Chemistry of Heterocyclic Compounds, Vol.35, No. 1, 1999

SILYL MODIFICATIONS OF BIOLOGICALLY ACTIVE COMPOUNDS 6*. ORGANOSILICON COMPLEXES OF RHENIUM(V) WITH MIXED LIGANDS

H. Spies, Th. Fietz, A. Zablotskaya, S. Belyakov, and E. Lukevics

Neutral organosilicon complexes of rhenium with mixed ligands of general formula ReO(SSS)(S–Q–OSiRR'$_2$) have been synthesized. An X-ray crystallographic investigation of (2-triphenylsiloxyethanethiolato)(3-thiapentan-1,5-dithiolato)oxorhenium has been carried out and its neurotropic properties have been studied.

The possibility of using coordination compounds of technetium and rhenium in radionuclidic diagnostics (^{99m}Tc) and therapy (^{186}Re) [2, 3] has stimulated the search for new chelate systems and also approaches which affect the accumulation and distribution of radioactive compounds within an organism. An important facet for the solution of this problem, especially for compounds affecting the central nervous system, is to increase their lipophilicity to facilitate their passage through the blood-brain barrier.

It has been demonstrated as a result of a number of studies [4-9] that silylation significantly increases the lipophilicity of biologically active compounds and consequently facilitates their transportation within the organism. For example, silylation of the hydroxy groups of aliphatic and heterocyclic aminoalkanols creates positive physiological effects. This is true not only to reversibly silylated (hydrolytically unstable) compounds but also to compounds containing triorganosilyl(oxy) groups stable to hydrolysis under physiological conditions.

We propose to apply this principle to complex compounds of rhenium to improve their physicochemical and biological properties. We have synthesized a series of neutral silicon-containing rhenium complexes with mixed ligands with the general formula [ReO(SSS)(S—Q—OSiRR'$_2$)] in which the oxorhenium residue ReO^{3+} is coordinated by the tridentate dithiolate ligand SSS (HS—CH_2—CH_2—S—CH_2—CH_2—SH) and by a monodentate thiolate (S—Q—OSiRR'$_2$, where S—Q is a 2-mercaptoethanol, 3-mercaptopropanol, or 4-hydroxythiophenol residue) containing a silylated hydroxy function with a variety of organosilicon substituents.

Chloro(3-thiapentane-1,5-dithiolato)oxorhenium(V) **1** was synthesized by a published method [10].

(2-Hydroxyethanethiolato)(3-thiapentane-1,5-dithiolato)oxorhenium(V) **2** was prepared by the reaction of compound **1** with mercaptoethanol in boiling acetonitrile. (3-Hydroxypropanethiolato)- **3** and (4-hydroxyphenylthiolato)(3-thiapentane-1,5-dithiolato)oxorhenium(V) **4** were made analogously.

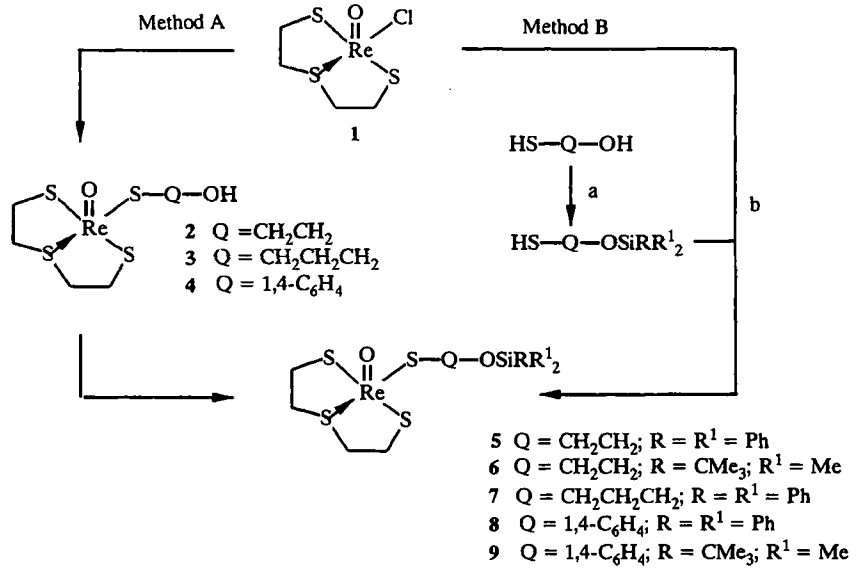
The silylated complexes were synthesized in two ways. In method A silylation of the γ-hydroxyl groups was carried out with the previously prepared 3+1 complex with mixed ligands in which the monodentate ligand had a free hydroxyl group. In method B an organosilicon ligand was first synthesized, followed by reaction with

* For part 5, see [1].

Latvian Institute of Organic Synthesis, Riga, LV-1006. e-mail: aez@osi.lanet.lv, and Forschungszentrum Rossendorf, Dresden, Germany. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 1, 116-125, January 1999. Original article submitted August 4, 1998.

 0009-3122/99/3501-0112$22.00

the oxorhenium(V) precursor **1**. Silylation by either method A or B was carried out with various triorganochlorosilanes in the presence of an amine. The synthesized triphenylsiloxy- (**5**, **6**, and **8**) and *tert*-butyldimethylsiloxy compounds (**6** and **9**) are stable to oxygen and moist air and also to separation conditions (silica gel).



As a result of the X-ray crystallographic study (Fig. 1) compound **5** is observed to have distorted tetragonal pyramidal structure resulting from coordination of the sulphur atoms of the tridentate and monodentate ligands to the Re=O unit. The Re=O distance is 1.688(11) Å. The Re atom is displaced by -0.734(2) Å from the $S_{(2)}S_{(5)}S_{(8)}S_{(9)}$ plane. The bond angles $S_{(2)}$—$Re_{(1)}$—$S_{(8)}$ and $S_{(5)}$—$Re_{(1)}$—$S_{(9)}$ (130.3(1)° and 153.2(1)° respectively) are considerably different from one another so that the coordination polyhedron around the rhenium atom is not a pyramid but a distorted bipyramid. A stereoscopic view of the coordination polyhedron is show in Fig. 2. The normal equations for the mean squared planes for the two fragments of the polyhedron and the displacement of the atoms from them are given in Table 1. The Re atom is practically in the $S_{(2)}S_{(8)}O_{(32)}$ plane but the four sulphur

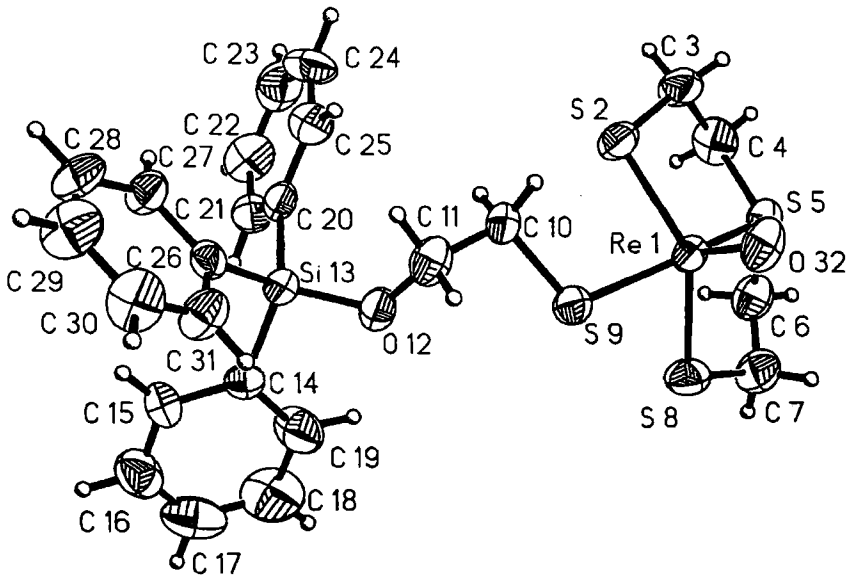


Fig. 1. Overall view of the molecule of compound **5**

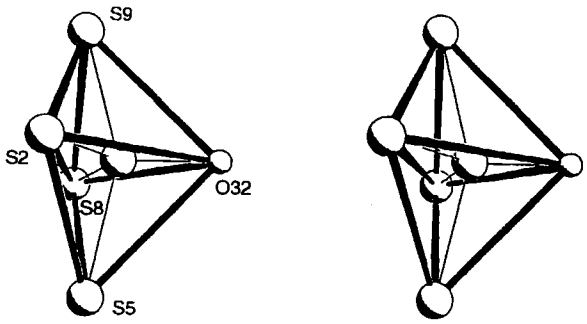


Fig. 2. Stereoscopic view of the coordination polyhedron in compound **5**

atoms do not lie in one plane. The dihedral angle between the $S_{(5)}S_{(2)}S_{(8)}$ and $S_{(9)}S_{(2)}S_{(8)}$ triangles is 158.8(2)°. The silicon atom has tetrahedral configurations without any increasing of the coordination. Coordinates of the non-hydrogen atoms, interatomic distances, bond angles, and torsion angles for compound **5** are given in Tables 2 – 5.

TABLE 1. Equations for the Planes $Ax + By + Cz - D = 0$ and Displacements of the Atoms

Planes	*A*	*B*	*C*	*D*	Atoms and their displacements from the plane (Å)
S(2) S(5) S(8) S(9)	-0,875	-0,413	-0,252	-2,216	S(2) 0,211 (4) S(5) –0,201 (4) S(8) 0,249 (4) S(9) -0,192 (3) Re(1) –0,734 (2) O(32) -2,42 (4)
S(2) S(8) O(32)	-0,327	-0.902	-0,283	0,388	Re(1) 0,031 (1) S(5) –2,294 (3) S(9) 2,256 (3)

TABLE 2. Coordinate of Non-hydrogen Atoms in the Molecule of Compound **5**

Atom	*x/a*	*y/b*	*z/c*
1	2	3	4
Re(1)	0,2115 (1)	0,1363 (1)	0,0097 (1)
S(2)	0,2381 (3)	0,0694 (3)	-0,1708 (2)
C(3)	0,3602 (15)	-0,0874 (13)	-0,1705 (11)
C(4)	0,3280 (15)	-0,1656 (11)	-0,0733 (12)
S(5)	0,3139 (3)	0,0787 (3)	0,0533 (2)
C(6)	0,1868 (14)	-0,1242 (12)	0,1434 (11)
C(7)	0,1205 (15)	-0,0222 (13)	0,2232 (11)
S(8)	0,0504 (3)	0,1267 (3)	0,1500 (3)
S(9)	0,0315 (3)	0,3052 (3)	0,1500 (2)
C(10)	0,0507 (11)	0,3494 (10)	-0,1879 (9)
C(11)	-0,0527 (12)	0,4740 (11)	-0,2134 (10)

TABLE 2 (continued)

1	2	3	4
O(12)	-0,1889 (8)	0,4689 (8)	-0,2067 (6)
Si(13)	-0,2909 (3)	0,4860 (3)	-0,3111 (2)
C(14)	-0,4649 (10)	0,5024 (9)	-0,2434 (9)
C(15)	-0,5827 (11)	0,5776 (11)	-0,2894 (11)
C(16)	-0,7111 (14)	0,5909 (14)	-0,2380 (13)
C(17)	-0,7241 (17)	0,5281 (16)	-0,1411 (16)
C(18)	-0,6087 (19)	0,4512 (16)	-0,0942 (15)
C(19)	-0,4810 (15)	0,4406 (13)	-0,1432 (13)
C(20)	-0,2375 (11)	0,3470 (10)	-0,4044 (9)
C(21)	-0,3246 (12)	0,2796 (10)	-0,4200 (10)
C(22)	-0,2922 (16)	0,1788 (13)	-0,4882 (12)
C(23)	-0,1625 (18)	0,1362 (15)	-0,5402 (13)
C(24)	-0,0693 (15)	0,1997 (14)	-0,5261 (12)
C(25)	-0,1076 (13)	0,3034 (13)	-0,4583 (11)
C(26)	-0,2939 (10)	0,6274 (10)	-0,3951 (9)
C(27)	-0,2948 (12)	0,6295 (11)	-0,5115 (10)
C(28)	-0,3138 (15)	0,7428 (14)	-0,5715 (11)
C(29)	-0,3322 (16)	0,8492 (13)	-0,5192 (12)
C(30)	-0,3323 (16)	0,8511 (13)	-0,4054 (13)
C(31)	-0,3133 (13)	0,7418 (11)	-0,3428 (10)
O(32)	0,3320 (9)	0,1968 (8)	-0,0506 (7)

It was established from a study of the neurotropic properties of compound **5** that it possesses anticonvulsive activity and has protective properties with respect to corazole. Under the action of compound **5** the dose of corazole causing clonic convulsions is increased by 1.3 and the lethal dose is increased by a factor of 1.8. However it appears to be ineffective with maximum electroshock (therapy). Compound **5** does not affect skeletal muscle tone and the coordination of movement.

Compound **5** has tranquilizing properties, increases the length of barbiturate narcosis by 50%, strengthens the effect of amphetamine, increases the motor activity of animals over 30 min by about a factor of 2 and over 60 min by a factor of 1.6. Compound **5** lowers the body temperature of animals by 2.1°C/30 and has a low acute toxicity (LD_{50} > 500mg/kg).

TABLE 3. Bond Lengths (*d*) in the Molecule of Compound **5**

Bond	*d*, Å	Bond	*d*, Å
S(2)—Re(1)	2,285 (3)	C(15)—C(14)	1,375 (14)
S(5)—Re(1)	2,378 (3)	C(19)—C(14)	1,394 (18)
S(8)—Re(1)	2,298 (3)	C(16)—C(15)	1,379 (18)
S(9)—Re(1)	2,304 (3)	C(17)—C(16)	1,360 (25)
O(32)—Re(1)	1,688 (11)	C(18)—C(17)	1,369 (24)
C(3)—S(2)	1,819 (13)	C(19)—C(18)	1,367 (25)
S(5)—C(4)	1,807 (15)	C(21)—C(20)	1,362 (19)
C(6)—S(5)	1,819 (15)	C(25)—C(20)	1,387 (16)
S(8)—C(7)	1,827 (14)	C(22)—C(21)	1,365 (19)
C(10)—S(9)	1,818 (11)	C(23)—C(22)	1,375 (23)
Si(13)—O(12)	1,647 (8)	C(24)—C(23)	1,380 (27)
C(14)—Si(13)	1,863 (11)	C(25)—C(24)	1,385 (21)
C(20)—Si(13)	1,875 (11)	C(27)—C(26)	1,395 (16)
C(26)—Si(13)	1,849 (12)	C(31)—C(26)	1,306 (17)
C(4)—C(3)	1,518 (20)	C(28)—C(27)	1,409 (19)
C(7)—C(6)	1,484 (18)	C(29)—C(28)	1,428 (21)
C(11)—C(10)	1,510 (14)	C(30)—C(29)	1,364 (22)
O(12)—C(11)	1,408 (15)	H(30)—C(30)	1,930 (21)

TABLE 4. Bond Angles (ω) in the Molecule of Compound 5

Angle	ω, deg	Angle	ω, deg
Re(1)—S(2)—C(3)	106,475 (0,444)	C(10)—C(11)—O(12)	112,251 (1,057)
S(2)—Re(1)—S(5)	84,074 (0,106)	H(11a)—C(11)—H(11b)	107,872 (1,681)
S(2)—Re(1)—S(8)	130,261 (0,135)	H(11a)—C(11)—O(12)	109,152 (1,180)
S(2)—Re(1)—S(9)	88,220 (0,104)	H(11)—C(11)—O(12)	109,157 (1,300)
S(2)—Re(1)—O(32)	116,140 (0,302)	C(14)—C(15)—H(15)	119,484 (1,308)
Re(1)—S(5)—C(4)	107,823 (0,409)	C(14)—C(15)—C(16)	121,026 (1,211)
Re(1)—S(5)—C(6)	106,032 (0,392)	C(15)—C(14)—C(19)	117,218 (1,085)
S(5)—Re(1)—S(8)	84,290 (0,111)	C(14)—C(19)—C(18)	121,544 (1,309)
S(5)—Re(1)—S(9)	153,176 (0,121)	C(14)—C(19)—H(19)	119,229 (1,728)
S(5)—Re(1)—O(32)	101,093 (0,282)	H(15)—C(15)—C(16)	119,490 (1,325)
Re(1)—S(8)—C(7)	106,614 (0,459)	C(15)—C(16)—H(16)	119,709 (1,801)
S(8)—Re(1)—S(9)	81,226 (0,109)	C(15)—C(16)—C(17)	120,577 (1,283)
S(8)—Re(1)—O(32)	113,533 (0,303)	H(16)—C(16)—C(17)	119,714 (1,764)
Re(1)—S(9)—C(10)	112,707 (0,328)	C(16)—C(17)—H(17)	120,160 (1,919)
S(9)—Re(1)—O(32)	105,363 (0,280)	C(16)—C(17)—C(18)	119,666 (1,615)
S(2)—C(3)—C(4)	111,558 (0,885)	H(17)—C(17)—C(18)	120,175 (2,165)
C(3)—C(4)—S(5)	107,814 (0,972)	C(17)—C(18)—H(18)	120,040 (2,225)
C(4)—S(5)—C(6)	104,382 (0,705)	C(17)—C(18)—C(19)	119,916 (1,679)
S(5)—C(6)—C(7)	108,578 (0,099)	H(15)—C(18)—C(19)	120,044 (2,029)
C(6)—C(7)—S(8)	111,225 (0,921)	C(18)—C(19)—H(19)	119,227 (1,841)
S(9)—C(10)—C(11)	110,114 (0,739)	C(20)—C(21)—H(21)	118,171 (1,404)
C(11)—O(12)—Si(13)	126,674 (0,719)	C(20)—C(21)—C(22)	123,660 (1,194)
O(12)—Si(13)—C(14)	105,008 (0,447)	C(21)—C(20)—C(25)	115,839 (1,111)
O(12)—Si(13)—C(20)	112,081 (0,432)	C(20)—C(25)—C(24)	122,332 (1,444)
O(12)—Si(13)—C(26)	110,652 (0,517)	C(20)—C(25)—H(25)	118,834 (1,519)
Si(13)—C(14)—C(15)	121,301 (0,859)	H(21)—C(21)—C(22)	118,169 (1,663)
Si(13)—C(14)—C(16)	150,819 (0,658)	C(21)—C(22)—H(22)	120,174 (1,624)
Si(13)—C(14)—C(19)	121,473 (0,842)	C(21)—C(22)—C(23)	119,653 (1,640)
C(14)—Si(13)—C(20)	109,342 (0,533)	H(22)—C(22)—C(23)	120,173 (1,694)
C(14)—Si(13)—C(26)	110,380 (0,434)	C(22)—C(23)—H(23)	120,452 (2,335)
Si(13)—C(20)—C(21)	121,079 (0,792)	C(22)—C(23)—C(24)	119,109 (1,476)
Si(13)—C(20)—C(25)	123,045 (0,067)	H(23)—C(23)—C(24)	120,440 (2,076)
C(20)—Si(13)—C(26)	109,308 (0,495)	C(23)—C(24)—H(24)	120,345 (1,886)
Si(13)—C(26)—C(27)	121,930 (0,908)	C(23)—C(24)—C(25)	119,308 (1,330)
Si(13)—C(26)—C(31)	120,628 (0,858)	H(24)—C(24)—C(25)	120,346 (2,022)
H(3a)—C(3)—H(3b)	107,962 (1,753)	C(24)—C(25)—H(25)	118,834 (1,478)
H(3a)—C(3)—C(4)	109,310 (1,654)	C(26)—C(27)—H(27)	119,955 (1,350)
H(3b)—C(3)—C(4)	109,317 (1,438)	C(26)—C(27)—C(28)	120,090 (1,139)
C(3)—C(4)—H(4a)	110,141 (1,533)	C(27)—C(26)—C(31)	116,956 (1,037)
C(3)—C(4)—H(4b)	110,143 (1,534)	C(26)—C(31)—C(30)	120,852 (1,182)
H(4a)—C(4)—H(4b)	108,466 (1,795)	C(26)—C(31)—H(31)	119,568 (1,383)
H(6a)—C(6)—H(6b)	108,352 (1,911)	H(27)—C(27)—C(28)	119,955 (1,381)
H(6a)—C(6)—C(7)	109,977 (1,378)	C(27)—C(28)—H(28)	119,360 (1,754)
H(6b)—C(6)—C(7)	109,982 (1,417)	C(27)—C(28)—C(29)	121,283 (1,245)
C(6)—C(7)—H(7a)	109,379 (1,416)	H(28)—C(28)—C(29)	119,358 (1,786)
C(6)—C(7)—H(7b)	109,384 (1,712)	C(28)—C(29)—H(29)	119,793 (1,761)
H(7a)—C(7)—H(7b)	108,010 (1,761)	C(28)—C(29)—C(30)	120,414 (1,343)
H(10a)—C(10)—H(10b)	108,152 (1,337)	H(29)—C(29)—C(30)	119,793 (1,742)
H(10a)—C(10)—C(11)	109,640 (1,266)	C(29)—C(30)—H(30)	119,803 (1,702)
H(10b)—C(10)—C(11)	109,636 (1,181)	C(29)—C(30)—C(31)	120,403 (1,338)
C(10)—C(11)—H(11a)	109,157 (1,241)	H(30)—C(30)—C(31)	119,794 (1,730)
C(10)—C(11)—H(11b)	109,153 (1,121)	C(30)—C(31)—H(31)	119,580 (1,488)
C(10)—C(11)—O(12)	112,251 (1,057)		
H(11a)—C(11)—H(11b)	107,872 (1,681)		

TABLE 5. Torsion Angles (τ) in the Molecule of Compound **5**

Angle	τ, deg
1	2
H(4a)—C(4)—C(3)—H(3a)	66,604 (2,243)
H(4b)—C(4)—C(3)—H(3a)	-52,992 (1,901)
H(4a)—C(4)—C(3)—H(3b)	-51,371 (2,215)
H(4b)—C(4)—C(3)—H(3b)	-170,967 (1,589)
H(7a)—C(7)—C(6)—H(6a)	172,656 (1,846)
H(7b)—C(7)—C(6)—H(6a)	54,543 (2,025)
H(7a)—C(7)—C(6)—H(6b)	53,404 (2,384)
H(7b)—C(7)—C(6)—H(6b)	-64,709 (2,199)
H(11a)—C(11)—C(10)—H(10a)	-67,628 (1,729)
H(11b)—C(11)—C(10)—H(10a)	50,055 (1,905)
O(12)—C(11)—C(10)—H(10a)	171,216 (1,180)
H(11b)—C(11)—C(10)—H(10a)	173,783 (1,525)
H(11b)—C(11)—C(10)—H(10b)	-68,534 (1,890)
O(12)—C(11)—C(10)—H(10b)	52,626 (1,502)
H(15)—C(15)—C(14)—C(19)	-179,897 (1,350)
C(16)—C(15)—C(14)—C(19)	0,103 (1,683)
C(18)—C(19)—C(14)—C(15)	1,840 (2,164)
H(19)—C(19)—C(14)—C(15)	-178,167 (1,799)
H(16)—C(16)—C(15)—C(14)	178,923 (1,889)
C(17)—C(16)—C(15)—C(14)	-1,085 (2,407)
H(16)—C(16)—C(15)—H(15)	-1,081 (2,589)
C(17)—C(16)—C(15)—C(15)	178,911 (1,870)
H(17)—C(17)—C(16)—C(15)	-179,859 (1,906)
C(18)—C(17)—C(16)—C(15)	0,147 (2,408)
H(17)—C(17)—C(16)—C(16)	0,131 (3,255)
C(18)—C(17)—C(16)—H(16)	-179,863 (1,801)
H(18)—C(18)—C(17)—C(16)	-178,236 (2,378)
C(19)—C(18)—C(17)—C(16)	1,766 (2,941)
H(18)—C(18)—C(17)—H(17)	1,771 (3,877)
C(19)—C(18)—C(17)—H(17)	-178,227 (2,349)
C(14)—C(19)—C(18)—C(17)	-2,803 (2,725)
H(19)—C(19)—C(18)—C(17)	177,204 (2,072)
C(14)—C(19)—C(18)—H(18)	177,199 (2,208)
H(19)—C(19)—C(18)—H(18)	-2,794 (3,514)
H(21)—C(21)—C(20)—C(25)	176,829 (1,352)
C(22)—C(21)—C(20)—C(25)	-3,173 (1,726)
C(24)—C(25)—C(20)—C(21)	1,487 (1,793)
H(25)—C(25)—C(20)—C(21)	-178,527 (1,499)
H(22)—C(22)—C(21)—C(20)	-176,127 (1,561)
C(23)—C(22)—C(21)—C(20)	3,885 (2,000)
H(22)—C(22)—C(21)—H(21)	3,871 (2,418)
C(23)—C(22)—C(21)—H(21)	-176,117 (1,448)
H(23)—C(23)—C(22)—C(21)	177,308 (1,708)
C(24)—C(23)—C(22)—C(21)	-2,703 (2,168)
H(23)—C(23)—C(22)—H(22)	-2,688 (2,890)
C(24)—C(23)—C(22)—H(22)	177,308 (1,708)
H(24)—C(24)—C(23)—C(22)	-178,871 (1,768)
C(25)—C(24)—C(23)—C(22)	1,127 (2,212)
H(24)—C(24)—C(23)—H(23)	1,125 (2,638)
C(25)—C(24)—C(23)—H(23)	-178,877 (1,842)
C(20)—C(25)—C(24)—C(23)	-0,547 (1,666)
H(25)—C(25)—C(24)—C(23)	179,458 (1,494)
C(20)—C(25)—C(24)—H(24)	179,451 (1,462)
H(25)—C(25)—C(24)—H(24)	-0,544 (2,062)
H(25)—C(27)—C(26)—H(31)	-179,683 (1,021)
C(28)—C(27)—C(26)—C(31)	0,320 (1,264)
C(30)—C(31)—C(26)—C(27)	0,020 (1,796)
H(31)—C(31)—C(26)—C(27)	-179,980 (1,518)
H(28)—C(28)—C(27)—C(26)	179,496 (1,259)
C(29)—C(28)—C(27)—C(26)	-0,506 (1,587)

TABLE 5 (continued)

1	2
H(28)—C(28)—C(27)—H(27)	-0,501 (1,934)
C(29)—C(28)—C(27)—H(27)	179,496 (1,178)
H(29)—C(29)—C(28)—C(27)	-179,665 (1,457)
C(30)—C(29)—C(28)—C(27)	0,334 (1,950)
H(29)—C(29)—C(28)—H(28)	0,332 (2,566)
C(30)—C(29)—C(28)—H(28)	-179,670 (1,385)
H(30)—C(30)—C(29)—C(28)	180,000 (1,941)
C(31)—C(30)—C(29)—C(28)	0,000 (2,451)
H(30)—C(30)—C(29)—H(29)	0,020 (3,131)
C(20)—C(31)—C(30)—C(29)	-0,181 (1,940)
H(31)—C(31)—C(30)—C(29)	179,813 (1,446)
C(26)—C(31)—C(30)—H(30)	179,822 (1,512)
H(31)—C(31)—C(30)—H(30)	-0,183 (2,558)

EXPERIMENTAL

All compounds were identified by elemental analysis and ^{1}H NMR spectroscopy. Elemental analysis results agreed with calculated values.

^{1}H NMR spectra were recorded with a Bruker WH-90 machine and ^{29}Si NMR spectra with a Bruker AC-360 machine in $CDCl_3$ with Me_4Si as internal standard. The ^{1}H NMR spectra of all compounds had resonances at 1.91-4.29 ppm (8H, m, —$SCH_2CH_2SCH_2CH_2S$—). Compounds were separated by column chromatography Kieselgel 60 (Merck) silica gel.

Monocrystals of compound **5** ($C_{24}H_{27}O_2ReS_4Si$) were grown form $CHCl_3$–MeOH solvent system: triclinic space, group P1. Unit cell parameters: a = 10.218(3), b = 11.281(3), c = 11.980(3) Å, α = 88.04(2), β = 86.25(2), γ = 71.82(2)°, V = 1309.1(6) Å^3, Z = 2, F(OOO) = 680, d_{calc} = 1.750(1) g/cm^3. Intensities of 3437 independent reflexions were measured on an automatic four-circle Syntex $P2_1$ diffractometer (MoKα radiation, graphite monochromator, $\theta/2\theta$ scanning, $2\theta_{max}$ = 45°). In the calculations 3120 reflexions with $|F| > 4.0\sigma|F|$ have been used. The position of the rhenium atom was found from the Patterson function. The remaining non-hydrogen atoms were localized by successive Fourier syntheses. The structure was refined full matrix least squares analyses with anisotropic temperature factors. The coordinates of the hydrogen atoms were determined geometrically. Since the crystal showed considerable X-ray absorption (crystal dimensions 0.10 × 0.30 × 0.50 mm, μ = 5.03 mm-1) azimuthal scanning corrections for absorption were applied [11]. The final residual factor was equal to 0.0556. The AREN suite of programs was used for the calculations [12]. The atomic coordinates for the structure of **5** are given in Table 2.

Chloro(3-thiapentane-1,5-dithiolato)oxorhenium(V) (1) was synthesized by a known method [10].

(2-Hydroxyethanethiolato)(3-thiapentane-1,5-dithiolato)oxorhenium(V) (2). 2-Mercaptoethanol (156 mg, 2 mmole) was added with stirring to a boiling solution of compound **1** (408.4 mg, 1.047 mmole) in acetonitrile (10 ml). After 20 min the solvent was evaporated, the residue was dissolved in hot chloroform and purified by column chromatography with 19:1 chloroform/methanol as eluant. Ethanol (2 ml) was added to the eluate to crystallize the product. The crystalline product was washed with diethyl ether and dried to give **2** (426 mg, 94%), m.p. 130-133°C. Found, %: C 17.03, H 3.77, S 29.26. Calc. for $C_6H_{13}O_2ReS_4$, %: C 16.70, H 3.04, S 29.71. ^{1}H NMR Spectrum, ppm: 4.82 (1H, t, OH, J = 5.2 Hz), 3.72 (2H, t, SCH_2, J = 7.55 Hz), 3.66 (2H, m, CH_2O).

(3-Hydroxypropanethiolato)(3-thiapentane-1,5-dithiolato)oxorhenium(V) (3) was obtained from **1** and 3-mercaptopropanol by the method described above in 81% yield, m.p. 120-123°C. Found, %: C 19.10, H 3.58, S 26.25. Calc. for $C_7H_{15}O_2ReS_4$, %: C 18.87, H 3.39, S 28.78. ^{1}H NMR Spectrum, ppm: 4.48 (1H, t. OH, J = 5.2 Hz), 3.66 (2H, t, CH_2S, J = 7.4 Hz), 3.52 (2H, m, CH_2O), 1.89 (2H, m, CH_2).

(4-Hydroxyphenylthiolato)(3-thiapentane-1,5-dithiolato)oxorhenium(V) (4) was obtained from **1** and 4-hydroxythiophenol by the method described above in 75% yield, m.p. 200-202°C. Found, %: C 24.31, H 3.03, S 26.25. Calc. for $C_{10}H_{13}O_2ReS_4$, %: C 25.04, H 2.73, S 26.74. ^{1}H NMR Spectrum, ppm: 7.27 (2H, d, o-CH, J = 8.5 Hz), 6.76 (2H, d, m-CH, J = 8.5 Hz).

Preparation of silylated complexes. A. (2-Triphenylsiloxyethanethiolato)(3-thiapentane-1,5-dithiolato)oxorhenium(V) (5). Triphenylchlorosilane (200 μg) and triethylamine (200 μg) were added to solution of compound **2** (43.1 mg, 100 μmole) in absolute tetrahydrofuran (4 ml). The mixture was stirred for 30 min, filtered, the solvent evaporated, and the product was purified by column chromatography with chloroform as eluant. Ethanol (2 ml) was added to the eluate which crystallized to give the product (82%), m.p. 123-130°C. Found, %: C 41.53, H 4.06, S 18.49. Calc. for $C_{24}H_{27}O_2ReS_4Si$, %: C 41.78, H 3.94, S 18.59. ^{1}H NMR Spectrum, ppm: 7.66 (6H, d, *o*-CH, J = 7.5 Hz), 7.41 (3H, t, *p*-CH, J = 7.5 Hz), 7.36 (6H, t, *m*-CH, J = 7.5 Hz), 4.16 (2H, t, SCH_2), 4.08 (2H, t, OCH_2). ^{19}Si NMR Spectrum, ppm: -13.12.

(3-Triphenylsiloxypropanethiolato)(3-thiapentane-1,5-dithiolato)oxorhenium(V) (7) was prepared by method A from compound **3** and triphenylchlorosilane. Yield 80%, m.p. 244-247°C. Found, %: C 42.39, H 4.25, S 18.02. Calc. for $C_{25}H_{29}O_2ReS_4Si$, %: C 42.65, H 4.15, S 18.21. ^{1}H NMR Spectrum, ppm: 7.3-7.7 (15H, m, Ar), 3.98 (2H, t, CH_2S, J = 6.5 Hz), 3.85 (2H, t, OCH_2, J = 6.5 Hz), 2.18 (2H, quintet, CH_2S, J = 6.5 Hz).

(4-Triphenylsiloxyphenylthiolato)(3-thiapentane-1,5-dithiolato)oxorhenium(V) (8) was prepared by method A from compound **4** and triphenylchlorosilane. Yield 80%, m.p. 237-240°C. Found, %: C 45.00, H 3.75, S 17.24. Calc. for $C_{28}H_{27}O_2ReS_4Si$, %: C 45.57, H 3.69, S 17.38. ^{1}H NMR Spectrum, ppm: 7.66 (6H, d, *o*-CH, J = 7.4 Hz), 7.43 (3H, t, *p*-CH, J = 7.4 Hz), 7.42 (2H, d, 2-CH, J = 8.4 Hz), 7.37 (6H, t, *m*-CH, J = 7.4 Hz), 6.88 (2H, d, 3-CH, J = 8.4 Hz).

B. Silylated ligands. A mixture of 2-mercaptoethanol or 4-hydroxythiophenol (10 mmole), *tert*-butyldimethylchlorosilane (1.66 g, 12 mmole) and imidazole (1.08 g, 15 mmole) in dimethylformamide (10 ml) was stirred at room temperature for 24 h. The precipitate was filtered off, the solvent was evaporated, and the products were used in the condensation reactions without further purification.

Preparation of organosilicon complexes. O-*tert*-butyldimethylsiloxyethanethiol or 4-*tert*-butyldimethylsiloxythiophenol (230 μmole) was added to complex **1** (86.2 mg, 221 μmole) in acetonitrile (5 ml). The mixture was boiled until a deep brown color appeared. The solvent was evaporated, the residue was dissolved in chloroform and the product isolated by chromatography on silicagel with chloroform as eluant. Ethanol (several ml) was added to the fraction containing the product which crystallized on standing.

(2-*tert*-Butyldimethylsiloxyethanethiolato)(3-thiapentane-1,5-dithiolato)oxorhenium(V) (6) was prepared by method B. Yield 79%, m.p. 224°C. Found, %: C 26.67, H 5.06, S 23.32. Calc. for $C_{12}H_{27}O_2ReS_4Si$, %: C 26.40, H 4.99, S, 23.49. ^{1}H NMR Spectrum, ppm: 3.99 (4H, m, SCH_2CH_2O), 0.91 (9H, s, CMe_3), 0.10 (6H, s, $SiMe_2$).

(4-*tert*-Butyldimethylsiloxyphenylthiolato)(3-thiapentane-1,5-dithiolato)oxorhenium(V) (9) was prepared by method B. Yield 80%, m.p. 212°C. Found, %: C 32.22, H 4.48, S 21.42. Calc. for $C_{16}H_{27}O_2ReS_4Si$, %: C 32.36, H 4.58, S 21.59. ^{1}H NMR Spectrum, ppm: 7.53 (2H, d, *o*-CH, J = 8.5 Hz), 6.86 (2H, d, *m*-CH, J = 8.5 Hz), 0.98 (9H, s, CMe_3), 0.21 (6H, s, $SiMe_2$).

BIOLOGICAL SECTION

Neurotropic activity was studied with mice (line BALB/c) and random male rats. An oil solution of the substance under study was injected intraperitoneally up to 30 min before the experiment [13].

The effect of the substance was estimated as follows 1) its effect on coordination of movement and muscle tone ("rotating bar", "tubes", and "pulling up on the cross-bar" tests); 2) its effect on body temperature; 3) analgesic effect ("hot plate" test); 4) anti-convulsive effect (maximal electric shock and corazole convulsion tests); 5) its effect on the duration of hexenal and ethanol narcosis; 6) its effect on the duration of life under conditions of hypoxic hypoxia; 7) its effect on locomotor activity and body temperature on concurrent treatment with amphetamine; 8) its effect on unavoidable stress situations and on processes of memorization and retrograde amnesia.

The experimental results were treated statistically. The express method [14] was used to find the mean values of the LD_{50} and ED_{50} of 12-20 observations. Estimation of the significance of differences between the means ($M \pm m$) was based on Student's criteria. Differences were considered significant at a probability of $P \leq 0.05$.

The authors express their thanks to Dr. S. K. Germane for carrying out the pharmacological experiments and also to the International Buro BMBF (Germany) for financial assistance.

REFERENCES

1. E. Lukevics, I. Segal, I. Birgele, and A. Zablotskaya, Khim. Geterotsikl. Soedin., No. 9, 1253 (1998).
2. J. D. Dunitz, Technetium and Rhenium. Their Chemistry and its Applications. Topics Curr. Chem., J. D. Dunitz (editor), New York (1996), p. 176.
3. B. Johannsen and H. Spies, Transition Met. Chem., **22**, 318 (1977).
4. E. Lukevics, I. Segal, A. Zablotskaya, and S. Germane, Chem. Heterocycl. Comp., **32**, 682 (1996).
5. E. Lukevics, I. Segal, and A. Zablotskaya, AFMC Intern. Med. Chem. Symp. Tokyo, 3-8 September 1995. Abstract P1M055.
6. A. H. Beckett, D. C. Taylor, and J. W. Garrod, J. Pharm. Pharmacol., **27**, 588 (1975).
7. M. Lalonde and T. H. Chan, Synthesis, 817 (1985).
8. J. Grzybowska, J. Teodorczyk, R. Piekos, and A. Put, Sci. Pharm., **51**, 301 (1982).
9. M. Gerlach, P. Jutzi, J. P. Stasch, and Z. Przuntek, Z. Naturforsch. B, **38**, 237 (1983).
10. Th. Fietz, H. Spies, H.-J. Pietzsch, Inorg. Chim Acta, **231**, 233, (1995).
11. H. D. Flack, Acta Crystallogr., **A33**, 890 (1977).
12. V. I. Andrianov, Kristallografiya, **32**, 228 (1987).
13. E. Lukevics, I. Segal, A. Zablotskaya, and S. Germane, Molecules, **2**, 180 (1997).
14. V. V. Prozorovskii, M. P. Prozorovskaya, and V. M. Demchenko, Pharmacology and Toxicology [in Russian], Khimiya, Moscow (1978), p. 497.