)	116.4(2)	116.0(2)	117.0(2)	116.9(1)	117.5,[a] 118.1,[b] 117.3[c]
C(4)–C(13)–C(12)	119.5(2)	119.4(2)	119.7(2)	119.4(1)	119.5
N(1)–C(2)–C(14)	119.7(2)	115.8(1)	118.3(2)	119.5(1)	115.1,[a] 117.8,[b] 115.4[c]
N(3)–C(2)–C(14)	118.2(2)	119.7(1)	116.6(2)	116.0(1)	120.0,[a] 117.0,[b] 118.0[c]
C(2)–C(14)–C(19)	122.2(2)	117.7(2)	121.1(2)	119.2(1)	119.7
C(2)–C(14)–C(15)	120.1(3)	121.1(2)	119.9(2)	121.7(1)	120.3
C(15)–C(14)–C(19)	117.7(2)	121.1(2)	118.9(2)	119.0(2)	119.5
C(14)–C(15)–X1	122.2(2)	123.1(2)	—	116.0(2)	—
C(16)–C(15)–X1	118.0(3)	117.7(2)	—	124.2(2)	—
C(15)–X1–X2	103(3)	—	—	118.7(2)	—

[a] Mean value of **2** and **4**. [b] Same for **5** and **7**. [c] Perimidine. [d] **2**. [e] **4**, **5**. [f] **2**, **4**, **5** and **7**.

chemical shift values of 1-methylperimidine[10] with those obtained for 1-methyl-2-phenylperimidine (**5**) it appears that the introduction of an aryl group in the 2-position of the perimidine ring does not significantly affect the chemical shifts of the carbon signals, except for C_2 ($\Delta\delta = 8.5$ ppm).

The solid-state ^{13}C CP/MAS-NMR data are reported in Table 2 and are consistent with the X-ray crystal structure results for compounds **2**, **3**,[9] **5** and **7**.

X-Ray crystallography

A view of the molecular structures with the crystallographic numbering scheme is shown in Fig. 1 (note that this numbering is different from that of Scheme 1). The molecular geometries and the main hydrogen interactions are given in Tables 4 and 5. The results of the least-squares plane calculations[12] show that the perimidine and the aryl rings are not planar in terms of the achieved precision. The conformational parameters[13] together with those of deformation[14] around the central bond of the naphthalene moiety are listed in Table 5.

In compound **7**, each six-membered ring of the anthryl group exhibits significant deviations from planarity and the outer rings make angles of 2.5(1) and 1.6(1)° with the central one.

The *ortho* substitution of the H by an OH in 2-(2-hydroxyphenyl)perimidine (**2**) seems to affect significantly the conformation of the molecule because of the strong OH···N intramolecular hydrogen bond (IMHB) (Table 5). The perimidine moiety and the phenyl rings are almost coplanar, with a dihedral angle of 3.5(2)° while for derivatives **4**, **5** and **7** they tend to be perpendicular showing angles in the range 64.7(2)–77.8(2)°.

The pattern of bond distances and angles in the perimidine moiety is quite similar in all derivatives. However, the following differences are observed: in **2**, the C(2)–C(14) distance is significantly shorter than in 2-(9-anthryl)perimidine (**4**), 1-methyl-2-phenylperimidine (**5**) or 1-methyl-2-(2-methoxyphenyl)perimidine (**7**), probably due to a certain degree of electron delocalization between the aryl and the heterocyclic ring. To a lesser extent, in **2** and **4**, where there is an N–H involved in hydrogen interactions, the N(1)–C(2) and C(2)–N(3) bonds appear to be shortened and lengthened, respectively, with a greater degree of charge delocalization than in **5** and **7**. The N(1)–C(2)–N(3) and C(2)–N(3)–C(4) angles in **2** [122.0(2) and 120.2(2)°] also reflect the influence of the hydrogen bonding. This conclusion is supported by theoretical calculations (Table 5), where the computed angles at C(2) and N(3) have mean values of 125.1 and 118.3°, in agreement with the corresponding experimental ones for **4**, **5** and **7**. Moreover, the substitution of the N–H by an N–Me in the perimidine ring

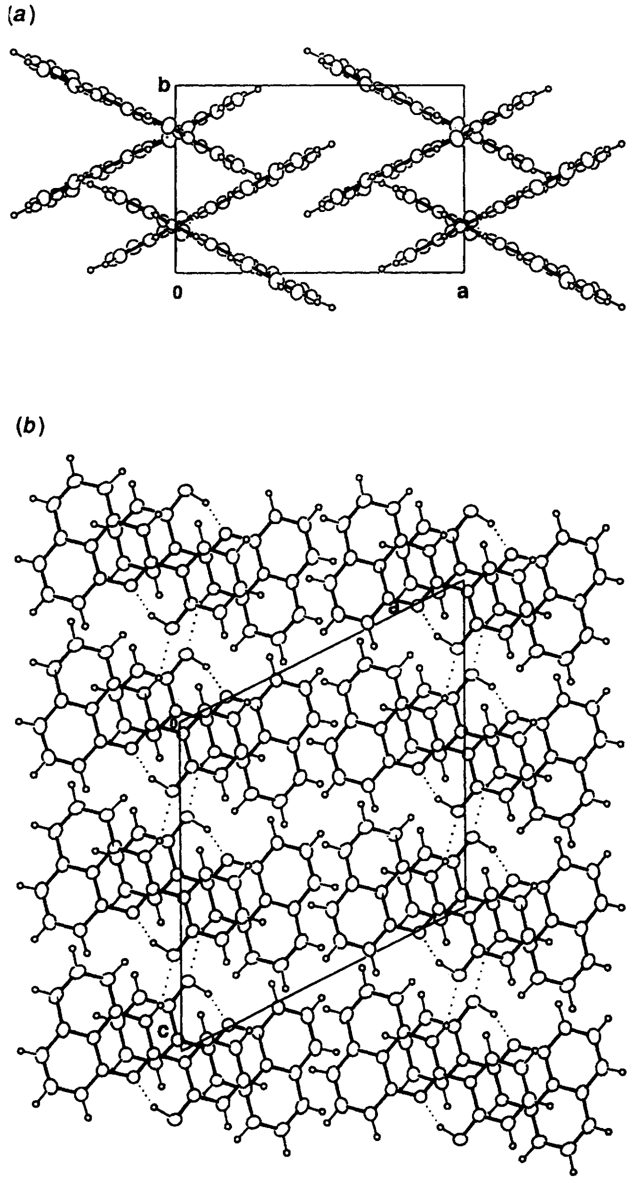


Fig. 2 Projections of the unit cell[11] down the *c* and *b* axis [(*a*) and (*b*)] for compound **2** showing the alternating hydrophobic and hydrophylic layers in the crystal

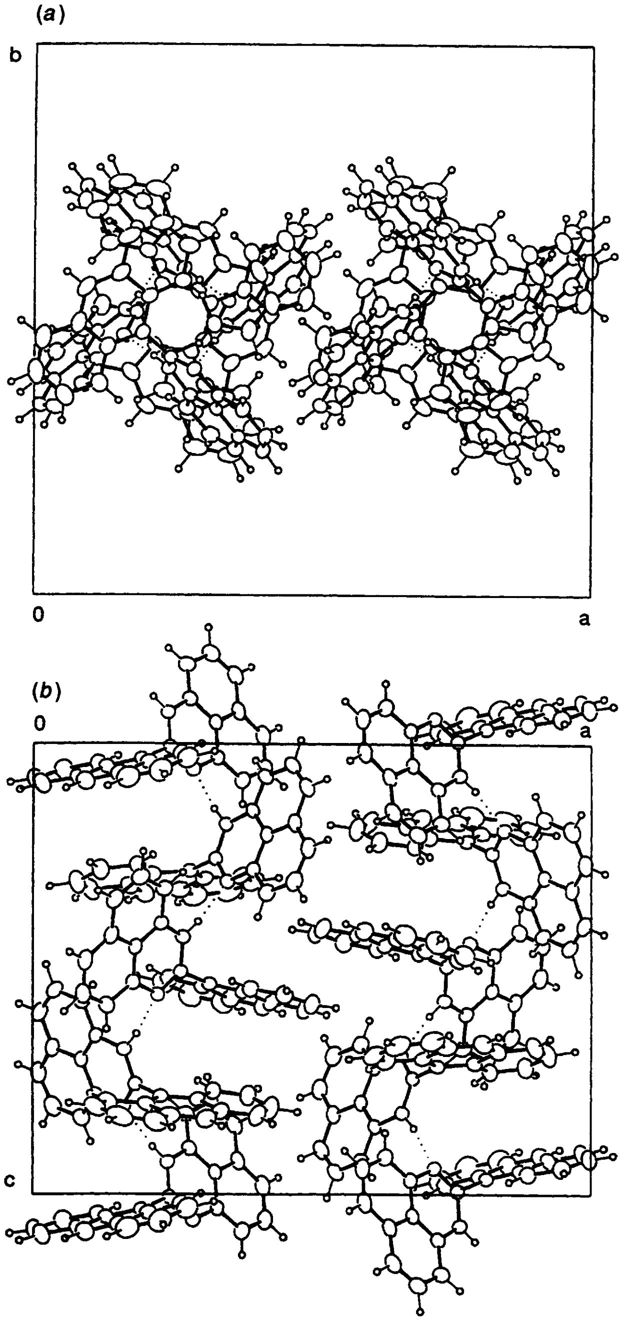


Fig. 3 Perspective views[11] of the hydrogen bonded helix down the *c* and *b* axis [(*a*) and (*b*)] for compound **4**. Each conformational enantiomer packs along the 4_1 and 4_3 screw-axis, respectively.

affects both the experimental and theoretical endocyclic angles at N(1) and C(12).

The packing of the molecules is illustrated in Figs. 2–4. Intermolecular hydrogen bonds between the N–H and the hydroxy group link molecules in **2**, to form chains along the *c* axis. There are no bonding interactions between them.

In compound **4**, N–H···N hydrogen bonds connect molecules in a helix system around the fourfold screw axis parallel to *c*. The remaining packing interactions are hydrophobic.

AM1 semiempirical calculations

A semiempirical analysis using the AM1 Hamiltonian[15] was performed in order to study the lack of planarity of the perimidine system and the influence of the conformation on the molecular stability. The crystallographic data were used as the starting point for the full geometric optimization. The perimidine molecule was also calculated since, up to now, no suitable crystals for the X-ray analysis could be obtained. As far as the bond distances and angles are concerned, just a few differences are observed. For these the values are given in Tables 4 and 5, otherwise, only the averaged ones are reported.

When the perimidine moiety is compared with that of the perimidine itself, the increases in the angle at C(2) and the shortening of the N(1)–C(2) and C(2)–N(3) bonds are the most remarkable features. Moreover, in **5** and **7**, the angles at N(1) and C(12) reflect the influence of the methyl group at N(1), in a similar way to that proposed by Domenicano and Murray-Rust[16] for the benzene rings. In contrast to the X-ray results, the perimidine is planar except in **7**, probably induced by the steric crowding. The heterocyclic ring is puckered adopting a distorted envelope conformation tending towards a boat, according to the Cremer and Pople parameters[13] and similar to the experimental ones (q_2 = 0.034, q_3 = 0.016 Å, φ_2 = −2 and θ_2 = 64°).

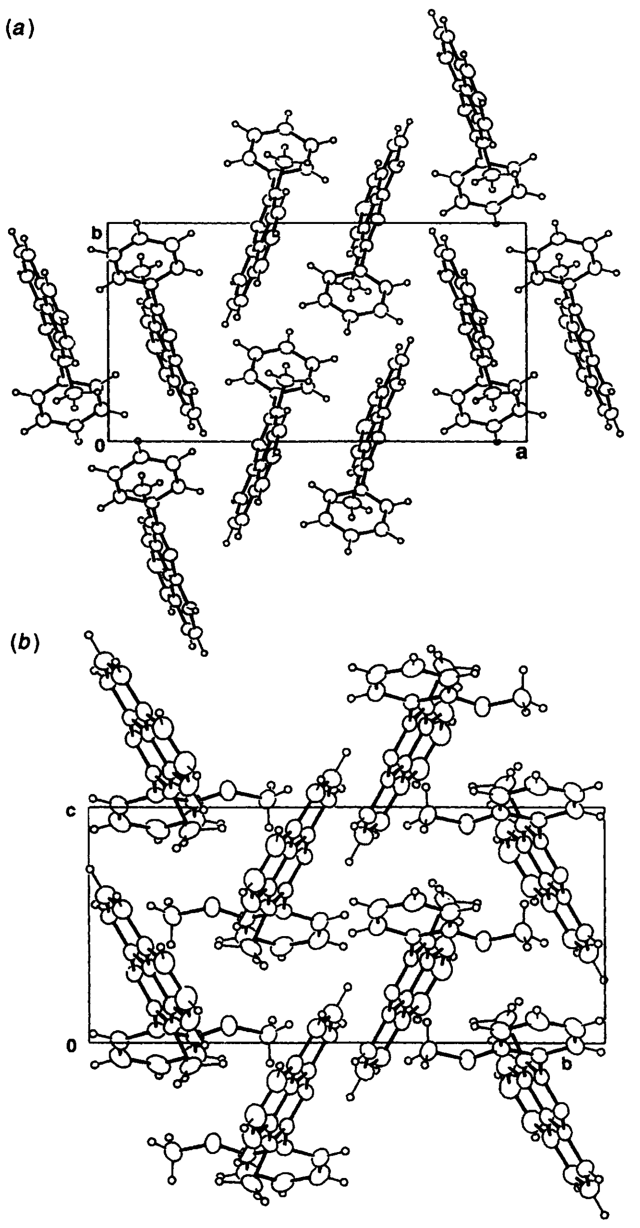


Fig. 4 Crystal packing[11] of compounds **5** and **7** as projected along the *c* and *a* axis [(*a*) and (*b*)] respectively

The conformational analysis was performed rotating the substituent at the 2-position of the perimidine moiety through 180° around the C(2)–C(14) bond and keeping the optimized geometrical parameters fixed except those close to the C(2)–C(14) bond and those involved in the substituent at the *ortho* position. All the *free* molecules present a coplanar orientation of the substituent and the perimidine ring (Fig. 5).

For the 2-(2-hydroxyphenyl)perimidine (**2**), besides the shortening of the C(2)–C(14) bond in agreement with the experimental results, the minimum energy conformation has the phenyl ring at 54.5° out of the plane of the perimidine ring. About 3 kcal mol^{-1} † are required to bring this angle to the experimental value of 3.5°. Thus, in the solid state, the conformation of **2** depends on the presence of the strong O–H···N intramolecular hydrogen bond. In the dimethyl derivative **7**, the phenyl ring is twisted to overcome the nitrogen–oxygen lone pair repulsion, placing the methoxy substituent on the same side of the N(1), as in the structure of the 2-(2-methoxyphenyl)perimidine (**3**) previously reported,[9] where the methoxy group is involved in an intramolecular hydrogen bond. The computed energy profiles show flat minima for **4**, **5** and **7** (Fig. 5) and conformational changes in the ranges 72–108°. 45–135° and 55–110° require less than 0.5 kcal mol^{-1}, respectively. Note that the experimental values for these compounds are within these ranges, while the greatest disagreements are presented by molecules with IMHBs: 2-(2-hydroxyphenyl)perimidine (**2**), and 2-(2-methoxyphenyl)-perimidine (**3**).[9] The lack of planarity of the perimidine ring in **2**, **4** and **5** is probably a consequence of the packing forces.

Experimental

Melting points were determined on a Büchi 530 apparatus and are uncorrected. ^{1}H (200.13 MHz) and ^{13}C (50.32 MHz) NMR spectra were recorded on a Bruker AC-200 using $CDCl_3$ or [$^2H_6$]DMSO; all chemical shifts (δ) are reported in parts per million (ppm) downfield from tetramethylsilane (TMS) using $CDCl_3$ (δ_H = 7.26, δ_C = 77.0) and [$^2H_6$]DMSO (δ_H = 2.49, δ_C = 39.5) as internal standards. Combustion analyses were performed with a Perkin-Elmer 2400 CHN instrument.

Synthesis

Literature procedures were used to prepare 1-amino-8-

Table 5 Torsion angles, ring puckering and deformation parameters and hydrogen interactions. C(1–13), C(4–13), C(8–13) and C(14–19) stand for the centroids of the corresponding phenyl rings (Å, °). For compounds **2**: R1 = H, X1 = O(20), X2 = H; **4**: R1 = H, X1 = C(16), X3 = C(27); **5**: R1 = C(20), X1 = X3 = H and **7**: R1 = C(20), X1 = O(21), X2 = C(22), see Fig. 1

		2	**4**	**5**	**7**
N(1)–C(2)–C(14)–C(15)	Exp	178.2(3)	−101.3(2)	−105.5(2)	−64.7(2)
	AM1	126.4	−90.1	−113.5	−70.6
N(1)–C(2)–C(14)–C(19)	Exp	−3.5(4)	77.8(2)	77.7(2)	120.0(2)
	AM1	−54.5	90.1	69.2	113.1
C(2)–C(14)–C(15)–X1	Exp	−2.9(4)	—	—	3.5(2)
	AM1	−1.6	−0.8	—	5.4
C(14)–C(15)–X1–X2	Exp	—	—	—	176.3(2)
	AM1	10.7	—	—	−165.4
q^2		0.018(3)	0.037(2)	0.023(2)	0.027(1)
q^3		0.007(3)	−0.018(2)	−0.002(2)	0.013(1)
φ^2		−157(8)	−173(2)	−177(4)	−20(3)
θ^2		70(8)	101(2)	94(5)	64(2)
χ_τ		−0.3(2)	0.4(1)	0.0(1)	0.5(1)
$\chi_{4.12}$		−0.5(5)	−0.7(4)	1.3(4)	−0.9(3)
$\chi_{7.9}$		−0.5(5)	0.3(4)	1.1(4)	−0.2(3)

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† 1 cal = 4.184 J.

Table 5 (*cont.*)

	Interatomic distances				
X–H···Y	X–H	X···Y	H···Y	X–H···Y	Symmetry
(*a*) Compound I					
O(20)–H(20)···N(3)	1.05(4)	2.511(3)	1.53(4)	153(5)	x, y, z
N(1)–H(1)···O(20)	0.93(4)	3.100(4)	2.24(4)	153(2)	$x, \frac{1}{2} - y, \frac{1}{2} + z$
(*b*) Compound II					
N(1)–H(1)···N(3)	0.92(2)	2.911(2)	2.00(2)	170(2)	$-\frac{1}{4} + y, \frac{3}{4} - x, -\frac{1}{4} + z$
C(9)–H(9)···C(4–13)	1.01(3)	3.901(2)	2.92(3)	164(2)	$\frac{3}{4} - y, \frac{3}{4} + x, \frac{3}{4} - z$
C(18)–H(18)···C(8–13)	1.02(4)	3.658(3)	2.78(4)	144(3)	$x, \frac{1}{2} + y, 1 - z$
(*c*) Compound III					
C(6)–H(6)···C(8–13)	0.98(3)	3.599(2)	2.86(3)	134(2)	$\frac{1}{2} - x, -\frac{1}{2} + y, \frac{1}{2} - z$
C(11)–H(11)···C(14–19)	0.99(3)	3.759(2)	2.96(3)	138(2)	$x, y, 1 + z$
C(18)–H(18)···C(4–13)	1.01(3)	3.613(3)	2.78(3)	140(2)	$1 - x, -y, -z$
(*d*) Compound IV					
C(20)–H(201)···O(21)	0.96(3)	3.152(2)	2.49(2)	126(2)	$x, \frac{1}{2} - y, -\frac{1}{2} + z$
C(18)–H(18)···C(8–13)	0.96(3)	3.792(2)	2.93(3)	151(2)	$-x, -y, -z$
C(19)–H(19)···C(1–13)	0.97(2)	3.555(2)	2.98(2)	119(1)	$-x, -y, -z$
C(20)–H(202)···C(1–13)	1.06(3)	3.546(2)	2.65(3)	142(2)	$x, \frac{1}{2} - y, -\frac{1}{2} + z$
C(22)–H(222)···C(14–19)	0.98(3)	3.774(4)	3.07(3)	130(2)	$x, \frac{1}{2} - y, \frac{1}{2} + z$

Table 6 Crystal analysis parameters at room temperature

	2	**4**	**5**	**7**
Crystal data				
Formula	$C_{17}H_{12}N_2O$	$C_{25}H_{16}N_2$	$C_{18}H_{14}N_2$	$C_{19}H_{16}N_2O$
Crystal habit	Brown prism	Yellow prism	Green prism	Yellow prism
Crystal size/mm	0.03 × 0.13 × 0.43	0.20 × 0.20 × 0.50	0.07 × 0.20 × 0.33	0.17 × 0.33 × 0.5
Symmetry	$P2_1/c$	$I4_1/a$	$P2_1/n$	$P2_1/c$
Unit cell determination:	Least-squares fit from reflections with θ < 45°			
	61 reflections	78 reflections	70 reflections	75 reflections
Unit cell dimensions/Å, °	13.1392(10)	20.8101(5)	17.6446(14)	11.4275(6)
	7.6778(3)	20.8101(5)	9.2154(4)	16.8070(13)
	13.4780(7)	16.8186(7)	8.3780(3)	7.9243(3)
	90, 116.447(4), 90	90, 90, 90	90, 102.862(5), 90	90, 99.830(4), 90
Packing: V/Å^3, Z	1217.4(1), 4	7883.5(4), 16	1328.1(1), 4	1499.6(2), 4
D_c/g cm^{-3}, M, F(000)	1.420, 260.3, 544	1.256, 344.4, 2880	1.292, 258.3, 544	1.277, 288.4, 608
μ/cm^{-1}	6.78	5.37	5.59	5.96
Experimental data				
Technique	Four-circle diffractometer: Philips PW1100, Bisecting geometry Graphite oriented monochromator: Cu-Kα, $\omega/2\theta$ scans, Detector apertures 1 × 1°. θ_{max} = 65°, 1 min/reflex			
Scan width:	1.4°	1.4°	1.4°	1.6°
Number of reflections:				
Independent	2054	3102	2262	2549
Observed [3σ(I) crit.]	1353	2447[a]	1681[a]	2211[a]
Solution and refinement				
Solution	Sir88 + Dirdif92	Sir88	Sir88	Dirdif92
Refinement: L.S. on F_o	Full matrix	Full matrix	Full matrix	Full matrix
Parameters:				
Number of variables	229	308	237	263
Degrees of freedom	1124	2139	1444	1948
Ratio of freedom	5.9	7.9	7.1	8.4
Final ⟨shift/error⟩	0.05	0.06	0.06	0.01
H atoms	From difference synthesis			
Weighting-scheme	Empirical as to give no trends in $\langle \omega\Delta^2F \rangle$ *vs.* $\langle \lvert F_{obs} \rvert \rangle$ and $\langle \sin\theta/\lambda \rangle$			
Max. thermal value/Å^2	U22[C(10)] = 0.080(2)	U22[C(24)] = 0.158(3)	U11[C(20)] = 0.094(2)	U33[C(10)] = 0.109(2)
Final ΔF peaks/e Å^{-3}	±0.15	±0.12	±0.12	±0.18
Final R and R_w	0.046, 0.050	0.044, 0.051	0.041, 0.049	0.048, 0.059

[a] 8, 1 and 2 reflections [compounds **4**, **5** and **7**] were affected by secondary extinction and were considered as unobserved in the last cycles of refinement.

methylaminonaphthalene,[4a] 2-phenylperimidine (**1**),[3a] and 2-(2-methoxyphenyl)perimidine (**3**).[9] Column chromatography was carried out using silica gel (240–300 mesh).

2-Arylperimidines. General procedure. Equivalent amounts of 1,8-diaminonaphthalene or 1-amino-8-methylaminonaphthalene (0.019 mol) and the appropriate aldehyde (0.019 mol) were refluxed for 4–8 h in 40 cm^3 of xylene in the presence of 0.6 g, of 10% palladium-on-carbon catalyst. The hot reaction mixture

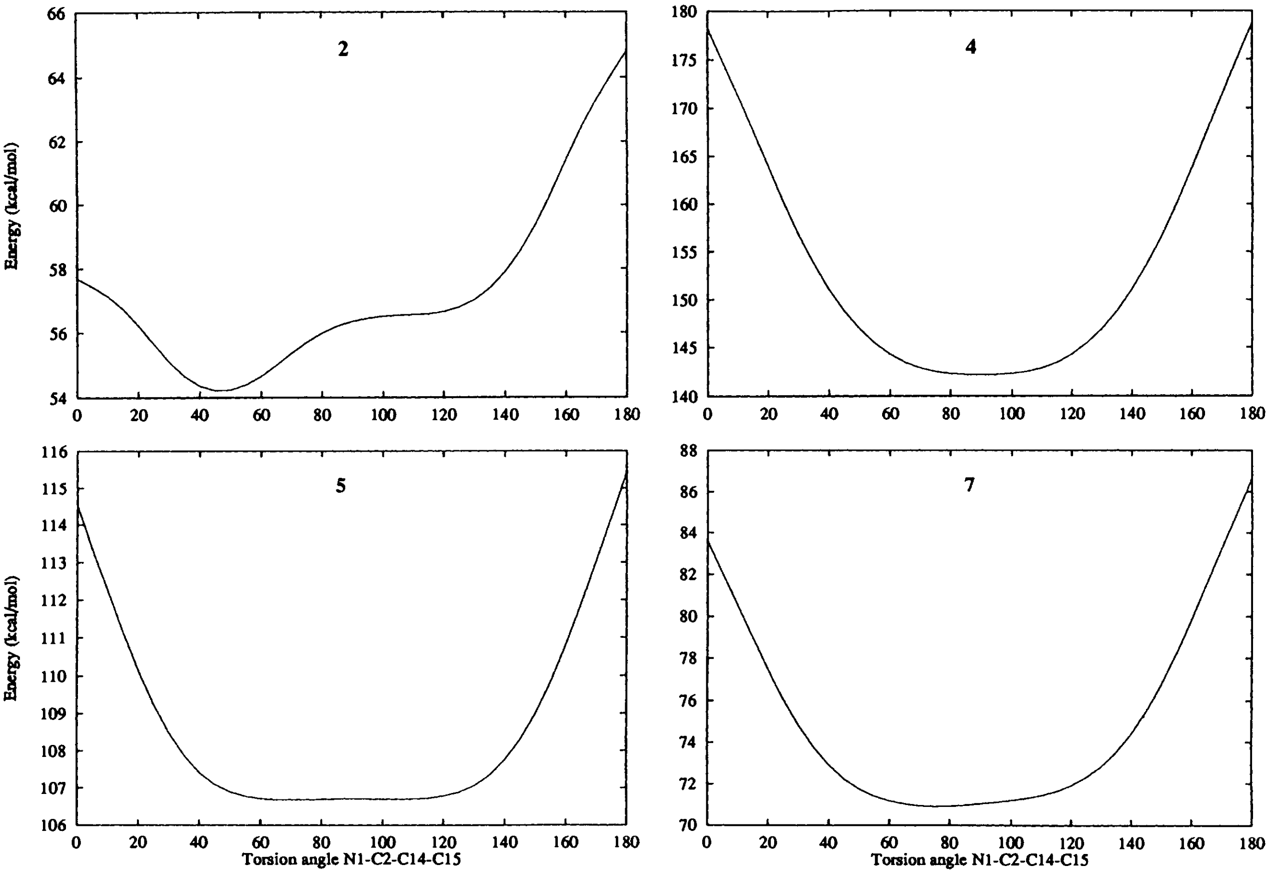

Fig. 5 Theoretical (AM1) energy profiles[17] of molecules **2**, **4**, **5** and **7**

was filtered and the filtrate chilled to precipitate the product. Addition of diethyl ether was necessary in some cases to start precipitation.

2-(2-*Hydroxyphenyl*)*perimidine* (**2**).—Mp 243–246 °C from xylene (lit.,[4b] 243–244 °C), 77% yield.

2-(9-*Anthryl*)*perimidine* (**4**).—Mp 254–255 °C from chloroform–hexane (1 : 1), 54% yield (Found: C, 87.0; H, 5.1; N, 8.4. $C_{25}H_{16}N_2$ requires C, 87.18; H, 4.78; N, 8.13%).

1-*Methyl*-2-*phenylperimidine* (**5**).—Mp 175–176 °C from chloroform (lit.,[4c] 173–174 °C), 70% yield.

1-*Methyl*-2-(2-*hydroxyphenyl*)*perimidine* (**6**).—Mp 243–245 °C from xylene, 35% yield (Found: C, 74.15; H, 5.2; N, 9.7. $C_{18}H_{14}N_2O{\cdot}H_2O$ requires: C, 73.95; H, 5.52; N, 9.58%).

1-*Methyl*-2-(2-*methoxyphenyl*)*perimidine* (**7**).—A mixture of 2-(2-hydroxyphenyl)perimidine (**2**) (1 g, 0.0038 mol), methyl iodide (0.48 cm^3, 0.0076 mol), potassium hydroxide (0.43 g, 0.0076 mol) and anhydrous potassium carbonate (5.32 g, 0.038 mol) in 40 cm^3 of acetone were heated for 4 h. The mixture was cooled and the solvent evaporated off. The crude reaction mixture was chromatographed with chloroform–ethyl acetate (9 : 1) and compound **7** was obtained in the fraction of R_f 0.42. Mp 144–146 °C from diethyl ether, 65% yield (Found: C, 78.8; H, 5.75; N, 9.6. $C_{19}H_{16}N_2O$ requires C, 79.14; H, 5.59; N, 9.72%).

X-Ray structure determination of compounds 2, 4, 5 and 7. Crystal data and the main experimental conditions are reported in Table 6. X-Ray crystals of **2** were obtained from ethanol, **4** from chloroform–cyclohexane, **5** from chloroform and **7** from [$^2H_6$]DMSO. The structures were solved by direct methods[18] or its application to the differences in structure factors.[19] The non-hydrogen atoms were refined anisotropically and the hydrogen atoms, obtained from the difference Fourier synthesis, were included and refined as isotropic. The calculations were performed using the XRAY 80 System[20] on a VAX6410 computer.

The atomic scattering factors were taken from the *International Tables for X-Ray Crystallography*,[21] and the weighting schemes were established using the PESOS program.‡[22]

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‡ Supplementary data [see section 5.6.3 of 'Instructions for Authors (1995)', January issue]. Lists of the thermal components, hydrogen parameters and bond distances and angles have been deposited at the Cambridge Crystallographic Data Centre.

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