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Nitrenium Ions. Part 3.[1] Acid-catalyzed Reactions of 2-*tert*-Butylindole with Nitrosoarenes. Crystal Structures of 2-*tert*-Butyl-3-*p*-tolylimino-3*H*-indole and 3-*tert*-Butyl-3-*p*-tolylamino-1,3-dihydroindol-2-one†

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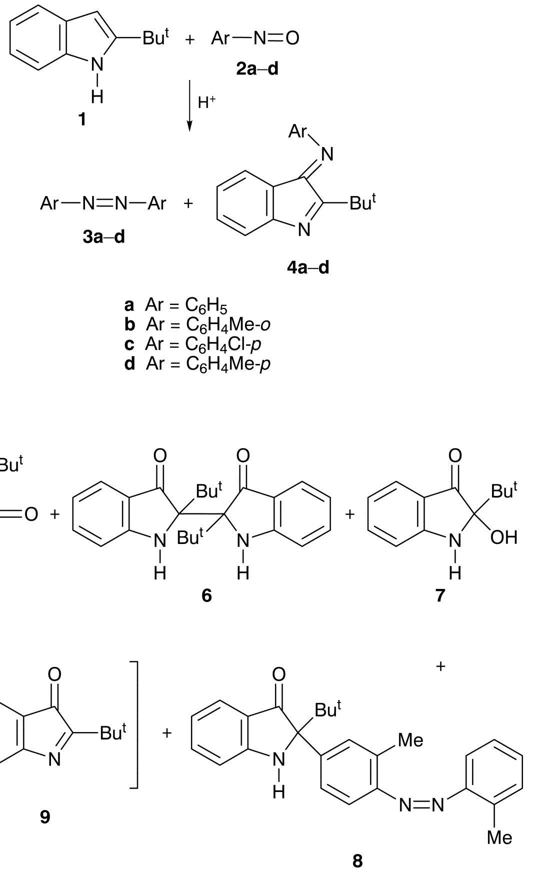
In the presence of acids nitrosoarenes form nitrenium ions which react with heterocycles such as indoles.

The studies on nitrenium ions are mostly devoted to their potential carcinogenicity.[15] Our interest is focused on the reactivity of different heterocycles with nitrosoarenes activated by monochloroacetic acid. The results here described for 2-*tert*-butylindole support the hypothesis that nitrosoarenes in the presence of acids give rise to the equilibrium (1) and that the formed nitrenium ions react with heterocycles such as indoles.

$$\mathrm{Ar{-}N{=}O + H^+ \rightleftharpoons Ar{-}\underset{+}{\ddot{N}}{-}OH} \qquad (1)$$

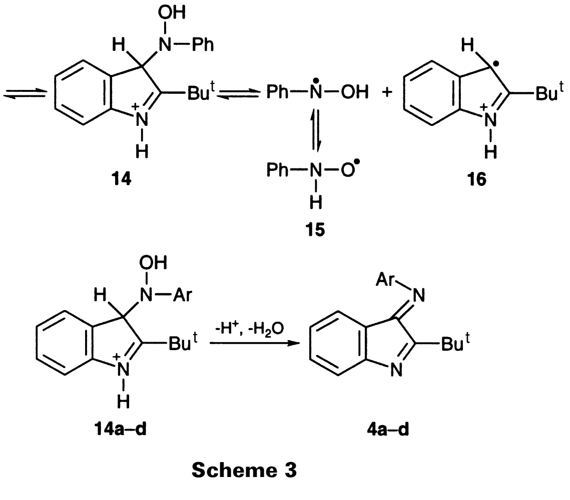


Scheme 1

The reaction of 2-*tert*-butylindole **1** with activated nitrosoarenes **2a–d** were carried out in dichloromethane in a 1 : 2 ratio in the presence of catalytic amounts of monochloroacetic acid at room temperature. The isolated products are shown in Scheme 1. The structures of compounds **4d** and **5d** were elucidated by X-ray analysis.

The reaction of nitrosoarenes with 2-*tert*-butylindole in the presence of acids highlights two important results on the reactivity of protonated nitrosoarenes; (a) the formation of azocompounds **3** and (b) the formation of indolenines **4**, which are characterised by a new carbon–nitrogen bond. The first aspect, together with the detection of the phenylaminoxyl signal in the reaction carried out in the EPR cavity, clearly support the involvement of a reductive pathway in these reactions. The problem now is to establish whether an outer or inner-sphere electron transfer is operating. Since the reduction potential E_{pc} of nitrosobenzene in monochloroacetic acid is −1.32 V (*vs*. Ag–Ag$^+$) and the oxidation potential E_{pa} of **1** is +0.57 V (*vs*. Ag–Ag$^+$) it may be argued, on the basis of the general rules,[25] that an outer-sphere electron transfer can be ruled out; in fact, the endothermicity of the sole electron transfer based on the redox potentials of the reactions amounts to 43.6 kcal, instead the maximum limiting value is around *ca*. 10 kcal.[25] Thus, the formation of phenylnitroxide could be explained by an homolytic retrogression of the σ-complex **14** (inner-sphere electron transfer) forming the phenylaminoxyl **15** and the indole radical cation **16** as shown in Scheme 3.

In general, when arylnitrenium ions are generated in the presence of nucleophiles, they react at the conjugated position of the benzene ring,[11c,28,29] but in our case the activated nitrosoarenes (*N*-aryl-*N*-hydroxynitrenium ions) react



Scheme 3

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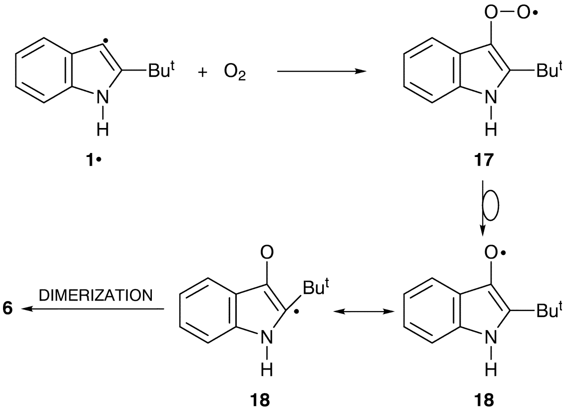
†Dedicated to Professor Dietrich Döpp on the occasion of his 60th birthday.



Scheme 4

through the nitrogen, forming a new carbon–nitrogen bond affording the σ-complex **14**, which leads to compounds **4** by deprotonation and elimination of water, as shown in Scheme 3 and as has been previously observed.[20]

The formation of compounds **5a**–**d** could be easily explained by 1,2-addition[30] of water to compounds **4** followed by *tert*-butyl group migration,[31] which are both documented processes. In fact, compounds **4** reacted in wet dichloromethane in the presence of monochloroacetic acid to give compounds **5**.

An alternative mechanism to the radical pathway described before may arise from the different ground states of arylnitrenium ions. These species are mostly ground state singlet,[33] which justifies their reactivity described above. But there are many literature data regarding triplet arylnitrenium ions: one of these reports the formation of the parent amine.[33] The triplet arylnitrenium ion could promote transfer of an hydrogen atom from indole **1** forming an arylhydroxylamine [$\mathrm{ArN(H)OH^{\bullet+}}$] radical cation and the indolyl radical $\mathbf{1^{\bullet}}$. The radical cation $\mathrm{ArN(H)OH^{\bullet+}}$ may form the arylaminoxyl through the equilibrium (2) and the indolyl radical $\mathbf{1^{\bullet}}$ may be the species responsible for the formation of compound **6**.

$$\mathrm{Ar{-}N(H){-}OH^{\bullet+} \rightleftharpoons Ar{-}N(H){-}OH^{\bullet} + H^{+}} \qquad (2)$$

It is well known that C-centred radicals react with oxygen forming peroxyls[34] leading to alkoxyls.[35] Therefore in our case, the sequence of reactions shown in Scheme 4 could be invoked in order to explain the formation of compound **6**.

The results here described clearly demonstrate that nitrosoarenes in acids give rise to the equilibrium (1) involving the formation of arylhydroxynitrenium ions, which lead to compounds characterised by a carbon–nitrogen bond formation and products deriving from redox processes. The radical pathway attributed to an inner-sphere mechanism or to an hydrogen-atom transfer from 2-*tert*-butylindole to the nitrenium ion triplet state remains a difficult task to be confirmed, even if the involvement of the nitrenium ion triplet state in redox processes has also been recently proposed by others.[33]

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Techniques used: Elemental analysis, IR, ^{1}H NMR, ^{13}C NMR, EPR spectroscopy, mass spectrometry, X-ray analysis

References: 44

Schemes: 4

Figs. 1 and 2: Perspective views of **4d** and **5d**

Table 1: Yields of the reaction products of **1** with **2a**–**d** in the presence of monochloroacetic acid

Table 2: Bond distances, angles and torsion angles of compounds **4d** and **5d**

Table 3: Crystallographic data for compounds **4d** and **5d**

Appendix: Tables of atomic coordinates and equivalent isotropic displacement parameters, bond lengths and angles, anisotropic displacement parameters, and hydrogen coordinates and isotropic displacement parameters

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