PENTAAZABICYCLONONANES

Joseph H. Boyer* and Govindarajulu Kumar

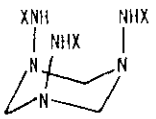
Department of Chemistry, University of New Orleans, New Orleans, LA 70148, U.S.A.

Abstract - The synthesis of 3-benzamido-6,8-dibenzoyl-1,3,5,6,8-pentaazabicyclo[3.2.2]-nonane 2 and 2,7-dibenzoyl-4-benzamido-1,2,4,6,7-pentaazabicyclo[4.2.1]nonane 3 provides the first examples of pentaazabicyclononanes.

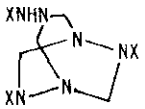
Treatment of 1,3,5-tribenzamidohexahydro-1,3,5-triazine 1 as the monohydrate[1,2] with ethyl orthoformate and a few drops of concentrated sulfuric acid in toluene at 110°C for 0.5 h gave 3-benzamido-6,8-dibenzoyl-1,3,5,6,8-pentaazabicyclo[3.2.2]nonane 2. When sulfuric acid was not present in the mixture a different isomerization of the heterocycle 1 gave 2,7-dibenzoyl-4-benzamido-1,2,-4,6,7-pentaazabicyclo[4.2.1]nonane 3, 2-phenyl-1,3,4-oxadiazole 4,[3] and 1-benzoyl-4-benzamido-Δ^2-1,2,4-triazoline 5. Structures 1-3 and 5, were determined by x-ray crystallographic analyses.[2] Compounds 2 and 3 introduced 1,3,5,6,8-pentaazabicyclo[3.2.2]nonane and 1,2,4,6,7-pentaazabicyclo-[4.2.1]nonane as parent molecules of new ring systems. Except for compounds 2, 3, and examples claimed in a patent to be 2,4,6,8,9-pentaazabicyclo[3.3.1]nonadienes 6 [4] pentaazabicyclononanes remain unknown.

An anticipated interaction between the hexahydrotriazine 1 and ethyl orthoformate to give 2,8,9-tribenzoyl-2,3,5,7,8,9-hexaazatricyclo[3.3.1.$1^{3,7}$] decane 7 was patterned after a similar conversion of cis-cis-1,3,5-tris-benzylaminocyclohexane 8 to 2,4,10-tribenzyl-2,4,10-triazaadamantane 9.[5] Formation of the hexaazatricyclodecane 7 was not detected.

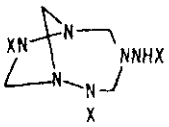
When ethyl orthoformate was not included in the reaction mixture, the hexahydrotriazine 1 in toluene containing a catalytic amount of concentrated sulfuric acid, was recovered and gave the pentaazabicyclo[3.2.2]nonane 2 in a trace amount. Longer heating gave intractable mixtures. Similar treatment in the absence of both ethyl orthoformate and concentrated sulfuric acid had negligible effect on the hexahydrotriazine; again prolonged heating brought about degradation and the formation of many products.



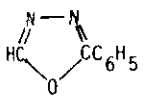
1 X = C_6H_5CO



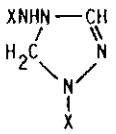
2 X = C_6H_5CO



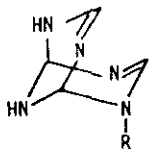
3 X = C_6H_5CO



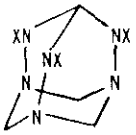
4 X = C_6H_5CO



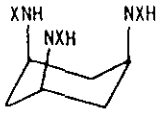
5 X = C_6H_5CO



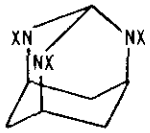
6



7 X = C_6H_5CO

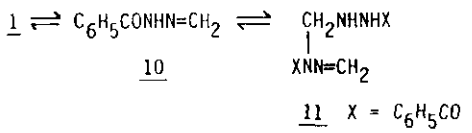


8 X = $CH_2C_6H_5$



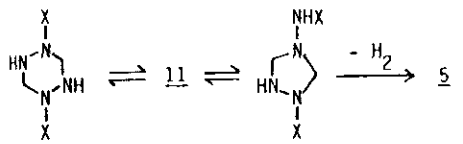
9 X = $CH_2C_6H_5$

A rationale for the formation of products 2 - 5 depended on the presence of the hydrazone 10 derived from the hexahydrotriazine 1 by depolymerization.[6,7] The hydrazone 10 afforded 1,4-dibenzoyl-hexahydro-s-tetrazine 12 and 1-benzoyl-4-benzamidotetrahydro-1,2,4-triazole 13 by ring-closures from the dimer 11.[8] A reaction between the reduced tetrazine 12 and the dimer 11 then afforded the pentaazabicyclo[3.2.2]nonane 2 with the formal ejection of benzhydrazide. From the isomeric dimer 13 a reaction with the dimer 11 afforded the pentaazabicyclo[4.2.1]nonane 3. A critical role for ethyl orthoformate, beyond the known reaction with benzhydrazide to form the oxadiazole 4[3] which thereby favorably shifted the equilibrium 1 ⇌ 2 (3), has not been ascertained. Dehydrogenation of the triazolidine 13 to the triazoline 5 was assumed.



10

11 X = C_6H_5CO



12 X = COC_6H_5 13 X = COC_6H_5

$$C_{16}H_{16}N_4O_2 + C_{16}H_{16}N_4O_2 \rightleftharpoons C_{25}H_{24}N_6O_3 + C_7H_8N_2O(C_6H_5CON_2H_3)$$

12 (13) 11 2 (3)

$$C_6H_5CON_2H_3 \xrightarrow[-\ C_2H_5OH]{HC(OC_2H_5)_3} 4$$

EXPERIMENTAL

Instruments included Pye-Unicam SP-200 IR, Varian A-60 and T-60 NMR Spectrometers. Elemental analyses were provided by Micro-Tech Laboratories, Inc., Skokie, Illinois.

3-Benzamido-6,8-dibenzoyl-1,3,5,6,8-pentaazabicyclo[3.2.2]nonane 2. To a suspension of the monohydrate of 1,3,5-trisbenzamidohexahydrotriazine 1[1,9] (0.9 g, 0.002 mol) in toluene (25 ml) triethylorthoformate (0.30 g, 0.002 mol) and a drop of concentrated sulfuric acid were added. The mixture was heated at 110°C for 30 min. Toluene was removed and the residue was separated chromatographically (silica gel, chloroform) to give a colorless solid (0.31 g, 34%), mp 238-240°C (decomp.) after recrystallization from toluene; ir (KBr) : 3200-3500 (broad, NH) 1620-1660 cm^1 (C O); nmr ($CDCl_3$): δ 4.5 (broad s, 4H, N-CH_2-N) 5.0 (broad s, 4H, N-CH_2-N), 7.2-7.8 (m, 15H, aromatic) and 8.8 (broad s, 1H, NH); anal. calcd. for $C_{25}H_{24}N_6O_3$: C, 65.79; H, 5.26; N, 18.42; found: C, 65.70; H, 5.29; N, 18.26.

2,7 Dibenzoyl-4-benzamido-1,2,4,6,7-pentaazabicyclo[4.2.1]nonane 3. A suspension of 1,3,5-trisbenzamidohexahydrotriazine 1[1,9] (0.9 g, 0.002 mol) in toluene (25 ml) was mixed with triethylorthoformate (0.30 g, 0.002 mol) and heated at 110°C for 30 min. Toluene was removed and the residue was separated chromatographically (silica gel, chloroform) to give 2-phenyl-1,3,4-oxadiazole 4 as a colorless liquid (0.075 g, 8%); ir (neat): 3110, 1605, 1550, 1480, 1100, 1060, 700, and 680 cm^{-1}; nmr ($CDCl_3$): δ 8.50 (s, 1H, H-5), 7.33-7.76 (m, 3H, phenyl), 7.83-8.26 (m, 2H, phenyl).[10] Further elution gave the bicyclononane 3 (0.26 g, 28%) as a colorless solid, mp 217-219°C after recrystallization from toluene; ir (KBr): 3250 (NH) and 1650 cm^{-1} (CO); nmr ($CDCl_3$): δ 3.6-5.5 (m, 8H, CH_2), 7.3-7.8 (m, 15H, aromatic) 9.2 (s, 1H, NH); anal. calcd. for $C_{25}H_{24}N_6O_3$: C, 65.79; H, 5.26; N, 18.42; found: C, 65.74; H, 5.50; N, 18.43. The recrystallization of product 3 for x-ray crystallographic analysis also gave a few crystals of the triazoline 5, a structure confirmed by x-ray crystallographic analysis but not characterized further.

ACKNOWLEDGMENT

Financial support was received from ONR.

REFERENCES

1. H. H. Fox, J. Org. Chem., 1958, 23, 468.

2. We are indebted to R. Gilardi, C. George, and J. L. Flippen-Anderson of the Naval Research

Laboratory, Washington, D. C., for the x-ray analyses of compounds 1 (the three benzamido groups are all on the same side of the hexahydrotriazine ring), 2, 3, and 5. The data will be published elsewhere.

3. C. Ainsworth, J. Amer. Chem. Soc., 1955, 77, 1148.

4. a. Neth. Appl. 6,500,521; Chem. Abstr., 1966, 64, 2116. b. J. C. Hinshaw, Report 1983, Order No. AD-A128309, Avail. NTIS; from Gov. Rep. Announce. Index (U.S.), 1983, 83, 4502; Chem. Abstr. 1984, 100, 6470h.

5. H. Stetter and J. Bremen, Chem. Ber., 1973, 106, 2523.

6. Hexahydro-s-triazines (trimers of imines) often react as monomeric imines in thermal and acid catalyzed reactions.[7]

7. E. M. Smolin and L. Rapoport, in "S-Triazines and Derivatives"; Arnold Weissberger, Ed., Interscience Publishers, Inc., New York, 1959, Chapter IX, p 473-544.

8. S. R. Johns, J. A. Lamberton, and E. R. Nelson, Austr. J. Chem., 1973, 26, 1297; 1971, 24, 1859. Reversibly formed dimers 12, 13 (X = Ar) of formaldehyde arylhydrazones were isolated as derivatives from further condensation with formaldehyde.

9. The monohydrate $C_{24}H_{24}N_6O_3 \cdot H_2O$, mp 160-163°C (dec) gave satisfactory elemental analysis;[1] we obtained values for an anhydrous analytic sample, mp 160-163°C (dec): calcd for $C_{24}H_{24}N_6O_3$: C, 64.85; H, 5.44; N, 18.91; found: C, 64.43; H, 5.51; N, 19.00.

10. T. R. Vakula and V. R. Srinivasan, Ind. J. Chem., 1969, 580.

Received, 25th August, 1986