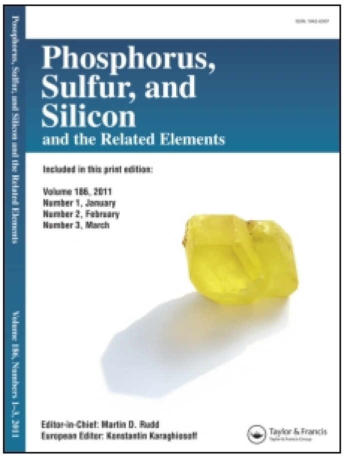

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CRYSTAL AND MOLECULAR STRUCTURE OF 1-AMINO-BENZYLPHOSPHONOUS ACID MONOHYDRATE

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CRYSTAL AND MOLECULAR STRUCTURE OF 1-AMINO-BENZYLPHOSPHONOUS ACID MONOHYDRATE

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Dedicated to Prof. Dr. P. Sartori on the occasion of his 60th birthday

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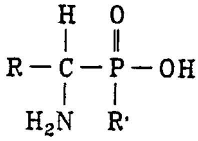
The crystal and molecular structure of 1-amino-benzylphosphonous acid monohydrate ($C_7H_{10}PO_2N \cdot H_2O$) has been determined from single crystal MoKα diffractometer data. The crystals are monoclinic: $P2_1/n$, a = 540.0(4), b = 666.3(3), c = 2485.1(19)pm, β = 90.70(6)°, Z = 4. The structure was solved by direct methods and refined to a final R = 0.0519. The molecule exists as a zwitterion, C_6H_5—$CH(NH_3^+)$—PO_2H^-. The crystal structure is stabilized by several hydrogen intermolecular bonds.

Key words: 1-Amino-benzylphosphonous acid; X-ray study; crystal structure; molecular structure; hydrogen bonds

INTRODUCTION

Phospha-analogues of 1-aminoalkylcarboxylic acids are of considerable importance in chemistry, biology and medicine. Basically three variations are known:



$$R-\underset{H_2N}{\overset{H}{C}}-\underset{R'}{\overset{O}{\overset{\|}{P}}}-OH$$

1: R'=OH	1-amino-alkylphosphonic acid
2: R'=alkyl, aryl	1-amino-alkylphosphinic acid
3: R'=H	1-amino-alkylphosphonous acid

1-amino-alkylphosphonic acids (1) and 1-amino-alkylphosphinic acids (2) have been studied intensively with respect to chemical aspects and biological activities.[1-3] Considerably less is known about compounds of type 3, the 1-amino-alkylphosphonous acids. Some synthetic approaches for 1-amino-alkylphosphonous acids 3 were developed[4-8] and seventeen 1-amino-alkylphosphonous acids with structures isosteric to natural protein amino acids have been prepared,[7,8] but still some relevant compounds of these series are unknown up to now.[9] While analogous 2- and 3-amino-alkylphosphonous acids have been isolated from abundant natural materials[10,11] no sources in nature for 1-amino-alkylphosphonous acids 3 were detected up to now.

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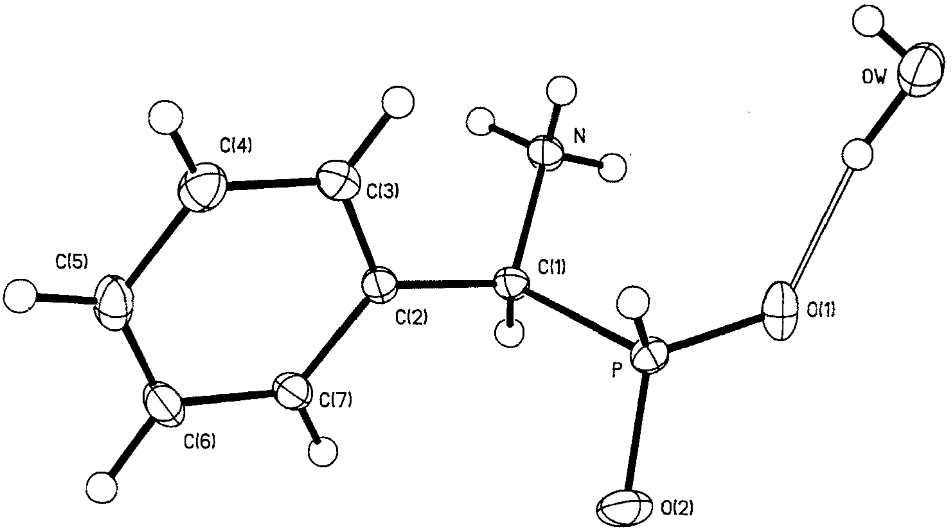

FIGURE 1 Asymmetric unit of the crystal structure

In a previous publication[9] we presented a convenient synthesis for 1-aminobenzylphosphonous acid and substituted derivatives like X—C_6H_4—$CH(NH_2)$—PO_2H_2 (X = H, the title compound, and X = p—CH_3, p—OCH_3, p—Br, o—Cl, m—Cl, p—Cl, m—NO_2) by direct amidoalkylation of hypophosphorous acid. Here we will report on results from X-ray studies leading to crystal and molecular structures of the parent compound C_6H_5—$CH(NH_2)$—PO_2H_2.

TABLE I

Crystallographic data and refinement details

crystal system	monoclinic
unit cell dimensions	a = 540.0(4) pm
	b = 666.3(3) pm
	c = 2485.1(19) pm
	β = 90.70(6) °
	V = 894.1 * 10^6 pm^3
space group, Z	$P2_1/n$, 4
formula mass $C_7H_{10}PO_2N \cdot H_2O$	189.2 g/mol
density (exp., calc)	1.39, 1.41 g/cm^3
lin. absorption coefficient μ (Mo Kα)	2.67 cm^{-1}
range of 2Θ	3° ≤ 2Θ ≤ 55°
unique data (obsd., all)	1533, 2008
parameters refined	157
R (obsd., all)	0.0519, 0.0680
R_w (obsd., all)	0.0532, 0.0590
final $\Delta\rho$ (max.,min.)	0.54, -0.68 [* 10^{-6} el./pm^3]

DISCUSSION

The molecular structure and labelling of the non-H-atoms is shown in Figure 1 (H-atoms are labelled as the corresponding non-H-atoms).

Atomic parameters are given in Table II, bond lengths in Table III and bond angles in Table IV. The bond lengths and bond angles do not show unusual and in most cases not even significant deviation from standard values.

The molecule of 1-amino-benzylphosphonous acid exists in a betainic form as expected for compounds of type 1–3 and exhibits four-coordinate phosphorus. The H-atom HP is bound directly to the phosphorous atom. This finding is in agreement with NMR data from solution state, where a coupling constant $^1J_{PH}$ = 518 Hz is found.[9] The O-atoms of the phosphonous group are in resonance with each other, as indicated by the bond-lengths for P—O(1) and P—O(2) which are 149.8(2) and 148.9(2) pm, respectively. The conformation of the title compound is determined by the torsion angles as given in Table V.

TABLE II

Coordinates and isotropic U values (as multiples of 10 pm^2) with estimated standard deviations in parentheses. For the non-H-atoms the U values as given are derived from the anisotropic U_{ij} by $U = 1/3[U_{11}a^2a^{*2} + \ldots U_{23}bcb^*c^* \cdot \cos\gamma]$

Atom	x	y	z	U
P	0.1861(1)	0.0052(1)	0.5948(1)	28(1)
C(1)	0.0607(4)	-0.2490(3)	0.5834(1)	26(1)
C(2)	0.0619(4)	-0.3654(3)	0.6354(1)	27(1)
C(3)	-0.1215(4	-0.3406(4)	0.6739(1)	35(1)
C(4)	-0.1052(5)	-0.4446(4)	0.7221(1)	42(1)
C(5)	0.0907(5)	-0.5703(4)	0.7328(1)	44(1)
C(6)	0.2729(5)	-0.5944(4)	0.6950(1)	43(1)
C(7)	0.2583(4)	-0.4934(3)	0.6464(1)	34(1)
N	-0.1896(3)	-0.2415(3)	0.5568(1)	31(1)
O(1)	0.1097(4)	0.1392(3)	0.5492(1)	47(1)
O(2)	0.4559(3)	-0.0148(3)	0.6066(1)	47(1)
OW	-0.3249(5)	0.3469(3)	0.5406(1)	55(1)
HP	0.089(4)	0.051(3)	0.634(1)	17(5)
H(1)	0.157(4)	-0.307(4)	0.557(1)	26(6)
H(3)	-0.257(5)	-0.255(4)	0.668(1)	37(7)
H(4)	-0.216(6)	-0.435(5)	0.747(1)	47(8)
H(5)	0.078(6)	-0.630(5)	0.766(1)	65(10)
H(6)	0.425(6)	-0.688(5)	0.703(1)	68(10)
H(7)	0.379(5)	-0.510(4)	0.619(1)	31(7)
HN(1)	-0.166(5)	-0.189(4)	0.523(1)	33(7)
HN(2)	-0.301(5)	-0.173(4)	0.577(1)	29(6)
HN(3)	-0.256(5)	-0.368(5)	0.552(1)	41(7)
HW(1)	-0.174(7)	0.256(7)	0.546(2)	100(13)
HW(2)	-0.411(8)	0.284(7)	0.554(2)	81(14)

TABLE III

Bond lengths [pm]

P-C(1)	184.5(3)	P-O(1)	149.8(2)
P-O(2)	148.9(2)	C(1)-N	149.9(3)
C(1)-C(2)	150.6(3)	C(2)-C(3)	139.6(3)
C(2)-C(7)	138.6(3)	C(3)-C(4)	138.6(4)
C(4)-C(5)	137.2(4)	C(5)-C(6)	137.7(4)
C(6)-C(7)	138.4(4)	C(1)-H(1)	93(2)
C(3)-H(3)	94(3)	C(4)-H(4)	87(3)
C(5)-H(5)	93(4)	C(6)-H(6)	105(3)
C(7)-H(7)	96(3)	P-HP	115(2)
N-HN(1)	92(3)	N-HN(2)	91(3)
N-HN(3)	92(3)	OW-HW(1)	102(4)
OW-HW(2)	71(4)		

TABLE IV

Bond angles [°]

P(1)-P-O(1)	109.5(1)	C(1)-P-O(2)	107.8(1)
O(1)-P-O(2)	117.5(1)	C(2)-C(1)-N	113.0(2)
P-C(1)-C(2)	110.1(2)	P-C(1)-N	111.4(1)
C(1)-C(2)-C(3)	122.1(2)	C(1)-C(2)-C(7)	118.8(2)
C(3)-C(2)-C(7)	119.0(2)	C(2)-C(3)-C(4)	119.7(2)
C(3)-C(4)-C(5)	120.8(2)	C(2)-C(7)-C(6)	120.5(2)
C(4)-C(5)-C(6)	119.7(2)	C(5)-C(6)-C(7)	120.3(2)
C(7)-C(6)-H(6)	119(2)	C(6)-C(5)-H(5)	129(2)
C(5)-C(6)-H(6)	121(2)	C(4)-C(5)-H(5)	112(2)
C(3)-C(4)-H(4)	123(2)	C(2)-C(3)-H(3)	121(2)
C(4)-C(3)-H(3)	119(2)	C(5)-C(4)-H(4)	116(2)
C(2)-C(7)-H(7)	117(2)	C(6)-C(7)-H(7)	123(2)
C(2)-C(1)-H(1)	113(2)	N-C(1)-H(1)	102(2)
C(1)-P-HP	102(1)	P-C(1)-H(1)	107(2)
O(1)-P-HP	111(1)	O(2)-P-HP	108(1)
C(1)-N-HN(1)	107(2)	C(1)-N-HN(2)	112(2)
HN(1)-N-HN(2)	114(2)	C(1)-N-HN(3)	112(2)
HN(1)-N-HN(3)	107(2)	HN(2)-N-HN(3)	105(2)
HW(1)-OW-HW(2)	97(4)		

Viewing along the P—C(1)-bond a conformation close to an antiperiplanar arrangement is found, i.e. for the HP—P—C(1)—H path. The conformation observed for the C(1)—C(2) skeleton is characterized by an almost planar orientation of the phenyl ring and the C(1)—H(1)-bond, whereas the phosphonous group is nearly perpendicular to this plane.

The crystal structure is stabilized by several intermolecular hydrogen bonds in-

TABLE V

Selected torsion angles [°]

O(1)-P-C(1)-N	-35.4(2)	O(2)-P-C(1)-N	-164.4(2)
HP-P-C(1)-N	82.0(11)	O(1)-P-C(1)-C(2)	-161.6(2)
HP-P-C(1)-C(2)	-44.2(11)	N-C(1)-C(2)-C(3)	-45.0(3)
N-C(1)-C(2)-C(7)	138.5(2)	P-C(1)-C(2)-C(3)	80.3(2)
P-C(1)-C(2)-C(7)	-96.3(2)	O(1)-P-C(1)-H(1)	75(2)
O(2)-P-C(1)-H(1)	-167(2)	HP-P-C(1)-H(1)	-167(2)

TABLE VI

Hydrogen bonds

H-bond D-H···A	D···A[pm]	H···A[pm]	D-H···A[°]
OW-HW(1)···O(1)	273.0(4)	172(4)	169(4)
OW-HW(2)···O(1^{a})	336.3(5)	276(4)	144(4)
···O(2^{a})	314.8(4)	250(4)	155(4)
N-HN(1) ···O(1^{b})	276.0(3)	185(3)	168(3)
N-HN(2) ···O(2^{a})	273.4(3)	185(3)	170(2)
N-HN(3) ···OW^{c}	286.6(4)	196(3)	168(3)

Symmetry code:
(a) -x,-y,1-z; (b) -1+x,y,z; (c) x,-1+y,z

volving the amino and phosphonous group as well as the water molecule. All types of hydrogen bonds are listed with their geometric parameters in Table VI.

EXPERIMENTAL

Clear, colorless crystals of 1-amino-benzylphosphonous acid suitable for X-ray analysis were obtained by recrytallization from water at room temperature. Preliminary Weißenberg photographs around [100] and Precession photographs around [010] indicated a monoclinic crystal with systematic absences h0l for $h + 1 = 2n + 1$ and 0k0 for $k = 2n + 1$, consistent with the space group $P2_1/n$. The observed density $\rho = 1.39$ g/cm^3, determined by floatation in a CCl_4/toluene-mixture, indicates a unit cell containing four molecules. The X-ray measurements were done on a computer-controlled 4-circle diffractometer (SIEMENS/STOE AED-1) with graphite-mono-chromatized MoKα radiation ($\lambda = 71.073$ pm, ω:Θ-scan for intensities) using a crystal with the dimensions $0.15 \cdot 0.25 \cdot 0.60$ mm^3. Cell parameters were determined by least-squares refinement of the setting angles of 32 reflections in the range $26° \leqq 2\Theta \leqq 35°$. A unique data set was collected in the range $3° \leqq 2\Theta \leqq 55°$. Due to the poor diffraction power of the crystals, no data beyond $2\Theta = 55°$ was accessible. Absorption errors were considered negligible and henceforth no corrections were applied. The structure was solved by direct methods and refined by the method of least squares using the observed reflections only ($3\sigma_F$). The function minimized was $\Sigma w(|F_o| - |F_c|)^2$ with the weights $w = 1/(\sigma_F^2 + 0.0009|F_o|^2)$. Initial refinement calculations did not take into account a residual high-level peak in the electron-density map. In subsequent steps this peak was interpreted as an O-atom of a water molecule which allowed a successful refinement of the non-hydrogen model. The H-atoms were located in difference maps of the electron density and refined isotropically. The final model with 157 varied parameters was refined to a final $R = 0.0519$. All experimental and computational data are summarized in Table I. All calculations were performed with the program system SHELXTL (NICOLET) on an ECLIPSE S/140-minicomputer (DATA GENAERAL). In the figures non-hydrogen atoms are represented by 25% probability ellipsoids, hydrogen atoms with radii of 15 pm.

More details about the structural analysis may be obtained from the Fachinformationszentrum Karlsruhe, Gesellschaft für wissenschaftlich-technische Information mbH, W-7514 Eggenstein-Leopoldshafen 2.

(The deposit number is available on request from the authors).

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