Ring Expansion and Rearrangement Reactions of *N*-Heteroarylmethyl Radicals

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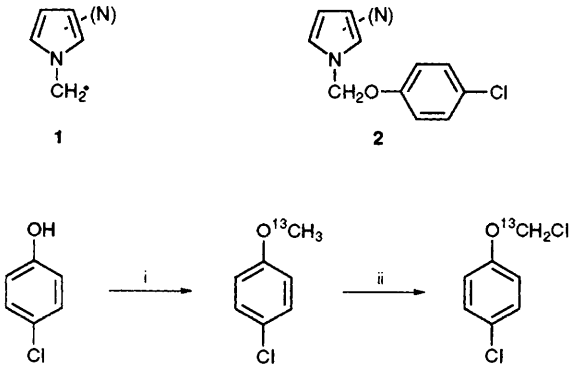
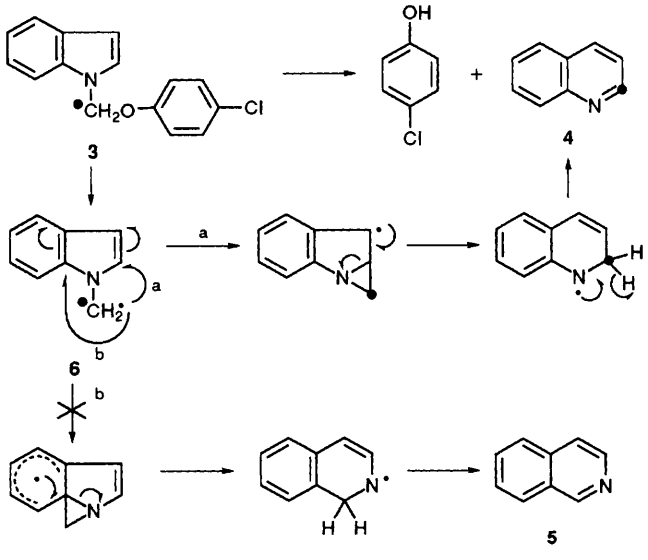
Flash vacuum pyrolysis of *N*-(*p*-chlorophenoxymethyl)azoles (*e.g.* **2** and **3**) gives ring expanded products (*e.g.* **4** and **8**) formed *via* *N*-heteroarylmethyl radicals (*e.g.* **1** and **6**); the mechanism of ring expansion generally involves a novel 'walk'-rearrangement of the radical centre.

There is considerable current interest in ring-expansion reactions of carbon-centred radicals, generated in solution under standard reductive conditions.[1] We describe here a gas-phase variant of these processes which leads to oxidative ring-expansion of *N*-heteroarylmethyl radicals **1** *via* novel 'walk' rearrangements of the intermediates.

The radicals **1** were generated (along with the *p*-chlorophenoxyl radical) by flash vacuum pyrolysis (FVP) of the corresponding *N*-(4-chlorophenoxy)methyl derivative **2** at 700 °C. The precursors **2**† were themselves obtained in *ca.* 60% yield by alkylation of the parent heterocycle using α,4-dichloroanisole under basic conditions in dimethyl sulfoxide solution.[2] ^{13}C-Labelled dichloroanisole was obtained by the method shown in Scheme 1.[3,4]



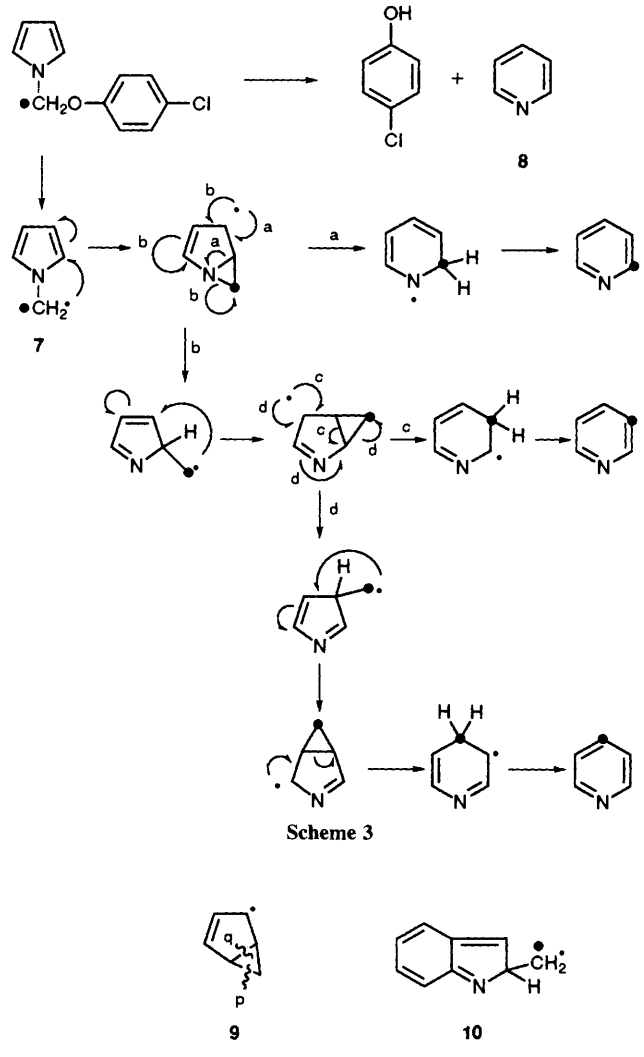
Scheme 1 *Reagents and conditions:* i, $^{13}CH_3I$, K_2CO_3, dimethylformamide; ii, PCl_5, heat



Scheme 2

FVP of the indolyl derivative **3** at 700–800 °C (10^{-2} Torr‡) gives rise to *p*-chlorophenol (90%) as expected, and to quinoline **4**, (66%) as the only ring-expanded product. No isoquinoline **5** could be detected. The expansion process is therefore initiated exclusively by attack of the *N*-indolylmethyl radical **6** at the 2-position of the indole ring (Scheme 2 route a). Well-precedented attack at the 7a-position by a neophyl-type rearrangement[5,6] (Scheme 2 route b) which would give rise to isoquinoline, clearly does not occur in this case. The mechanism was confirmed by pyrolysis of a ^{13}C-labelled derivative (highlighted atoms in Scheme 2), and, as predicted, the majority of the label (>90%) is found at C-2 of the quinoline (^{13}C NMR).

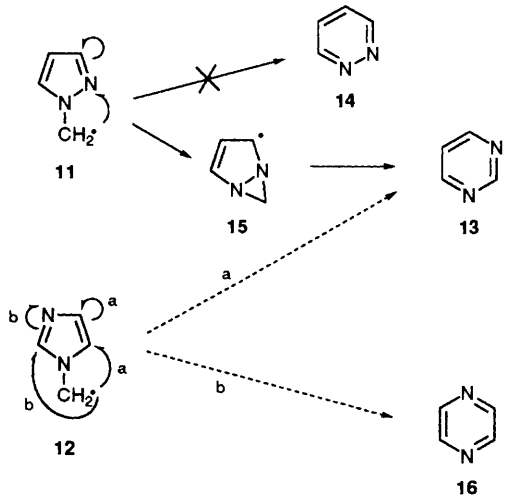
Although ring-expansion of the *N*-pyrrolylmethyl radical **7** similarly gives pyridine (**8**; 59%), the detailed mechanism of the rearrangement as revealed by the labelling experiment (^{13}C NMR), differs significantly from the *N*-indolylmethyl



Scheme 3

† All new compounds were characterised by their spectra and by elemental analysis.

‡ 1 Torr ≈ 133 Pa.



Scheme 4

case. Surprisingly, the label is distributed over all positions of the pyridine ring, with the majority located at the 3-position. This result may be explained by a 'walk'-rearrangement of the initial radical (Scheme 3).§ The occurrence of such a rearrangement is consistent with the results of an EPR study of the hydrocarbon analogue **9**, in which exocyclic cleavage (bond p- leading to the 'walk') is known to be favoured over endocyclic cleavage (bond q- leading to ring expansion).[8] In the pyrrolyl case, ring expansion by route c (Scheme 3) is apparently most favourable, and indeed it is known that drastic pyrolysis of *N*-alkylpyrroles under radical-chain conditions[9,10] often gives 3-substituted pyridines as the major ring-expanded product.

§ A 1,5-shift of the *N*-substituent prior to radical formation could give a similar labelling pattern, but this is known to require much higher temperatures in our apparatus.[7]

A similar mechanism *via* the relatively disfavoured *ortho*-quinonoid intermediate **10** can explain residual label (<10%), found at the 3-position in the indolylmethyl experiment.

Ring expansion of the *N*-azolylmethyl radicals **11** and **12** produced contrasting results (Scheme 4). Thus the *N*-pyrazolylmethyl radical **11** expands regiospecifically to give pyrimidine **13** rather than pyridazine **14** and this is probably due to the cleavage of the particularly weak N–N bond of the diaziridinyl intermediate **15**. These results confirm that **11** is a viable intermediate in the pyrolysis of dipyrazolylmethane,[11] from which pyrimidine has also been obtained. In contrast, the *N*-imidazolylmethyl radical **12** yields both pyrimidine **13** and pyrazine **16** in 3.7 : 1.0 ratio.

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