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The Synthesis and Crystal and Molecular Structures of 3,7-Diacetyl- and 3,7-Bis(thioacetyl)-1,5-dimethyl-3,7-diazabicyclo[3.3.1]nonanes

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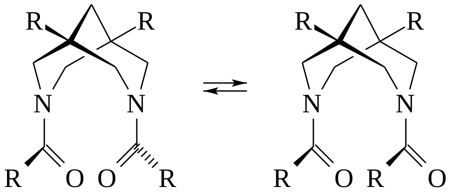
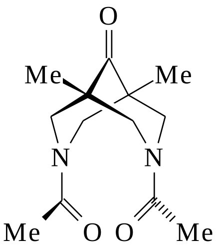
Until recently, investigations of the conformational behavior of 3,7-diazabicyclo[3.3.1]nonanes have been mainly devoted to the analysis of the cage conformation [1]. In particular, a large number of studies have dealt with the comparison of the stabilities of the chair–chair and chair–boat conformations, depending on the nature and the mutual arrangement of substituents. Meanwhile, the factors that control the orientations of substituents at nitrogen have scarcely been studied, although model compounds suitable for these studies have long been known [2–4]. An interesting class of these compounds is represented by the 3,7-diacyl derivatives of 3,7-diazabicyclo[3.3.1]nonane. The substituents in these compounds are either antiparallel (**a**) or parallel (**b**), **a** being the predominant species in solution; in the presence of La^{3+} ions, **b** predominates. Hence, compounds of this type can potentially serve as molecular switches [5].

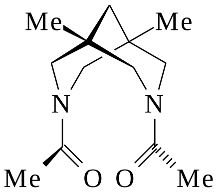


a **b**

In this paper, we report the results of an X-ray diffraction study of three model compounds of this type, namely: 3,7-diacetyl-1,5-dimethyl-3,7-diazabicyclo[3.3.1]nonan-9-one (**1**), 3,7-diacetyl-1,5-dimethyl-3,7-diazabicyclo[3.3.1]nonane (**2**), and 3,7-bis(thioacetyl)-1,5-dimethyl-3,7-diazabicyclo[3.3.1]nonane (**3**):



1



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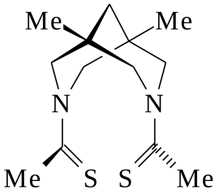

3

These compounds were synthesized from 5,7-dimethyl-1,3-diazaadamantan-6-one (**4**), prepared by a procedure in [6] and then subjected to the Kishner–Wolff reduction by modified procedure [7] to give 5,7-dimethyl-1,3-diazaadamantane (**5**).

3,7-Diacetyl-1,5-dimethyl-3,7-diazabicyclo[3.3.1]-nonan-9-one (1). A solution of compound **4** (10.0 g, 55 mmol) in acetic anhydride (70 ml) was kept for 24 h at room temperature and for 2 h at 100–120°C and then cooled. Water (70 ml) was added, and the mixture was stirred for 2 h. The subsequent preparation can be performed in two ways: (1) the reaction mixture was evaporated *in vacuo* to dryness, and the residue was recrystallized from dioxane; or (2) the reaction mixture was treated with a 40–45% KOH to pH ~ 10, and the product was filtered off, dried, and recrystallized from dioxane.

Either procedure gives 9.7–10.4 g of compound **1** (yield 70–75%) as colorless crystals, mp 263–264°C (lit.: 264–265°C [8]).

^{1}H NMR (400 MHz, CDCl$_3$): 1.00 (s, 6H, CH$_3$), 2.12 (s, 6H, –CO–C$\underline{H}_3$), 2.72, 3.25, 4.05, and 5.01 (4 dd, J = 2.8 and 13.35 Hz, 4 × 2H, HC$\underline{H}$a–d).

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Table 1. Unit cell parameters of compounds **1–3** and experimental details

Parameter	**1**	**2**	**3**
a, Å	7.629(2)	7.616(2)	13.919(4)
b, Å	17.514(3)	17.327(6)	16.533(6)
c, Å	9.782(2)	10.010(3)	12.755(3)
β,°	98.70(2)	98.98(2)	90
V, Å^3	1292(1)	1304.8(7)	2935(2)
Z	4	4	8
d_{calcd}, g/cm^3	1.42	1.21	1.224
Space group	C2/c	C2/c	Pccn
Number of reflections	1122	1290	2897
R	0.041	0.044	0.059
R_w	0.095	0.096	0.128

Table 2. Atomic coordinates (×10^4) for molecule **1**

Atom	*x*	*y*	*z*
N_3	912(2)	1840(1)	1352(2)
O_1	–125(2)	2900(1)	219(2)
O_2	0	–270(1)	2500
C_1	1446(3)	901(1)	3312(2)
C_2	2246(3)	1410(1)	2268(2)
C_4	–577(3)	1390(1)	666(2)
C_9	0	426(2)	2500
C_{10}	990(3)	2598(1)	1087(2)
C_{11}	2457(3)	3060(1)	1870(3)
C_{12}	2922(3)	418(1)	4109(3)

Table 3. Atomic coordinates (×10^4) for molecule **2**

Atom	*x*	*y*	*z*
N_3	904(1)	1835(1)	1372(1)
O_1	–117(1)	2910(1)	257(1)
C_1	1446(2)	893(1)	3278(1)
C_2	2243(2)	1401(1)	2275(1)
C_4	–615(2)	1387(1)	717(1)
C_9	0	386(1)	2500
C_{10}	1000(2)	2595(1)	1099(1)
C_{11}	2507(2)	3057(1)	1853(2)
C_{12}	2942(2)	410(1)	4063(2)

Table 4. Atomic coordinates (×10^4) for molecule **3**

Atom	*x*	*y*	*z*
S_1	–930.7(9)	8277.3(6)	–1497.5(8)
S_2	1132.3(7)	6220.5(6)	73.7(7)
N_3	–42(2)	7221(2)	–2726(2)
N_7	–26(2)	5806(2)	–1480(2)
C_1	750(2)	5925(2)	–3244(2)
C_2	789(3)	6851(2)	–3245(3)
C_4	–976(3)	6904(2)	–3081(3)
C_5	–1022(2)	5980(2)	–3093(2)
C_6	–959(2)	5637(2)	–1977(2)
C_8	803(2)	5587(2)	–2130(2)
C_9	–189(2)	5657(2)	–3736(2)
C_{10}	1613(3)	5607(3)	–3847(3)
C_{11}	–1985(3)	5740(3)	–3557(3)
C_{12}	17(3)	7835(2)	–2052(2)
C_{13}	1009(4)	8150(3)	–1797(4)
C_{14}	74(2)	6060(2)	–490(2)
C_{15}	–833(3)	6188(3)	137(3)

3,7-Diacetyl-1,5-dimethyl-3,7-diazabicyclo[3.3.1]-nonane (2). Compound **2** was prepared from **5** by the procedure used for compound **1**, yield 72–77%, mp 195–197°C.

^{1}H NMR (400 MHz, $CDCl_3$): 0.83 (s, 6H, CH_3), 1.31 (s, 2H, CH_2), 1.95 (s, 6H, –C(O)–C$\underline{H}_3$), 2.25 and 2.76 (dd each, 2H each, J = 2.7 and 13.2 Hz, HC$\underline{H}$a and HC$\underline{H}$b), 3.59 and 4.54 (d each, 2H each, J = 13.2 Hz, HC$\underline{H}$c and HC$\underline{H}$d).

For $C_{13}H_{22}N_2O_2$ anal. calcd. (%): C, 65.54; H, 9.24; N, 11.76.

Found (%): C, 65.08; H, 9.20; N, 11.70.

3,7-Bis(thioacetyl)-1,5-dimethyl-3,7-diazabicyclo[3.3.1]nonane (3). P_2S_5 (2.5 g, 11 mmol) was added to a solution of compound **2** (1.0 g, 4.2 mmol) in anhydrous pyridine (10 ml). The mixture was refluxed for 2 h (during this period, it separated into two layers) and cooled. Water (20 ml) was added, and the mixture was stirred. The light brown crystalline precipitate was filtered off, washed with ethanol, and dried in air. Recrystallization from a $CH_3OH–CHCl_3$ mixture gave 0.4 g of compound **3** (yield 35%), mp 258–261°C.

^{1}H NMR (400 MHz, $CDCl_3$): 1.05 (s, 6H, C$\underline{H}_3$), 1.64 (s, 2H, CH_2), 2.17 (s, 6H, C(S)–C$\underline{H}_3$), 2.76, 3.29, 4.09, and 5.06 (dd each, 2H each, J = 2.6 and 13.3 Hz, HC$\underline{H}$a–d).

For $C_{13}H_{22}N_2S_2$ anal. calcd. (%): C, 57.73; H, 8.20; N, 10.36.

Found (%): C, 55.31; H, 7.97; N, 9.77.

The crystals of **1** and **2** are monoclinic, those of **3** are orthorhombic. The unit cell parameters and the intensities of reflections with $I > 2\sigma(I)$ for crystals of **1–3** were measured on a Siemems R3m four-circle automated diffractometer (λMoK_α, graphite monochromator, $\theta/2\theta$

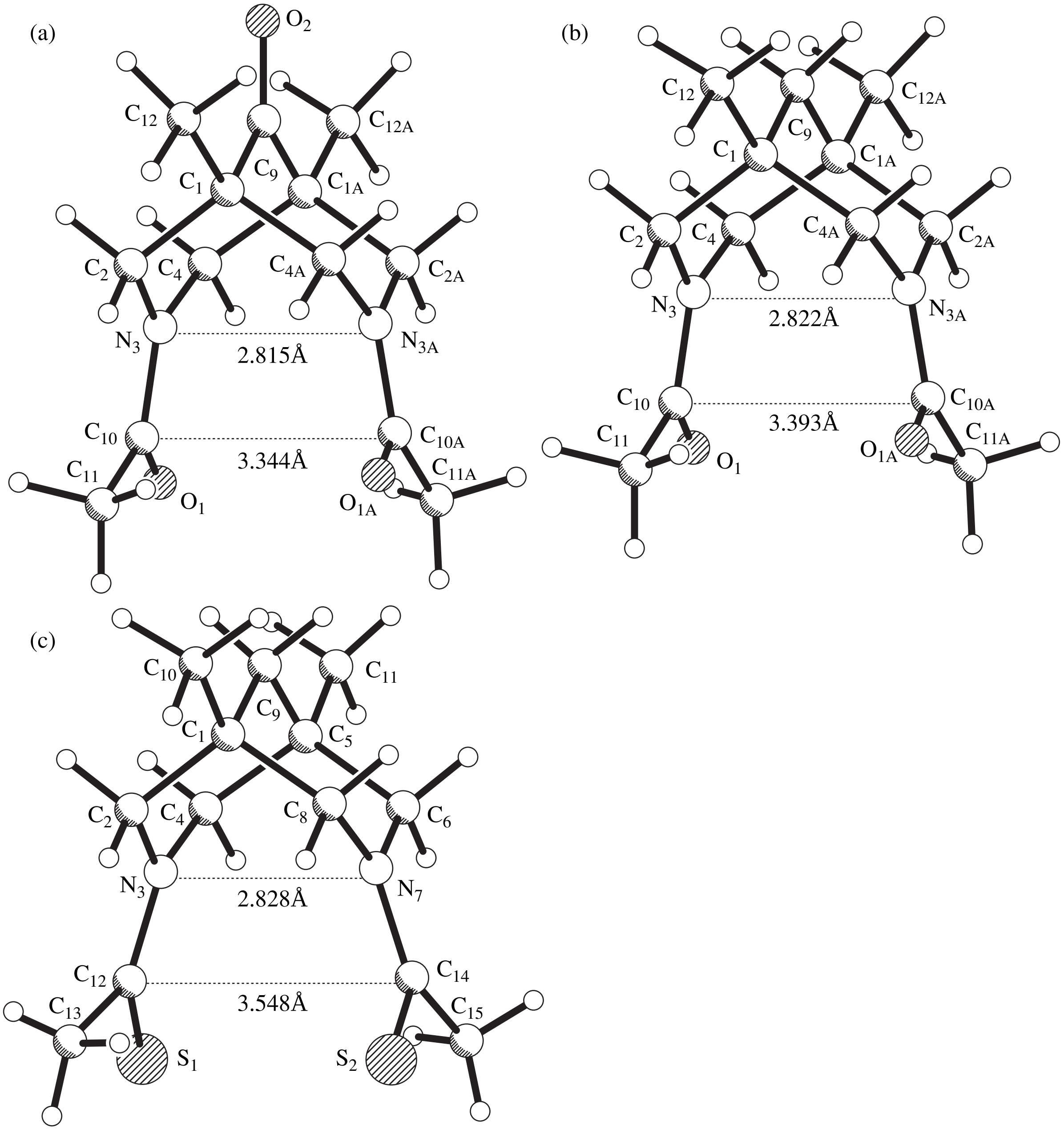

Fig. 1. Perspective views of molecules (a) **1**, (b) **2**, and (c) **3**.

scan mode, θ < 26°) at room temperature. The structures of **1**–**3** were solved by direct methods and refined by full-matrix least-squares calculation (on F^2's), first, in the isotropic and then in the anisotropic approximation for non-hydrogen atoms. All hydrogen atoms were objectively revealed in a electron density difference map and refined in the isotropic approximation. Calculations were performed by the SHELXTL PLUS program package [9] (PC version).

The unit cell parameters of compounds **1**–**3** and details of data collection are listed in Table 1. The coordinates of non-hydrogen atoms of the symmetry-independent part of molecules **1** and **2** are given in Tables 2 and 3, and the coordinates of non-hydrogen atoms of **3** are listed in Table 4. The perspective views of molecules **1**–**3** with the atom numbering are shown in Fig. 1.

The six-membered rings in molecules **1**–**3** occur in a chair conformation with a slight flattening of the "wings" and are characterized by the puckering parameters [10] presented in Table 5.

The $N_3 \ldots N_7$ nonbonded distances in molecules **1**–**3** are virtually identical (2.815(2), 2.822(2), and 2.828(2) Å, respectively).

Table 5. Puckering parameters for molecules **1**–**3**

Molecule	**1**		**2**		**3**	
Ring	C_9–C_{1A}–C_4–N_3–C_2–C_1	C_9–C_1–C_{4A}–N_{3A}–C_{2A}–C_{1A}	C_9–C_{1A}–C_4–N_3–C_2–C_1	C_9–C_1–C_{4A}–N_{3A}–C_{2A}–C_{1A}	C_9–C_1–C_2–N_3–C_4–C_5	C_9–C_5–C_6–N_7–C_8–C_1
S	1.124	1.124	1.124	1.124	1.133	1.141
θ, deg	3.61	3.61	4.49	4.49	4.42	3.95
ψ_2, deg	15.04	15.04	9.47	9.47	6.98	1.59

It is significant that, according to the X-ray diffraction data, the acyl and thioacyl groups at the N_3 and N_7 atoms in molecules **1**–**3** are antiparallel. The angles between the planes of the acyl groups in the 3- and 7-positions in **1**–**3** are 22°, 24°, and 32°, respectively.

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