Reactions of 1,2-Dimethylimidazole, Particularly its Metallation [1]

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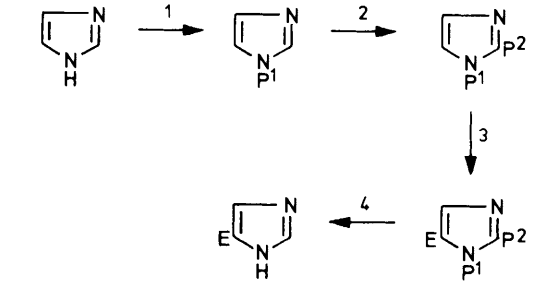
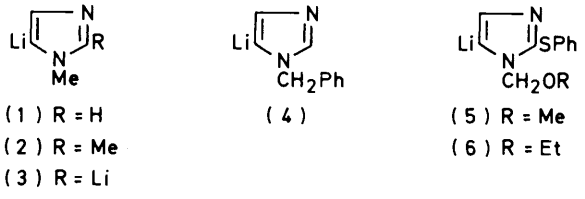
A re-examination of the metallation of 1,2-dimethylimidazole has shown that, after quenching of reaction mixtures with suitable reagents, single products may arise from substitution either in the 2-methyl group or in the 5-position or mixtures of both products may arise, depending on the metallating reagent, solvent, and reaction conditions. 1,2-Dimethylimidazol-5-yl-lithium was prepared by reaction of 1,2-dimethyl-5-trimethylstannylimidazole (13) with n-butyl-lithium in tetrahydrofuran at −100 °C. The corresponding 5-trimethylsilyl compound (12) was metallated by n-butyl-lithium exclusively in the 2-methyl group. 1,2-Dimethylimidazol-5-yl-lithium was shown to undergo transmetallation reactions at temperatures higher than −100 °C. An improved procedure is given for the synthesis of 1,2-dimethylimidazole-5-carbaldehyde *via* hydroxymethylation of 1,2-dimethylimidazole and oxidation of the 5-hydroxymethyl group with nitric acid.

In connection with other work we became interested in the problem of providing 4(5)-mono- and 4,5-di-substituted imidazoles, which are not particularly accessible by other routes, from relatively cheap commercially available imidazoles along lines suggested, for example (see later), in Scheme 1. This involves diprotection of imidazole in the 1- and 2-positions followed by substitution in the 5-position and removal of the protecting groups. Ideally, the protecting groups should be available from cheap reagents and removable at the same time under mild conditions.



Scheme 1

We considered that metallation of a suitably 1,2-diprotected imidazole, for example with a lithium compound, and reaction of the resulting imidazol-5-yl-metal derivative with suitable electrophiles would provide a useful way of accomplishing step 3 in Scheme 1. Only five imidazol-5-yl-lithium compounds, (1), (2), and (4)—(6), were known at the start of our work. The major isomer formed on metallation of 1-methylimidazole with 1 equivalent of n-butyl-lithium is the 2-isomer [the 5-isomer (1) is formed in <2% yield]; [2] 2 equivalents of n-butyl-lithium yield the dilithiated derivative (3).[3] With 1 equivalent of n-butyl-lithium 1-benzylimidazole similarly gives the 2-lithiated compound as the major product (30% yield of product) together with the 5-isomer (4) (12% yield).[4] 1,2-Dimethylimidazole is reported to be metallated by n-butyl-lithium [5] or phenylsodium [6] exclusively in the 5-position, to give compound (2) in the former case. A more recent investigation,[7] however, suggests that metallation of 1,2-dimethylimidazole with n-butyl-lithium can occur exclusively in the 2-methyl group but other investigators [8,9] have reported that metallation occurs both in the 5-position and in the 2-methyl group. Breslow's group [10] have described the synthesis of lithium compounds (5) and (6) by metallation of the corresponding 1,2-diprotected imidazole with lithium diisopropylamide (LDA) (n-butyl-lithium was reported to cleave the C–S bonds).



(1) R = H
(2) R = Me
(3) R = Li

(4)

(5) R = Me
(6) R = Et

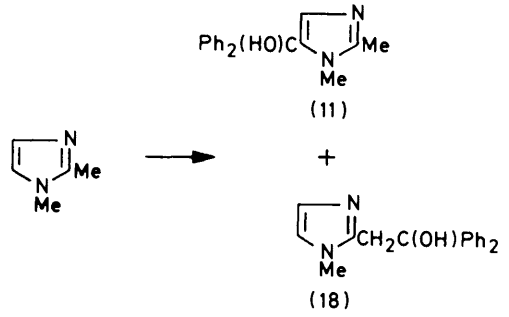
Imidazole is mercuriated in the 4(5)-position and its 4(5)-alkyl derivatives are mercuriated in the adjacent position [11,12] but there are obvious disadvantages to the use of mercury compounds.

In view of the commercial availability of 1,2-dimethylimidazole and the apparently conflicting reports in the literature regarding its metallation with n-butyl-lithium we decided first to exploit the synthesis and uses of 1,2-dimethylimidazol-5-yl-lithium (2) as a model system for further work on metallations of other 1,2-diprotected imidazoles.

Tertov *et al.*[5] reacted what they believed to be 1,2-dimethylimidazol-5-yl-lithium (2) with *N*-bromodiethylamine, iodophenylacetylene, dimethylformamide, benzaldehyde, and benzophenone to give what they claimed to be the 5-bromo-(7)(26%), 5-iodo- (8)(47.5%), and 5-formyl-derivatives (9)-(20%), and compounds (10)(59.5%) and (11)(73%), respectively. Because benzophenone gave the highest yield of quenched product we decided to re-investigate this reaction first. In our hands it gave a crude product (59%) (Table; expt. 1) which was shown by ^{1}N n.m.r. analysis (integration of the 1-Me singlets) to be a mixture of carbinols (11) and (18) (ratio 1 : 4). These were separated by fractional crystallisation and the major isomer, previously claimed by the Russians to be (11), was shown to be compound (18).

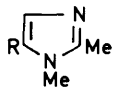
In attempts to metallate 1,2-dimethylimidazole regioselectively in the 5-position we have used various metallating reagents in different solvents under different reaction conditions. Benzophenone was used to quench the lithium compounds in all cases. The results are summarised in the Table. Using methyl-lithium (expt. 7), n-butyl-lithium (expts. 2→3→4), or t-butyl-lithium (expt. 8) in ether, higher temperatures were found to favour formation of the carbinol (11). Exclusive formation of this carbinol by direct metallation of 1,2-dimethylimidazole was not achieved, however. Whereas in most cases mixtures of the two carbinols were obtained, the

Table. Metallation of 1,2-dimethylimidazole



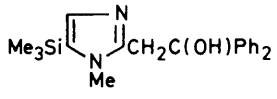
Expt. no.	Metallating agent	Solvent	Temp.[a] (°C)	Ratio (11) : (18)	Yield [b] (%)
1	Bu^nLi	Et_2O	−10° → −15°	1 : 4	59
2	Bu^nLi	Et_2O	R.T. → 0°	2 : 1	30
3	Bu^nLi	Et_2O	R.T. → R.T.	2.5 : 1	60
4	Bu^nLi	Et_2O	R.T. → reflux	3 : 1	63
5	Bu^nLi/TMEDA	Et_2O	−10° → −15°	0 : 1	57
6	Bu^nLi	Et_2O	−110° → −20° to −30°	0 : 1	54
7	MeLi	Et_2O	R.T. → R.T.	3 : 1	13.5
8	Bu^tLi	Et_2O	R.T. → R.T.	1.7 : 1	57
9	$LiN(Pr^i)_2$	Et_2O	−70° → 70°	0 : 1	1.3
10	PhNa	Et_2O	−15° → 15°	0 : 1	8 [c]
11	Bu^nLi	Hexane	0° → −15°	1 : 1.5	35
12	Bu^nLi	THF	0° → −15°	0 : 1	57

[a] The first temperature is that at which the metalling agent was added, the second that at which the reaction was quenched (R.T. is ambient temperature). [b] Total yield (%). [c] Literature yield 70%.



(7) R = Br
(8) R = I
(9) R = CHO
(10) R = CH(OH)Ph
(11) R = $C(OH)Ph_2$
(12) R = $SiMe_3$
(13) R = $SnMe_3$
(14) R = $SnBu_3$
(15) R = D
(16) R = SMe
(17) R = CH_2OH

(18) R = $CH_2C(OH)Ph_2$
(19) R = $CH_2CH(OH)$pyridyl-2
(20) R = $CH_2CH(OH)C_6H_4Me$-4
(21) R = CH_2SMe
(22) R = $C(SMe)_3$



(23)

use of n-butyl-lithium in ether in the presence of *NNN'N'*-tetramethylethylenediamine (TMEDA) (expt. 5), n-butyl-lithium in tetrahydrofuran (expt. 12), LDA in ether (expt. 9), or phenylsodium in ether (expt. 10) (*cf.* ref. 6) resulted in exclusive formation of carbinol (18). This carbinol (18) was formed exclusively also when 1,2-dimethylimidazole was metallated in ether with n-butyl-lithium at −110 °C and the reaction mixture quenched at −20 to −30 °C with benzophenone (expt. 6). Addition of benzophenone at −110 °C yielded only starting material.

Next we examined the effect of varying the quenching reagent. In agreement with the literature [7] successive treatment of 1,2-dimethylimidazole in ether at −15 °C with n-butyl-lithium, pyridine-2-carbaldehyde, and acid gave carbinol (19) (67%) as the only isolable product. Expansion of the multiplet at δ 2.90—3.40 p.p.m. in the ^1H n.m.r. spectrum of this compound allows the coupling constants to be extracted for the prochiral methylene group protons in this ABX system (J_{AB} = 15.4 Hz, J_{AX} = 4.02 Hz, and J_{BX} = 7.71 Hz). Similar expansion of the signal for the methine proton centred at δ 5.22 p.p.m. shows it to be two doublets with J_{BX} = 7.71 Hz and J_{AX} = 4.02 Hz. A similar product (20) (82% yield) was obtained by metallation of 1,2-dimethylimidazole in tetrahydrofuran at −110 °C with n-butyl-lithium followed by addition of 4-methylbenzaldehyde. The same compound (20) (70% yield) was obtained also following metallation of 1,2-dimethylimidazole in tetrahydrofuran at −74 °C with potassium di-isopropylamide-lithium t-butoxide (KDA) [13] followed by addition of 4-methylbenzaldehyde at −50 °C. In contrast, metallation of 1,2-dimethylimidazole followed by addition of benzaldehyde (see before) using the conditions described by Tertov *et al.*[5] (−15 °C) gave a low yield (21%) of carbinol (10) as the only isolable product. The yield improved slightly (33%) when the reaction was carried out at ambient temperature.

We were unable to repeat the preparations of 5-bromo- (7) and 5-iodo-1,2-dimethylimidazole (8) and 1,2-dimethylimidazole-5-carbaldehyde (9) described by Tertov *et al.*[5] When we attempted to repeat their synthesis of 5-bromo-1,2-dimethylimidazole (7) [5] a low yield of an impure product was obtained. In the other reactions starting materials were recovered. Metallation of 1,2-dimethylimidazole with n-butyl-lithium in ether at −10 °C followed by addition of *N*-bromosuccinimide (initially at −78 °C) gave 4,5-dibromo-1,2-dimethylimidazole (35% yield). In a similar reaction with iodine as the quenching reagent a low yield (16%) of 5-iodo-1,2-dimethylimidazole (8) was obtained. The low yields of the isolable products in these reactions may reflect the fact that

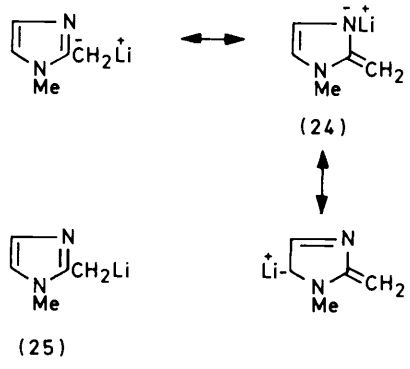
they are stable whilst other products formed are too unstable to isolate. In the reactions with elemental bromine or iodine or in the reaction with *N*-bromosuccinimide any 2-halogenomethyl derivatives formed would be expected to polymerise by attack on the basic ring N-atom.[14]

When 1,2-dimethylimidazole is metallated in ether with n-butyl-lithium at ambient temperature and the reactions quenched with chlorotrimethylsilane, chlorotrimethylstannane, or chlorotri-n-butylstannane, only the 5-substituted product, (12), (13), and (14), respectively, is formed in moderate to high yield. Tin compound (14) proved difficult to purify probably because, unlike trimethyltin hydroxide, a product in the synthesis of compound (13), which is very soluble in water and removable in the aqueous phase, tri-n-butyltin hydroxide is considerably more soluble in organic solvents.[15]

Quenching of a similar reaction mixture with deuterium oxide gave only the 5-deuteriated derivative (15) (50% yield), together with starting material (50% yield), with no trace of a product arising from deuteriation either in the 4-position or in the 2-methyl group. Quenching with dimethyl disulphide, even at −70 °C,* gave an inseparable mixture (ratio 1 : 1) (54% yield) of the 5-substituted derivative (16) (see later) and the 2-methylthiomethyl compound (21). When 1,2-dimethylimidazole was metallated in diethyl ether at ambient temperature with n-butyl-lithium and the mixture quenched with dimethyl disulphide at the same temperature prior to work-up in the usual way, a moderate yield (41%) of the orthothioacetal (22) was obtained. This arises presumably by initial formation of compound (21) followed by two successive metallation and quenching reactions.

In an attempt to displace the trimethylsilyl group in compound (12) we treated this compound with n-butyl-lithium in tetrahydrofuran at ambient temperature and quenched the product with benzophenone. The only compound isolated, (23), was that arising from metallation in the 2-methyl group. However, when the corresponding tin compound (13) was treated similarly (at −20 °C), the product was (18). Loss of the tin group in this case suggested initial exchange by lithium at this position. On lowering the temperature both of addition of n-butyl-lithium and benzophenone (in tetrahydrofuran) to −100 °C the only isolable product was (11) (94% yield). A C–Sn bond has a significantly lower dissociation energy (193 KJ mol^{-1}) than a C–Si bond (250—335 KJ mol^{-1}).[16] Thus, it is possible to prepare 1,2-dimethylimidazol-5-yl-lithium exclusively in this way. Apparently, at higher temperatures, transmetallation of the 2-methyl group occurs and leads to a different product. 1,2-Dimethyl-5-methylthioimidazole (16) was prepared unambiguously (quantitative yield) by successive treatment of the tin derivative (13) in tetrahydrofuran with n-butyl-lithium (at −100 °C), dimethyl disulphide (at −100 °C also), and acid.

In an extensive study on the metallation of 2-methylthiazole with n-butyl-lithium at −78 °C Crousier and Metzger [17,18] concluded that independent metallation in the 2-methyl group and in the 4- (trace only) and 5-positions occurs and that these lithium compounds are not formed by proton–metal equilibration. Following deuteriation of reaction mixtures formed at various temperatures these authors concluded that, even at −100 °C, the kinetic acidities of the C-5 and 2-methyl protons are very similar and that the 2-lithiomethyl derivative is unstable, decomposing almost entirely at 5 °C. They ruled out formation of a mesomeric anion analogous to (24).



Our results, particularly the deuteriation experiment in which only 5-deuterio-1,2-dimethylimidazole (15) could be detected in the product, appear to exclude a mesomeric ion (24) too as well as independent metallation in the 2-methyl group and in the 5-position. It seems more likely that the product of kinetic control of the reaction is the 2-lithiomethyl derivative (25) which rearranges by transmetallation reactions at higher temperatures. We have shown that the former lithium compound is formed exclusively on metallation of 1,2-dimethylimidazole in ether at −110 °C (Table; expt. 6). A Russian group [19] has reported that the protons in the 2-methyl group are the most acidic in 1,2-dimethylimidazole. Because of the proximity of the lithiomethyl group in compound (25) to the electron-withdrawing pyridine-like N-atom its C–Li bond is expected to be more polar in character and therefore weaker than the C–Li bond in the isomeric lithium compound (2). From the results summarised in the Table it can be seen that the yield of the product (11) arising from quenching 1,2-dimethylimidazol-5-yl-lithium (2) with benzophenone increases with temperature. The total yield of products formed in experiments 1, 3, and 4 is approximately the same in each case, however, which suggests that, as the amount of carbinol (11) increases, the amount of the isomeric carbinol (18) [arising from (25)] decreases correspondingly. Thus, in contrast to the behaviour at −100 °C of 2-methylthiazole [17,18] (already described), 1,2-dimethylimidazole appears to undergo regioselective metallation in its 2-methyl group at a similar temperature. The formation of compound (18) from tin compound (13) can only be explained by initial formation of 1,2-dimethylimidazol-5-yl-lithium (proved by the low temperature quenching reactions with benzophenone and dimethyl disulphide) and transmetallation of its 2-methyl group at the higher temperatures.

As well as the amount of each lithium compound, (2) or (25), present, which we have shown is dependent on temperature, the major factor determining the nature of the product appears from our results to be the hardness or softness of the quenching electrophile.[20] Removal of a proton from the 5-position of 1,2-dimethylimidazole generates a harder base (anionic charge present in a sp^2-hybridised orbital) than removal of one from the 2-methyl group (charge probably present in a p-orbital, assuming sp^2-hybridisation of the side-chain C-atom). Thus, the harder acids (electrophilic quenching reagents) [D_2O, R_3SnCl (R = Me, Bu), Me_3SiCl] give rise to products of exclusive substitution in the 5-position whilst softer reagents, *e.g.* Me_2S_2, give rise to mixtures of products when both lithium compounds are present. Thus, whether quenching reagents lead to products of exclusive substitution in the 2-methyl group or in the 5-position or give mixtures will depend on their relative rates of reaction with the two lithium compounds, (2) and (25). This, in turn, is determined by the hardness or softness of the quenching reagent.

* In this experiment the 1,2-dimethylimidazole was metallated in diethyl ether in the presence of TMEDA at −70 °C, after which the mixture was allowed to warm to ambient temperature before being re-cooled to −70 °C prior to quenching

The other results summarised in the Table reflect change both in type and aggregation size of the metallating reagent. Kinetically, Type I metallating reagents (alkyl- or aryl-lithium compounds) become more basic as the aggregate size diminishes whilst Type II reagents (*e.g.* n-butyl-lithium–amine complexes and lithium dialkylamides) are more basic kinetically than Type I reagents.[21] Thus, the carbinol (18) is formed exclusively by metallation of 1,2-dimethylimidazole with n-butyl-lithium in tetrahydrofuran (Table; expt. 12) (the reagent is dimeric in this solvent and therefore more basic kinetically [21]) whereas, in hexane (in which the reagent is believed to be hexameric [21]) a mixture of the isomeric carbinols, (11) and (18) (ratio 1 : 1.5) (Table; expt. 11) is formed. The kinetically more basic n-butyl-lithium–TMEDA complex also yields carbinol (18) exclusively, even in ether (Table; expt. 5).

Noteworthy is the fact that we have not detected products arising from metallation in the 1-methyl group whereas metallation of 1-methylpyrazole and its derivative occurs in the 1-methyl group as well as in other positions to give anions that are reported [22] to be interconvertible.

Another route to 4(5)-substituted 1,2-dimethylimidazoles of the type which we required for further work involves hydroxymethylation of 1,2-dimethylimidazole in the 5-position followed by oxidation of the hydroxymethyl group in the product to an aldehyde group with lead(IV) tetra-acetate in pyridine.[23] Minor modifications in procedure (see Experimental section) have allowed us to improve yields in the hydroxymethylation step from 25% to approximately 50%, whilst oxidation of the hydroxymethyl group with nitric acid [24] was preferred in our hands (yield 77%) to the use of lead(IV) tetra-acetate which gave yields inferior to those (70%) recorded in the literature.[23]

Experimental

I.r. spectra (liquids as films and solids as Nujol mulls between sodium chloride discs) were recorded with a Perkin-Elmer 257 spectrometer, ^{1}H n.m.r. spectra with a Perkin-Elmer R32 (90 MHz) or Varian Associates EM360 (60 MHz) instrument, ^{13}C n.m.r. spectra with a Varian Associates CFT20 spectrometer (20 MHz) (with $SiMe_4$ as internal standard in all cases), and mass spectra with an AEI-GEC MS902S or MS12 spectrometer.

Small-scale distillations were carried out with a Kugelrohr microdistillation apparatus and the ' b.p.' temperatures recorded in these cases are strictly speaking those of the oven at the time of distillation. In all cases organic extracts were combined, dried ($MgSO_4$), and evaporated on a rotary evaporator under reduced pressure and light petroleum had b.p. 40—60 °C, unless stated otherwise. Solvents were dried by standard procedures and all the metallation reactions were carried out under dry, oxygen-free nitrogen. 1,2-Dimethylimidazole and n-butyl-lithium in hexane were supplied by Aldrich Chemical Co. Column chromatography was carried out by gradient elution on ' Camag ' basic alumina (pH 9.3—9.7, 100—250 mesh) or ' Merck ' Kieselgel Type 60H. Ether refers to diethyl ether throughout.

1,2-Dimethylimidazol-5-yldiphenylmethanol (11) and *1-Methylimidazol-2-yl-methyldiphenylmethanol* (18) (*Table: Expt.* 4).—1.93M-n-Butyl-lithium in hexane (8.8 ml, 17.0 mmol) was added dropwise to a stirred solution of 1,2-dimethylimidazole (1.6 g, 17.0 mmol) in ether (40 ml) at ambient temperature. The mixture was stirred for 1.5 h, after which it was heated slowly to reflux temperature. Then a solution of benzophenone (3.1 g, 17.0 mmol) in ether (25 ml) was added dropwise. The mixture was heated under reflux for a further 1.5 h, water (20 ml) was added, and the mixture was stirred for 20 min before 10% aqueous hydrochloric acid (40 ml) was added. The aqueous layer was separated and basified with 4M-sodium hydroxide. The precipitate was filtered off, washed with water, and dried in a vacuum desiccator to give a product (2.88 g, 63%) shown by ^{1}H n.m.r. spectroscopy in deuteriochloroform (integration of 1-Me singlets) to be a mixture of the title methanols (ratio 3 : 1, respectively). Recrystallisation of the mixture from carbon tetrachloride gave *1-methylimidazol-2-ylmethyldiphenylmethanol* (18) (2.1 g, 45%), m.p. 186 °C; $\nu_{max.}$ 1 600 (Ph) and 3 050—3 300 cm^{-1} (OH); δ ($CDCl_3$) 3.30 (3 H, s, 1-Me), 3.51 (2 H, s, CH_2), 6.63 (1 H, s, 5-H), 6.88 (1 H, s, 4-H), and 7.25 p.p.m. (11 H, m, Ph_2 and OH); δ [$(CD_3)_2SO$] 147.50 (s, C-2), 145.55, 127.71, 126.75, 126.25, 125.64, and 120.53 * (Ph, C-4 and C-5), 76.72 (s, C-OH), 36.17 (q, 1-Me), and 32.14 p.p.m. (t, CH_2) (Found: C, 77.5; H, 6.3; N, 10.0%; M^+, 278. $C_{18}H_{18}N_2O$ requires C, 77.7; H, 6.5; N, 10.1%; *M*, 278); whilst several recrystallisations of the residue (after evaporation of the carbon tetrachloride) from the same solvent gave *1,2-dimethylimidazol-5-yl-diphenylmethanol* (11) (0.7 g, 15%), m.p. 170—171 °C (lit.,[5] 186—187 °C; wrong assignment of structure—see Discussion); $\nu_{max.}$ 1 600 (Ph) and 3 000—3 250 cm^{-1} (OH); δ ($CDCl_3$) 2.07 (3 H, s, 2-Me), 3.19 (3 H, s, 1-Me), 5.90br (1 H, s, exchangeable, OH), 5.95 (1 H, s, H-4), and 7.28 p.p.m. (10 H, m, Ph_2); δ ($CDCl_3$) 146.34 (s, C-2), 145.25 (s, C-5), 135.98 (s, quaternary aromatic C), 127.64, 126.81, 126.08, and 125.83 * (Ph and C-4), 76.40 (s, C-OH), 31.84 (q, 1-Me), and 12.68 p.p.m. (q, 2-Me) (Found: C, 76.6; H, 6.2; N, 9.6%; M^+, 278).

1-Methylimidazol-2-ylmethyldiphenylmethanol (18) (*Table: Expt.* 6).—To a stirred solution of 1,2-dimethylimidazole (0.5 g, 5.2 mmol) in ether (30 ml) was added 1.12M-n-butyl-lithium in hexane (4.5 ml, 5.0 mmol) at −110 °C. After 1 h, the reaction mixture was warmed to −30 °C and benzophenone (0.9 g, 5.0 mmol) in ether (5 ml) was added slowly whilst the temperature was kept between −20 and −30 °C. After 30 min at − 20 °C, the mixture was warmed slowly to ambient temperature. Water (10 ml) was added and the product was extracted with chloroform to give 1-methylimidazol-2-ylmethyldiphenylmethanol (18) (0.78 g, 54%), m.p. 186 °C (from carbon tetrachloride), identical in other respects (i.r. and ^{1}H n.m.r. spectra and t.l.c.) with the sample prepared as described in the preceding experiment.

Metallation of 1,2-*Dimethylimidazole*; *Experiments summarised in the Table.*—Experiments 1—3, 5, 7—9, 11, and 12 (Table) were carried out in a manner similar to that described before for experiment 6. Experiment 10 with phenylsodium was carried out as described in the literature.[6] Where mixtures were formed the yield given is the total yield and the ratio (11) : (18) was obtained by integrating the 1-Me signals in the ^{1}H n.m.r. spectrum of the crude product in deuteriochloroform.

2-(*1-Methylimidazol-2-yl*)-1-(*2-pyridyl*)*ethanol* (19).—1.0M-n-Butyl-lithium in hexane (10 ml, 10.0 mmol) was added dropwise to a stirred solution of 1,2-dimethylimidazole (1.0 g, 10.0 mmol) in ether (80 ml) at −15 °C. After 25 min, pyridine-2-carbaldehyde (0.95 ml, 10.0 mmol) was added. The reaction mixture was allowed to warm gradually to ambient temperature; it was then stirred over a weekend. 50% Aqueous ammonium chloride (5 ml) was added, the ethereal layer collected, and the aqueous layer extracted with ether (5 × 40 ml) to give the *product* (19) as a pale yellow solid (1.33 g, 67%),

* These signals were too close together for meaningful assignments to be made.

m.p. 133—134 °C (from carbon tetrachloride–light petroleum); second recrystallisation from carbon tetrachloride–chloroform (with charcoal), m.p. 135—136 °C; $\nu_{max.}$ 3 000—3 300 cm^{-1} (OH); δ ($CDCl_3$) 2.90—3.40 (2 H, m, CH_2), 3.47 (3 H, s, 1-Me), 4.98br (1 H, s, exchangeable, OH), 5.22 (1 H, dd, CH), 6.76 (1 H, s, imidazole 5-H), 6.92 (1 H, s, imidazole 4-H), 7.10—7.30 (1 H, m, pyridine 5-H), 7.40—7.80 (2 H, m, pyridine 3-H and 4-H), and 8.55 p.p.m. (1 H, dd, pyridine 6-H); δ ($CDCl_3$) 161.98 (s, pyridine C-2), 147.96 (d, pyridine C-6), 145.75 (s, imidazole C-2), 136.32 (d, pyridine C-4), 126.34 (d, imidazole C-4), 121.77 (d, imidazole C-5), 120.00 (d, pyridine C-3 and C-5), 71.90 (d, CH), 33.32 (t, CH_2), and 32.06 p.p.m. (q, 1-Me) (Found: C, 65.1; H, 6.4; N, 20.7%; M^+, 203. $C_{11}H_{13}N_3O$ requires C, 65.0; H, 6.4; N, 20.7%; *M*, 203).

2-(1-*Methylimidazol*-2-*yl*)-1-(4-*methylphenyl*)*ethanol* (20).—(*a*) 1.12M-n-Butyl-lithium in hexane (4.46 ml, 5.0 mmol) was added dropwise to a stirred solution of 1,2-dimethylimidazole (0.5 g, 5.0 mmol) in tetrahydrofuran (150 ml) at −110 °C. After 1.5 h, 4-methylbenzaldehyde (0.6 g, 5.0 mmol) was added dropwise at this temperature and the mixture was stirred for a further 30 min. The mixture was then allowed to warm slowly to ambient temperature, water (10 ml) was added, and work-up in the usual way gave the *title compound* (20) (0.9 g, 82%), m.p. 161 °C (from chloroform–carbon tetrachloride); $\nu_{max.}$ 3 000—3 300 cm^{-1} (OH); δ [$CDCl_3$–$(CD_3)_2$SO] 2.28 (3 H, s, Me), 2.92 (2 H, d, CH_2), 3.38 (3 H, s, 1-Me), 4.65br (1 H, s, exchangeable, OH), 4.90 (1 H, t, CH), 6.80 (2 H, s, 4-H and 5-H), and 7.15 p.p.m. (4 H, m, aromatic); δ [$CDCl_3$–$(CD_3)_2$SO] 145.76 (s, imidazole C-2), 140.56 (s, quaternary aromatic C-4), 136.27 (s, quaternary aromatic C-1), 128.39 (d, imidazole C-4), 126.22 (d, aromatic C-2 and C-6), 125.09 (d, imidazole C-5), 119.87 (d, aromatic C-3 and C-5), 71.32 (d, C-OH), 35.57 (t, CH_2), 31.87 (q, 1-Me), and 20.53 p.p.m. (q, Me) (Found: C, 72.2; H, 7.5; N, 12.95%; M^+, 216. $C_{13}H_{16}N_2O$ requires C, 72.2; H, 7.5; N, 12.95%; *M*, 216).

(*b*) To a stirred solution of potassium t-butoxide (0.34 g, 3.0 mmol) and di-isopropylamine (0.30 g, 3.0 mmol) in tetrahydrofuran (6.0 ml) cooled to −74 °C was added 1.76M-n-butyl-lithium in hexane (1.36 ml, 2.4 mmol). The mixture was stirred at − 74 °C for 10 min and a solution of 1,2-dimethylimidazole (0.19 g, 2.0 mmol) in tetrahydrofuran (3 ml) was added dropwise. After 20 min the reaction mixture was warmed to −50 °C and 4-methylbenzaldehyde (0.36 g, 3.0 mmol) was added using a syringe. The mixture was allowed to warm gradually to ambient temperature and stirred for a further 10 min at this temperature. Methanol (2.0 ml) was added, followed by 20% aqueous ammonium chloride (3 ml). The solvent and unchanged volatile reagents were removed by distillation under reduced pressure and the residue extracted with chloroform, to give the product (20) (0.3 g, 70%), m.p. 161 °C (from carbon tetrachloride–chloroform) identical in other respects (t.l.c. and i.r., and ^1H and ^{13}C n.m.r. spectra) with the sample prepared as described in (*a*).

1,2-*Dimethylimidazol*-5-*ylphenylmethanol* (10).—1.93M-n-Butyl-lithium in hexane (8.8 ml, 17.0 mmol) was added to a stirred solution of 1,2-dimethylimidazole (1.6 g, 17.0 mmol) in ether (25 ml) at ambient temperature followed, after 2 h, by addition of benzaldehyde (1.8 g, 17.0 mmol). The mixture was stirred for a further 1.5 h, water (5 ml) was added, and the mixture was extracted with 10% hydrochloric acid (2 × 20 ml). The combined acidic extracts were made alkaline by addition of 4M-sodium hydroxide and the precipitate was filtered off, washed with water, and dried to give the crude product (10), (1.1 g, 33%), m.p. 195—197 °C (from toluene) (lit., 194—195 °C,[9] 178—179 °C,[8] and 177—178 °C [5]); $\nu_{max.}$ 3 200—3 700 cm^{-1} (OH); δ [$CDCl_3$–$(CD_3)_2$SO] 2.27 (3 H, s, 2-Me), 3.47 (3 H, s, 1-Me), 5.74 (1 H, s, CH), 6.31 (1 H, s, H-4), and 7.35 p.p.m. (6 H, m, Ph and OH) (Found: M^+, 202. $C_{12}H_{14}N_2O$ requires *M*, 202).

5-*Iodo*-1,2-*dimethylimidazole* (8).—1.9M-n-Butyl-lithium in hexane (8.8 ml, 17.0 mmol) was added during a period of 1 h to a stirred solution of 1,2-dimethylimidazole (1.5 ml, 1.62 g, 17.0 mmol) in ether (45 ml) at 0 °C. The resulting mixture was stirred at 0 °C for 1 h, after which it was cooled to −74 °C. Finely ground iodine (4.3 g, 17.0 mmol) was added in one portion. Stirring was continued for 1.5 h at −74 °C after which the reaction mixture was allowed to warm slowly to ambient temperature; it was then stirred for a further 3 h at this temperature. The mixture was then poured into 0.1M-sodium thiosulphate, and the product (8) (0.3 g) filtered off, washed with ether, and dried in a vacuum desiccator. Additional product (8) (0.31 g) was obtained from the ethereal extracts, giving a total yield of 16.0%, m.p. 182—183 °C (crude) (lit.,[5] 182—183 °C); δ[$(CD_3)_2$SO–$(CD_3)_2$CO] 2.40 (3 H, s, 2-Me), 3.52 (3 H, s, 1-Me), and 6.89 p.p.m. (1 H, s, 4-H) (Found: M^+, 222. $C_5H_7IN_2$ requires *M*, 222).

4,5-*Dibromo*-1,2-*dimethylimidazole*.—1.93M-n-Butyl-lithium in hexane (18.0 ml, 35.0 mmol) was added dropwise to a stirred solution of 1,2-dimethylimidazole (3.0 g, 31.0 mmol) in ether (25 ml) at −10 °C. The reaction mixture was stirred for 1.0 h and then cooled to −78 °C. *N*-Bromosuccinimide (10.5 g, 59.2 mmol) was added. After 30 min, the reaction mixture was allowed to warm slowly to ambient temperature after which water (25 ml) was added followed by saturated aqueous sodium hydrogensulphite (5 ml) and 10% sulphuric acid (25 ml). The aqueous layer was collected and the organic layer extracted twice with 10% sulphuric acid. The combined aqueous extracts were made alkaline with 4M-sodium hydroxide and the precipitate was filtered off, washed with water, and dried in a vacuum desiccator, to give the product (2.8 g, 35%), m.p. 77—78 °C (from ethyl acetate) (lit.,[25] 88—90 °C); δ ($CDCl_3$) 2.40 (3 H, s, 2-Me) and 3.60 p.p.m. (3 H, s, 1-Me) (Found: M^+, 254. $C_5H_6Br_2N_2$ requires *M*, 254).

1,2-*Dimethyl*-5-*trimethylsilylimidazole* (12).—1.28M-n-Butyl-lithium in hexane (27.0 ml, 34.6 mmol) was added dropwise using a syringe to a stirred solution of 1,2-dimethylimidazole (3.2 g, 34.0 mmol) in ether (60 ml) at ambient temperature. After the mixture had been stirred for 1 h at ambient temperature, chlorotrimethylsilane (5.0 ml, 4.28 g, 39.4 mmol) was added slowly. A white precipitate appeared after 1 h. The reaction mixture was stirred for a further 6 h, water (15 ml) was added, the ethereal layer was separated, and the aqueous layer extracted twice with ether (2 × 20 ml). The combined organic layer and ethereal extracts were dried (Na_2SO_4) and the solvent removed to give a dark green oil. Distillation (Kugelrohr apparatus) gave white shiny crystals of the *trimethylsilylimidazole* (12) (4.05 g, 72%), b.p. 45—50 °C at 0.1 mmHg, m.p. 89—90 °C (from hexane); $\nu_{max.}$ 750, 840, 1 250, and 1 460 cm^{-1} (C–Si); δ ($CDCl_3$) 0.30 (9 H, s, $SiMe_3$), 2.35 (3 H, s, 2-Me), 3.55 (3 H, s, 1-Me), and 6.91 p.p.m. (1 H, s, 4-H); δ ($CDCl_3$) 148.30 (s, C-2), 136.23 (d, C-4), 130.0 (s, C-5), 32.49 (q, 1-Me), 12.56 (q, 2-Me), and 1.35 p.p.m. (q, $SiMe_3$) (Found: C, 57.25; H, 9.5; N, 16.5%; M^+, 168. $C_8H_{16}N_2Si$ requires C, 57.1; H, 9.6; N, 16.6%; *M*, 168).

1,2-*Dimethyl*-5-*trimethylstannylimidazole* (13).—1.12M-n-Butyl-lithium in hexane (17.9 ml, 20.0 mmol) was added dropwise to a stirred solution of 1,2-dimethylimidazole (2.0 g, 20.0 mmol) in ether (100 ml) at ambient temperature. After 3.5 h a solution of chlorotrimethylstannane (4.0 g, 20.0 mmol) in

ether (15 ml) was added and the reaction mixture was kept overnight at ambient temperature. Saturated aqueous ammonium chloride (20 ml) was added, the ethereal layer separated, and the aqueous layer extracted with ether (3 × 20 ml) to give a pale yellow solid. This was sublimed at 80 °C and 0.5 mmHg, to give the *product* (13) (3.0 g, 58%), m.p. 96 °C, $\nu_{max.}$ 730—820 cm^{-1} (SnMe); δ ($CDCl_3$) 0.34 (9 H, s, $SnMe_3$), 2.40 (3 H, s, 2-Me), 3.57 (3 H, s, 1-Me), and 6.85 p.p.m. (1 H, s, 4-H); δ ($CDCl_3$) 147.46 (s, C-2), 135.60 (d, C-4), 129.28 (s, C-5), 33.44 (q, 1-Me), 12.68 (q, 2-Me), and −9.62 p.p.m. (q, $SnMe_3$) (Found: C, 37.1; H, 6.0; N, 11.15%; M^+, 260. $C_8H_{16}N_2Sn$ requires C, 37.1; H, 6.2; N, 10.8%; *M*, 260.

1,2-*Dimethyl*-5-*tri*-*n*-*butylstannylimidazole* (14).—1.0M-n-Butyl-lithium in hexane (12.0 ml, 12.0 mmol) was added to a stirred solution of 1,2-dimethylimidazole (1.2 g, 12.0 mmol) in ether (60 ml) at ambient temperature. After 1 h, a solution of chlorotri-n-butylstannane (3.9 g, 12.0 mmol) in ether (20 ml) was added dropwise and the reaction mixture was stirred for a further 3.5 h at this temperature. Saturated aqueous ammonium chloride (10 ml) was added and work-up as described in the preceding experiment gave a yellow oil (6.25 g) which proved difficult to purify (see Discussion). It was chromatographed on alumina. Gradient elution with ethyl acetate–light petroleum gave a product (14) with the following spectroscopic properties: $\nu_{max.}$ 750 cm^{-1} (C–Sn); δ ($CDCl_3$) 0.60—1.80 (27 H, m, 3 × Bu^n), 2.42 (3 H, s, 2-Me), 3.56 (3 H, s, 1-Me), and 6.89 p.p.m. (1 H, s, 4-H); δ ($CDCl_3$) 147.57 (s, C-2), 136.44 (d, C-4), 129.12 (s, C-5), 33.69 (q, 1-Me), 26.72 (q, 2-Me), 27.68 (t, CH_2), 15.84 (t, CH_2), 13.14 (q, Me in Bu^n), and 9.62 p.p.m. (t, CH_2Sn) (Found: M^+, 386. $C_{17}H_{34}N_2Sn$ requires *M*, 386). The spectra also exhibited peaks due to a trace of impurity.

5-*Deuterio*-1,2-*dimethylimidazole* (15).—To a stirred solution of 1,2-dimethylimidazole (2.0 g, 20.0 mmol) in ether (100 ml) was added 1.44M-n-butyl-lithium in hexane (14.0 ml, 20.0 mmol) at ambient temperature. After 2.5 h, deuterium oxide (10.0 ml) was added and the mixture was stirred vigorously for 20 min. Sodium chloride was added to saturate the aqueous phase and the mixture was shaken vigorously for a few min. The ethereal layer was separated and the aqueous layer extracted with dry ether. The ethereal layer and extracts were combined, dried ($MgSO_4$), and the solvent evaporated, to give a pale orange oil (2.01 g, 100%), shown by ^1H n.m.r. spectroscopy to be a mixture of the title compound (15) and starting material (ratio *ca.* 1 : 1); δ ($CDCl_3$) 2.37 (6 H, s, 2-Me), 3.60 (6 H, s, 1-Me), 6.94 (1 H, s, 4-H), and 7.00 p.p.m. (2 H, s, 4-H and 5-H) (Found: M^+, 96 and 97. $C_5H_8N_2$ and $C_5DH_7N_2$ require *M*, 96 and *M*, 97, respectively).

1,2-*Dimethyl*-5-*methylthioimidazole* (16) *and* 1-*Methyl*-2-*methylthiomethylimidazole* (21).—1.28M-n-Butyl-lithium in hexane (13.3 ml, 17.0 mmol) was added to a solution of TMEDA (1.97 g, 17.0 mmol) in ether (25 ml) at −70 °C. The mixture was stirred for 15 min after which a solution of 1,2-dimethylimidazole (1.6 g, 17.0 mmol) in ether (25 ml) was added. After a further 1 h at −70 °C, the reaction mixture was allowed to warm gradually to ambient temperature and stirred for 15 min. Then it was re-cooled to −70 °C and a solution of dimethyl disulphide (1.6 g, 17.0 mmol) in ether (20 ml) was added dropwise; the mixture was then stirred for a further 3 h. Water (10 ml) was added, the organic layer was collected, and the aqueous layer extracted with ether (3 × 20 ml). The combined extracts were dried and solvent evaporated to give a yellow oil (2.3 g) which was chromatographed on silica. Ethyl acetate–methanol eluted a small amount of unchanged dimethyl disulphide, an inseparable mixture of the title compounds (1.29 g, 54%) [δ ($CDCl_3$) 2.03 (3 H, s, SMe′), 2.20 (3 H, s, 2-Me), 2.36 (3 H, s, SMe), 3.55 (3 H, s, 1-Me′), 3.67 (3 H, s, 1-Me), 3.74 (2 H, s, CH_2), 6.85 (1 H, s, 5′-H), 6.88 (1 H, s, 4′-H), and 7.05 p.p.m. (1 H, s, 4-H)], and a small amount of unchanged 1,2-dimethylimidazole.

1,2-*Dimethyl*-5-*methylthioimidazole* (16).—1.12M-n-Butyl-lithium in hexane (1.1 ml, 1.2 mmol) was added dropwise to a stirred solution of 1,2-dimethyl-5-trimethylstannylimidazole (0.3 g, 1.2 mmol) in tetrahydrofuran (25 ml) at −100 °C. After 1 h, dimethyl disulphide (0.2 ml, 0.212 g, 2.4 mmol) was added. The reaction mixture was allowed to warm to ambient temperature and stirred for a further 1.5 h. Saturated aqueous ammonium chloride (5 ml) was added and work-up in the usual way gave a yellow oil which was chromatographed on alumina. Gradient elution with light petroleum–ethyl acetate gave the *product* (16) (0.16 g, 100%) as a colourless oil which became semicrystalline on cooling; $\nu_{max.}$ 1 260, 1 400, and 1 440 cm^{-1} (SMe); δ ($CDCl_3$) 2.25 (3 H, s, 2-Me), 2.45 (3 H, s, SMe), 3.64 (3 H, s, 1-Me), and 7.13 p.p.m. (1 H, s, 4-H); δ ($CDCl_3$) 147.17 (s, C-2), 133.39 (d, C-4), 132.07 (s, C-5), 29.78 (q, 1-Me), 20.77 (q, 2-Me), and 13.90 p.p.m. (q, SMe) (Found: M^+, 142.0564. $C_6H_{10}N_2S$ requires *M*, 142.0564).

1-*Methyl*-2-*tris*(*methylthio*)*methylimidazole* (22).—1.28M-n-Butyl-lithium in hexane (12.2 ml, 15.6 mmol) was added dropwise to a stirred solution of 1,2-dimethylimidazole (1.5 g, 15.6 mmol) in ether (40 ml) at ambient temperature. After 1.5 h, dimethyl disulphide (1.5 g, 15.6 mmol) in ether (2 ml) was added dropwise. Stirring was continued for a further 3 h at ambient temperature, after which water (10 ml) was added the organic layer separated, and the aqueous layer extracted twice with ether (2 × 20 ml) to give the *orthothioester* (22) (0.9 g) as an orange, viscous oil, which solidfied on cooling, m.p. 125—126 °C (from light petroleum–toluene); $\nu_{max.}$ 1 280 and 1 440 cm^{-1} (SMe); δ ($CDCl_3$) 2.00 (9 H, s, SMe), 4.04 (3 H, s, 1-Me), and 6.92 (2 H, s, 4-H and 5-H); δ ($CDCl_3$) 142.81 (s, C-2), 125.21 (d, C-4), 123.61 (d, C-5), 69.34 (s, quaternary side-chain C), 34.54 (q, 1-Me), and 12.59 p.p.m. (q, S–Me_3) [Found: C, 41.1; H, 6.0; N, 11.7%; M^+, 234.0316; M^+–SMe, 187.0362; M^+ − $C(SMe)_3$, 81.0449. $C_8H_{14}N_2S_3$ requires C, 41.0; H, 6.0; N, 11.95%; *M*, 234.0317; *M* − SMe, 187.0362; *M* − $C(SMe)_3$, 81.0453].

1-*Methyl*-5-*trimethylsilylimidazol*-2-*yldiphenylmethanol* (23).—1.76M-n-Butyl-lithium in hexane (1.36 ml, 2.4 mmol) was added dropwise to a stirred solution of 1,2-dimethyl-5-trimethylsilylimidazole (10) (0.34 g, 2.0 mmol) in tetrahydrofuran (12 ml) at ambient temperature. After 2.5 h, a solution of benzophenone (0.36 g, 2.0 mmol) in tetrahydrofuran (6 ml) was added. A deep red solution was obtained which eventually turned yellow. After the mixture had been stirred at 22 °C for a further 2.5 h, 20% aqueous ammonium chloride (5 ml) was added, the organic layer was separated, and the aqueous layer extracted twice with ether to give an off-white solid, which was recrystallised from carbon tetrachloride (with charcoal), to give the *product* (23) (0.18 g, 26%), m.p. 174 °C; $\nu_{max.}$ 760, 840, 1 250, and 1 470 (C–Si) and 3 050—3 200 cm^{-1} (OH); δ ($CDCl_3$) 0.44 (9 H, s, $SiMe_3$), 3.46 (3 H, s, 1-Me), 3.75 (2 H, s, CH_2), 7.15 (1 H, s, H-4), and 7.50 p.p.m. (11 H, m, Ph_2 and OH); δ ($CDCl_3$) 149.05 (s, C-2), 146.85 (s, C-5), 136.23 (d, C-4), 127.81, 126.59, and 125.98 * (aromatic), 37.49 (t, CH_2), 32.35 (q, 1-Me), and 1.08 p.p.m. (q, Si–Me_3) (Found: C, 72.7;

* The C–OH signal overlapped with the signals due to the solvent ($CDCl_3$) whilst only three signals were visible as a multiplet for the aromatic C-atoms.

H, 7.4; N, 8.0%; M^+, 350. $C_{21}H_{26}N_2OSi$ requires C, 72.0; H, 7.5; N, 8.0%; *M*, 350).

Reaction of 1,2-*Dimethyl-5-trimethylstannylimidazole* (13) *with n-Butyl-lithium.*—(*a*) *At* −15 *to* −20 °C. A solution of 1,2-dimethyl-5-trimethylstannylimidazole (13) (0.3 g, 1.15 mmol) in tetrahydrofuran (20 ml) was cooled to −20 °C and 1.12M-n-butyl-lithium in hexane (1.1 ml, 1.2 mmol) was added at such a rate that the temperature did not rise above −18 °C. After 1.25 h, a solution of benzophenone (0.22 g, 1.2 mmol) in tetrahydrofuran (3 ml) was added dropwise between −20 and −15 °C. The reaction mixture was then allowed to warm slowly to ambient temperature; saturated aqueous ammonium chloride (4 ml) was added and the organic layer was separated. The aqueous layer was then extracted twice with chloroform to give a pale yellow solid. This was washed several times with ether to give 1-methylimidazol-2-ylmethyldiphenylmethanol (18) (0.15 g, 47%), m.p. 186 °C (from carbon tetrachloride), identical in other respects (t.l.c. and i.r. and ^{1}H n.m.r. spectra) with the samples prepared as described before.

(*b*) *At* −100 °C. The reaction described in (*a*) was repeated at −100 °C and gave 1,2-dimethylimidazol-5-yldiphenylmethanol (11) (0.3 g, 94%), m.p. 170—171 °C (from carbon tetrachloride), identical in other respects (i.r. and ^{1}H n.m.r. spectra) with the samples prepared as described before.

5-*Hydroxymethyl*-1,2-*dimethylimidazole* (17).—A mixture of 1,2-dimethylimidazole (14.0 g, 0.15 mol) and 37% (w/v) aqueous formaldehyde (220 ml) in a buffer medium of acetic acid (20 ml) and anhydrous sodium acetate (24.6 g, 0.3 mol) was heated gently under reflux for 2 to 3 days. The excess of aqueous formaldehyde was removed by distillation under reduced pressure (water pump) until solid began to appear. Water (100 ml) was added and this process was repeated twice. The residue was made alkaline by addition of 4M-potassium hydroxide. Sodium chloride was added until the solution became saturated and the resulting mixture was extracted continuously with chloroform for 12 h. The extract was dried ($MgSO_4$) and the solvent removed to give a pale yellow solid, which was washed several times with ether. This solid was boiled with a carbon tetrachloride–chloroform (9 : 1) mixture to give the product (17) (8.2—8.6 g, 45—47%), m.p. 164—165 °C (from chloroform–carbon tetrachloride) (lit.,[23] 166—167 °C); δ [$CDCl_3$–$(CD_3)_2SO$] 2.30 (3 H, s, 2-Me), 3.53 (3 H, s, 1-Me), 4.50 (2 H, s, CH_2), 4.52 (1 H, s, exchangeable, OH), and 6.70 p.p.m. (1 H, s, 4-H); δ [$CDCl_3$–$(CD_3)_2SO$] 145.62 (s, C-2), 131.35 (s, C-5), 125.28 (d, C-4), 53.81 (t, CH_2), 29.99 (q, 1-Me), and 12.69 p.p.m. (q, 2-Me).

1,2-*Dimethylimidazole*-5-*carbaldehyde* (9).—A mixture of 5-hydroxymethyl-1,2-dimethylimidazole (4.0 g, 31.7 mmol) and concentrated nitric acid (5.6 ml, large excess) was heated on a steam-bath for 4 h. On cooling, a saturated solution of potassium carbonate was added until carbon dioxide gas evolution ceased. The precipitated inorganic material was filtered off and washed several times with chloroform. The filtrate was extracted with chloroform (4 × 20 ml). The combined extracts were dried ($MgSO_4$), and the solvent evaporated off, to give an off-white solid. The crude product was boiled in carbon tetrachloride. Any insoluble material was filtered off and the filtrate evaporated, to give the pure aldehyde (9) (3.0 g, 77%), m.p. 77—78 °C (from light petroleum–carbon tetrachloride) (lit., m.p. 77—78 °C[5]; 75—77 °C [23]); $\nu_{max.}$ 1 660 cm^{-1} (CO); δ ($CDCl_3$) 2.44 (3 H, s, 2-Me), 3.90 (3 H, s, 1-Me), 7.70 (1 H, s, 4-H), and 9.70 p.p.m. (1 H, s, CHO); δ ($CDCl_3$) 178.46 (d, CHO), 152.35 (s, C-2), 142.69 (d, C-4), 131.73 (s, C-5), 31.98 (q, 1-Me), and 12.68 p.p.m. (q, 2-Me).

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