

# Unexpected Formation of 5,12-Dimethyl-3,7,10,14,15,16-tetraazapentacyclo-[7.5.1.12.8.15,16.112,15]octadecane, a Novel Caged Nitrogen Heterocycle, and Preparation and X-Ray Crystal Structure of Its Copper(II) Chloride Complex

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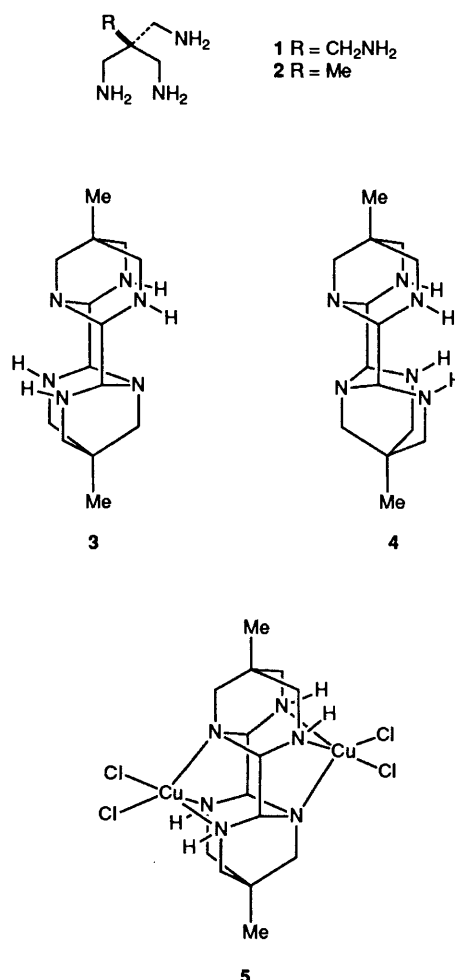
1,1,1-Tris(aminomethyl)ethane **2** is shown to condense with glyoxal in methanol, in the absence of metal ions, to give a novel caged nitrogen heterocycle **3** whose structure has been confirmed by spectral data and through X-ray crystallographic analysis of its copper(II) chloride complex **5**.

Tetrakis(aminomethyl)methane **1** and glyoxal reportedly give fibre-forming high polymers when mixed in equal proportions.<sup>1</sup> In contrast, the process gives monomeric products when either reactant is used in excess.<sup>1</sup> We were attracted by this report because of our interest in heterocycles derived from 2,2'-bi(hexahydropyrimidines),<sup>2-4</sup> and because the product from the above reaction, when the tetraamine is used in excess, was described as a 2,2'-bi(hexahydropyrimidine).<sup>1</sup> We chose to study the reaction of a related amine, tris(aminomethyl)ethane **2**, with glyoxal under conditions that had previously been used by us to give monomeric products from 1,3-diamines.<sup>2</sup> A complex mixture of noncrystalline products was formed after normal reaction times of 2-3 h in methanol, but prolonged heating afforded a single, caged nitrogen heterocycle which is the subject of this communication.

The reaction of **2** in a fivefold excess with glyoxal afforded, after 3.5 h, only unchanged amine **2** and a new substance, C<sub>14</sub>H<sub>26</sub>N<sub>6</sub>, m.p. 287-290 °C, which separated from the warm reaction mixture.† The spectral properties of the compound were consistent with either of the caged substances **3** or **4** but the compound could not be made to condense with a third molecule of glyoxal. The latter result at first suggested that the structure of the compound was **3** and not **4** since incorporation of glyoxal would be difficult from **4**. However, structures **3** and **4** have symmetry elements, point groups C<sub>2h</sub> and C<sub>2v</sub> respectively, that yield identical numbers of non-equivalent protons and carbons making it impossible to distinguish the compounds from each other directly from <sup>1</sup>H or <sup>13</sup>C NMR spectral data. Similarly, the possibility of using nuclear Overhauser enhancement experiments were ruled out from symmetry considerations.

Eventually, the caged compound was converted to a stable, blue-green copper(II) complex (cage-2CuCl<sub>2</sub>) by treatment with copper(II) chloride in methanol.‡ The formation of a stable complex was surprising since earlier experiments on the bi(hexahydropyrimidines) with the chiral shift reagent,

Eu(hfc)<sub>3</sub> {tris[3-(heptafluoropropylhydroxymethylene)-(+)-camphorato]europium(III)} had been abortive and given only massive line broadening.<sup>5</sup> The structure of the complex **5**, determined by single crystal X-ray crystallographic analysis,§ confirmed the caged nature of the organic portion of the complex and revealed the novel staggered arrangement of the



† Aqueous glyoxal (1.5 g of 40%) was added dropwise to an ice-cooled solution of 1,1,1-tris(aminomethyl)ethane (6.0 g) in ethanol (50 ml). The mixture was warmed gently on a steam bath for 3.5 h then refrigerated and the caged amine **3** collected as a microcrystalline solid (1.1 g, 38%) m.p. 287-290 °C;  $\nu_{\max}$  (Nujol) 3316, 3304, 3292, 1470, 1248, 1200, 1163, 1138, 1113, 1078, 977, 950, 920, 903 and 860 cm<sup>-1</sup>; <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  0.60 (s, CH<sub>3</sub>), 2.16 (br s, NH), 2.96 (s, NCH<sub>2</sub>), 2.97 (d, *J* 11.3 Hz, NCH<sub>a</sub>H<sub>b</sub>), 3.14 (d, *J* 12.1 Hz, NCH<sub>a</sub>H<sub>b</sub>) and 3.89 (s, NCHN); *m/z* 279 (M+1, 20%), 278 (100), 248 (18), 233 (16), 221 (16), 181 (51), 179 (26), 111 (24), 97 (51), 95 (20), 83 (29), 70 (32) and 55 (35); satisfactory elemental analyses were obtained for compound **3** and the complex **5**.

‡ A solution of copper(II) chloride (0.235 g) in methanol (3.5 ml) was added to the caged amine **3** (0.186 g) in methanol (30 ml) at room temperature and the mixture refluxed overnight. The mixture was cooled and the green powder collected and recrystallized from water to give the copper complex **5** as blue-green prisms, m.p. 273-275 °C (decomp.);  $\nu_{\max}$  (KBr) 3451, 3192, 2968, 2944, 2903, 2884, 1629, 1459, 1405, 1386, 1355, 1323, 1300, 1219, 1179, 1142, 1103, 1058, 1034, 936, 848, 771, 710 and 582 cm<sup>-1</sup>;  $\lambda_{\max}$  (H<sub>2</sub>O) 260 ( $\epsilon$  5835) and 230 sh.

§ Crystal data for **5**. C<sub>14</sub>H<sub>26</sub>N<sub>6</sub>·2CuCl<sub>2</sub>, *M* = 547.3, monoclinic, space group *P*2<sub>1</sub>/*c*, *a* = 9.265(2), *b* = 9.865(1), *c* = 12.145(3) Å,  $\beta$  = 118.33(1)°, *V* = 977.1(4) Å<sup>3</sup>, *D<sub>c</sub>* = 1.86 g cm<sup>-3</sup>, *Z* = 2,  $\mu$ (Mo-K $\alpha$ ) = 27.48 cm<sup>-1</sup>. Crystal size 0.13 × 0.14 × 0.20 mm,  $2\theta_{\max}$  = 50°. 1514 Reflections were considered observed [*I* > 3 $\sigma$ (*I*)] out of 1706 unique data, with *R*<sub>merge</sub> 0.015 for 100 pairs of equivalent *0kl* reflections. There is a crystallographic centre of symmetry in the middle of the molecule, so the asymmetric unit is half of the molecular formula. Final residuals *R*, *R<sub>w</sub>* were 0.022, 0.037. Atomic coordinates, bond lengths and angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre. See Notice to Authors, Issue No. 1.

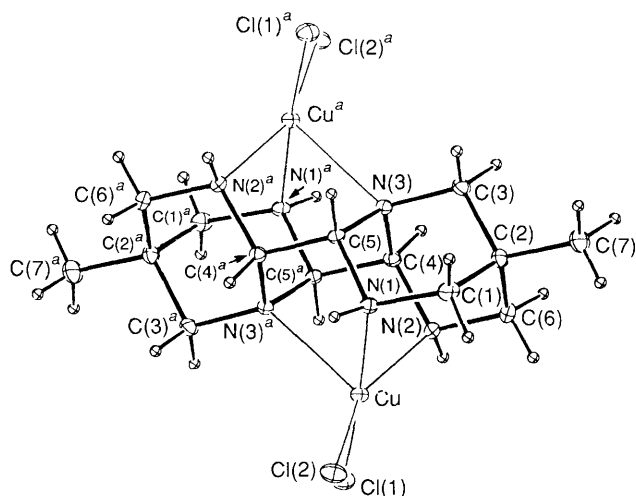


Fig. 1 ORTEP drawing of **5**. <sup>a</sup> Indicates symmetry transformation  $1-x, -y, 1-z$ .

cage (Fig. 1). The nitrogen ligand precursor must therefore have had structure **3**. Interestingly, the metal complex **5** contains two unsymmetrical, trigonal bipyramidal coordinated metal ions with one secondary nitrogen and the tertiary nitrogen from each face of the heterocycle sharing meridional positions with the remaining secondary nitrogen at an apical position. The metal bonds to the tertiary nitrogens are considerably longer than the corresponding bonds to the secondary nitrogens.

Similar treatment of glyoxal with the tetraamine **1** appears to give a related caged compound whose structure will be reported in a full paper with a description of the intermediate bi(hexahydropyrimidines).

The present study reveals yet another pathway that can be taken by bi(hexahydropyrimidines) during their reaction with active carbonyl reagents.<sup>2</sup> The products raise certain mechanistic questions concerning the conversion of bi(hexahydropyrimidine) intermediates to these molecules. Our investigations into such reactions and their control factors are being continued. In addition, such 'outside' metal complexes, particularly those with a rigid ligand physically separating two metal ions, are extremely rare and will be investigated further.

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