All non-H atoms were refined anisotropically. All H atoms were located from a difference synthesis and refined isotropically. Corrections for absorption were considered unnecessary; transmission factors were estimated to be in the range 0.577–0.649.

Data collection: Siemens *P*3 software. Cell refinement: Siemens *P*3 software. Data reduction: *SHELXTL/PC XDISK* (Sheldrick, 1990*b*). Program(s) used to solve structure: *SHELXS*86 (Sheldrick, 1990*a*). Program(s) used to refine structure: *SHELXL*93 (Sheldrick, 1993). Molecular graphics: *SHELXTL/PC XP*. Software used to prepare material for publication: *SHELXL*93.

Supplementary data for this paper are available from the IUCr electronic archives (Reference: MU1350). Services for accessing these data are described at the back of the journal.

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Acta Cryst. (1998). C**54**, 324–327

Monosodium 3-(Dimethylammonio)-1-hydroxy-1,1-propanediyldiphosphonate Monohydrate (Monosodium Olpadronate Monohydrate)

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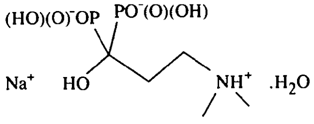
Abstract

The crystal structure of the title compound, $Na^+.C_5H_{14}NO_7P_2^-.H_2O$, contains zwitterionic olpadronate anions coordinated to Na^+ cations. The interactions in the crystal define broad chains which have Na^+ ions at their core and bis-phosphonate groups near the Na^+ centres, with the positively charged ends of the zwitterions extending outwards. Strong hydrogen bonds provide both intra- and interchain connectivity.

Comment

The title compound, (I), has been shown to be a highly effective drug for preventing or reverting bone loss (Van Beek *et al.*, 1994) and is much more soluble than other bis-phosphonates in common use, suggesting better digestive tolerance. Its dimethylated side chain offers unique properties for modulating bone-mass metabolism (Boonekamp *et al.*, 1986, 1987; Löwik *et al.*, 1988; Van Der Pluijm *et al.*, 1991; Feretti *et al.*, 1995; Vega *et al.*, 1994) without disturbing cell vitality and bone quality, according to experimental assays.



(I)

A number of structural studies of drugs containing bis-phosphonate groups have been known for some time, in particular, that of olpadronate free acid (Shkol'nikova *et al.*, 1987). This knowledge has not diminished our interest in the structures of sodium salts of bis-phosphonates and, in particular, that of olpadronate, mainly because among the recent related literature (Coiro & Lamba, 1989; Leroux *et al.*, 1989; Shkol'nikova *et al.*, 1990; Rachdaoui *et al.*, 1990; Vega *et al.*, 1996) only a few sodium salts are to be found, in spite of their favourable bio-availability. We report here the crystal and molecular structure of monosodium olpadronate monohydrate, (I). Unfortunately, the precision of the results previously reported for the free acid (Shkol'nikova *et al.*, 1987) precluded any detailed analysis, making meaningful comparisons possible only in qualitative terms.

A view of the molecule and its surroundings in the lattice is shown in Fig. 1. The molecule exists as a zwitterion with an overall charge of −1; the protonated dimethylamine group bears a positive charge and the two phosphonate groups each have a single negative charge. Each phosphonate has one protonated O atom, the extra electronic charge being shared by the remaining two non-protonated O atoms. This fact defines two distinct types of P—O bonds, as shown by the mean values of the following bond lengths and angles: P—OH 1.579 (7), P—O 1.496 (8) Å, O—P—OH 109.0 (24), O—P—O 116.9 (19)°; these are in accord with the results found for related molecules (Coiro & Lamba, 1989; Vega *et al.*, 1996) and confirms the partial double-bond character of the non-protonated O atoms.

As in the free acid, the phosphonate groups have staggered conformations with atoms O11, P1, C1, P2 and O21 nearly coplanar [O11—P1—C1—P2 −168.9 (2)

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and O21—P2—C1—P1 −170.0 (2)°]. This leads to a high similarity of both structures around the bis-phosphonate groups. The main difference is found in the sequence O1—C1—C2—C3—N, which is planar in the free acid but twisted in (I), with an O1—C1—C2—C3 torsion angle of 74.4 (3)°. In the free acid, therefore, the hydroxy group at C1 is almost coplanar with the C1—C2—C3—N side chain and the molecule has approximate *Cm* symmetry with a quasi-mirror plane that bisects the bis-phosphonate group. In (I), this is not the case, as a strong intermolecular N—H···O interaction (Table 2) stabilizes the severe twist about the C1—C2 bond.

There are three different modes in which the olpadronate molecule interacts with the cation: a tridentate mode (through two O atoms from different phosphonate groups, O12 and O22, and the hydroxy O atom O1), a bidentate mode (again through two O atoms from different phosphonate groups, O13 and O23), and a bridging mode (involving O13). The resulting coordination polyhedron around Na^+ is a distorted octahedron (Table 1 and Fig. 1) defined by O1, O12, O22, O13($-x$, $-y$, $1-z$), O13($-1+x$, y, z) and O23($-1+x$, y, z). The bridging of two centrosymmetrically related Na^+ ions by O13($-x$, $-y$, $1-z$) and O13($-1+x$, y, z) gives rise to a rather close Na···Na approach of 3.38 Å.

The complex interactions define a continuous broad-chain structure running parallel to the crystallographic *a* axis, with the cations at its core. The anions are disposed as expected from their polar character: while the negative part of each molecule is close to the centre of the chain, the positively charged side chain stretches away as far as possible. A similar situation was found for alendronate (Vega *et al.*, 1996).

All non-alkyl H atoms are involved in a fairly complex hydrogen-bonding scheme (Table 2). Three of them (namely those involving H12, H21 and H1*WB*) are within the chains, while the other three provide inter-chain cohesion, defining a three-dimensional structure. The water molecule is particularly well connected, linking to the structure through three hydrogen bonds, as a donor in two of them and as an acceptor in the other. Evidence of this strong interaction is found in the rather high dehydration temperature (*ca* 430 K). As long as a temperature of *ca* 470 K (where decomposition starts) is not exceeded, the process is absolutely reversible after one day under ambient conditions, confirming that the hydrated form is the stable one at room temperature.

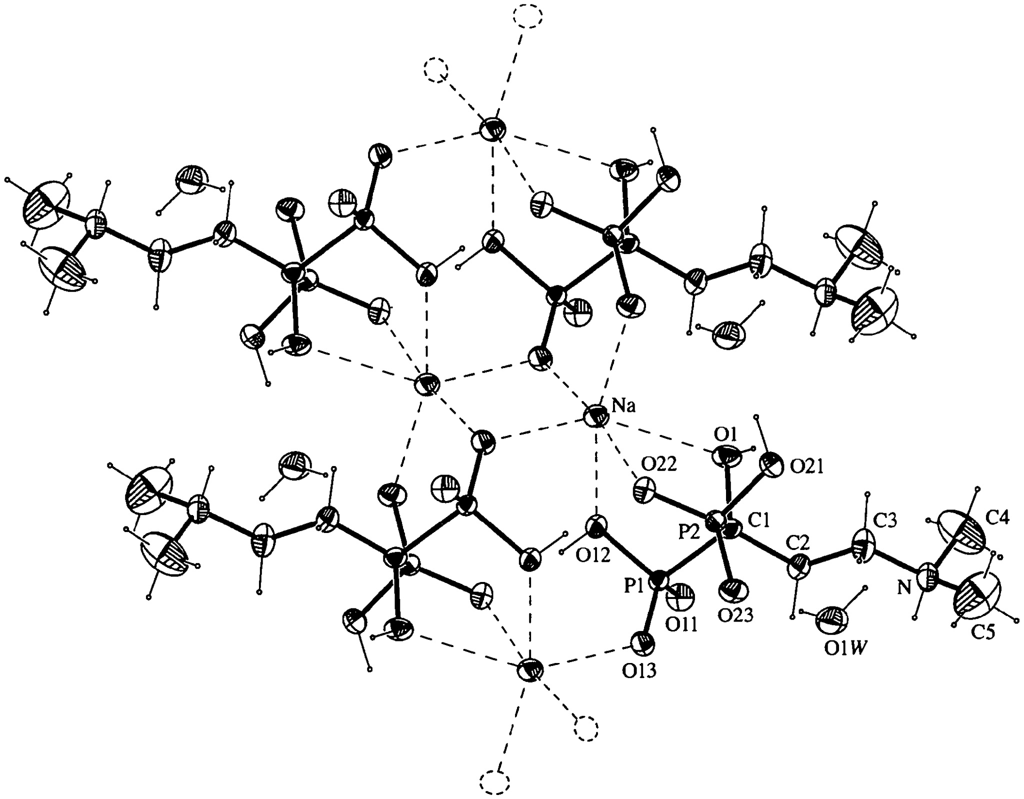

Fig. 1. View of the molecule showing the numbering scheme and displacement ellipsoids drawn at the 50% probability level. Coordination to Na is depicted by dashed lines.

Experimental

The title compound was obtained from Gador S. A. Crystals suitable for X-ray diffraction were obtained by slow evaporation from a solution of the compound in water.

Crystal data

$Na^+.C_5H_{14}NO_7P_2^-.H_2O$
$M_r = 303.12$
Triclinic
$P\bar{1}$
$a = 5.929\ (1)$ Å
$b = 9.131\ (1)$ Å
$c = 11.716\ (1)$ Å
$\alpha = 107.94\ (1)°$
$\beta = 96.29\ (1)°$
$\gamma = 93.88\ (1)°$
$V = 596.3\ (1)$ Å^3
$Z = 2$
$D_x = 1.688$ Mg m^{-3}
D_m not measured

Mo $K\alpha$ radiation
$\lambda = 0.71073$ Å
Cell parameters from 25 reflections
$\theta = 7.5–15.0°$
$\mu = 0.43$ mm^{-1}
$T = 293\ (2)$ K
Prism
0.32 × 0.28 × 0.04 mm
Colourless

Data collection

Enraf–Nonius CAD-4 diffractometer
$\omega/2\theta$ scans
Absorption correction: numerical integration (*SHELX*76; Sheldrick, 1976)
$T_{\min} = 0.89$, $T_{\max} = 0.98$
3281 measured reflections
2865 independent reflections

1876 reflections with $I > 2\sigma(I)$
$R_{\rm int} = 0.073$
$\theta_{\max} = 27.97°$
$h = -7 \rightarrow 7$
$k = -12 \rightarrow 11$
$l = -1 \rightarrow 15$
2 standard reflections every 98 reflections intensity decay: <1%

Refinement

Refinement on F^2
$R[F^2 > 2\sigma(F^2)] = 0.042$
$wR(F^2) = 0.125$
$S = 1.10$
2865 reflections
167 parameters
H atoms riding
$w = 1/[\sigma^2(F_o^2) + (0.0418P)^2 + 0.7443P]$ where $P = (F_o^2 + 2F_c^2)/3$

$(\Delta/\sigma)_{\max} < 0.001$
$\Delta\rho_{\max} = 0.52$ e Å^{-3}
$\Delta\rho_{\min} = -0.53$ e Å^{-3}
Extinction correction: none
Scattering factors from *International Tables for Crystallography* (Vol. C)

Table 1. *Selected geometric parameters (Å, °)*

Na—O23^{i}	2.303 (3)	P2—O23	1.490 (2)
Na—O13^{i}	2.331 (3)	P2—O22	1.499 (2)
Na—O12	2.340 (3)	P2—O21	1.586 (2)
Na—O13^{ii}	2.392 (3)	P2—C1	1.854 (3)
Na—O22	2.447 (3)	O1—C1	1.434 (4)
Na—O1	2.709 (3)	C1—C2	1.534 (4)
P1—O13	1.486 (2)	C2—C3	1.527 (5)
P1—O11	1.508 (2)	C3—N	1.499 (5)
P1—O12	1.571 (2)	N—C4	1.455 (5)
P1—C1	1.860 (3)	N—C5	1.478 (6)
O13—P1—O11	114.96 (14)	O1—C1—C2	113.4 (3)
O13—P1—O12	111.33 (13)	O1—C1—P2	104.0 (2)
O11—P1—O12	109.11 (14)	C2—C1—P2	113.5 (2)
O13—P1—C1	109.92 (14)	O1—C1—P1	109.6 (2)
O11—P1—C1	107.91 (14)	C2—C1—P1	106.0 (2)
O12—P1—C1	102.87 (13)	P2—C1—P1	110.4 (2)
O23—P2—O22	118.82 (14)	C3—C2—C1	116.2 (3)
O23—P2—O21	107.60 (14)	N—C3—C2	110.1 (3)
O22—P2—O21	107.95 (14)	C4—N—C5	110.7 (4)
O23—P2—C1	108.93 (14)	C4—N—C3	115.0 (4)
O22—P2—C1	107.71 (14)	C5—N—C3	108.2 (4)
O21—P2—C1	104.99 (14)		

Symmetry codes: (i) $x - 1, y, z$; (ii) $-x, -y, 1 - z$.

Table 2. *Hydrogen-bonding geometry (Å, °)*

D—H···A	D—H	H···A	D···A	D—H···A
N—H1N···O11^{i}	0.910 (4)	1.777 (4)	2.677 (4)	169.5 (3)
O1—H1···O11^{ii}	0.908 (4)	1.762 (4)	2.660 (4)	169.3 (3)
O21—H21···O1W^{iii}	0.966 (4)	1.650 (4)	2.616 (4)	178.1 (3)
O12—H12···O22^{iv}	0.829 (3)	1.722 (3)	2.547 (3)	172.5 (4)
O1W—H1WA···O21^{v}	0.892 (4)	2.069 (3)	2.894 (3)	153.5 (3)
O1W—H1WB···O23	0.930 (8)	1.725 (3)	2.648 (3)	169.9 (3)

Symmetry codes: (i) $1-x, 1-y, 1-z$; (ii) $-x, 1-y, 1-z$; (iii) $x-1, y, z$; (iv) $-x, -y, 1-z$; (v) $1-x, 1-y, 2-z$.

One of the side-chain C atoms (C3) showed disorder and was refined with two positions (occupancy factors 0.82/0.18). All non-H atoms in the structure (with the exception of the lower occupancy C3) were refined anisotropically. H atoms attached to C atoms were placed at idealized positions and allowed to ride with isotropic displacement parameters 1.2 times larger than those of their hosts. Those bonded to O atoms were located in a ΔF synthesis, and subsequently refined with restrained O—H distances and individual isotropic displacement parameters. Data collection was performed at the Laboratorio Nacional de Difraccion (LANADI).

Data collection: *CAD-4/PC* (Enraf–Nonius, 1993). Cell refinement: *CAD-4/PC*. Data reduction: *MolEN* (Fair, 1990). Program(s) used to solve structure: *XS* in *SHELXTL/PC* (Sheldrick, 1991). Program(s) used to refine structure: *SHELXL*93 (Sheldrick, 1993). Molecular graphics: *XP* in *SHELXTL/PC*. Software used to prepare material for publication: *CIFTAB* (Sheldrick, 1993), *PARST* (Nardelli, 1983) and *CSD* (Allen *et al.*, 1983).

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Supplementary data for this paper are available from the IUCr electronic archives (Reference: SX1043). Services for accessing these data are described at the back of the journal.

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A Dihydrate Complex of Molybdosilicic Acid and Hexamethylphosphoramide, $[\{(CH_3)_2N\}_3PO]_5[H_4SiMo_{12}O_{40}].2H_2O$

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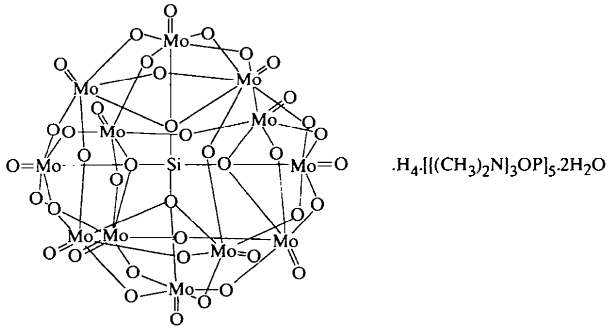
Abstract

The molybdosilicic acid residue, $H_4SiMo_{12}O_{40}$, has the Keggin structure, with *M*—O distances varying between 1.796 (4) and 2.112 (3) Å. In the hexamethylphosphoramide groups, all N atoms except one show a planar coordination.

Comment

Complexes of polyoxometalates have attracted much attention because of their special properties of intermolecular charge transfer and photosensitivity (Niu *et al.*, 1996). Some of these compounds, such as $[H_2quinolin\text{-}8\text{-}ol]_3[PW_{12}O_{40}].EtOH.2H_2O$ (Attanasio *et al.*, 1990), $[(1,1,3,3\text{-tetramethylurea})_3H]_3[\alpha\text{-}PW_{12}O_{40}](1,1,3,3\text{-tetramethylurea})$ (Hill *et al.*, 1988) and $\alpha\text{-}H_3PMo_{12}O_{40}.6DMA.CH_3CN.0.5H_2O$ (where DMA is *N*,*N*-dimethylacetamide; Williamson *et al.*, 1987), have been studied extensively. The X-ray structure analysis of the title compound, (I), was carried out to study the intermolecular charge-transfer behaviour in the complex, which possesses second and third-order non-linear optical properties.



$.H_4.[[(CH_3)_2N]_3OP]_5.2H_2O$

(I)

The MoO_6 groups of molybdosilicic acid, $H_4SiMo_{12}O_{40}$, exhibit octahedral geometry; three such groups share edges to form an Mo_3O_{13} assembly and four such assemblies share corners to form an almost spherical $Mo_{12}O_{40}$ unit which has at its centre four O atoms arranged tetrahedrally, defining a cavity wherein the Si atom is located. The mean Si—O distance is 1.629 (3) Å and the O—Si—O angles indicate an ideal tetrahedral geometry for SiO_4. The *M*═O bonds project radially outwards with bond lengths varying from 1.668 (4) to 1.687 (4) Å. The Mo—O distances for the bridging O atoms are in the range 1.796 (4)–2.112 (3) Å and those involving O atoms of the central tetrahedron are longer, with an average value of 2.348 (3) Å. The P═O distances in the organic groups vary from 1.467 (4) to 1.524 (4) Å and show delocalized character (Allen *et al.*, 1987).

All N atoms in the hexamethylphosphoramide groups show planar coordination, except for the N3*A* atom, which is pyramidal. Except for a possible protonation of N3*A*, direct evidence for any other proton transfer from $H_4SiMo_{12}O_{40}$ and hence for the formation of the $[SiMo_{12}O_{40}]^{4-}$ anion has not been found. However, close non-bonding distances between O1*C*···O1*D* [2.373 (8) Å], O1*B*···O1*E* [2.409 (6) Å] and O1*A*···O22 [2.662 (5) Å], along with longer P═O, Mo3—O22 and Mo6—O22 distances, suggest that protons may have

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