Dimeric Products from *tert*-Butyl(*N*,*N*-dimethylamino)carbodiimide

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Received April 15, 1994 (Revised Manuscript Received November 10, 1994)

Introduction

In 1989, our laboratory reported the preparation of several products from *N*-*tert*-butyl-*N'*-(dimethylamino)-carbodiimide, **1**.[1] This carbodiimide was reactive and slowly solidified to a product that was not characterized. A similar observation had been made by Wadsworth and Emmons[2] in 1967 for the related *tert*-octyl(*N*,*N*-dimethylamino)carbodiimide that also was reactive and formed a new product that was characterized only as being a dimer. This work was undertaken to determine the structure and properties of the product from **1**.

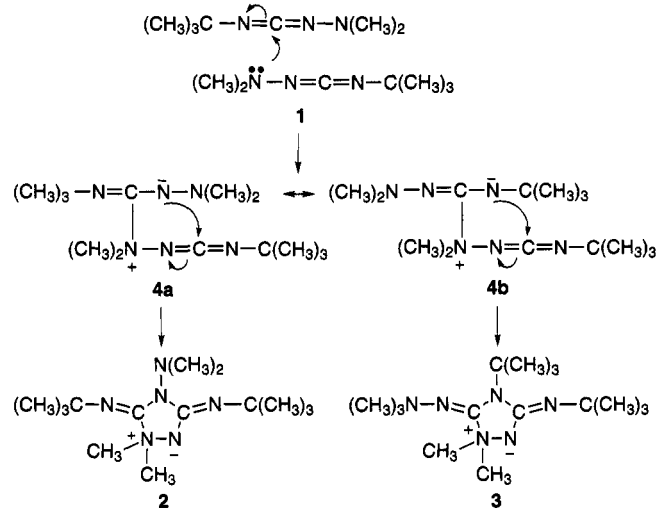
Results

Tert-butyl (*N*,*N*-dimethylamino)carbodiimide was prepared as described in 1989 in a two-step process.[1] After several days the liquid carbodiimide solidified. Two different dimeric products were indicated by proton NMR.

The structures **2** and **3**, which are inner salts, were considered most liekly based on the proposed mechanism for dimerization shown in Scheme 1.

On recrystallization the isomers formed different shaped crystals, and these were separated mechanically. It was not possible to determine the structures with certainty from IR, NMR, and mass spectra, and X-ray crystallographic analysis was necessary. Suitable crystals for X-ray analysis[3] were obtained by recrystallization from n-pentene, and on analysis structures **2** and **3** were confirmed as the structures of the two isomers. Inner salts with the functional group found in **2** and **3** have not been reported previously, but the related amine imides, $RCON^{-}-N^{+}R'_3$, have been reported and are reviewed.[4]

Scheme 1. Proposed Mechanism of Dimerization of *tert*-Butyl(*N*,*N*-dimethylamino)carbodiimide



The isomers show coupled C=N absorptions in the IR at 1623 and 1664 for **2** and 1624 and 1739 cm^{-1} for **3**. Both show two different *tert*-butyl methyl protons and two different dimethylamino protons in the ^1H NMR. Both show eight peaks in the ^{13}C NMR as expected for structures **2** and **3**. In the mass spectra **2** shows a molecular ion at *m/e* 282, while **3** does not.

Properties of the Carbodiimide Dimers (2 and 3). Wadsworth and Emmons[2] had reported that the dimeric product they obtained was converted back to the carbodiimide on heating. We have observed similar behavior with a mixture of **2** and **3**.

In 1989 our laboratory reported that the carbodiimide **1** reacted with morpholine to form a stable product.[1] The reactivity of the dimers toward morpholine was studied. Compounds **2** and **3** failed to react with morpholine either at room temperature or in refluxing benzene over a 48 h period. Reaction of the mixture of carbodiimide dimers with morpholine in the presence of base 1,4-diazabicyclo-[2.2.2]octane (DABCO) in refluxing benzene gave the previously reported morpholine derivative of **1**.

Previously we reported 4-(dimethylamino)-1-methyl-3-(phenylamino)-Δ^2-1,2,4-triazoline, **5a**, from the reaction of 1,1-dimethyl-4-phenyl semicarbazide with 1 equiv of phosgene.[1] The proposed pathway of formation of this product involved intermediates which were *N*-phenyl-*N'*-(dimethylamino)carbodiimide and an analog of **2**, in which phenyl groups replace the *tert*-butyl groups. This analog underwent a Von Braun type of demethylation reaction with a nucleophile which could have been either pyridine or chloride ion.[5]

Several attempts were made to demethylate compound **2**. Neither dimer was observed to react with pyridine. Reaction of compound **2** with sodium iodide was attempted on a small scale in deuterated acetone. The

(1) Cooley, J. H.; Evain, E. J.; Willett, R. D.; Blanchette, J. T. *J. Org. Chem.* **1989**, *54*, 1048.

(2) Wadsworth, W. S.; Emmons, W. D. *J. Org. Chem.* **1967**, *32*, 1279.

(3) Unit cell data for compounds **2**, **3**, and **7** are as follows: Crystal structure analysis of **2**. Lattice constants of **2**, a triclinic crystal, were determined to be a = 6.111(2) Å, b = 9.411(2) Å, c = 15.666(3) Å, α = 84.53(3)°, b = 81.11(3)°, c = 87.87(3)° with Cu Kα radiation (1.54178 Å). Full-matrix least-squares refinement with hydrogen atoms included at calculated positions gave a final R value of 0.0575 for data with $|F| > 3\sigma(F)$. Crystal structure analysis of **3**. Lattice constants of **3**, a triclinic crystal, were determined to be a = 8.613(2) Å, b = 10.183-(2) Å, c = 11.122(2) Å, α = 96.09(3)°, b = 108.27(3)°, c = 102.98(3)° with Cu Kα radiation (1.54178 Å). Least-squares refinement with hydrogen atoms included at calculated positions gave a final R value of 0.0865 for data with $|F| > 3\sigma(F)$. Crystal structure analysis of **7**. Lattice constants of this monoclinic crystal were determined to be a = 6.670(3) Å, b = 20.455(8) Å, c = 16.987(7) Å, α = 96.90(2)°. Full-matrix least-squares refinement with hydrogen atoms included at calculated positions gave a final R value of 0.0525 for data with $|F| > 3\sigma(F)$. The author has deposited atomic coordinates for **2**, **3**, and **7** with the Cambridge Crystallographic Data Centre. The coordinates can be obtained, on request, from the Director, Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge, CB2 1EZ, UK.

(4) (a) McKillip, W. J.; Sedor, E. A.; Culbertson, B. M.; Wawzonek, S. *Chem. Rev.* **1973**, 255. (b) Wawzonek, S. *Ind. Eng. Prod. Res. Dev.* **1980**, *19*, 338–349.

(5) (a) Von Braun, J. *Chem. Ber.* **1900**, *33*, 1438. (b) Cooley, J. H.; Evain, E. J. Synthesis **1989**, 1.

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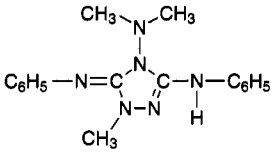
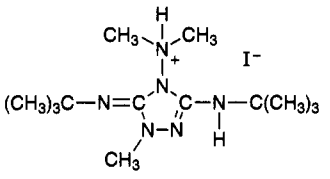
progress of reaction was followed by NMR for a month with no change being observed. Displacement of the methyl group from the inner salt **2** by iodide would be expected to form a strongly basic anion. No change in the basicity of the solution was observed. Acetic acid was added to neutralize the negative charge of the inner salt and form some of the ammonium compound, and still no reaction was observed. A reaction did occur when trifluoroacetic acid, **2**, and sodium iodide were allowed to stand at room temperature for a long period of time. The product was **5b**, N^3-*tert*-butyl-5-(*tert*-butylimino)-4,5-dihydro-N^4,N^4,1-trimethyl-1*H*-1,2,4-triazole-3,4-diamine monohydriodide. The successful demethylation of **2** is consistent with the pathway proposed in our earlier paper for formation of **5a**.



5a

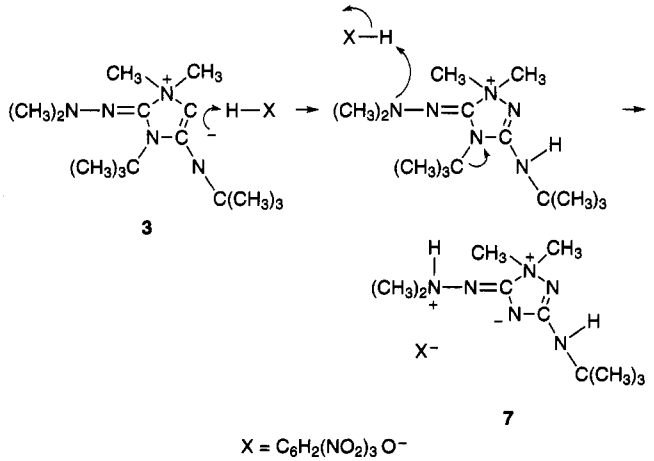


5b

An attempt was made to demethylate **3** with sodium iodide in acetone-d_6. No change was observed in the NMR in a month. No attempt was made to demethylate **3** with sodium iodide and trifluoracetic acid. As shown below **3** reacts with picric acid to produce a picrate with loss of the *tert*-butyl group. Because of this different reactivity of **3** under acid conditions, demethylation under these conditions was not attempted.

Picrate salts are commonly reported derivative of the amine imide inner salts.[4,6] Compound **2** reacted with picric acid to form the expected picrate derivative **6**. However, compound **3** reacted with picric acid to form a picrate derivative which contained only one of the original *tert*-butyl groups of **3**. From the IR, NMR, and mass spectra it was not possible to assign a structure for this product. X-ray structural analysis was necessary and established structure **7** for this compound which contains both the zwitterionic inner salt and an onium ion. A proposed mechanism of reaction of compound **3** with picric acid is given in Scheme 2.

Scheme 2. Proposed Mechanism of Reaction of Compound 3 with Picric Acid



3

7

X = $C_6H_2(NO_2)_3O^-$

Experimental Section

General. ^1H and ^{13}C NMR spectra were obtained in the indicated solvent from either an IBM NR/200 FTNMR or an IBM NR/300 FTNMR spectrometer; reported chemical shifts are in ppm (δ) relative to either $CHCl_3$ (δ 7.24) or TMS (δ 0.00). Infrared spectra were recorded on a Digilab Qualimatic FTIR instrument using NaCl plates. MS measurements were made with a VG 7070HS mass spectrometer. Melting points were determined by using a Thomas-Hoover apparatus and were corrected. Elemental analyses were carried out by Desert Analytics, Tucson, AZ.

Materials. Unless indicated otherwise, reagents were purchased from Aldrich Chemical Co. Inc., Milwaukee, WI. Solvents were glass distilled and were obtained from either Burdick and Jackson Laboratories Inc., Muskegon, MI, or from EM Science, Cherry Hill, NJ. Phosgene gas was acquired in lecture bottles from Matheson Gas Products, Newark, CA.

Formation of Dimeric Products 2 and 3. *N*-*tert*-Butyl-(*N'*,*N'*-dimethylamino)carbodiimide, **1**, was prepared as described earlier.[1] After several days the liquid had solidified and the IR absorption at 2100 cm^{-1} typical of the carbodiimide had disappeared. A combustion analysis of this mixture indicated the same formula as the starting carbodiimide. Anal. Calcd for $C_{14}H_{30}N_6$: C, 59.53; H, 10.70; N, 29.76. Found: C, 59.47; H, 10.91; N, 29.59.[7] The ^1H NMR showed the presence of two dimeric compounds. Four peaks were attributed to *tert*-butyl groups, and four peaks were attributed to *N*,*N*-dimethyl groups. The ratio of the isomers obtained by integration of the spectrum was 52:48. These products were recrystallized from n-pentane, and the crystalline form of each was distinctive; one was needles and the other was plates. These were separated mechanically.

4-(Dimethylamino)-3-(*tert*-butylamino)-5-(*tert*-butylimino)-4,5-dihydro-1,1-dimethyl-1*H*-1,2,4-triazolium, inner salt (2): (52%) colorless needles from n-pentene, mp 136–136.5 °C; IR (Nujol) 2924, 2854, 1664, 1623, 1349, 1272, 1206, 1191, 1101, 1032, 1031, 1016, 957 cm^{-1}; ^1H NMR (acetone-d_6): δ 1.18 (s, 9H), 1.66 (s, 9H), 2.47 (s, 6H), 3.47 (s, 6H) ppm; ^{13}C NMR (acetonitrile-d_3) δ 29.48, 30.41, 46.29, 48.58, 49.42, 56.99, 135.75, 179.96 ppm; MS (CI) *m/z* (relative intensity) 283 (M + 1, 0.34), 282 (M^+, 0.09), 267 (0.70), 239 (1.93), 225 (1.96), 183 (2.26), 154 (1.36), 141 (9.86), 126 (1.66), 113 (2.29), 85 (100), 71 (1.75), 58 (26.97). Anal. Calcd for $C_{14}H_{30}N_6$: C, 59.53; H, 10.70; N, 29.76. Found: C, 59.80; H, 10.79; N, 30.04.

4-*tert*-Butyl-3-(*tert*-butylamino)-5-(dimethylhydrazono)-4,5-dihydro-1,1-dimethyl-1*H*-1,2,4-triazolium, inner salt (3):[6] (48%) colorless plates, mp 96–97 °C; IR (Nujol) 2923, 2855, 1739, 1624, 1350, 1237, 1202, 1100, 1026, 985, 889 cm^{-1}; ^1H NMR (acetone-d_6) δ 1.20 (s, 9H), 1.36 (s, 9H), 2.98 (s, 6H), 3.00 (s, 6H) ppm; ^{13}C NMR (acetone-d_6) δ 30.70, 31.50, 44.10, 56.70, 51.50, 53.40, 143.10, 152.70 ppm; MS (CI, 70 eV) *m/z* (relative intensity), (no molecular ion detected), 268 (0.13), 226 (9.09), 211 (7.50), 183 (2.66), 168 (2.28), 154 (2.64), 141 (6.47), 127 (3.72), 113 (2.20), 85 (100), 71 (3.06), 57 (37.00). Anal. Calcd for $C_{14}H_{30}N_6$: C, 59.53; H, 10.70; N, 29.76. Found: C, 59.48; H, 10.94; N, 29.90.

N^3-*tert*-Butyl-5-(*tert*-butylimino)-4,5-dihydro-N^4,N^4,1-trimethyl-1*H*-1,2,4-triazole-3,4-diamine, Monohydriodide (5a). A mixture of **2** (0.5403 g, 1.91 mmol), sodium iodide (0.2868 g, 1.91 mmol), and trifluoroacetic acid (0.15 mL, 1.91 mmol) was stirred for 72 h. At this point the reaction mixture contained only **2**, and the reaction mixture was set aside for 1 month after which colorless crystals were isolated by filtration (0.62 g, 82%): mp 146–148 °C; IR (Nujol) 3225, 2925, 2854, 1633, 1593, 1459, 1365, 1201 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.39 (s, 9H), 1.46 (s, 9H), 3.10 (s, 6H), 3.79 (s, 3H), 4.65 (s, 1H), 6.05 (s, 1H) ppm; ^{13}C NMR ($CDCl_3$) δ 28.69, 31.23, 39.43, 45.73, 53.18, 57.44, 146.86, 148.47 ppm; MS *m/z* (relative intensity) 268 (M^+, 0.85), 254 (21.24), 225 (22.66), 210 (16.31), 194 (3.90), 169 (12.11), 154 (44.29), 142 (3.12), 127 (41.56), 113 (100), 112 (12.13), 98 (2.73), 83 (4.69), 72 (2.73), 71 (5.86), 68 (10.91), 63 (0.39), 57 (46.04). Anal. Calcd for $C_{13}H_{29}N_6I$: C, 39.39; H, 7.37; N, 21.21. Found: C, 39.57; H, 7.57; N, 21.43.

4-(Dimethylamino)-3-(*tert*-butylamino)-5-(*tert*-butylimino)-4,5-dihydro-1,1-dimethyl-1*H*-1,2,4-triazolium Picrate (6). A solution of **2** (0.0533 g, 0.25 mmol) and picric acid (0.0575

(6) Wawzonek, S.; Yeakey, E. *J. Am. Chem. Soc.* **1965**, *30*, 2781.

(7) Sample prepared by P. Marchus for C, H, and N analysis.

g, 0.25 mmol) in 6 mL of dry methanol was heated for 20 min and stirred at room temperature for 24 h. The solvent was removed, and upon recrystallization from CCl_4/EtOAc (1:1 mixture), 0.0908 g (71%) of yellow solid product was isolated: mp 100–102 °C; IR (Nujol) 3441, 2928, 2855, 1774, 1636, 1366, 1303, 1259, 1122, 1073 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.38 (s, 6H), 2.93 (s, 6H), 3.26 (s, 6H), 5.29 (s, 1H), 8.78 (s, 2H) ppm; ^{13}C NMR ($CDCl_3$) δ 28.29, 30.97, 43.98, 54.10, 55.44, 55.87, 125.47, 126.47, 134.00, 142.04, 157.55, 162.07 ppm; MS *m/z* (relative intensity) (no molecular ion peak detected) 283 (0.51), 277 (2.71), 268 (2.90), 253 (11.28), 239 (12.62), 226 (6.25), 225 (34.81), 210 (27.20), 194 (17.09), 183 (32.67), 169 (13.67), 154 (80.37), 149 (2.73), 141 (14.06), 138 (4.93), 127 (41.70), 126 (13.67), 113 (100), 104 (2.32), 98 (20.75), 91 (3.51), 85 (100), 78 (3.81), 75 (6.64), 68 (19.92), 57 (100). Anal. Calcd for $C_{20}H_{33}N_9O_7$: C, 46.95; H, 6.50; N, 24.64. Found: C, 47.05; H, 6.60; N, 24.62.

3-(*tert*-Butylamino)-5-(2,2-dimethylhydrazino)-1,1-dimethyl-1*H*-1,2,4-triazolium, Inner Salt, Compound with 2,4,6-Trinitrophenol (1:1) (7). A solution of **3** (0.0624 g, 0.22 mmol) and picric acid (0.0650 g, 0.28 mmol) in 6 mL of dry methanol was heated for 20 min and stirred at room temperature for 24 h. After the solvent was removed, the yellow, solid product was recrystallized from CCl_4/EtOAc (1:1) and a mixture was isolated: 0.088 g (88%), mp 166–167 °C; IR (Nujol) 3379, 2924, 2855, 1675, 1631, 1598, 1579, 1569, 1365, 1337, 1267, 1166 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.22 (s, 9H), 3.09 (s, 6H), 3.15 (s, 6H), 4.39 (s, 1H), 8.83 (s, 2H) ppm; ^{13}C NMR ($CDCl_3$) δ 28.4, 46.4, 51.2, 54.7, 126.0, 128.0, 142.2, 162.6, 167.5, 170.0 ppm; MS (EI, 70 eV) *m/z* (relative intensity) (no molecular ion peak detected) 229 (4.46), 212 (1.70), 211 (18.43), 210 (4.44), 195 (3.15), 180 (5.15), 168 (4.07), 154 (6.17), 149 (22.28), 143 (8.44), 139 (20.70), 126 (56.24), 111 (56.73), 98 (33.15), 83 (61.47), 70 (19.26), 57 (100). Anal. Calcd for $C_{16}H_{25}N_9O_7$: C, 42.18; H, 5.53; N, 27.68. Found: C, 42.08; H, 5.61; N, 27.60.

JO940598R