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CRYSTAL STRUCTURES OF DEOXYVASICINONE AND ITS SALTS

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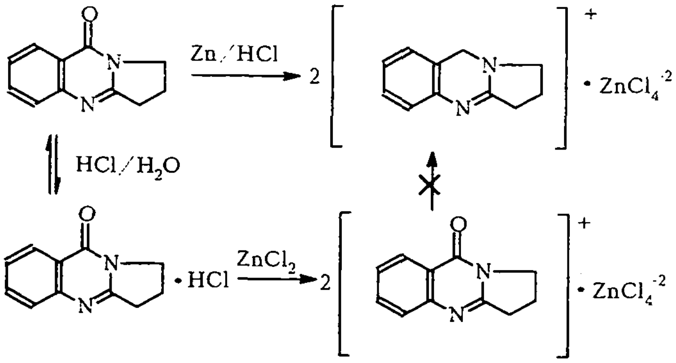
The structures of the alkaloid deoxyvasicinone and of its complexes with HCl and $CoCl_2 \cdot 2HCl$ have been established by the method of x-ray structural investigation. The formation of complex salts of deoxyvasicinone differs from that of alkaloids with similar structures — peganine and deoxypeganine.

We have shown previously that the reduction of deoxyvasicinone with zinc in hydrochloric acid proceeds through the formation of a complex salt of deoxyvasicinone with zinc chloride [1]. The yields of reduced product were stable at 70%, variations in the reaction conditions and the ratio of the reactants not leading to any increase [2]. In view of this, we assumed that under these conditions a complex compound of deoxyvasicinone is formed in which the carbonyl group becomes protected from reduction — i.e., the reaction takes place in accordance with the scheme given below.



However, this complex was stable only in acid solution and we did not succeed in isolating it from the reaction mixture or obtaining it in a blank experiment. We have therefore obtained a more stable analog of it — the complex salt of deoxyvasicinone with cobalt chloride — by the procedure of [1].

In order to study the fine structure of the alkaloid deoxyvasicinone (DOV) and its salts, we have carried out an x-ray structural analysis: the structure of the crystals is shown in Fig. 1.

Analysis of the crystal structure of DOV (1) showed that the molecules of the base lie parallel in the plane of the *yz* axes at distances of the normal van der Waals interactions (Fig. 1). The complexes of DOV with HCl (2) and with $CoCl_2 \cdot 2HCl$ (3) consist of the Cl^- and $(CoCl_4)^{2-}$ anions, respectively, and the deoxyvasicinone cation (in the latter case, of two solvated DOV cations). In the DOV complexes the N1 atom is protonated in a similar way to what is observed in the complexes of peganine [3, 4] and deoxypeganine [2, 5].

In the crystal packing of (2) the DOV cation forms hydrogen bonds with the Cl anion of the $N^+-H\cdots Cl^-$ type, as is shown by the $N1\cdots Cl$ distance of 3.01 Å, the $N1-H\cdots Cl$ distance of 2.10 Å, and the $N1-H\cdots Cl$ angle of 166°. The carbonyl group of the initial DOV cation approaches the N3 atom of the molecule, which is translated with the aid of a 2_1

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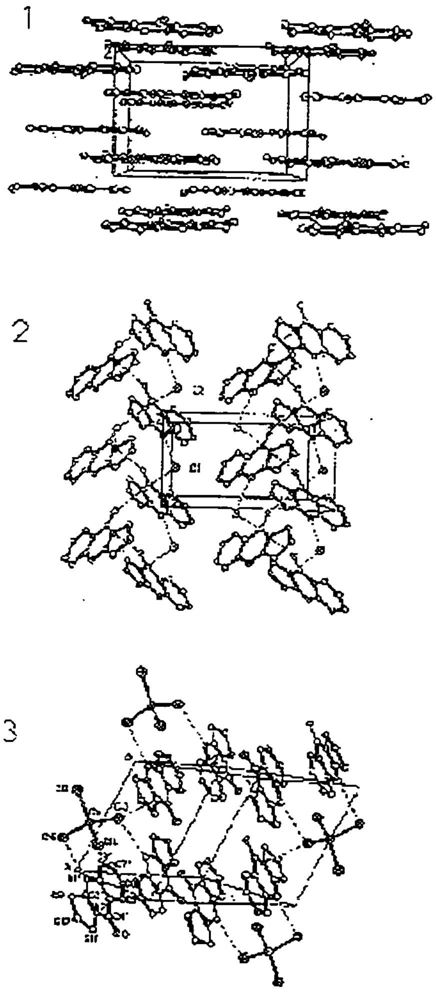

Fig. 1

screw axis along the crystallographic x axis (O$\cdots$N3 distance 2.88 Å), while in the opposite direction the N3 atom is close to the Cl$^-$ anion (N3$\cdots$Cl distance 3.29 Å). These interactions are of the donor–acceptor type. In the crystal of the complex (**3**) intermolecular interaction is effected differently. Here, in the independent part of the unit cell there are a $CoCl_4^{-2}$ anion and two DOV cations, which are located parallel to the $\bar{1}11$ plane. Through the N1$^+$ atoms these two protonated DOV molecules form H-bonds with the $CoCl_4^{2-}$ anion. The N1$\cdots$Cl3 and N1'$\cdots$Cl4 distances are 3.14 and 3.08 Å, respectively. In addition, the Cl3 atom simultaneously participates in a donor–acceptor interaction with N3' (Cl3$\cdots$N3' distance 3.18 Å).

Thus, in the crystals of the salt of deoxyvasicinone with HCl and of its complex with $CoCl_4^{-2}$, in contrast to the analogous solvates and complexes of peganine [3, 4] and deoxypeganine [2, 5], we have observed acceptor screening of the N3 atom by the Cl anion and the O atom of the carbonyl group for the first time. These structural features of the DOV complexes agree with the above-mentioned hypothesis concerning the process of its reduction, since complexes sterically hindered for reduction are formed.

The geometric parameters (bond lengths and valence angles) of DOV in structures (**1**), (**2**), and (**3**) are given in Tables 1 and 2. These figures agree well with the corresponding standard values [6]. In all the structures the DOV molecule is planar, with the exception of the five-membered ring *C*, which assumes an envelope conformation in which the C10 atom departs from the plane of the other atoms. The slight lengthening of the N1=C2 double bond (1.283 Å) and shortening of the N3–C2 bond (1.372 Å) in comparison with the analogous nonconjugated bonds in the DOV molecule show an interaction of the π-electron system of the double bond with the unshared pair of the N3 atom. According to Bayer's scheme [7] in structure (**1**) the order of the π-bond in has fallen to 0.75 and in N3–C2 it has risen to 0.25.

TABLE 1. Bond Lengths r (Å) and Valence Angles ω (deg) in Structures (**1**) and (**2**)

Bond	r_1	r_2	Angle	ω_1	ω_2
O-C4	1.220(5)	1.216(9)	C2-N1-C8a	115.8(4)	120.9(5)
N1-C2	1.283(5)	1.303(7)	N1-C2-N3	126.0(4)	121.7(5)
N1-C8a	1.401(5)	1.404(7)	N1-C2-C9	126.0(4)	125.4(6)
C2-N3	1.372(5)	1.326(8)	N3-C2-C9	108.0(4)	112.8(5)
C2-C9	1.487(7)	1.481(9)	C2-N3-C4	122.8(3)	124.7(5)
N3-C4	1.387(6)	1.385(8)	C2-N3-C11	113.9(3)	111.6(5)
N3-C11	1.457(5)	1.473(8)	C4-N3-C11	123.3(3)	123.6(5)
C4-C4a	1.449(6)	1.453(9)	N3-C4-C4a	113.0(4)	113.6(5)
C4a-C5	1.397(6)	1.404(8)	O-C4-N3	120.9(4)	120.3(6)
C4a-C8a	1.404(6)	1.395(9)	O-C4-C4a	126.1(4)	126.1(6)
C5-C6	1.369(7)	1.35(1)	C4-C4a-C5	121.2(4)	121.3(6)
C6-C7	1.389(7)	1.40(1)	C4-C4a-C8a	120.5(4)	120.8(5)
C7-C8	1.377(7)	1.39(1)	C5-C4a-C8a	118.3(4)	117.8(6)
C8-C8a	1.391(6)	1.372(9)	C4a-C5-C6	121.2(4)	121.1(7)
C9-C10	1.511(7)	1.51(1)	C5-C6-C7	120.2(4)	120.9(7)
C10-C11	1.525(7)	1.49(1)	C6-C7-C8	119.9(5)	118.9(7)
			C7-C8-C8a	120.4(4)	119.9(7)
			N1-C8a-C4a	121.9(4)	118.1(5)
			N1-C8a-C8	118.1(4)	120.4(6)
			C4a-C8a-C8	120.0(4)	121.4(6)
			C2-C9-C10	106.3(4)	102.3(6)
			C9-C10-C11	106.0(4)	109.0(7)
			N3-C11-C10	103.8(3)	104.1(6)

TABLE 2. Bond Lengths r (Å) and Valence Angles ω (deg) in Structure (**3**)

Bond	r_A	r_b	Angle	ω_A	ω_b
O-C4	1.22(1)	1.250(9)	C2-N1-C8a	123.1(7)	123.6(7)
N1-C2	1.33(1)	1.37(1)	N1-C2-N3	120.8(8)	121.2(10)
N1-C8a	1.47(1)	1.41(1)	N1-C2-C9	128.0(7)	129.0(7)
C2-N3	1.33(1)	1.353(9)	N3-C2-C9	111.2(9)	109.7(8)
C2-C9	1.56(1)	1.47(2)	C2-N3-C4	122.7(9)	121.5(8)
N3-C4	1.46(1)	1.41(1)	C2-N3-C11	110.5(7)	112.4(9)
N3-C11	1.53(2)	1.53(2)	C4-N3-C11	126.8(7)	125.9(7)
C4-C4a	1.48(2)	1.50(1)	O-C4-N3	118.1(10)	117.1(9)
C4a-C5	1.45(1)	1.39(2)	O-C4-C4a	125.4(9)	126.1(10)
C4a-C8a	1.40(1)	1.41(1)	N3-C4-C4a	116.5(7)	116.7(7)
C5-C6	1.39(2)	1.43(2)	C4-C4a-C5	122.9(8)	124.0(7)
C6-C7	1.39(2)	1.40(1)	C4-C4a-C8a	119.2(8)	120.0(9)
C7-C8	1.47(2)	1.38(2)	C5-C4a-C8a	117.9(10)	116.0(8)
C8-C8a	1.38(2)	1.47(1)	C4a-C5-C6	122.1(9)	122.7(8)
C9-C10	1.52(2)	1.56(1)	C5-C6-C7	119.8(11)	121.3(12)
C10-C11	1.55(1)	1.50(2)	C6-C7-C8	118.0(13)	117.9(10)
Co-Cl1	2.338(3)		C7-C8-C8a	122.0(9)	120.7(8)
Co-Cl2	2.252(3)		N1-C8a-C4a	117.7(9)	116.7(8)
Co-Cl3	2.323(3)		N1-C8a-C8	122.2(7)	121.9(7)
Co-Cl4	2.179(3)		C4a-C8a-C8	120.2(8)	121.5(9)
			C2-C9-C10	105.7(7)	107.2(8)
			C9-C10-C11	104.6(10)	105.6(11)
			N3-C11-C10	106.8(9)	104.7(8)
			Cl1-Co-Cl2	114.5(1)	
			Cl1-Co-Cl3	112.1(1)	
			Cl2-Co-Cl3	107.6(1)	
			Cl1-Co-Cl4	105.0(1)	
			Cl2-Co-Cl4	111.6(1)	
			Cl3-Co-Cl4	105.7(1)	

Previously, in quinazolines protonated at N1 a tendency has been observed to an averaging of the lengths of the N=C and N−C bonds in ring *B* [2-5], where the order of the π-bond in N1=C2 decreases to 0.7-0.8 and in C2−N3 it increases to 0.6-0.7; consequently, in them the total order of the π-bond becomes greater than unity. Such a tendency to a change in the N1=C2 and N3−C2 bond lengths is observed in quinazol-4-ones protonated at N1 — in structures (**2**) and (**3**), although in the latter structure the errors in the determination of bond lengths, amounting to 0.02 Å, do not permit this to be stated unambiguously (see Table 2).

TABLE 3. Coordinates ($\times 10^4$) of the Nonhydrogen Atoms in Structures (**1**) and (**2**)

Atom	x	y	z	U eq	x	y	z	U eq
	Structure 1				**Structure 2**			
O	1450(6)	7513(3)	2824(2)	69(1)	−1274(10)	1650(5)	9988(3)	69(2)
N1	1240(6)	8692(3)	6087(3)	49(1)	−6881(8)	395(4)	8883(3)	42(1)
C2	1284(7)	9455(5)	5243(4)	48(2)	−5572(10)	1272(6)	8589(3)	40(2)
N3	1353(6)	9088(3)	4143(3)	46(1)	−3768(8)	1702(4)	8975(3)	41(1)
C4	1403(8)	7803(5)	3811(3)	49(2)	−2995(12)	1228(6)	9688(4)	46(2)
C4a	1370(7)	6907(4)	4741(3)	45(1)	−4457(11)	254(6)	10019(3)	43(2)
C5	1397(7)	5569(4)	4569(4)	54(2)	−3968(13)	−310(7)	10750(4)	56(2)
C6	1335(8)	4723(5)	5447(5)	64(2)	−5343(16)	−1207(8)	11059(4)	68(3)
C7	1246(8)	5185(5)	6535(4)	64(2)	−7287(15)	−1614(6)	10653(5)	65(3)
C8	1204(8)	6499(5)	6728(4)	59(2)	−7805(14)	−1063(6)	9929(4)	54(2)
C8a	1278(7)	7367(4)	5843(3)	45(1)	−6393(11)	−157(6)	9617(3)	42(2)
C9	1243(9)	10893(5)	5284(4)	65(2)	−5914(13)	1909(7)	7819(4)	57(2)
C10	1572(9)	11354(5)	4104(4)	68(2)	−4026(15)	2886(10)	7816(5)	85(3)
C11	1337(8)	10167(4)	3361(4)	58(2)	−2601(11)	2712(6)	8532(4)	57(2)
Cl					1010(3)	4496(2)	7007(1)	52(1)

TABLE 4. Coordinates ($\times 10^4$) of the Nonhydrogen Atoms in Structure (**3**)

Atom	x	y	z	Ueq	x	y	z	Ueq
	Cation A				**Cation B**			
O	−1406(10)	3542(7)	6321(6)	75(4)	5386(9)	−3261(7)	6627(5)	65(3)
N1	2033(9)	7188(7)	7286(5)	40(3)	9663(9)	−76(7)	8120(5)	44(3)
C2	2240(11)	6347(8)	7711(7)	40(4)	8473(11)	−126(9)	7347(7)	43(4)
N3	1111(9)	5131(7)	7381(6)	44(4)	7088(9)	−1222(7)	6830(5)	43(3)
C4	−436(12)	4663(9)	6565(7)	52(5)	6763(11)	−2336(9)	7098(7)	46(4)
C4a	−663(11)	5598(9)	6092(7)	45(4)	8100(11)	−2285(8)	7934(6)	41(4)
C5	−2102(14)	5258(11)	5250(8)	61(5)	8021(12)	−3325(9)	8255(7)	46(4)
C6	−2289(16)	6150(13)	4809(8)	67(6)	9270(14)	−3222(10)	9087(8)	54(5)
C7	−1032(17)	7386(13)	5144(8)	72(7)	10695(14)	−2074(11)	9601(8)	54(5)
C8	430(14)	7720(10)	5984(8)	55(5)	10846(12)	−1029(10)	9290(7)	50(5)
C8a	590(11)	6848(9)	6433(7)	42(4)	9546(11)	−1129(8)	8449(7)	41(4)
C9	3702(13)	6589(9)	8617(7)	51(5)	8437(13)	897(11)	6936(8)	60(5)
C10	3423(15)	5250(11)	8708(10)	79(7)	6846(16)	277(11)	6017(8)	69(6)
C11	1631(14)	4373(10)	7999(8)	59(5)	5916(14)	−1054(11)	6001(8)	60(5)
	Anion							
Co	4519(2)	1759(1)	8198(1)	41(1)				
Cl1	2855(4)	1216(3)	6592(2)	71(1)				
Cl2	7068(4)	3353(3)	8642(3)	71(1)				
Cl3	5035(3)	−88(2)	8396(2)	53(1)				
Cl4	2923(3)	2365(2)	9201(2)	50(1)				

EXPERIMENTAL

The crystals were first investigated by the photo method. In each case, the space group and the parameters of the unit cell were established from precession x-ray diagrams. These parameters were subsequently refined on a Syntex $P2_1$ diffractometer. The crystallographic and other characteristics of the structures investigated are given below:

1	**2**	**3**
$a=7.203(2)$	$a=5.875(2)$	$a=8.331(2)$ $\alpha=109.95°$
$b=10.333(3)$	$b=10.552(3)$	$b=11.248(3)$ $\beta=98.68°$
$c=11.981(3)$	$c=16.958(5)$	$c=14.679(4)$ $\gamma=104.14°$
$V=891.7(1.2)$ Å^3	$V=1051.3(0.6)$ Å^3	$V=1211.7(1.5)$ Å^3
$d_{calc}=1.387$ g/cm^3	$d_{calc}=1.413$ g/cm^3	$d_{calc}=1.571$ g/cm^3
space gr. $P2_12_12_1$	space gr. $P2_12_12_1$	space gr. $P\bar{1}$
$Z=4$	$Z=4$	$Z=2$
582, $I > 2\sigma(I)$	824, $I > 2\sigma(I)$	2545, $I > 2\sigma(I)$
R=0.047	R=0.054	R=0.089

A three-dimensional set of intensities was obtained on the above diffractometer by the $\theta/2\theta$ scanning method using CuK_α radiation (graphite monochromator), $\sin\theta/\lambda < 0.56$. The structures were interpreted by the SHELXS-86 programs [8] (PC DOS version), and it was possible to find a model of the molecule in the automatic regime. The subsequent Fourier syntheses and cycles of refinement permitted the localization of all the nonhydrogen atoms.

The structures were refined by the method of least squares (MLS) in the full-matrix anisotropic approximation by the SHELX-76 program [9]. The coordinates of the H atoms were calculated geometrically and were refined isotropically. The coordinates of the nonhydrogen atoms of structures (**1**), (**2**), and (**3**) from the last stage of MLS are given in Tables 3 and 4. All the calculations were performed on a personal computer of the IBM PC AT type.

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