

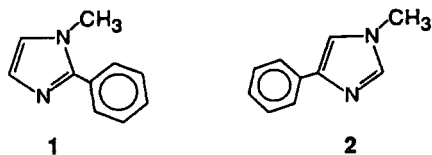
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The crystal and molecular structures are reported for two isomeric imidazoles: 1-methyl-2-phenylimidazole (**1**) and 1-methyl-4-phenylimidazole (**2**). In molecule **2** the phenyl ring is rotated by 7.3° from the heterocyclic plane due to steric interactions. The steric congestion is much more severe in **1**, with the adjacent methyl and phenyl substituents minimizing nonbonded interactions via a 32.3° rotation of the phenyl ring and a 0.159 \AA displacement of the methyl carbon from the heterocyclic plane.

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Imidazole rings serve as axial ligands coordinated to iron in a variety of heme proteins and for this reason are commonly used as axial ligands in metalloporphyrin model systems. It has been suggested that steric interactions between the porphyrin core and substituents appropriately located on the imidazole ring can significantly influence the thermodynamics and kinetics of substrate binding as well as the detailed molecular structure in both proteins and model systems [1,2]. As part of a study to determine how steric congestion within an imidazole axial ligand influences the chemistry of metalloporphyrin complexes, we synthesized and structurally characterized two isomeric imidazoles, 1-methyl-2-phenylimidazole (**1**) and 1-methyl-4-phenylimidazole (**2**). It is shown herein that the anticipated steric congestion in the former imidazole is manifested by a large rotation of the phenyl ring from the heterocyclic plane with a concomitant displacement of the methyl group from the same plane.



Figures 1 and 2 illustrate the structural details of **2**. The heterocyclic ring is highly planar (average deviation 0.003 \AA) from which the methyl carbon C4 deviates by 0.027 \AA and the phenyl C5 by 0.048 \AA . The phenyl ring is rotated 7.3° from the imidazole plane (Figure 2), which reduces steric contact with H3 and N2 to the distances $\text{N2} - \text{H6} = 2.61 \text{ \AA}$ and $\text{H3} - \text{H10} = 2.31 \text{ \AA}$. In a related study, 1-(4-imidazolylsulfonyl)-4-phenylimidazole it was found [3] that the 4-phenyl plane is rotated by 7.2° .

Of more interest is the structure of **1**, shown in Figures 3 and 4. Again the heterocyclic ring is highly planar (average deviation = 0.001 \AA), with the phenyl carbon C5 in this plane (deviation 0.008 \AA). The methyl carbon C4, however, is substantially displaced out of the imidazole

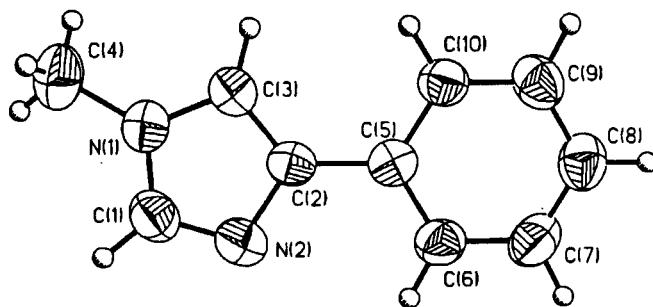


Figure 1. Drawing of 1-methyl-4-phenylimidazole (**2**) with the thermal ellipsoids at the 50% probability level.

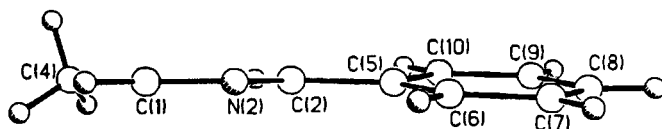


Figure 2. A view of **2** side-on to the heterocyclic plane showing the 7.3° rotation of the phenyl ring.

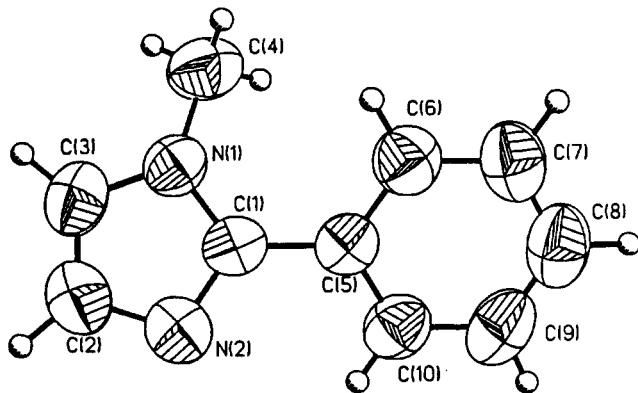


Figure 3. Drawing of 1-methyl-2-phenylimidazole (**1**) with the thermal ellipsoids at the 50% probability level.

plane by 0.159 \AA . The phenyl ring is rotated from the imidazole plane by 32.3° and in a direction opposite to the

methyl displacement. The combination of methyl group displacement and phenyl ring rotation reduces the non-bonded contacts H4c - H6 and H4a - H6, which are 2.53 Å and 2.32 Å, respectively (Figure 4). The out-of-plane position of the methyl in **1**, which corresponds to a dihedral angle C2-C3-N1-C4 of 7.6(2)°, is clearly steric in origin, since the deviation is at least five times that seen in less sterically congested *N*-methyl imidazoles [4]. An examination of intermolecular contacts in **1** showed that no atom comes closer than 3.4 Å to C4, meaning that the presence of strong packing forces responsible for the observed methyl distortion can be discounted.

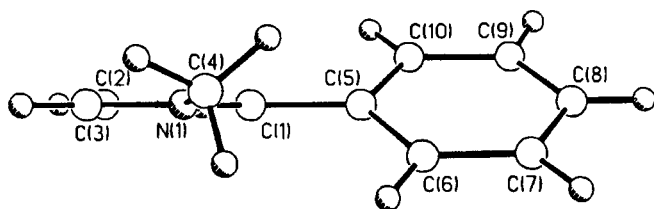


Figure 4. A view of **1** side-on to the heterocyclic plane showing the 32.3° rotation of the phenyl ring and the out-of-plane position of the methyl group.

The X-ray structure of 1-(2-pyridyl)-5-methylimidazole, which is somewhat related to **1**, has been reported [5]. In this case the methyl is bonded to carbon and is in the imidazole plane (deviation 0.005 Å). The steric congestion due to the adjacent methyl and pyridyl groups is reduced by a 37° twist of the pyridyl ring and by a 0.19 Å

Table 1
Crystallographic Data for Compounds **1** and **2**

	1	2
Formula	C ₁₀ H ₁₀ N ₂	C ₁₀ H ₁₀ N ₂
FW	158.20	158.20
Crystal system	orthorhombic	orthorhombic
Space group	Pcab	P2 ₁ 2 ₁ 2
<i>a</i> , Å	9.009(3)	5.662(1)
<i>b</i> , Å	11.819(5)	7.351(2)
<i>c</i> , Å	16.284(6)	20.465(13)
<i>V</i> , Å ³	1733.9(10)	851.8(6)
<i>Z</i>	8	4
ρ_{calc} , g/cm ³	1.21	1.23
F(000)	672	336
Radiation	MoK α , 0.71069 Å	MoK α , 0.71069 Å
μ , cm ⁻¹	0.70	0.70
Crystal dimensions, mm	0.5x0.5x0.5	0.4x0.3x0.2
Scan type	θ -2 θ	θ -2 θ
Scan range, 2 θ	3.5-45°	3.5-45°
Data collected	1398	731
Unique reflections, <i>I</i> > 1.0 σ (<i>I</i>)	1054	667
Number of variables	136	124
<i>R</i>	0.041	0.038
<i>R_w</i>	0.049	0.049
Residual electron density, e/Å ³	0.12	0.12

Table 2
Atom Coordinates (x 10⁴) and Isotropic Thermal Parameters (x 10³) for **1**

Atom	<i>x</i>	<i>y</i>	<i>z</i>	<i>U</i> , Å ²
N1	1616(2)	7841(1)	4407(1)	71
C1	1403(2)	6746(1)	4188(1)	66
N2	2104(2)	6050(1)	4695(1)	88
C2	2777(2)	6755(2)	5249(1)	98
C3	2499(2)	7834(2)	5084(1)	86
C4	910(2)	8854(2)	4078(1)	98
C5	511(2)	6359(1)	3490(1)	66
C6	394(2)	6960(2)	2759(1)	82
C7	-468(3)	6575(2)	2118(1)	95
C8	-1207(2)	5575(2)	2184(2)	102
C9	-1082(2)	4946(2)	2888(2)	99
C10	-233(2)	5337(2)	3545(1)	82
H2	3367(20)	6457(16)	5689(9)	120
H3	2796(18)	8530(8)	5341(10)	94
H4a	1400	9143	3599	118
H4b	918	9418	4502	118
H4c	-97	8663	3944	118
H6	948(17)	7650(8)	2708(11)	98
H7	-581(25)	6999(13)	1620(6)	114
H8	-1817(20)	5337(17)	1733(9)	121
H9	-1633(21)	4264(10)	2983(13)	118
H10	-126(21)	4913(13)	4044(6)	98

Table 3
Bond Distances (Å) and Angles (deg) for **1**

N1-C1	1.356(2)	N1-C3	1.360(2)
N1-C4	1.458(2)	C1-N2	1.326(2)
C1-C5	1.465(2)	N2-C2	1.369(3)
C2-C3	1.328(3)	C6-C7	1.377(3)
C6-C5	1.391(2)	C7-C8	1.361(4)
C8-C9	1.372(4)	C9-C10	1.393(3)
C10-C5	1.384(2)		
C1-N1-C3	106.8(1)	C1-N1-C4	128.7(1)
C3-N1-C4	124.0(1)	N1-C1-N2	111.2(1)
N1-C1-C5	125.4(1)	N2-C1-C5	123.4(1)
C1-N2-C2	104.2(2)	N2-C2-C3	111.5(2)
N1-C3-C2	106.3(2)	C7-C6-C5	121.5(2)
C6-C7-C8	120.2(2)	C7-C8-C9	119.8(2)
C8-C9-C10	120.5(2)	C9-C10-C5	120.3(2)
C1-C5-C6	123.1(1)	C1-C5-C10	119.2(1)
C6-C5-C10	117.7(2)		

displacement of the pyridyl carbon bonded to the imidazole ring from the imidazole plane. This study and our results suggest that large deviations from the imidazole plane occur only for substituents bonded to nitrogen.

In order to confirm that the distortions found in the crystal structure of **1** are due to steric interactions between the methyl and phenyl substituents and are not a consequence of packing forces, the molecular mechanics program CAChe [6] was applied to the isolated molecule. Energy minimization of **1** subject to the condition that the angles N1-C1-C5 and N2-C1-C5 be fixed at the experimentally determined values of 125.4° and 123.4°, respectively, produced a phenyl ring rotation of 37.5° and a C2-C3-N1-C4 dihedral angle of 3.8° (representing a displace-

Table 4

Atom Coordinates ($\times 10^4$) and Isotropic Thermal Parameters ($\times 10^3$) for **2**

Atom	x	y	z	U, Å ²
N1	-3199(4)	6696(3)	6847(1)	55
C1	-1020(6)	6260(4)	7045(1)	64
N2	-263(4)	4725(3)	6790(1)	64
C2	-2062(4)	4142(3)	6393(1)	46
C3	-3889(5)	5357(4)	6426(1)	53
C4	-4516(6)	8330(4)	7033(1)	78
C5	-1946(5)	2427(3)	6030(1)	47
C6	-48(5)	1248(4)	6114(1)	57
C7	17(6)	-397(4)	5778(2)	67
C8	-1741(7)	-857(4)	5351(1)	65
C9	-3590(6)	308(4)	5253(1)	63
C10	-3701(5)	1936(3)	5589(1)	54
H1	-109	6986	7343	75
H3	-5368	5283	6198	64
H4a	-6180	8095	6998	86
H4b	-4094	9312	6747	86
H4c	-4138	8654	7475	86
H6	1218(30)	1541(36)	6408(9)	65
H7	1354(34)	-1171(33)	5855(13)	79
H8	-1633(56)	-1958(21)	5100(12)	74
H9	-4849(34)	41(41)	4954(11)	75
H10	-5000(28)	2726(26)	5537(12)	62

Table 5

Bond Distances (Å) and Angles (deg) for **2**

N1-C1	1.337(4)	N1-C3	1.365(3)
N1-C4	1.464(4)	C1-N2	1.316(4)
N2-C2	1.371(3)	C2-C3	1.369(4)
C2-C5	1.464(3)	C6-C7	1.391(4)
C6-C5	1.392(4)	C7-C8	1.366(5)
C8-C9	1.368(5)	C9-C10	1.381(4)
C10-C5	1.390(4)		
C1-N1-C3	106.4(2)	C1-N1-C4	126.0(2)
C3-N1-C4	127.6(2)	C1-N2-C2	105.1(2)
N1-C1-N2	112.7(3)	N2-C2-C3	109.2(2)
N2-C2-C5	122.4(2)	C3-C2-C5	128.4(2)
N1-C3-C2	106.6(2)	C7-C6-C5	120.1(3)
C6-C7-C8	120.7(3)	C7-C8-C9	119.7(3)
C8-C9-C10	120.3(3)	C9-C10-C5	121.0(3)
C2-C5-C6	120.6(2)	C2-C5-C10	121.3(2)
C6-C5-C10	118.0(2)		

ment of the methyl out of the imidazole plane). Thus, the molecular mechanics calculation reproduces reasonably well the phenyl ring rotation of 32.3° found in the solid state. Similarly, energy minimization of molecule **2** produced a phenyl ring rotation of 7.6° and essentially no displacement of the methyl from the imidazole plane; these results are very close to those found in the crystal structure. The conclusion is that the displacements from planarity found in the solid state structures of **1** and **2** are indeed steric in origin.

EXPERIMENTAL

The imidazoles **1** and **2** were synthesized and purified as previously described [2]. Crystallographic data for **1** and **2** are given in Table 1. Rod-shaped crystals of **1** were grown by slow cooling of a diethyl ether solution. The crystals are very hygroscopic and were handled in a glove bag; the one selected was mounted in a glass capillary. Large rod-shaped crystals of **2** were obtained by fractional crystallization at 0° of a diethyl ether solution of a mixture of **2** and its synthetic co-product, 1-methyl-5-phenylimidazole (the latter was obtained as plates by cooling to -20°). The crystal of **2** selected was mounted on a glass fiber with epoxy, which was applied to coat the entire crystal. X-ray data for **1** and **2** were collected at 20° on a Nicolet R3m diffractometer using the θ -2 θ technique. Three standard reflections were monitored every 100 reflections. The structures were solved by direct methods using the SHELXTL 4.1 program. All non-hydrogen atoms were refined anisotropically. For **1**, all ten hydrogens were located in the difference Fourier map and refined isotropically subject to the restriction of a C-H bond length of 0.96 Å. The methyl group in **1** was treated as rigid based on the position of the carbon and the best-determined three hydrogens. For **2**, all hydrogens were also located in the difference map and were constrained to a bond length of 0.96 Å; the methyl and imidazole ring hydrogens were refined at theoretical positions. Atom coordinates, bond lengths, and bond angles for **1** and **2** are given in Tables 2-5.

Acknowledgment.

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