An Improved Preparation of *N*-(*t*-Butyl)-*N*-(3,5-dinitrobenzoyl)-nitroxyl

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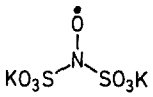
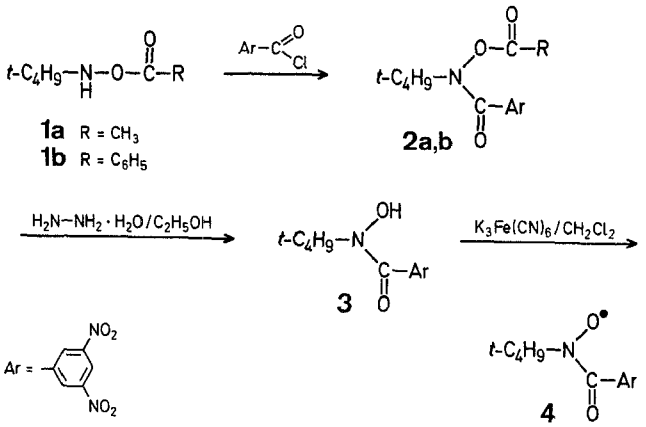
The stability of nitroxyl radicals is well documented[1,2] and their isolation has been achieved in many cases. Their reactivity is generally increased by substitution of electron-withdrawing groups at the nitrogen atom[2,3]; the oxidation of phenols to quinones by Fremy's radical



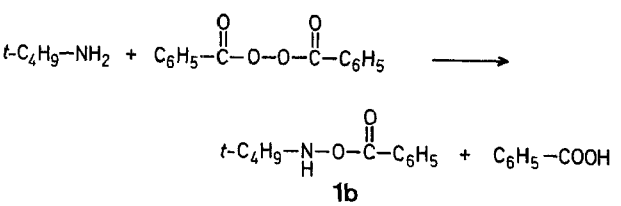
being a well known example[4].

The synthesis and isolation[5] of stable acyl *t*-butyl nitroxyls has recently been achieved. We wish to report an improved synthesis of *N*-(*t*-butyl)-*N*-(3,5-dinitrobenzoyl)-nitroxyl (**4**). This compound is particularly useful[6] because of its oxidising power, solubility in organic solvents, and thermodynamic stability, thus providing an attractive alternative to Fremy's radical.

There are several disadvantages in the reported synthesis[5] (**1a**→**4**). The three-step preparation of *O*-acetyl-*N*-(*t*-butyl)-hydroxylamine (**1a**) via *N*-(*t*-butyl)-hydroxylamine is tedious and difficult to accomplish in good yield. This is due to the volatility of the hydroxylamine and its susceptibility to aerial oxidation. The hydrolysis of the *O*-acyl derivative **2a** requires an inert atmosphere and the conversion to the hydroxamic acid **3** could only be achieved in varying yield (60–90%) and purity.



Our improved procedure (**1b**→**4**) avoids the above difficulties and allows the formation of large quantities of the acylnitroxyl **4**. Our approach was based on the one-step preparation[7] of *O*-benzoyl-*N*-(*t*-butyl)-hydroxylamine (**1b**) from the readily available *t*-butylamine.



This key compound, unlike the *O*-acetyl analogue (**1a**) in the previous synthesis[5], is stable over a prolonged period and is easily handled. It is converted to **2b** in high yield by treatment with 3,5-dinitrobenzoyl chloride. A major improvement in the conversion of hydroxamic acylates to hydroxamic acids was achieved by transamidation using hydrazine hydrate; ester **2b** was converted to pure **3** in quantitative yield [hydrolysis of **2b** with aqueous barium hydroxide followed by acidification using acetic acid (to avoid contamination by benzoic acid) and ether extraction gave **3** in 60% yield]. Hydroxamic acid **3** was used without further purification in the final oxidation yielding *N*-(*t*-butyl)-*N*-(3,5-dinitrobenzoyl)-nitroxyl (**4**) sufficiently pure for preparative or kinetic purposes.

***N*-(*t*-Butyl)-*N*-(3,5-dinitrobenzoyl)-nitroxyl (4):**

O-Benzoyl-N-(t-butyl)-hydroxylamine (**1b**): This compound is prepared by a modification of Zinner's procedure[7]. In a three-necked 1000 ml flask equipped with a mechanical stirrer and a nitrogen inlet is placed freshly recrystallised dibenzoyl peroxide (69.2 g, 0.28 mol) and benzene (400 ml). *t*-Butylamine (66 ml, 0.63 mol) is added dropwise and the temperature raised to 40–50 °C (higher temperatures lead to reduced yield of **1b**). Immediate reaction sets in and the reaction mixture is stirred for 1 h. Additional *t*-butylamine (50 ml, 0.48 mol) is added and stirring continued until the test[8] for peroxides is only mildly positive. Ether (100 ml) is added to the mixture and the amine salt filtered off and washed with ether (100 ml). The filtrate is placed in a conical flask and magnetically stirred with portions of an acidic iron(II) sulphate solution[9] until the precipitation of iron(III) salts ceases. The organic layer is separated, washed with concentrated sodium hydrogen carbonate solution (3 × 100 ml) and with water (100 ml), and dried with magnesium sulphate. The solvent is evaporated in vacuo to give **1b** as a sweet smelling pale amber liquid; yield: 48.2 g (91% based on dibenzoyl peroxide). The product is sufficiently pure for the next step [as shown by T.L.C. (silica gel/chloroform) and spectral comparison with the distilled product]. Distillation of **1b** should be avoided as it partially decomposes with formation of benzoic acid; b.p. of **1b**: 74–76 °C/3 torr.

$C_{11}H_{15}NO_2$ (193.2)

M.S. (70 eV): $m/e = 193$ (M^+, 0.5%); 105 (100); 77 (38).

I.R. (film): $\nu = 3230$ w (NH); 1720 s (C=O); 1274 s; 710 s cm^{-1}.

^{1}H-N.M.R. ($CDCl_3$/TMS): $\delta = 1.24$ [s, 9H, $C(CH_3)_3$]; 7.3–7.6 (m, 3 H_{arom}); 7.5 (br s, 1H, exchangeable with D_2O); 7.99–8.09 ppm (dd, 2H, $J = 1.8$ Hz and 7.9 Hz).

^{13}C-N.M.R. ($CDCl_3$/TMS_{int}): $\delta = 26.5$ (CH_3); 56.0 [$C(CH_3)_3$]; 128.4, 129.2, 129.9, 133.2 (C_{arom}); 166.6 ppm (C=O).

O-Benzoyl-N-(t-butyl)-N-(3,5-dinitrobenzoyl)-hydroxylamine (**2b**): 3,5-Dinitrobenzoyl chloride (22.0 g, 0.095 mol) is added to a solution of *O*-benzoyl-*N*-(*t*-butyl)-hydroxylamine (**1b**; 20.2 g, 0.104 mol) and pyridine (16 ml) in dry benzene (200 ml) and the mixture is refluxed under nitrogen for 4 h. Pyridine hydrochloride is then filtered off and the filtrate washed successively with 2 molar hydrochloric acid (3 × 100 ml) and water (3 × 100 ml). The organic phase is dried with magnesium sulphate and evaporated in vacuo to give a pale yellow solid [36.1 g (98%); m.p. 100 °C; >95% purity by ^{1}H-N.M.R. analysis]. Recrystallization from methanol gives **2b** as colourless needles; yield: 29.6 g (80%); m.p. 106–107 °C.

$C_{18}H_{17}N_3O_7$	calc.	C 55.81	H 4.42	N 10.85
(387.4)	found	55.5	4.4	11.0

M.S. (70 eV): $m/e = 331$ ($M^+ - NO_2$, 2%); 266 (3); 252 (22); 195 (71); 149 (67); 121 (18); 105 (100).

I.R. (KBr): $\nu = 1765$ (*O*-acyl C=O); 1665 (amide C=O) cm^{-1}.

^{1}H-N.M.R. ($CDCl_3$/TMS): $\delta = 1.64$ [s, 9H, $C(CH_3)_3$]; 7.3–7.9 (complex, 5H); 8.77 (d, 2H, $J = 2.0$ Hz); 8.92 ppm (t, 1H, $J = 2.0$ Hz).

^{13}C-N.M.R. ($CDCl_3$/TMS_{int}): $\delta = 27.5$, 64.3, 120.0, 125.3, 128.0, 129.2, 129.8, 135.1, 139.1, 147.9, 165.2, 165.6 ppm.

N-(t-Butyl)-N-(3,5-dinitrobenzoyl)-hydroxylamine (**3**): Hydrazine hydrate (19.2 g, 0.381 mol) is added to a stirred solution of *O*-benzoyl-*N*-(*t*-butyl)-*N*-(3,5-dinitrobenzoyl)-hydroxylamine (**2b**; 19.8 g, 0.051 mol) in absolute ethanol (150 ml) and stirring is continued for 30 min at 40 °C. Then, ice/water (300 ml) is added to the purple mixture. The resultant colourless plates are isolated by suction, washed with pentane (3 × 50 ml), and allowed to air dry [14.4 g (99%)]. Recrystallization from etha-

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nol/water (1/1) affords colourless needles; yield: 13.1 g (91%); m.p. 175–175.5 °C (Ref.[5], m.p. 160 °C).

$C_{11}H_{13}N_3O_6$	calc.	C 46.64	H 4.63	N 14.84
(283.0)	found	46.4	4.8	14.5

M.S. (70 eV): $m/e = 283$ (M^+, 7%); 267 (7); 252 (81); 212 (58); 195 (100).

I.R. (KBr): $\nu = 3360$ m (OH); 1630 s (C=O); 1550 s; 1350 s cm^{-1}.

^{1}H-N.M.R. ($CDCl_3$/DMSO-d_6/TMS): $\delta = 1.54$ [s, 9H, $C(CH_3)_3$]; 8.8–9.0 (m, $3H_{arom}$); 9.6 ppm (br s, 1H, exchangeable with D_2O).

^{13}C-N.M.R. ($CDCl_3$/DMSO-d_6/TMS_{int}): $\delta = 26.7$, 61.4, 118.8, 128.5, 140.9, 147.4, 166.1 ppm.

N-*(t-Butyl)*-N-*(3,5-dinitrobenzoyl)-nitroxyl* **(4)**: A suspension of *N*-(*t*-butyl)-*N*-(3,5-dinitrobenzoyl)-hydroxylamine (**3**; 3.09 g, 0.011 mol) in dichloromethane (50 ml) is shaken with a saturated solution of potassium hexacyanoferrate(III) in aqueous 2-molar sodium hydroxide (125 ml; excess). The organic layer immediately turns dark green. It is separated, washed with aqueous 2 molar sodium hydroxide (2 × 15 ml) and with water (2 × 25 ml), and dried with magnesium sulfate. The solvent is removed in vacuo at room temperature to give **4** as a green crystalline solid; yield: 3.0 g (97%); m.p. 100 °C (Ref.[5], m.p. 100 °C).

$C_{11}H_{12}N_3O_6$ (282.2)

M.S. (10 eV): $m/e = 282$ (M^+, 100%); 195 (38).

I.R. (KBr): $\nu = 1690$ m (C=O); 1550 s; 1345 s cm^{-1}.

U.V. (acetonitrile): $\lambda_{max} = 650$ ($\varepsilon = 13$), 350 (1770), 213 nm (23000).

E.S.R. (benzene): 3 lines ($a_N = 7.22$ G).

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