Conformational Analysis of Benzoannulated Nine-Membered Rings. Part 3. 1,4,5,7-Tetrahydro-3*H*-2,6-benzodiselenine and its 4-Spiro Derivatives†

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The ^1H and ^{13}C nmr spectra of 1,4,5,7-tetrahydro-3*H*-2,6-benzodiselenine (**1**) and three 4-spiro derivatives **2-4** as well as the ^{77}Se nmr spectra of **2** have been recorded at different temperatures in order to investigate their conformational behavior. It was found that in analogy to corresponding dithionins the molecules adopt a chiral ground state conformation (Figure 2), and coalescence effects are due to racemization.

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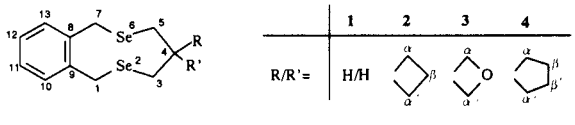
Recently, we reported the conformational behaviour of 1,4,5,7-tetrahydro-3*H*-2,6-benzodithionin derivatives investigated by dynamic ^1H and ^{13}C nmr, X-ray analysis and force-field calculations [1,2]. In this paper is shown that corresponding diselena analogues **1-4** (Scheme 1) display very similar dynamics. The temperature-dependent ^1H and ^{13}C nmr spectra (Tables 1 and 2) show that compounds **1-4** consist of interconverting enantiomers. The discussion of their ^1H and ^{13}C chemical shifts is identical to that of the sulphur analogues [1]. In the present compounds, however, we have the opportunity to monitor an third nmr-active nucleus, namely ^{77}Se which has been shown to be well-suited for dynamic nmr [3]. It turned out that the interconversion barriers of the spiro compounds **2-4** are virtually equal to those of the sulphur analogues. We estimated 48 ±1 kJ/mol from ^{13}C and 49 ±1 kJ/mol from ^{77}Se nmr. Figure 1 shows the temperature-dependent ^{77}Se nmr of **2**. Note the strong temperature dependence of the ^{77}Se chemical shift (here it is −5 Hz/K); the center of the two signals with equal intensities at 218 K (bottom trace) extrapolated to 323 K, results exactly in the ^{77}Se chemical shift of the averaged signal in the top trace.



Scheme. Structures of Compounds **1-4**

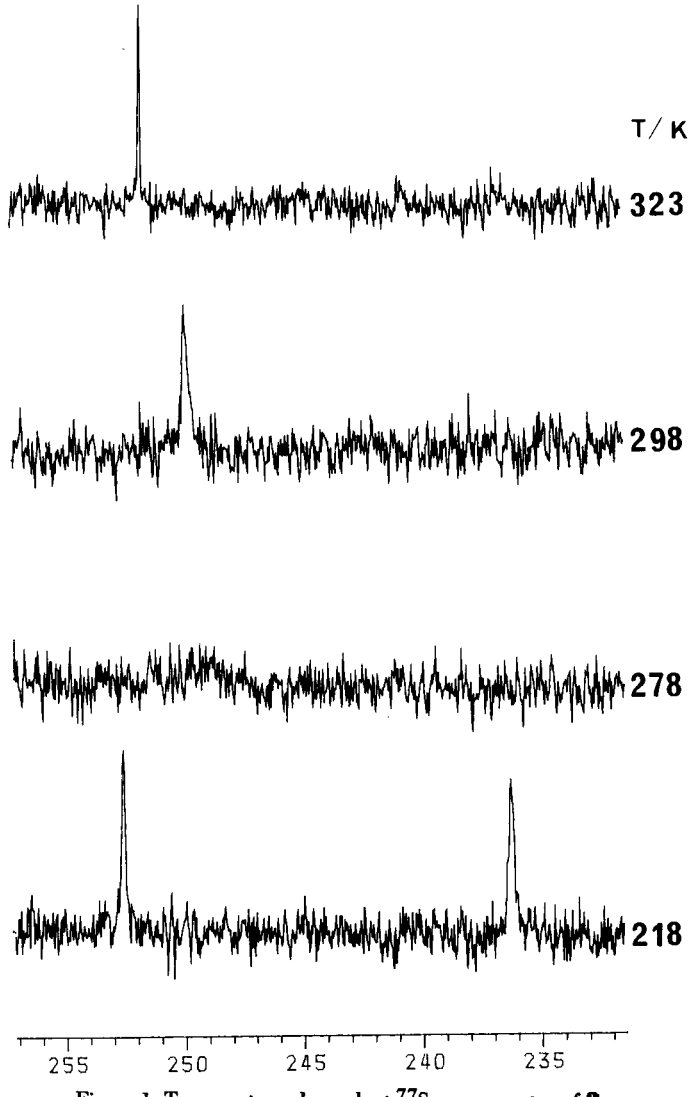


Figure 1. Temperature-dependent ^{77}Se nmr spectra of **2**.

Table 1

^{1}H Chemical; Shifts of **1-4** [a]

	Temp (K)	H-1/7	H-3/5	H-α/α'	H-4	H-10-H-13
1	296	3.88	2.62	–	2.01 [b]	7.14-7.18
						7.26-7.30
	203	4.11/3.73	2.4-2.7	–	1.75-2.20	7.15-7.18
			broad mult		broad mult	7.28-7.33
2	296	3.86	2.76 [c]	1.70-1.75	–	7.13-7.18
	203	4.25/3.62 [d]	3.30/3.03	1.38-1.83		7.13-7.22
		4.05/3.75	2.47/2.00 [b]	multiplets		7.37-7.39
3	296	3.93 [c]	2.82 [c]	4.15	–	7.17-7.20
						7.29-7.33
	203	4.26/3.69	3.60/3.15	4.30/4.16		7.13-7.28
		4.12/3.81	2.81/2.0 [b]	4.08/3.95		7.38-7.42
4	296	3.89	2.65	1.45-1.58		7.14-7.18
						7.26-7.30
	203	4.33/3.58	3.04 [e]	1.1-1.7		7.10-7.45
		4.07/3.73	2.22/2.1 [b]	broad mult		broad mult

[a] Recorded at 400.1 MHz in acetone-d_6 solutions. [b] Partially overlapped by solvent signal. [c] Already broadened at this temperatures due to coalescence effects. [d] Values connected by "/" belong to AB- or AX-pairs. [e] Very broad singlet.

Table 2

^{13}C Chemical Shifts of **1-4** [a]

	Temp (K)	C-1/7	C-3/5	C-4	C-8/9	C-10/13	C-11/12	C-α/α'	C-β/β'
1	296	25.0	23.7	34.8	140.3	130.8	127.8		
	203	24.5 [b]	23.1 [b]	34.4	139.9	130.5	127.5		
2	296	24.3	35.7 [b]	44.5	140.2 [b]	130.8	127.8	33.3	13.8
	203	25.1	38.3	44.0	143.2	131.1	127.6	32.8	13.6
		22.3	31.1		136.6	129.9	127.5	32.4	
3	296	24.6	32.0 [b]	45.9	–[c]	130.8	128.1	81.2	
	203	25.4	34.8	45.0	142.9	131.1	127.8	80.8	
		22.4	27.6		136.4	130.1		80.4	
4	296	24.7	35.8 [b]	48.9	140.2 [b]	130.6	127.8	39.6	25.0
	203	25.6	38.8	48.9	143.3	131.1	127.6	39.3	24.5
		22.6	30.9		136.6	129.9	127.4	38.8	24.3

[a] Recorded at 100.6 MHz in acetone-d_6 solutions. [b] Signals are broadened due to coalescence effects. [c] This signal does not appear at room temperature.

In contrast to **2-4** we could not observe any coalescence effect for **1** down to 218 K. This is in accordance with the finding for the unsubstituted benzodithionine [4] and confirms our assumption that the surprisingly high barriers in the substituted benzodithionines and benzodiselenines are originated in severe steric crowding between atoms of the substituents and atoms of the nine-membered rings during conformational interconversion. The ^{77}Se chemical shift difference for **1** (δ = 296) and **2** (δ = 250) at 298 K is 46 ppm corresponding well to one γ-*gauche*-effect [3a], C-α onto Se-2 and C-α' onto Se-6, respectively (Figure 2).

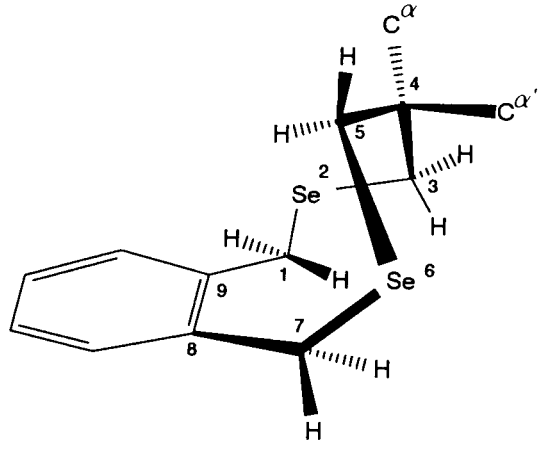


Figure 2. Ground state conformation of **2**; only one enantiomer shown.

EXPERIMENTAL

The nmr spectra were recorded on a Bruker AM-400 spectrometer (400.1 MHz ^{1}H, 100.6 MHz ^{13}C and 76.3 MHz ^{77}Se) using a 5 mm QNP probe head. The samples 0.2 molar in acetone-d_6 for ^{1}H and ^{13}C and in chloroform-d_1 for ^{77}Se nmr. Chemical shifts were referenced to solvent signals; ^{1}H (acetone-d_5): δ = 2.04; ^{13}C (central peak of acetone-d_6): δ = 29.8 ppm; in the case of ^{77}Se the standard is an external sample of diphenyl diselenide in chloroform-d_1 at room temperature (δ = 462). The ir spectra were obtained from Bruker IFS 48 spectrophotometer in potassium bromide plates, mass spectra from Varian CH7 spectrometer (70 eV). Melting points were determined on Boetius microheating table and are therefore corrected.

Table 1 shows the ^{1}H chemical shifts of compounds **1-4** at different temperatures and Table 2 presents the ^{13}C chemical shifts of compounds **1-4** at different temperatures.

Starting Materials.

The ditosylate of 2,2-bis(hydroxymethyl)propane [5], bis(hydroxymethyl)cyclobutane [6], bis(hydroxymethyl)cyclopentane [6], and 3,3-bis(iodomethyl)oxetane [7] were obtained according to the described procedure. 1,2-Bis(selenomethyl)benzene was obtained from potassium selenocyanate and α,α'-dibromo-*o*-xylene [8].

General Synthetic Procedure for Preparation of Compounds **1-4**.

To a suspension of an excess of sodium borohydride (0.9 g) in 500 ml of peroxide-free THF containing 5% of ethanol under bubbling of argon, warmed to 55°, a solution of 0.002 mole of 1,2-bis(selenocyanomethyl)benzene and 0.002 mole of the appropriate dihalogenide or ditosylate compound in 100 ml of THF/Ethanol (1:1) was added dropwise with stirring over 10 hours, and then stirred overnight. The solvent was evaporated, to the residue 50 ml of dichloromethane was added, washed with water and dried (magnesium sulphate). After evaporation of the solvent the residue was purified by column chromatography (silica gel/cyclohexane).

1,4,5,7-Tetrahydro-3*H*-2,6-benzodiselenine (**1**).

This compound was obtained in a yield of 0.3 g (49%), mp 97-98° [9]; ir: 608, 748, 762, 1193, 1221, 1282, 1412, 1448, 1486, 1559, 1680, 2885, 2895, 2924, 3008, 3052; ms: m/z (relative intensity) 306 ($M^{+\cdot}$, 14%).

Anal. Calcd. for $C_{11}H_{14}Se_2$: C, 43.44; H, 4.64. Found: C, 43.87; H, 5.02.

1,4,5,7-Tetrahydro-3*H*-2,6-benzodiselenine-4-spiro-1′-cyclobutane (**2**).

This compoud was obtained in a yield of 0.16 g (24%), mp 86-88°; ir: 606, 746, 764, 1176, 1239, 1407, 1450, 1486, 1559, 2850, 2882, 2918, 2923, 3012, 3058; ms: m/z (relative intensity) 346 ($M^{+\cdot}$, 7%).

Anal. Calcd. for $C_{14}H_{18}Se_2$: C, 48.85; H, 5.27. Found: C, 49.26; H, 4.95.

1,4,5,7-Tetrahydro-3*H*-2,6-benzodiselenine-4-spiro-1′-(3′-oxacyclobutane) (**3**).

This compound was obtained in a yield of 0.18 g (26%), mp 151-152°; ir: 606, 745, 764, 977, 1180, 1225, 1407, 1451, 1486, 1559, 1653, 2863, 2890, 2924, 2936, 3020, 3058; ms: m/z (relative intensity) 348 ($M^{+\cdot}$, 6%).

Anal. Calcd. for $C_{13}H_{16}OSe_2$: C, 45.10; H, 4.66. Found: C, 45.39; H, 5.01.

1,4,5,7-Tetrahydro-3*H*-2,6-benzodiselenine-4-spiro-1′-cyclopentane (**4**).

This compound was obtained in a yield of 0.14 g (20%), mp 91-93°; ir: 608, 749, 772, 1184, 1235, 1256, 1294, 1404, 1450, 1480, 1575, 1653, 2854, 2906, 2936, 2945, 3017, 3068; ms: m/z (relative intensity) 360 ($M^{+\cdot}$, 6%).

Anal. Calcd. for $C_{15}H_{20}Se_2$: C, 50.29; H, 5.63. Found: C, 49.99; H, 5.40.

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