Synthesis of 9-Aryl-6-carbamoyl-1,2-dihydropurines and a Study of their Tautomerism

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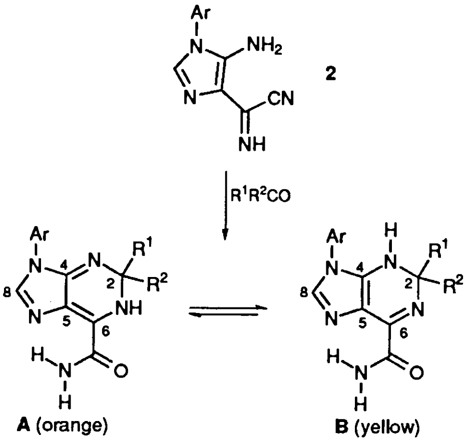
The title compounds have been prepared in high yield by reaction of the corresponding 4-(cyanoformimidoyl)-1-arylimidazol-5-amines with the carbonyl compounds R^1R^2CO ($R^1 = R^2 =$ Me, Et; $R^1 =$ H, $R^2 =$ Ph). The same 9-aryl-6-carbamoyl-1,2-dihydropurines ($R^1 = R^2 =$ Me) have also been isolated from the corresponding (*Z*)-*N*^{1}-(2-amino-1,2-dicyanovinyl)-*N*^{2}-arylformamidines by reaction with acetone in the presence of a base. In these cases the initially formed products are off-white solids, believed to be the oxazolidine derivatives **4**, which in solution rapidly undergo conversion into the respective 1,2-dihydropurines. The two tautomers of the dihydropurines have been fully characterised by ^{1}H and ^{13}C NMR spectroscopy and single-crystal X-ray structures have been obtained for both the orange and yellow tautomers of the dihydropurine derivative where Ar = Ph, $R^1 = R^2 =$ Me. In $[^2H_6]Me_2SO$ solution the presence of an *ortho*-substituent on the *N*-aryl ring causes an increase in the equilibrium concentration of the yellow tautomer. A single-crystal X-ray structure determination on the dihydropurine where Ar = 2,4-$(MeO)_2C_6H_3$; $R^1 = R^2 =$ Me has shown that in the solid state the aryl ring is twisted at 73.1(9)° to the plane of the heterocyclic ring and this may explain the observed behaviour in solution.

6-Carbamoyl-1,2-dihydropurines were first isolated by our group[1] from the reactions between aldehydes and ketones and 4-(cyanoformimidoyl)-1,2-dimethylimidazol-5-amine. Since then we have reported[2–5] several examples of 9-substituted 6-carbamoyl-1,2-dihydropurines prepared by a similar route and we have shown that the derivatives prepared from aldehydes are useful precursors to 1,9-disubstituted 6-carbamoylpurines.[2,3,5] It has been mentioned in an earlier paper[3] that in the ^{13}C NMR spectra these dihydropurines show sharp resonances for C(2) and C(8) and for substituents in the 2 position, but the ring carbon atoms C(4), C(5) and C(6) are very broad. This broadening was attributed to the slow equilibration of the two possible tautomers **A** and **B** (see Scheme 1), but it was never possible to determine from the available spectroscopic data which tautomer predominated in solution. In an attempt to resolve this problem we have synthesised a series of new 9-aryl-6-carbamoyl-1,2-dihydropurines and, by a combination of X-ray crystallography and spectroscopic methods, we have fully characterised the two tautomers both in the solid state and in solution (Table 1).

Results and Discussion

The dihydropurines **1a–s** (Scheme 1) were prepared by stirring a suspension of the corresponding 4-(cyanoformimidoyl)-1-arylimidazol-5-amine **2**[6] either in a large excess of the respective ketone or with a slight excess of benzaldehyde in a small amount of either ethanol or methanol at room temperature. The reactions were monitored by TLC (silica; 9:1 $CHCl_3$–EtOH) and reaction times varied between 20 min and 2–3 weeks. Depending upon the solvent used for the reaction and the rate of precipitation, these dihydropurines can be isolated as solids ranging in colour from orange to yellow depending upon the major tautomer present.

The dihydropurines ($R^1 = R^2 =$ Me) can also be obtained directly from a suspension of the corresponding (*Z*)-*N*^{1}-(2-amino-1,2-dicyanovinyl)-*N*^{2}-arylformamidines **3**[6] by reaction with acetone in the presence of a base, either 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) or $Ba(OH)_2$. In these reactions the initial product, which precipitates from solution within a few minutes, is an off-white solid **4a–f**, which can be isolated. These solids, when dissolved in ethanol or chloroform, form the



1a Ar = Ph, $R^1 = R^2 =$ Me
b Ar = 4-MeC_6H_4, $R^1 = R^2 =$ Me
c Ar = 4-$MeOC_6H_4$, $R^1 = R^2 =$ Me
d Ar = 4-$O_2NC_6H_4$, $R^1 = R^2 =$ Me
e Ar = 2-$MeOC_6H_4$, $R^1 = R^2 =$ Me
f Ar = 3,4-$(MeO)_2C_6H_3$, $R^1 = R^2 =$ Me
g Ar = 2,4-$Me_2C_6H_3$, $R^1 = R^2 =$ Me
h Ar = 2,4-$(MeO)_2C_6H_3$, $R^1 = R^2 =$ Me
i Ar = Ph, $R^1 = R^2 =$ Et
j Ar = 4-$MeOC_6H_4$, $R^1 = R^2 =$ Et
k Ar = 2-$MeOC_6H_4$, $R^1 = R^2 =$ Et
l Ar = 3,4-$(MeO)_2C_6H_3$, $R^1 = R^2 =$ Et
m Ar = 2,4-$Me_2C_6H_3$, $R^1 = R^2 =$ Et
n Ar = 2,4-$(MeO)_2C_6H_3$, $R^1 = R^2 =$ Et
o Ar = 4-$MeOC_6H_4$, $R^1 =$ H, $R^2 =$ Ph
p Ar = 2-$MeOC_6H_4$, $R^1 =$ H, $R^2 =$ Ph
q Ar = 3,4-$(MeO)_2C_6H_3$, $R^1 =$ H, $R^2 =$ Ph
r Ar = 2,4-$(MeO)_2C_6H_3$, $R^1 =$ H, $R^2 =$ Ph
s Ar = 2,4-$Me_2C_6H_3$, $R^1 =$ H, $R^2 =$ Ph

Scheme 1

Table 1 Microanalytical m.p. and mass spectroscopic data for the compounds **1a–s**

				Microanalytical data (%) Found (Calc.)[c]				
	Yield (%)	M.p./°C	Molecular formula	C	H	N	m/z $(M + 1)^+$[d]	M_r
1aA	75	185–187	$C_{14}H_{15}N_5O$	62.6 (62.4)	5.8 (5.6)	25.7 (26.0)	270	269
1aB	93[a] 79[b]	207–208d[e]	$C_{14}H_{15}N_5O$	62.2 (62.4)	5.6 (5.6)	26.4 (26.0)	270	269
1b	78[b]	174.6–176.4d[c]	$C_{15}H_{17}N_5O$	63.3 (63.3)	6.2 (6.3)	24.5 (24.6)	284	283
1c	71[a] 71[b]	179–180d	$C_{15}H_{17}N_5O_2$	59.9 (60.2)	5.8 (5.7)	23.1 (23.4)	300	299
1d	65[a]	254–256d	$C_{14}H_{14}N_6O_3$	53.7 (53.5)	4.8 (4.9)	26.5 (26.7)	315	314
1e	65[a] 84[b]	148d	$C_{15}H_{17}N_5O_2$	60.4 (60.2)	5.4 (5.7)	23.1 (23.4)	300	299
1f	54[a] 78[b]	138–139d	$C_{16}H_{19}N_5O_3$				330.1566 (M)	330.1542
1g	71	159–162d	$C_{16}H_{19}N_5O$ EtOH	63.0 (63.0)	7.1 (7.3)	20.4 (20.4)	298	297
1h	63	193–194d	$C_{16}H_{19}N_5O_3$	58.1 (58.4)	5.6 (5.8)	21.0 (21.3)	330	329
1i	67	110–118d	$C_{16}H_{19}N_5O$				297.1675 (M)	297.1668
1j	69	156–158d	$C_{17}H_{21}N_5O_2$				328.1794 (M)	328.1774
1k	68	179–180d	$C_{17}H_{21}N_5O_2$	62.3 (62.4)	6.6 (6.4)	21.3 (21.4)	328	327
1l	69	155–157d	$C_{18}H_{23}N_5O_3$				358.1869 (M)	358.1879
1m	59	169–170.5d	$C_{18}H_{23}N_5O$	66.2 (66.5)	7.4 (7.1)	21.2 (21.5)	326	325
1n	59	187–189d	$C_{18}H_{23}N_5O_3$	60.8 (60.5)	6.4 (6.4)	19.4 (19.6)	358	357
1o	79	142–143d	$C_{19}H_{17}N_5O_2$	65.5 (65.7)	4.9 (4.9)	19.9 (20.2)	348	347
1p	64	136–139d	$C_{19}H_{17}N_5O_2$	65.4 (65.7)	4.8 (4.9)	19.9 (20.2)	348	347
1q	58	165–168d	$C_{20}H_{19}N_5O_3$				378.1550 (M)	378.1566
1r	72	137–141d	$C_{20}H_{19}N_5O$				346.1664 (M)	346.1668
1s	74	164–167d	$C_{20}H_{19}N_5O_3$	63.5 (63.7)	5.0 (5.0)	18.8 (18.6)	378	377

[a] From the 4-(cyanoformimidoyl)-1-arylimidazol-5-amine. [b] From the (*Z*)-*N*^{1}-(2-amino-1,2-dicyanovinyl)-*N*^{2}-arylformamidine. [c] For those compounds where analytical data is missing acceptable data could not be obtained despite repeated recrystallisation, nevertheless these compounds were fully characterised by spectroscopic methods and by high resolution mass spectrometry. [d] Using fast atom bombardment. [e] d = decomp.

corresponding dihydropurines rapidly. Using this last reaction it has been possible to isolate in a pure form both tautomers of compound **1a**. Thus, reaction between **3a** and acetone in the presence of $Ba(OH)_2$ afforded the off-white solid **4a**. Careful monitoring of this reaction by TLC has shown that all the amidine is converted rapidly into 4-(cyanoformimidoyl)-1-phenylimidazol-5-amine before **4a** starts to precipitate from solution. After dissolution of **4a** in ethanol the yellow tautomer of **1a** is formed. This, unlike most of the other yellow tautomers, does not equilibrate rapidly to the orange tautomer in acetone solution, but if silica is added to the solution, or if it is chromatographed using silica, then the solution becomes orange and upon rapid concentration of the solution the pure orange tautomer can be isolated. When the orange tautomer is redissolved in acetone, chloroform or ethanol the solution turns yellow within a few minutes to give a mixture of the two tautomers.

In this way we have been able to obtain suitable crystals of both tautomers and by single crystal X-ray structure analysis it has been established that the orange tautomer has the structure **A**, while the yellow tautomer has the structure **B** (see Figs. 1 and 2). The full crystal structures of **1a** (**A**) and (**B**) will be reported elsewhere,[7] but from Fig. 1 it can be seen in structure **A** the imidazole ring and the atoms N(3) through to C(6) are coplanar and there is puckering at the N(1) and C(2) atoms. The space group is $P2_1/n$ which is centrosymmetric and there are enantiomers in the crystals. The N(3)–C(4) and N(7)–C(8) bonds are short [both 129(1) pm] indicative of double-bond character and the bond lengths of C(5)–C(6) and C(6)–N(1) are equal [135(1) pm]. The distance C(5)–C(6) is near a normal C=C length, but the C(6)–N(1) is unusually short [135(1) pm] consistent with delocalisation of the free sp^3 nitrogen lone pair with the C(5)–C(6) double bond. In the solid state there is strong intramolecular bonding between N(7) and one of the hydrogens of the amide substituent, and there is also intermolecular hydrogen bonding between the hydrogen on N(1) and the amide carbonyl group, and also between N(3) and the hydrogen of the 6-carbamoyl group. The phenyl group in this tautomer is almost coplanar with the imidazole ring with a dihedral angle of twist of 28.9(3)°, which may, in part, be due to the packing arrangement. There appears to be little conjugation between the phenyl group and the imidazole ring as the C(10)–N(9) bond

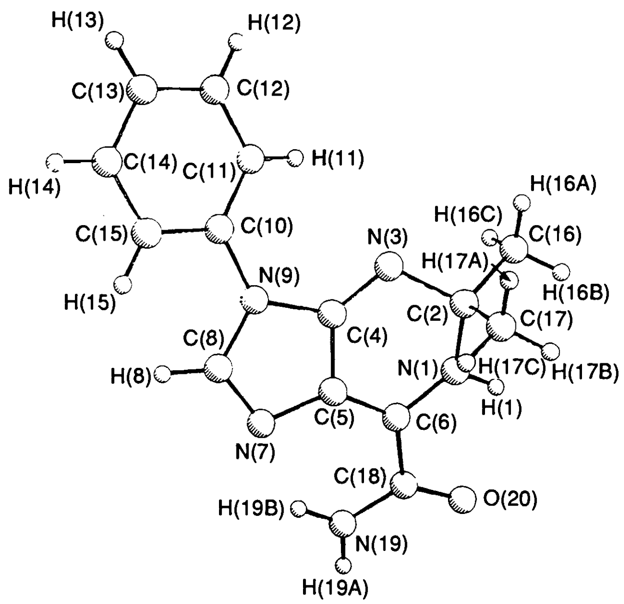


Fig. 1 X-ray crystal structure of the orange tautomer, 6-carbamoyl-2,2-dimethyl-9-phenyl-1,2-dihydropurine (**1aA**)

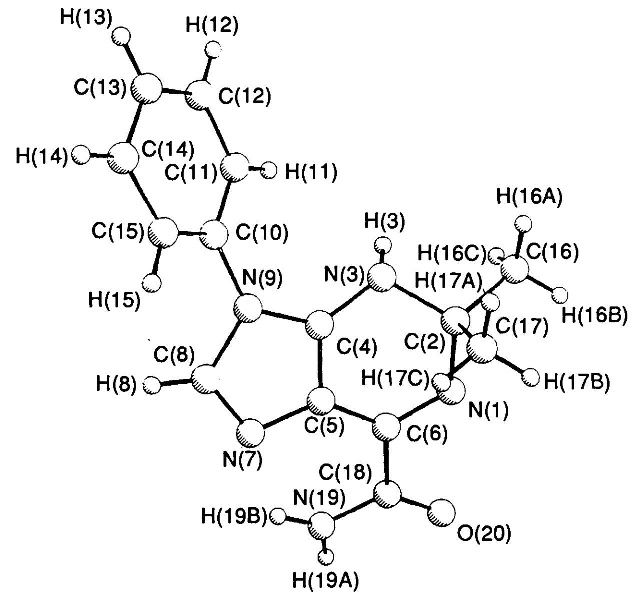


Fig. 2 X-ray crystal structure of the yellow tautomer, 6-carbamoyl-2,2-dimethyl-9-phenyl-2,3-dihydropurine (**1aB**)

length is 142(1) pm as expected for a C–N single bond. From Fig. 2 it can be seen that in the yellow tautomer (**B**) (space group $P2_1/n$), the 6-carbamoyl group is also strongly hydrogen bonded to N(7), and the dihydropyrimidine ring is puckered at N(3) and C(2). There is little difference in the bond lengths N(1)–C(2) and C(2)–N(3) from those observed for tautomer **A**, but the bonds C(6)–N(1), C(5)–C(4) are clearly double bonds [131(5) and 136(3) pm, respectively] and there is conjugation between the lone-pair electrons on N(3) and the C(4)–C(5)–C(6)–N(1) conjugated system as evidenced by the N(3)–C(4) bond length of 136(7) pm. In this compound the phenyl ring is twisted at an angle of 42.9°, *i.e.*, more than in tautomer **A** and the C(10)–N(9) bond length is longer, 146(1) pm, indicating even less conjugation between the phenyl group and the imidazole ring.

Microanalytical and mass spectral data (Table 2) indicate that the off-white solids **4a–f** have the same molecular formulae as those of the corresponding dihydropurines. In the IR spectra (Table 3) they all show an intense band in the region 3356–3410 cm^{-1} and usually two additional weaker bands in the NH stretching vibration region. In addition, they usually have two strong C=N stretching vibrations in the range 1616–1685 cm^{-1}. In all but one case it was impossible to obtain ^1H and ^{13}C NMR spectra as the compounds convert into the dihydropurines in solution so rapidly, but with **4d** reaction is slow enough to enable NMR spectra to be obtained. In $CDCl_3$ the ^1H NMR spectrum of **4d** shows bands at δ 1.7 (6 H, s, Me), 2.4 (3 H, s, Me), 5.3 (1 H, br s, NH), 6.5 (1 H, br s, NH), 7.2–7.7 (5 H, m, Ph + H2) and 9.2 (1 H, br s, NH). After 40 min the ratio of **4d** to the dihydropurine **1b** was approximately 5:1, changing to 1.5:1 after 90 min, and after several hours only the orange tautomer **A** of **1b** could be seen. The ^{13}C NMR spectrum in $[^2H_6]Me_2SO$ taken within several minutes of making up the solution showed bands for **4d** at δ 24.7 (Me), 31.3 (Me), 109.6, 114.8, 128.9 (ArH), 134.4 (ArH), 135.5, 136.1 (CH), 142.3, 147.9, 152.9 and 170.2. Conclusive evidence that the white compound is an imidazole derivative comes from the observation that reaction between 4-(cyanoformimidoyl)-1-benzylimidazole with acetone at room temperature gives the same white solid **4b** (in 50% yield) as obtained from the reaction between (*Z*)-N^1-(2-amino-1,2-dicyanovinyl)-N^2 benzylformamidine with acetone in the presence of DBU. This is supported by the NMR data, as the chemical shift values of both the C(2) proton (δ *ca.* 7.4) and the carbon (δ 136.1) are typical of an imidazole ring (*vide infra*). In both the ^1H and ^{13}C NMR spectra of **4b** the two methyl groups are equivalent and cannot be bonded to a C=N group, the ^{13}C NMR shows no evidence for C≡N groups, and the resonance at δ 109.6 can only reasonably be assigned to an sp^3 carbon bonded to a nitrogen and an oxygen atom. From this limited evidence, and the fact that these off-white compounds readily form 1,2-dihydropurines in solution two structures, **4** and **5** (see Scheme 2), are possible. On the spectroscopic evidence available it is difficult to distinguish between them. Structure **5** was originally postulated in an earlier paper[3] as a possible intermediate in dihydropurine formation, but we now favour the 5-iminooxazolidine structure **4** as shown in Scheme 2 on the basis that oxazolidines are well known species, and the ^{13}C chemical shift value of 109.6 ppm for the sp^3 carbon carrying the two methyl substituents is not unreasonable when compared with the data for other oxazolidines.[8] Also, in the puckered seven-membered oxazepine ring of **5** it may be expected that the ^1H and ^{13}C chemical shifts of two methyl groups would not be equivalent.* It is clear from the evidence described above that the first step in the reactions starting from (*Z*)-N^1-(2-amino-1,2-dicyanovinyl)-N^2-arylformamidines is the rapid, base-catalysed cyclisation to form the 4-(cyanoformimidoyl)imidazoles **2**, which then react with the carbonyl compound. From a study of acetylation reactions of similar compounds of type **2**[9] it is known that the 5-amino group is more nucleophilic than the imino nitrogen and we assume that the kinetic product of the reaction with the carbonyl compound is that formed by attack at the 5-position. We believe, however, that this reaction must be reversible (see Scheme 2), as formation of structure **4** can only arise if attack occurs at the imino nitrogen. In solution, compound **4** is expected[10] to be in equilibrium with the ring-opened form **6**, which could be the precursor to the dihydropurines **1** as observed experimentally.

In the ^1H NMR spectra of the dihydropurines **1a–s** (Table 4) it is possible, in most cases, to see characteristic bands for the two tautomers. For the compounds **1o–s** the rate of equilibration is faster in concentrated solution and only one set of broad bands is observed. When these spectra are re-run for

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* We are grateful to one of the referees for this suggestion.

Table 2 Microanalytical, m.p. and mass spectroscopic data for the compounds **4a–f**

	Molecular formula	Found (Calc.) (%) C	H	N	m/z $(M + 1)^{+a}$	M_r
4a	$C_{14}H_{15}N_5O$	62.6 (62.4)	5.4 (5.6)	25.6 (26.0)	270	269
4b	$C_{15}H_{17}N_5O$	63.4 (63.6)	6.0 (6.0)	24.7 (24.7)	284	283
4c	$C_{15}H_{17}N_5O_2$	59.8 (60.2)	5.8 (5.7)	23.2 (23.4)	300	299
4d	$C_{15}H_{17}N_5O$	63.3 (63.6)	6.2 (6.0)	24.5 (24.7)	284	283
4e	$C_{15}H_{17}N_5O_2$	59.9 (60.2)	5.4 (5.7)	23.1 (23.4)	300	299
4f	$C_{16}H_{19}N_5O_3$	58.0 (58.3)	5.5 (5.8)	21.4 (21.3)	330	329

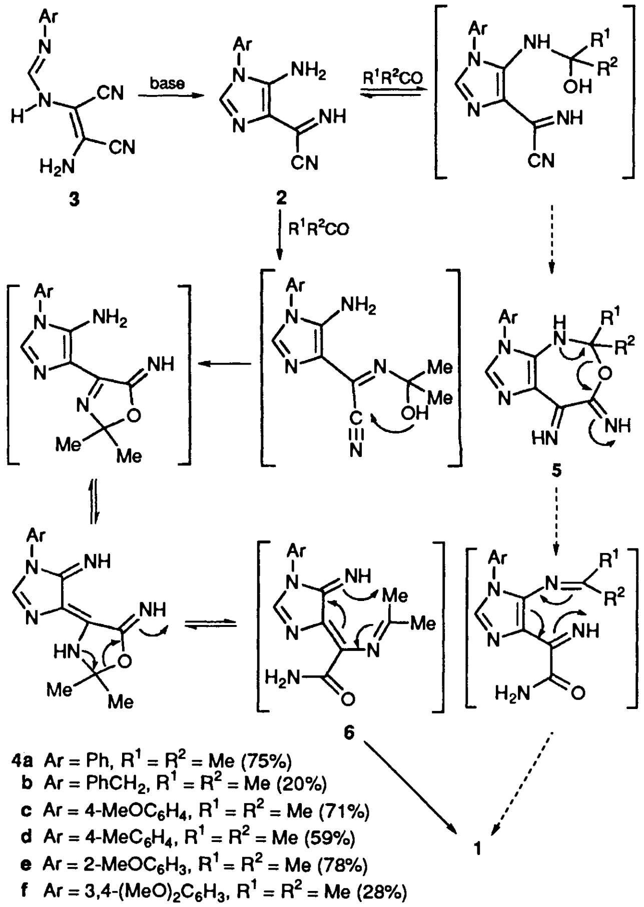
[a] Fast atom bombardment.

Table 3 IR spectroscopic data (cm^{-1})[a] for the compounds **4a–f**

Compound	ν(NH)	ν(C=N)	Other bands
4a	3399, 3351, 3254	1670, 1616	3048, 1605, 1594, 1570, 1236
4b	3356, 3240	1669, 1633	3040, 1604, 1565, 1235
4c	3400, 3300, 3262	1625	3110, 1600, 1575, 1540, 1250
4d[b]	3360, 3250	1685, 1650	3170, 1615, 1580, 1520, 1200
4e	3394, 3280, 3250	1669, 1630	3055, 1605, 1567, 1239
4f	3410, 3243	1670, 1631	3050, 1602, 1563, 1516, 1205

[a] Except where stated all spectra were Nujol mulls. [b] Bromoform mull.

more dilute solutions (0.5%) in $[^2H_6]Me_2SO$ it becomes possible to distinguish the bands due to the two tautomers even though both sets of bands are broadened. For compounds **1a–n** a change in concentration has little effect. Although the X-ray diffraction analysis establishes the structures of the two tautomers beyond doubt it is still necessary to establish the distribution of the tautomers in solution and this is not a trivial problem. The ^1H and ^{13}C spectroscopic data for a typical orange tautomer were established by recording the spectra of the crystals of the orange tautomer of compound **1h** which were used for the X-ray crystallographic analysis (see later). Both spectra were recorded within a few minutes of making up the solution to minimise the possibility of tautomerism. By allowing this solution to reach equilibrium it was then possible to establish the spectroscopic characteristics of the yellow tautomer, and further confirmation that these assignments were the correct ones was obtained from the spectra of the orange and yellow tautomers of **1a**. From a detailed examination of the ^1H and ^{13}C NMR spectra it has been established that in all cases the major tautomer in $[^2H_6]Me_2SO$ solution is the orange compound **A**, which has a characteristic band at δ 7.60–8.49 for the hydrogen on C(8). This band is at lower field than the equivalent hydrogens in 4-(cyanoformimidoyl)-1-arylimidazol-5-amines and 5-amino-1-arylimidazole-4-carbonitriles which resonate in the range δ 7.30–7.60.[6] The ^1H NMR spectra of the orange tautomers also show an NH band in the range δ 6.40–6.90 and the amide hydrogens at δ 8.18–8.24 and 8.30–8.32 when $R^1 = R^2 = Me$ and δ 6.0–6.33, 8.15–8.20 and 8.20–8.30 when $R^1 = R^2 = Et$ (see Table 4). In the case of the 2-phenyl derivatives **1o–s** the proton on N(1) can easily be identified as the band in the range δ 6.20–6.33 as it couples to the C(2) proton (J 5.0–5.5 Hz), and the amide bands are in the ranges δ 8.20–8.30 and 8.28–8.32. In the ^{13}C NMR spectra of the orange tautomers (Table 5) the C(4) carbon appears in the range δ 136.1–137.8 and C(8) at δ 148.3–151.7 (confirmed by DEPT), with C(5) at δ 120.4–122.4 and C(6) at δ 158.9–160.6.



4a Ar = Ph, $R^1 = R^2 = Me$ (75%)
b Ar = $PhCH_2$, $R^1 = R^2 = Me$ (20%)
c Ar = $4\text{-}MeOC_6H_4$, $R^1 = R^2 = Me$ (71%)
d Ar = $4\text{-}MeC_6H_4$, $R^1 = R^2 = Me$ (59%)
e Ar = $2\text{-}MeOC_6H_3$, $R^1 = R^2 = Me$ (78%)
f Ar = $3,4\text{-}(MeO)_2C_6H_3$, $R^1 = R^2 = Me$ (28%)

Scheme 2

Again it is noticeable that the chemical shift of C(8) is at lower field than the equivalent C(2) carbon in 4-(cyanoformimidoyl)-1-arylimidazol-5-amines and 5-amino-1-arylimidazole-4-carbonitriles (δ 135.9–137.4).[6]

In the ^1H NMR spectra of the minor, yellow tautomers **B** the hydrogen on C(8) is in the range δ 7.18–7.47, and for the compounds **1o–s** is usually masked by the multiplet for the aromatic hydrogens of the phenyl group on C(2). This range is very similar to that found for N-aryl imidazoles (*vide supra*) as expected, since the yellow tautomer can be regarded as an imidazole derivative. The NH and amide bands appear in the ranges δ 6.13–6.25, 7.67–7.68 and 8.21–8.25 ($R^1 = R^2 = Me$), δ 5.96–6.07, 7.61–7.66 and 8.16–8.20 ($R^1 = R^2 = Et$) and δ 6.51–6.62 (J 5.0–5.5 Hz) and 7.63–7.78 ($R^1 = Ph$, $R^2 = H$). The amide NH bands are coincident in the last series.

In the ^{13}C NMR spectra the yellow tautomers have C(4) at δ 146.6–148.7, C(8) at δ 135.2–136.6 (by DEPT), C(5) at δ 116.9–120.6 and C(6) at δ 155.3–156.0. Again the chemical shift of C(8) re-emphasises that the yellow tautomers have an imidazole ring. The bands in the spectra of the 2-phenyl derivatives were very broad and the chemical shifts could not be determined with any accuracy.

From a comparative study of the ^1H NMR spectra of the compounds **1a–s**, using identical concentrations in $[^2H_6]Me_2SO$ at a similar temperature, an interesting trend emerges. It can be seen from Table 4 that for N-phenyl, 4-substituted and 3,4-disubstituted N-phenyl derivatives the ratio of the tautomers **A** to **B** in $[^2H_6]Me_2SO$ is around 3–4:1 when $R^1 = R^2 = Me$ and $R^1 = Ph$, $R^2 = H$, and is somewhat higher (5–7:1) for the 2,2-diethyl derivatives. When the aryl group has a strongly electron-withdrawing substituent in the 4-position, *e.g.*, **1d** then the NMR spectrum shows only the orange tautomer **A** in $[^2H_6]Me_2SO$ solution. When the N-aryl group has an *ortho*

Table 4 ^{1}H NMR spectroscopic data for the compounds **1a–s**

Compound	Ratio **A**:**B**	δ_H([$^2H_6$]Me$_2$SO)
1a		**B** 1.50 (6 H, s, Me), 6.70 (< 1 H, br s, NH), 7.40 (1 H, t, ArH, *J* 8 Hz), 7.56 (2 H, t, ArH), 7.78 (2 H, d, ArH), 8.50 (1 H, br s, NH), 8.60 (1 H, br s, NH)
1b	3:1	**A** 1.50 (6 H, s, Me), 2.37 (3 H, s, Me), 6.60 (< 1 H, br s, NH), 7.35 (2 H, d, *J* 8 Hz, ArH), 7.78 (2 H, d, ArH), 8.14 (1 H, s, H8), 8.24 (1 H, br s, NH), 8.33 (1 H, br s, NH); **B** 1.48 (6 H, s, Me), 2.45 (3 H, s, Me), 6.13 (< 1 H, br s, NH), 7.40–7.50 (4 H, m, ArH), 7.65 (1 H, s, H8), 7.70 (1 H, br s, NH)
1c	3:1	**A** 1.50 (6 H, s, Me), 3.87 (3 H, s, OMe), 6.60 (1 H, br s, NH), 7.12 (2 H, d, *J* 9 Hz, ArH), 7.77 (2 H, d, *J* 9 Hz, ArH), 8.13 (1 H, s, H8), 8.24 (1 H, br s, NH), 8.32 (1 H, br s, NH); **B** 1.48 (6 H, s, Me), 3.91 (3 H, s, OMe), 6.14 (1 H, br s, NH), 7.20 (2 H, d, *J* 9 Hz, ArH), 7.54 (2 H, d, *J* 9 Hz, ArH), 7.60 (1 H, s, H8), 7.70 (1 H, br s, NH), 8.22 (1 H, br s, NH)
1d	> 20:1	**A** 1.59 (6 H, s, Me), 6.90 (1 H, br s, NH), 8.23 (1 H, br s, NH), 8.37 (2 H, d, *J* 9 Hz, ArH), 8.44 (2 H, d, ArH), 8.49 (1 H, s, H8)
1e	1.5:1	**A** 1.47 (6 H, s, Me), 3.90 (3 H, s, OMe), 6.47 (1 H, br s, NH), 7.12–7.22 (2 H, m, ArH), 7.28–7.35 (1 H, m, ArH), 7.40–7.50 (1 H, m, ArH), 7.52–7.61 (1 H, m, ArH), 7.80 (1 H, s, H8), 8.23 (1 H, br s, NH), 8.30 (1 H, s, NH); **B** 1.49 (6 H, s, Me), 3.90 (3 H, s, OMe), 6.18 (1 H, br s, NH), 7.12–7.22 (1 H, m, ArH), 7.28–7.35 (1 H, m, ArH), 7.36 (1 H, s, H8), 7.40–7.50 (1 H, m, ArH), 7.52–7.61 (1 H, m, ArH), 7.67 (1 H, br s, NH), 8.23 (1 H, br s, NH)
1f	3:1	**A** 1.50 (6 H, s, Me), 3.86 (3 H, s, OMe), 3.88 (3 H, s, OMe), 6.62 (1 H, br s, NH), 7.12 (1 H, d, *J* 8.5 Hz, ArH), 7.42 (1 H, dd, *J* 8.5, 2.5 Hz, ArH), 7.50 (1 H, d, *J* 2.5 Hz, ArH), 8.18 (1 H, s, H8), 8.23 (1 H, br s, NH), 8.32 (1 H, br s, NH); **B** 1.48 (6 H, s, Me), 3.90 (3 H, s, OMe), 3.92 (3 H, s, OMe), 6.21 (1 H, br s, NH), 7.13 (1 H, dd, *J* 8.5, 2.5 Hz, ArH), 7.18 (1 H, s, H8), 7.20 (1 H, d, *J* 8.5 Hz, ArH), 7.62 (1 H, d, *J* 2.5 Hz, ArH), 7.69 (1 H, br s, NH), 8.21 (1 H, br s, NH)
1g	1.5:1	**A** 1.43 (6 H, s, Me), 2.24 (3 H, s, Me), 2.41 (3 H, s, Me), 6.47 (1 H, br s, NH), 7.16–7.36 (3 H, m, ArH), 7.75 (1 H, s, H8), 8.22 (1 H, br s, NH), 8.32 (1 H, br s, NH); **B** 1.45 (6 H, s, Me), 2.17 (3 H, s, Me), 2.45 (3 H, s, Me), 6.25 (1 H, br s, NH), 7.16–7.35 (3 H, m, ArH), 7.36 (1 H, s, H8), 7.68 (1 H, br s, NH), 8.22 (1 H, br s, NH)
1h	1.2:1	**A** 1.43 (6 H, s, Me), 3.90 (6 H, s, OMe), 6.40 (1 H, br s, NH), 6.70 (1 H, dd, *J* 8, 2.5 Hz, ArH), 6.82 (1 H, d, *J* 2.5, 2.5 Hz, ArH), 7.38 (1 H, d, *J* 8 Hz, ArH), 7.71 (1 H, s, H8), 8.18 (1 H, br s, NH), 8.31 (1 H, br s, NH); **B** 1.44 (6 H, s, Me), 3.90 (6 H, s, OMe), 6.13 (1 H, br s, NH), 6.74 (1 H, dd, *J* 8, 2.5 Hz, ArH), 6.87 (1 H, d, *J* 2.5 Hz, ArH), 7.3 (1 H, s, H8), 7.67 (1 H, br s, NH), 8.25 (1 H, br s, NH)
1i	7:1	**A** 0.95 (6 H, t, *J* 8 Hz, Me), 1.62–1.80 (4 H, m, CH$_2$), 6.33 (< 1 H, br s, NH), 7.32 (1 H, m, ArH), 7.55 (2 H, m, ArH), 7.95 (2 H, m, ArH), 8.19 (1 H, s, H8), 8.20–8.30 (2 H, br s, NH); **B** 0.95 (6 H, t, *J* 8 Hz, Me), 1.62–1.80 (4 H, m, CH$_2$), 6.06 (< 1 H, br s, NH), 7.55–7.72 (6 H, m, ArH + H8), 8.15 (1 H, br s, NH)
1j	5:1	**A** 0.95 (6 H, t, *J* 8 Hz, Me), 1.65–1.80 (4 H, m, CH$_2$), 3.87 (3 H, s, OMe), 6.20 (1 H, br s, NH), 7.11 (2 H, d, *J* 9 Hz, ArH), 7.78 (2 H, d, *J* 9 Hz, ArH), 8.05 (1 H, s, H8), 8.20 (1 H, br s, NH), 8.30 (1 H, br s, NH); **B** 0.95 (6 H, t, *J* 8 Hz, Me), 1.65–1.80 (4 H, m, CH$_2$), 3.91 (3 H, s, OMe), 6.00 (1 H, br s, NH), 7.20 (2 H, d, *J* 9 Hz, ArH), 7.43 (1 H, s, H8), 7.52 (2 H, d, *J* 9 Hz, ArH), 7.66 (1 H, br s, NH), 8.17 (1 H, br s, NH)
1k	1.8:1	**A** 0.933 (6 H, t, *J* 7 Hz, Me), 1.55–1.80 (4 H, m, CH$_2$), 3.90 (3 H, s, OMe), 6.05 (1 H, br s, NH), 7.11–7.19 (1 H, m, ArH), 7.27–7.30 (1 H, m, ArH), 7.41–7.47 (1 H, m, ArH), 7.52–7.59 (1 H, m, ArH), 7.70 (1 H, s, H8), 8.19 (1 H, br s, NH), 8.24 (1 H, s, NH); **B** 0.93 (6 H, t, *J* 7 Hz, Me), 1.55–1.80 (4 H, m, CH$_2$), 3.90 (3 H, s, OMe), 5.96 (1 H, br s, NH), 7.11–7.19 (1 H, m, ArH), 7.23 (1 H, s, H8), 7.33–7.36 (1 H, m, ArH), 7.41–7.47 (1 H, m, ArH), 7.52–7.59 (1 H, m, ArH), 7.61 (1 H, br s, NH), 8.19 (1 H, br s, NH)
1l	4:1	**A** 0.96 (6 H, t, *J* 7 Hz, Me), 1.64–1.83 (4 H, m, CH$_2$), 3.86 (3 H, s, OMe), 3.87 (3 H, s, OMe), 6.27 (1 H, br s, NH), 7.12 (1 H, d, *J* 9 Hz, ArH), 7.41 (1 H, dd, *J* 9, 2.5 Hz, ArH), 7.59 (1 H, d, *J* 2.5 Hz, ArH), 8.14 (1 H, s, H8), 8.22 (1 H, br s, NH), 8.27 (1 H, br s, NH); **B** 0.96 (6 H, t, *J* 7 Hz, Me), 1.64–1.83 (4 H, m, CH$_2$), 3.91 (3 H, s, OMe), 3.92 (3 H, s, OMe), 6.07 (1 H, br s, NH), 7.08–7.18 (2 H, m, ArH), 7.22 (1 H, d, *J* 9 Hz, ArH), 7.47 (1 H, s, H8), 7.65 (1 H, br s, NH), 8.16 (1 H, br s, NH)
1m	2.2:1	**A** 0.91 (6 H, t, *J* 7 Hz, Me), 1.55–1.80 (4 H, m, CH$_2$), 2.28 (3 H, s, Me), 2.41 (3 H, s, Me), 6.05 (1 H, br s, NH), 7.17–7.27 (3 H, m, ArH), 7.67 (1 H, s, H8), 8.19 (1 H, br s, NH), 8.26 (1 H, br s, NH); **B** 0.91 (6 H, t, *J* 7 Hz, Me), 1.55–1.80 (4 H, m, CH$_2$), 2.18 (3 H, s, Me), 2.45 (3 H, s, Me), 6.05 (1 H, br s, NH), 7.17–7.27 (3 H, m, ArH), 7.35 (1 H, s, H8), 7.65 (1 H, br s, NH), 8.19 (1 H, br s, NH)
1n	1.3:1	**A** 0.92 (6 H, t, *J* 7.5 Hz, Me), 1.55–1.80 (4 H, m, CH$_2$), 3.88 (6 H, s, OMe), 6.00 (1 H, br s, NH), 6.72 (1 H, dd, *J* 8, 2.5 Hz, ArH), 6.85 (1 H, d, *J* 2.5, 2.5 Hz, ArH), 7.37 (1 H, d, *J* 8 Hz, ArH), 7.65 (1 H, s, H8), 8.15 (1 H, br s, NH), 8.20 (1 H, br s, NH); **B** 0.92 (6 H, t, *J* 7 Hz, Me), 1.55–1.80 (4 H, m, CH$_2$), 3.93 (6 H, s, OMe), 6.00 (1 H, br s, NH), 6.72 (1 H, dd, *J* 8, 2.5 Hz, ArH), 6.85 (1 H, d, *J* 2.5 Hz, ArH), 7.15 (1 H, s, H8), 7.37 (1 H, d, *J* 8 Hz, ArH), 7.65 (1 H, br s, NH), 8.20 (1 H, br s, NH)
1o	4:1 *	**A** 3.88 (3 H, s, OMe), 6.30 (1 H, s, H2), 7.15 (2 H, d, *J* 9 Hz, ArH), 7.32–7.62 (5 H, m, Ph), 7.86 (2 H, d, *J* 9 Hz, ArH), 8.21 (1 H, s, H8), 8.23 (< 1 H, br s, NH), 8.32 (< 1 h, br s, NH); **B** 3.91 (3 H, s, OMe), 6.02 (1 H, m, H2), 6.51 (1 H, d, *J* 7 Hz, NH), 7.20 (2 H, d, *J* 9 Hz, ArH), 7.32–7.62 (3 H, m, ArH + H8), 7.63 (< 2 H, s, NH)
1p	2:1 *	**A** 3.90 (3 H, s, OMe), 6.20 (1 H, d, *J* 3.5 Hz, H2), 7.12–7.65 (9 H, m, ArH + Ph), 7.85 (1 H, s, H8), 8.21 (< 1 H, br s, NH), 8.28 (< 1 H, br s, NH); **B** 3.90 (3 H, s, OMe), 6.08 (1 H, s, H2), 6.60 (< 1 H, s, NH), 7.12–7.65 (10 H, m, ArH + Ph + H8), 7.70 (< 2 H, br s, NH)
1q	3:1 *	**A** 3.88–3.95 (6 H, s, OMe), 6.33 (1 H, br s, H2), 7.10–7.68 (8 H, br m, ArH + Ph), 8.22 (2 H, br s, NH + H8), 8.32 (< 1 H, br s, NH); **B** 3.88–3.95 (6 H, s, OMe), 6.02 (1 H, br s, H2), 6.58 (< 1 H, br s, NH), 7.10–7.68 (9 H, br m, ArH + Ph + H8), 7.70–7.80 (< 2 H, br s, NH)
1r	2:1 *	**A** 3.89 (3 H, s, OMe), 3.91 (3 H, s, OMe), 6.20 (1 H, d, *J* 4 Hz, H2), 6.72 (1 H, m, ArH), 6.87 (1 H, dd, *J* 7.5, 2.5 Hz, ArH), 7.28–7.60 (6 H, m, ArH + Ph), 7.74 (1 H, s, H8), 8.20–8.30 (2 H, br s, NH); **B** 3.88 (3 H, s, OMe), 3.93 (3 H, s, OMe), 6.05 (1 H, d, *J* 5 Hz, H2), 6.56 (1 H, d, *J* 5 Hz, NH), 6.87 (1 H, dd, *J* 7.5, 2.5 Hz, ArH), 7.28–7.60 (6 H, m, ArH + Ph + H8), 7.70 (< 2 H, br s, NH)
1s	2:1 *	**A** 2.20 (3 H, s, Me), 2.44 (3 H, s, Me), 6.20 (1 H, d, *J* 3.5 Hz, H2), 7.28–7.60 (8 H, m, ArH + Ph), 7.80 (1 H, s, H8), 8.23 (< 1 H, br s, NH), 8.28 (< 1 H, br s, NH); **B** 2.1 (3 H, s, Me), 2.47 (3 H, s, Me), 6.00 (1 H, d, *J* 5.5 Hz, H2), 6.62 (1 H, d, *J* 5.5 Hz, NH), 7.28–7.60 (10 H, m, ArH + Ph + H8), 7.70 (< 2 H, br s, NH)

* Signals broadened.

Table 5 ^{13}C NMR spectroscopic data for the compounds **1a–s**[a]

		$\delta_C([^2H_6]Me_2SO)$												
		C(2)	C(4)	C(5)	C(6)	C(8)	C=O	C(10)	C(11)	C(12)	C(13)	C(14)	C(15)	Other bands
1a	**B**	76.1	136.6	122.0	159.6	148.3	166.2	139.9	124.4	133.2	129.5			33.1 (Me)
1b	**A**	76.2	136.6	122.3	159.8	148.6	166.3	137.6	124.5	133.5	138.8			24.6 (Me), 33.2 (Me)
	B	76.5	146.3	120.8	155.4	136.9	169.0	136.1	127.4	134.2	141.5			24.7 (Me), 31.8 (Me)
1c	**A**	76.2	136.6	122.4	159.9	149.0	166.5	133.1	126.5	118.4	161.1			33.2 (Me), 59.4 (MeO)
	B	76.5	146.6	120.6	155.4	136.2	169.1	131.4	129.3	118.9	162.9			31.8 (Me), 57.6 (MeO)
1d	**A**	76.5	137.8	121.5	159.6	146.7	166.0	145.6	123.4	129.0	147.7			33.3 (Me)
1e	**A**	76.3	136.1	121.6	157.4	151.2	166.6	127.8	131.5	124.7	132.8	116.7	160.4	33.2 (Me), 59.9 (MeO)
	B	76.4	148.3	118.7	155.3	136.4	169.1	126.7	131.5	124.7	134.4	116.7	157.5	32.0 (Me), 59.9 (MeO)
1f	**A**	76.3	136.6	122.4	160.0	149.0	166.5	133.3	116.1	117.1	150.8	153.0	109.9	33.2 (Me), 59.9 (OMe)
1g	**A**	76.4	136.4	121.8	160.5	150.9	166.6	135.8	131.4	131.6	142.0	135.5	138.9	22.0, 24.7, 33.2 (Me)
	B	76.5	148.1	119.1	155.4	136.2	169.1	134.7	131.3	131.7	143.1	135.7	138.7	21.4, 24.7, 31.9 (Me)
1h	**A**	76.2	135.9	120.8	158.8	151.7	166.7	121.8	132.5	109.0	164.0	103.7	160.8	32.0 (Me), 59.7, 60.0 (MeO)
	B	76.5	148.6	118.6	155.3	136.6	169.1	119.7	132.5	109.0	165.1	103.7	159.1	33.2 (Me), 59.7, 60.0 (MeO)
1i	**A**	82.5	137.8	121.2	159.6	148.0	166.4	140.1	124.2	133.3	129.4			12.2 (Me), 37.1 (CH_2)
1j	**A**	82.4	137.5	121.3	159.8	148.6	166.4	133.2	126.2	118.4	161.0			12.2 (Me), 37.1 (CH_2), 59.4 (MeO)
	B	82.3	147.1	118.8	156.0	135.3	169.0	131.4	129.5	119.0	162.9			12.2 (Me), 35.2 (CH_2), 59.6 (MeO)
1k	**A**	82.6	137.1	120.4	157.5	150.7	166.5	127.9	131.3	124.6	132.7	116.7	160.3	12.2 (Me), 37.6 (CH_2), 59.9 (MeO)
	B	82.4	148.7	116.9	156.0	135.3	169.1	126.7	131.7	124.9	134.5	116.8	158.0	12.0 (Me), 36.1 (CH_2), 59.8 (MeO)
1l	**A**	82.3	137.5	121.5	159.8	148.6	166.4	133.5	116.1	116.5	150.6	152.9	109.5	12.1 (Me), 36.9 (CH_2), 59.6, 59.9 (MeO)
	B	82.3	147.0	118.6	156.0	135.2	169.1	131.4	121.3	119.8	152.6	153.4	112.2	12.1 (Me), 35.0 (CH_2), 59.6, 59.9 (MeO)
1m	**A**	82.7	137.4	120.6	160.6	150.5	166.5	135.8	131.4	131.6	141.9	135.5	138.9	12.2 (Me), 37.7 (CH_2), 22.0, 24.6 (Me)
	B	82.4	148.5	117.0	156.0	135.2	169.0	134.7	131.3	131.7	143.1	135.7	137.4	12.0 (Me), 35.9 (CH_2), 21.3, 24.6 (Me)
1n	**A**	82.5	136.9	120.6	158.9	151.2	166.7	120.8	132.4	109.0	163.9	103.6	160.7	12.2 (Me), 37.7 (CH_2), 59.6, 60.0 (MeO)
	B	82.4	149.0	116.9	156.0	135.6	169.1	119.7	132.6	109.2	165.1	102.0	159.3	12.0 (Me), 36.0 (CH_2), 59.8, 59.9 (MeO)
1o	**A**	74.3	136.4	123.8	161.7	149.1	166.9	132.6	127.1	118.6	161.3			59.5 (MeO), 130.2, 131.8, 132.1, 147.1
1p	**A**	74.4	?	122.5	?	?	167.2	127.3	131.7	124.7	133.7	116.7	157.6	59.9 (MeO), 130.3, 131.8, 132.0, 147.3
1q	**A**	74.3	?	123.9	161.5	?	167.0	132.8	117.7	116.1	151.4	153.1	110.4	59.9 (MeO), 130.2, 131.8, 132.1, 147.3
1r	**A**	74.5	?	122.4	?	?	167.4	120.2	132.8	109.1	164.7	103.6	159.1	59.7, 60.0 (MeO), 130.4, 131.7, 132.0, 147.3
1s	**A**	74.2	?	123.2	162.3	150.8	166.4	?	131.5	131.7	142.4	135.7	138.9	21.8, 24.3 (Me), 130.1, 132.0, 147.7

[a] In many of these spectra, especially for the compounds **1n–s**, the bands for the minor (**B**) isomer were lost in the noise.

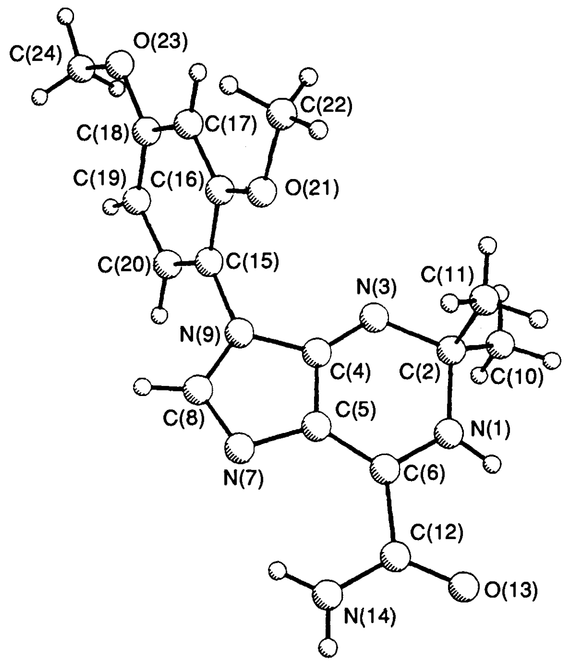


Fig. 3 X-ray crystal structure of the orange tautomer, 6-carbamoyl-2,2-dimethyl-9-(2,4-dimethoxyphenyl)-1,2-dihydropurine (**1h**)

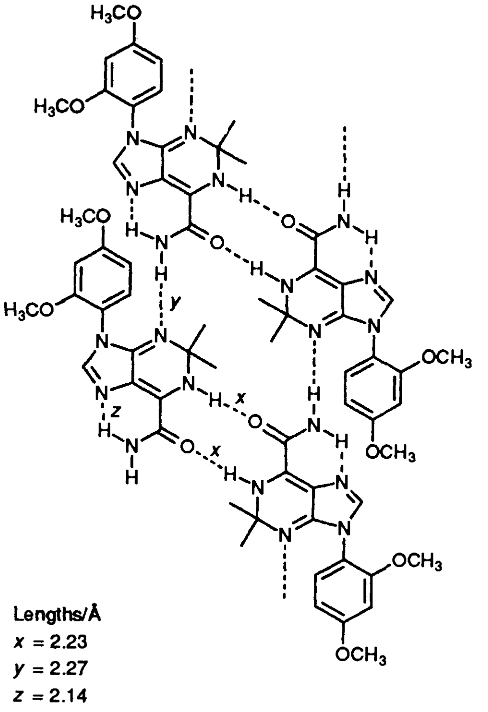


Fig. 4

substituent then the ratio of **A** to **B** drops to 1.2–2.2: 1. Thus an *ortho* substituent apparently reduces the equilibrium concentration of **A**, which has no hydrogen on N(3) in favour of **B** which has. This is unexpected since an N(3) hydrogen might be expected to increase steric congestion and result in destabilisation of the **B** tautomer. In an effort to find an explanation for this apparent anomaly the X-ray crystal structure determination of compound **1h** was undertaken. Unfortunately, crystals of this compound could only be obtained as the orange tautomer **A**, but in the solid state (see Fig. 3) it can be seen clearly that the aryl ring is twisted almost perpendicular relative to the plane of the imidazole ring [twist angle 73.1(9)°], although, surprisingly, the C(10)–N(9) bond length is the same length [142(1) pm] as that found for **1aA**. In all other respects the structure is very similar to that of the orange tautomer of **1a**. The origin of the twist may be due to the unfavourable *peri* interaction between the *ortho* methoxy group and the hydrogen on C(8) or an interaction with the hydrogen on N(3). There is also the possibility of lone-pair repulsion between N(3) and the oxygen of the methoxy group, although this seems an unlikely explanation since a similar change in equilibrium concentration of the two tautomers is also seen with an *ortho* methyl substituent. Why should this twist of the aryl substituent result in a decreased concentration of the orange tautomer in [$^2H_6$]Me$_2$SO solution, making the reasonable assumption that restricted rotation persists in solution? In [$^2H_6$]Me$_2$SO equilibration of the two tautomers is assumed to be a base-catalysed intermolecular hydrogen transfer. When the aryl group does not have an *ortho* substituent it is assumed that the aryl ring will be in conjugation with the imidazole ring and will lie more in the plane of the molecule thus hindering access to the N(3) position, slowing down the rate of formation of the yellow tautomer. In cases where the aryl group has an *ortho* substituent then it is possible that the twisting of the ring out of the plane allows freer access to the N(3) position. The effect of a 4-nitro substituent in increasing the concentration of the orange tautomer **B** is possibly due to an electronic effect. The powerful electron-withdrawing effect of the nitro group may, in effect, force the imidazole ring nitrogen to conjugate with the aromatic ring resulting in enhanced planarity and destabilisation of the yellow **B** tautomer. It has been suggested by a referee that the anomalous results may be due to the effect of the N(9) aryl group upon the basicity of N(7). This, in turn, could affect the H-bonding strength with the amide N–H favouring the yellow tautomer **B** (Fig. 4). It might be expected that such an effect should be evident from the ^{1}H chemical shifts of the N–H protons and, in particular, the ^{13}C chemical shifts of the amide C=O group. There is certainly a difference in the ^{13}C chemical shifts seen for the orange tautomers (δ 166) when compared with those of the yellow tautomers (δ 169), but this difference does not change significantly with a change in the aryl substituent.

Experimental

The 4-(cyanoformimidoyl)-1-arylimidazol-5-amines and (*Z*)-*N*^{1}-(2-amino-1,2-dicyanovinyl)-*N*^{2}-arylformamidines used in this work were prepared by the procedure described previously.[6] All solvents were purified and dried by established procedures.[11]

IR spectra were recorded either on a Perkin-Elmer model 298 or Shimadzu IR-435 spectrometer, ^{1}H and ^{13}C NMR spectra on a Bruker XL300 spectrometer, and mass spectra on a Kratos Concept instrument.

Crystallography.—Crystal data and refinement details for the compound **1hA** are presented in Table 6. The crystal was mounted on a glass fibre. All measurements were performed on a Rigaku AFC6S diffractometer employing graphite monochromated Mo-Kα radiation. The data were collected at a temperature of 23 ± 1 °C using the ω scanning technique to a maximum of 2θ value of 50.1. The structures were solved by direct methods using SHELX86[12] and refined by blocked-matrix least-squares based of *F* using SHELX76.[13] Non-hydrogens were refined anisotropically. Hydrogen atoms were refined isotropically or were included in the structure factor calculation in idealized positions, and were assigned isotropic thermal parameters which were 20% greater than the equivalent *B* value of the atom to which they were bonded.

Tables of fractional atomic coordinates, bond lengths and angles and thermal parameters are available on request from the Cambridge Crystallographic Data Centre. For details of the

Table 6 Crystal data and details of refinement

Compound	**1h** (A)
Formula	$C_{16}H_{19}N_3O_5$
M	329.36
Crystal system	Monoclinic
Space group	$C2/c$
a/Å	13.626(6)
b/Å	9.190(4)
c/Å	28.24(1)
β/°	107.80(4)
U/Å^3	3367(5)
Z	8
D_c/g cm^{-3}	1.299
F(000)	1392
μ/cm^{-1}	0.87
Crystal size/mm	0.40 × 0.40 × 0.20
Scan speed/deg min^{-1}	8.0
Scan range/deg	$1.05 + 0.30 \tan \theta$
Maximum 2θ/deg	50.1
Total data measured*	3323
No. of unique reflections	3173
No. of observed reflections $[F_o > 3\sigma(F_o)]$	1619
No. of parameters	269
ρ_{min}, ρ_{max}/e Å^{-3}	−0.2, 0.2
Maximum least-squares shift-to-error ratio	< 0.01
Weighting scheme parameter g in $w = 1/[\sigma^2(F) + gF^2]$	0.03
Final R	0.051
Final R_w	0.068

CCDC deposition scheme, see 'Instructions for Authors (1994)', *J. Chem. Soc., Perkin Trans. 2*, 1994, issue 1.

Typical Procedure for the Reactions of 4-(*Cyanoformimidoyl*)-1-*arylimidazol*-5-*amines with Carbonyl Compounds*.—(*i*) *With acetone and pentan*-2-*one*. A suspension of the imidazole (2.1 mmol) in the dry carbonyl compound (10 cm^3) and dry ethanol (2 cm^3) was stirred at room temperature for 3 days to 3 weeks until TLC (Silica Gel 60 F_{254}; 9:1 $CHCl_3$–EtOH) showed complete reaction. The precipitate was filtered off and a second crop of crystals was obtained by concentrating the filtrate. The combined crystals were washed with either diethyl ether or light petroleum and dried under vacuum. The compounds were usually analytically pure, but the compounds can be recrystallised from acetone. Attempts to purify by column or flash chromatography using silica usually resulted in some decomposition.

(*ii*) *With benzaldehyde*. Benzaldehyde (1.9 mmol) was added to a stirred suspension of the imidazole (240 mg) in dry methanol or ethanol (2 cm^3) at room temperature. After 10 to 50 min a red–orange solid precipitated and this was filtered off and washed with diethyl ether to give an analytically pure product.

Typical Procedure for the Reactions of (Z)-N^1-(2-*Amino*-1,2-*dicyanovinyl*)-N^2-*arylformamidines with Acetone to form* 9-*Aryl*-6-*carbamoyl*-1,2-*dihydropurines*.—DBU (72 µl, 0.4 mmol) was added to a solution or suspension of the formamidine (0.46 mmol) in acetone (3 cm^3). A white solid precipitated immediately and ethanol (60 cm^3) was then added to redissolve it. The solution was stirred at room temperature for several hours and the homogeneous orange solution was concentrated using a rotary evaporator. Addition of diethyl ether resulted in precipitation of the dihydropurine, which was filtered off and washed with diethyl ether before being dried under vacuum. The product was usually pure by TLC and microanalysis and required no further purification.

Typical Procedure for the Reactions of (Z)-N^1-(2-*Amino*-1,2-*dicyanovinyl*)-N^2-*arylformamidines with Acetone to form Compounds* **4a–f**.—To a suspension or solution of the formamidine (1.8 mmol) in acetone (3–5 cm^3) was added DBU (100 µl, 0.65 mmol) using a microsyringe. The solution became homogeneous and within a few minutes (5–15 min) an off-white solid precipitated. This was filtered and washed with dry diethyl ether. Even in the solid state the solid gradually turned yellow, presumably due to the formation of the yellow tautomer of the dihydropurine. Similarly, attempts to determine the m.p.s of these compounds results in decomposition to the dihydropurines. A typical observation was that the solid on being heated turned yellow around 120 °C, changed to orange at around 140 °C and finally melted with decomposition at the same temperature as that recorded for the corresponding dihydropurine.

When the off-white solid (0.09 mmol) was dissolved either in ethanol or chloroform at room temperature the solution turned yellow almost immediately and then changed to orange. After 2 h the solution was concentrated almost to dryness and light petroleum (b.p. 40–60 °C) was added to give the dihydropurine in quantitative yield.

Formation of Compound **4b** *from* 4-(*Cyanoformimidoyl*)-1-*benzylimidazol*-5-*amine*.—A solution of (*Z*)-*N*^{1}-(2-amino-1,2-dicyanovinyl)-*N*^{2}-benzylformamidine (0.5 g, 2.22 mmol) in acetone (7 cm^3) was stirred at room temperature over a period of 1.5 h, and the off-white precipitate of **4b** (0.31 g, 1.1 mmol, 50%) was filtered off and washed with diethyl ether. The IR spectrum (Nujol mull) of this compound was identical with that prepared by the procedure described in the previous experiment.

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