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Selective nitrosation of guanazine: preparation of azidoaminotriazole and nitrosoguanazine anion–Cu(II) complexes

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Abstract—Guanazine (3,4,5-triamino-1,2,4-triazole) is selectively nitrosated on C–NH_2 to produce nitrosoguanazine (3-nitrosamino-4,5-diamino-1,2,4-triazole). The nitrosoguanazine is used to prepare 5-azido-3-amino-1,2,4-triazole and nitrosoguanazine anion–Cu(II) complexes.
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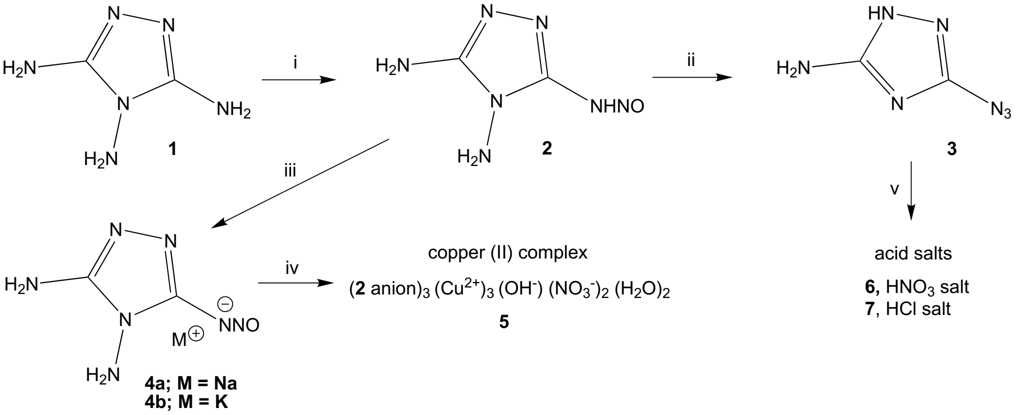
1. Introduction and discussion

Reports of isolation of primary nitrosamino compounds are rare, due, at least in part, to the fact that these compounds readily convert to diazonium salts under normal reaction conditions. Among these reported nitrosamino compounds, we found 3-nitrosamino-4-aryl-5-alkyl-1,2,4-triazoles[1] and 3-nitrosamino-5-amino-1,2,4-triazole.[2,3]

We have prepared a primary nitrosamino-triazole compound for use as an intermediate to other materials. Thus, we report here (Scheme 1): (a) The selective nitrosation of guanazine (**1**) (3,4,5-triamino-1,2,4-triazole) to



Scheme 1. Reagents and conditions: (i) 1 equiv HOAc, 1 equiv $NaNO_2$, H_2O, 0–25 °C/20 h (product **2** is possibly dimer);[8] (ii) H_2O, 75 °C/45 min; (iii) NaOH (**4a**) or KOH (**4b**), H_2O; (iv) $Cu(II)(NO_3)_2(2.5H_2O)$, H_2O; (v) dilute HNO_3 (**6**) or dilute HCl (**7**).

Keywords: Nitrosoguanazine; Azidoaminotriazole; Nitrosoguanazine anion–Cu(II) complexes.

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produce nitrosoguanazine (**2**) (3-nitrosamino-4,5-diamino-1,2,4-triazole); (b) The conversion of **2** to 5-azido-3-amino-1,2,4-triazole (**3**); and (c) The conversion of salts **4a**,**b** to nitrosoguanazine anion–Cu(II) complex **5**.

This work began with an interest in the preparation of **3**[4,5] as a versatile intermediate to new energetic materials. Our initial approach to **3**, involving selective diazotization of **1**, gave a low yield of impure **3**; thus, the approach was changed to the preparation and use of **2** as an intermediate to **3**.[6] The latter approach, involving selective nitrosation of **1**, produces high-purity **2**[7,8] that can be easily converted to **3** by heating in H_2O or H_2O/HOAc.[9]

Nitrosoguanazine **2** was treated with NaOH or KOH in water to give the respective salts, **4a** and **4b**.[10] Crystal structure analyses of **4a** (Fig. 1)[11] and **b**[11] show that nitrosation of **1** has occurred on $C–NH_2$ rather than on $N–NH_2$. Apparently, the $C–NH_2$, being the more basic amine, is more susceptible to NO^+ attack. Salt **4a** is a hydrate, while **4b** is free of water. The salts have high thermal stability as determined by DSC.[10]

Salts **4a** and **4b**, when treated with copper(II) nitrate in water, form nitrosoguanazine anion–Cu(II) complex **5**.[12] Crystal structure analysis of **5** (Fig. 2) shows that the complex contains three nitrosoguanazine anions, three Cu^{2+}, and hydroxide, along with two nitrate ions and two water molecules.[11] The complex is very similar in structure to those recently reported for 3-acetylamino-1,2,4-triazole anion and 3-acetylamino-5-amino-1,2,4-triazole anion.[13,14]

Azidoaminotriazole **3** is sufficiently basic that it readily forms acid salts, for example, HNO_3 salt **6** and HCl salt hydrate **7**.[15] Crystal structure analyses were performed on **6** (Fig. 3)[11] and **7**,[11] as well as on the free amine **3**.[11] The IR spectra of **3** and its salts **6** and **7** show very significant differences in the region of azide group absorption: compound **3** has a single very strong peak at 2147 cm^{-1}; **7** has a single peak (2151) of medium intensity; **6** shows two absorptions (2202 and 2165) and they are of weak intensity.

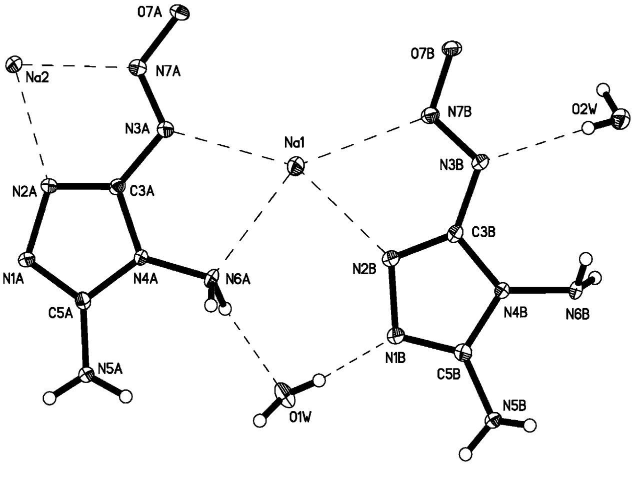

Figure 1. The crystal structure of **4a**, a hydrated sodium salt of **2**, as revealed by X-ray analysis; atoms are represented by displacement ellipsoids containing 50% of the probability density.

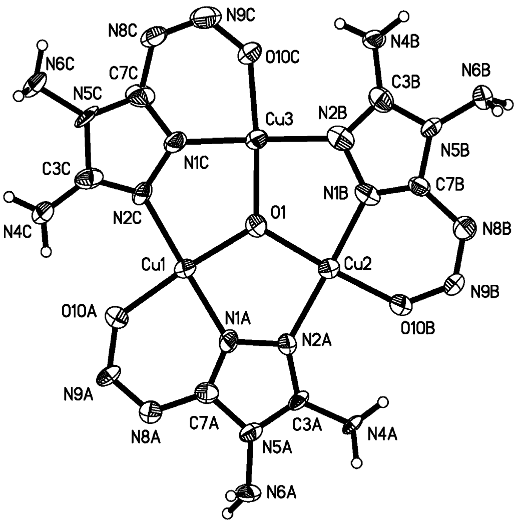

Figure 2. The crystal structure of the complex Cu(II) salt, **5**; as mentioned above, there are also two nitrate anions and two water molecules in the asymmetric unit that are not shown here because they occur above and below this roughly planar cluster and would obscure the view. The central oxygen is part of a hydroxyl ion; its proton lies above the plane and is not shown.

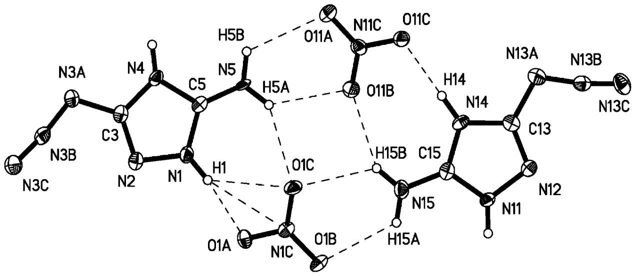

Figure 3. The crystal structure of **6**, a nitrate salt of **3**, as revealed by X-ray analysis; atoms are represented by '50% probability' displacement ellipsoids.

We anticipate that azidoaminotriazole and nitrosoguanazine, possessing multiple functionality including reactive amine groups, will be of interest as intermediates toward other new materials. In addition, it may be possible to produce new complexes similar to **5** by expanding to other types of heterocyclic anions.

2. Crystal structures

There are two separate ion pairs and two water molecules linked together in a cluster in the **4a** crystal. The anions are chemically identical, but differ in their ion–ion and hydrogen-bonding packing interactions, shown by the dashed lines in Figure 1. There are also two separate ion pairs in the asymmetric unit of **6** (Fig. 3), forming a cluster which appears to be symmetric, but it contains neither 2-fold nor inversion symmetry. The two anions differ because of different packing interactions, but not significantly.

The crystal structure of **5** (Fig. 2) should be considered to be low-precision, because its data come from a twinned crystal which compromised the overall quality of the collected crystal data. Two components were found from the diffraction pattern; both components were used to fit the unit cell and data from both components were used to refine. However, the structure refines to a high R value of 8.7% for the observed reflections, so there may be other unrecognized components affecting the data. Hydrogen atoms could not reliably be located, but considerations of the shape of the multi-atom ions, the relative weights of the nonhydrogen atoms and the overall charge balance led us uniquely to the reported structure.

3. Analytical methods

Differential scanning calorimetry (DSC) experiments for energetic complexes **5** *should be performed using amounts of 0.2 mg or less*: The IR spectra were recorded via attenuated total reflectance (ATR) on a ThermoNicolet Avatar 370 FT-IR Spectrometer. NMR spectra were recorded using either Varian 300 MHz Mercury Plus system or a Varian Inova system equipped with a 5 mm triple resonance triaxial PFG probe at 500 MHz for ^{1}H and 125 MHz for ^{13}C (referenced to residual solvent signals). Elemental analyses were performed by Galbraith Laboratories, Inc., Knoxville, TN. In general, for high-nitrogen heterocyclic compounds, we have experienced difficulty in obtaining consistent analytical values for N. The values found for N are often low, even though values for other elements (C, H, etc.) are acceptable. The analytical purity is further established using other techniques (NMR, IR, DSC, mp).

Acknowledgement

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References and notes

1. Gehlen, von H.; Dost, J. *Leibigs Ann. Chem.* **1963**, *665*, 144–149.
2. Hauser, M. US Patent 3,431,251, 1969.
3. Namestnikov, V. I.; Kofman, T. P.; Pevzner, M. S. USSR SU 1,027,159, 1983.
4. Kofman, T. P.; Kartseva, G. Yu.; Namestnikov, V. I.; Paketina, E. A. *Russ. J. Org. Chem.* **1998**, *34*, 1032–1039, Translated from *Zh. Org. Khim.*, **1998** *34*, 1084–1090.
5. Kofman, T. P. *Russ. J. Org. Chem.* **2001**, *37*, 1158–1168, Translated from *Zh. Org. Khim.*, **2001**, *37*, 1217–1227. (Refs. 4 and 5 report the use of **3** but do not provide synthesis/characterization data for this compound).
6. Fronabarger, J. W.; Sitzmann, M. E.; Williams, M. D. 'Azidoaminotriazole, Nitrosoguanazine, and Azidonitramine Compounds, Intermediates and Salts, and Processes Thereof', US Patent Application, 31 October 2005.
7. *Preparation of nitrosoguanazine* **2**: A solution of **1** (5.4 g, 47.3 mmol) in 90 mL water was stirred in an ice bath, $NaNO_2$ (3.36 g, 48.7 mmol) was added, followed by HOAc (2.92 g, 48.7 mmol) in water (54 mL) dropwise over 10 min. The flask was stoppered and held at 0 °C for 1 h before being warmed to 23 °C over 2 h. After an additional 1 h, the mixture was allowed to stand overnight (17 h) before the precipitate was removed by filtration and washed with water to give **2** (4.87 g, 72%), mp 143 °C dec. ^{1}H NMR (DMSO-d_6): 5.68 (s, 2H), 6.28 (s, 2H) 13.8 (broad); IR (ATR): 3301, 3171, 1680 (strong), 1636, 1564, 1504, 1256 (strong), 1146, 1067, 980, 901, 800, 752, 720 cm^{-1}. Calcd for $C_4H_{10}N_{14}O_2$: C, 16.79; H, 3.52; N, 68.51. Found: C, 16.69; H, 3.63; N, 68.29; DSC (20 °C/min): onset: 152; peak: 154.
8. Possibly **2** is a nitroso dimer of the form RNH(O)N=N(O)NHR. This possibility is supported by the IR spectrum which shows a strong absorption at 1256 cm^{-1}. Very little data are available for primary nitrosamines but the N=O stretching absorption for secondary nitrosamine dimers is in the 1300 region compared to 1430–1530 for the monomers: (Rao, C. N. R.; Bhaskar, K. R. In *The Chemistry of the Nitro and Nitroso Group, Part 1*; Feuer, H., Ed. Spectroscopy of the Nitroso Group; John Wiley: New York, 1969; p 144, see also Zahradnik, R.; Svatek, E.; Chvapil, M. *Chemicke Listy pro Vedu a Prumysl*, **1957**, *51*, 2232–2242.) A dimer is also suggested by the very low solubility of **2** in water compared to **1**. Compound **2** was not sufficiently soluble in DMSO for a molecular wt analysis (Galbraith Laboratories).
9. *Preparation of azidoaminotriazole* **3**: Compound **2** (0.86 g, 3 mmol) was stirred in water (7 mL), HOAc (0.09 g, 1.5 mmol) in water (2 mL) was added, and the mixture was heated to 78–80 °C over 15 min and then held at approx 75–77 °C for 45 min (*Note*: For a similar reaction in water alone without added HOAc, the yield of **3** was approximately 5% less). The warm mixture was filtered to remove a small amount of dark material and the filtrate was evaporated under reduced pressure. The residue was washed with 3 × 1.5 mL water to give **3** (0.56 g, 75%) as brownish yellow crystals, mp 175 °C, dec. ^{1}H NMR (DMSO-d_6): 6.31 (s, 2H), 11.91 (s, 1H); ^{13}C NMR (DMSO-d_6): 154.4, 157.3; IR (ATR): 3420, 3398, 3161, 2147 (N_3, very strong), 1670, 1601, 1544 (strong), 1461, 1410, 1361, 1225, 1107, 718 cm^{-1}. Calcd for $C_2H_3N_7$: C, 19.20; H, 2.42; N, 78.38. Found (crystals from water): C, 18.90; H, 2.42; N, 77.65. Found (crystals from methanol): C, 18.97; H, 2.41; N, 77.55; DSC (20 °C/min): onset: 174; peak: 184.
10. *Preparation of nitrosoguanazine salts* **4a** *and* **4b**: Compound **2** (0.92 g, 6.4 mmol) was stirred in water (15 mL) at 23 °C while slowly adding NaOH (0.27 g, 6.7 mmol) in water (9 mL) dropwise. Additional dilute NaOH was added as necessary to give complete solution. The water was evaporated and the residue was stirred with CH_3OH (5 mL) to give insoluble yellow-orange salt **4a** (0.77 g). CH_2Cl_2 (10 mL) added to the filtrate gave an additional 0.30 g; total yield of **4a** (1.07 g, 91%). ^{13}C NMR (D_2O): 154.7, 155.0; IR (ATR): 3310, 3109, 1660 (strong), 1620, 1580, 1560, 1499, 1330, 1282, 1239 (strong), 1143, 983, 944, 904, 890, 748, 720, 696 cm^{-1}. DSC (20 °C/min): endotherm: 131; onset: 259; peak: 265. Calcd for $C_2H_6N_7NaO_2$: C, 13.12; H, 3.30; N, 53.55; Na, 12.56. Found: C, 12.92; H, 3.66; N, 51.44, Na, 12.64.
    Compound **4b** was prepared similarly using KOH. The reaction residue (from removal of water), stirred with CH_3OH, gave **4b** (1.04 g, 91%). ^{13}C NMR (D_2O): 154.9, 155.0; IR (ATR): 3319, 3131, 1657, 1631, 1574, 1518, 1491, 1276, 1244, 1143, 1038, 956, 889, 723, 701 cm^{-1}. DSC (20 °C/min): onset: 228; peak: 247.

11. Crystallographic data have been deposited with the Cambridge Crystallographic Data Centre as supplementary publications CCDC-601041 for **3**, CCDC-601042 for **4a**, CCDC-601043 for **4b**, CCDC-601044 for **5**, CCDC-601045 for **6**, and CCDC-601046 for **7**. Copies of the data can be obtained freely on application to CCDC, 12 Union Road, Cambridge CB2 1EZ (UK); Tel.: +44 1223 336 408, fax: +44 1223 336 033, and e-mail: deposit@ccdc.cam.ac.uk.
12. *Preparation of complex* **5**: *Caution!* Compound **5** is an energetic material and can deflagrate (see below). To a solution of **4b** (0.24 g, 1.3 mmol) in water (3 mL) at 22 °C was added dropwise copper(II) nitrate hemipentahydrate (0.30 g, 1.3 mmol) in water (2 mL). The initial brown precipitate turns to green by the end of the addition. The mixture was stirred for 15 min before it was filtered to give **5** as a green solid (0.27 g, 79%). IR (ATR): 3312, 1661 (strong), 1623, 1544, 1503, 1390–1318 (very strong), 1166, 1138, 1080, 1070, 1046, 918, 820, 747, 726 cm^{-1}. When heated, the product deflagrates (with a burst of flame) in the vicinity of 230 °C; DSC (20 °C/min): onset: 218; peak: 231. Calcd for $C_6H_{17}Cu_3N_{23}O_{12}$: C, 9.08; H, 2.16; N, 40.57. Found: C, 9.00; H, 2.42; N, 39.41.

    Similarly, **4b** with $Cu(ClO_4)_2(6H_2O)$ gave a green perchlorate complex. *Caution!* This product is a sensitive powerful explosive; when heated, it explodes in the vicinity of 230 °C; DSC (20 °C/min): onset: 206; peak: 232. IR (ATR): 3335, 1665 (strong), 1557, 1505, 1388, 1357, 1080 (very strong) ($ClO_4{}^{-}$), 921, 726 cm^{-1}.

    Use of $CuSO_4(5H_2O)$ with **4b** gave a green sulfate complex. IR (ATR): 3321, 1657, 1626, 1549, 1504, 1386, 1324, 1100–1040 (very strong) ($SO_4{}^{-2}$), 972, 920, 746, 724 cm^{-1}.
13. Ferrer, S.; Haasnoot, J. G.; Reedijk, J.; Muller, E.; Biagini Cingi, M.; Mannoti Lanfranchi, M.; Lanfredi, A. M.; Ribas, J. *Inorg. Chem.* **2000**, *39*, 1859–1867.
14. Ferrer, S.; Lloret, F.; Bertomeu, I.; Alzuet, G.; Borras, J.; Garcia-Granda, S.; Liu-Gonzalez, M.; Haasnoot, J. G. *Inorg. Chem.* **2002**, *41*, 5821–5830.
15. *Preparation of acid salts* **6** *and* **7**: Compound **3** (50 mg) in 5 mL of water was acidified with dilute HNO_3 and the solution was evaporated to give crystals of **6** (60 mg). ^1H NMR (DMSO-d_6): 9.21 (br s); ^{13}C NMR (DMSO-d_6): 149.6, 153.7; IR (ATR): 3430, 3338, 2738, (2202, 2165, N_3, weak), 1714 (medium strong), 1590, 1530, 1434, 1301 (strong), 1183, 1048, 1034, 1002, 843, 815, 803, 727, 707 cm^{-1}. DSC (20 °C/min): onset: 172; peak: 174. Calcd for $C_2H_4N_8O_3$: C, 12.77; H, 2.14; N, 59.57. Found: C, 12.92; H, 2.31; N, 59.15.

    Salt **7** was prepared similarly using dilute HCl. IR (ATR): 3383, 3256, 3096, 2951, 2719, 2151 (N_3, medium strong), 1685 (strong), 1593, 1522, 1358, 1201, 1049, 1009, 873, 801, 757, 718 cm^{-1}. Calcd for $C_2H_6ClN_7O$: C, 13.38; H, 3.37; Cl, 19.74, N, 54.60. Found: C, 13.85; H, 3.33; Cl, 19.88, N, 55.43.