

Dipotassium dialuminium cyclooctaphosphate

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Key indicators: single-crystal X-ray study; $T = 296$ K; mean $\sigma(\text{P}-\text{O}) = 0.002$ Å; R factor = 0.042; wR factor = 0.124; data-to-parameter ratio = 32.7.

Single crystals of the title compound, $\text{K}_2\text{Al}_2\text{P}_8\text{O}_{24}$, were obtained by solid-state reaction. The monoclinic structure is isotypic with that of the Ga^{III} analogue and is built of eight-membered phosphate ring anions $\text{P}_8\text{O}_{24}^{8-}$ ($2/m$ symmetry) isolated from each other and further linked by isolated AlO_6 octahedra ($\bar{1}$ symmetry) by sharing corners. Each AlO_6 octahedron is linked to four $\text{P}_8\text{O}_{24}^{8-}$ rings in such a way that two rings are linked through bidentate diphosphate groups attached in the *cis* positions on two opposite parallel edges of the octahedron. The two other rings are linked *via* corner-sharing to the two remaining corners in the *trans* positions of the AlO_6 octahedron. Each $\text{P}_8\text{O}_{24}^{8-}$ ring anion is linked to eight AlO_6 octahedra. More accurately, each ring anion is linked to four AlO_6 octahedra through bidentate diphosphate groups attached in the *cis* positions to the AlO_6 octahedron and to the four remaining octahedra by sharing corners. This three-dimensional linkage delimits channels running parallel to $[001]$ in which the ten-coordinated K^+ cations (2 symmetry) are distributed over two columns. These columns alternate with empty octagonally-shaped channels expanding through the $\text{P}_8\text{O}_{24}^{8-}$ ring anions.

Related literature

The synthesis and an approximate unit cell with a slightly smaller β angle were reported for the title compound more than a quarter of a century ago (Grunze *et al.*, 1983). The crystal structures of isotypic compounds determined from single-crystal data have been reported for $\text{K}_2\text{Ga}_2\text{P}_8\text{O}_{24}$ (Palkina *et al.*, 1979) and $\text{K}_2\text{Mn}_2\text{P}_8\text{O}_{24}$ (Murashova & Chudinova, 1999). The isostructural potassium-containing cyclooctaphosphates $\text{K}_2\text{V}_2\text{P}_8\text{O}_{24}$ (Lavrov *et al.*, 1981), $\text{K}_2\text{Fe}_2\text{P}_8\text{O}_{24}$ (Grunze *et al.*, 1983) and $\text{K}_2\text{Cr}_2\text{P}_8\text{O}_{24}$ (Grunze & Chudinova, 1988) were reported without detailed structure analyses. For a review of the crystal chemistry of cyclooctaphosphates, see:

Durif (1995, 2005). For potential applications of aluminophosphates, see: Cheetham *et al.* (1999); Hartmann & Kevan (1999). For background to distortion indices, see: Momma & Izumi (2008).

Experimental

Crystal data

$\text{K}_2\text{Al}_2\text{P}_8\text{O}_{24}$	$V = 1011.4(2) \text{ \AA}^3$
$M_r = 763.92$	$Z = 2$
Monoclinic, $C2/m$	Mo $K\alpha$ radiation
$a = 16.598(2) \text{ \AA}$	$\mu = 1.31 \text{ mm}^{-1}$
$b = 12.2150(17) \text{ \AA}$	$T = 296 \text{ K}$
$c = 5.0705(7) \text{ \AA}$	$0.30 \times 0.10 \times 0.08 \text{ mm}$
$\beta = 100.315(4)^\circ$	

Data collection

Bruker APEXII CCD diffractometer	9643 measured reflections
Absorption correction: multi-scan (SADABS; Bruker, 2008)	2844 independent reflections
$T_{\min} = 0.562$, $T_{\max} = 0.748$	2252 reflections with $I > 2\sigma(I)$
	$R_{\text{int}} = 0.047$

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.042$	87 parameters
$wR(F^2) = 0.124$	$\Delta\rho_{\max} = 1.40 \text{ e \AA}^{-3}$
$S = 1.07$	$\Delta\rho_{\min} = -1.04 \text{ e \AA}^{-3}$
2844 reflections	

Table 1

Selected bond lengths (Å).

P1—O1 ¹	1.4861 (12)	P2—O5	1.4622 (14)
P1—O3	1.4956 (12)	P2—O2	1.4983 (12)
P1—O4	1.5701 (13)	P2—O6	1.5957 (10)
P1—O7	1.5794 (8)	P2—O4	1.6070 (13)

Symmetry code: (i) $-x + \frac{1}{2}, -y + \frac{1}{2}, -z + 1$.

Data collection: APEX2 (Bruker, 2008); cell refinement: SAINT (Bruker, 2008); data reduction: SAINT; program(s) used to solve structure: SHELXS97 (Sheldrick, 2008); program(s) used to refine structure: SHELXL97 (Sheldrick, 2008); molecular graphics: DIAMOND (Brandenburg, 1999), CaRine (Boudias & Monceau, 1998) and ORTEP-3 (Farrugia, 1997); software used to prepare material for publication: SHELXTL (Sheldrick, 2008).

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: WM2355).

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supporting information

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S1. Comment

The title compound, $\text{K}_2\text{Al}_2\text{P}_8\text{O}_{24}$, belongs to porous crystalline open-framework materials that gain growing interest for their potential applications as molecular sieves or catalysts (Cheetham *et al.* 1999; Hartmann & Kevan, 1999). The title cyclooctaphosphate is isotypic with $\text{K}_2\text{Ga}_2\text{P}_8\text{O}_{24}$ (Palkina *et al.*, 1979) and $\text{K}_2\text{Mn}_2\text{P}_8\text{O}_{24}$ (Murashova & Chudinova, 1999). This structural family also includes $\text{K}_2\text{V}_2\text{P}_8\text{O}_{24}$ (Lavrov *et al.*, 1981), $\text{K}_2\text{Fe}_2\text{P}_8\text{O}_{24}$ (Grunze *et al.*, 1983) and $\text{K}_2\text{Cr}_2\text{P}_8\text{O}_{24}$ (Grunze & Chudinova, 1988), the structures of which have not yet been refined from X-ray diffraction data.

The crystal structure of $\text{K}_2\text{M}_2\text{P}_8\text{O}_{24}$ is built up of 8-membered phosphate ring anions $\text{P}_8\text{O}_{24}^{8-}$ (symmetry $2/m$) (Fig. 1), further linked by isolated $M^{\text{III}}\text{O}_6$ octahedra to form the three-dimensional skeleton. Each MO_6 octahedron is linked to four ring anions $\text{P}_8\text{O}_{24}^{8-}$. Two ring anions are linked by corner-sharing in *trans* positions whereas the two others are connected in a bidentate fashion in *cis* positions on two opposite edges of the equatorial plane of the octahedron. This three-dimensional framework of $\text{K}_2\text{Al}_2\text{P}_8\text{O}_{24}$ delimits two kinds of channels expanding along the [001] direction (Fig. 2). The first channel is octagonally shaped since passing through the ring anions and is empty despite a size of ≈ 5.2 Å in diameter. The second channel, cross shaped, accommodates the K^+ ions in a [6 + 4] coordination. The K^+ ions are located over two columns shifted of about $c/2$ with respect to each other along the c axis. Thus they form two distinct K—K pairs with common square faces involving only O(5) oxygen atoms. In the first pair, corresponding to the shortest K—K distance (3.634 (9) Å) (Fig. 3), the four O(5) atoms delimit a pseudo-square face with O—O separations of 2.995 (2) and 3.064 (6) Å and O(5)—O(5)—O(5) angles of 90° . This pair corresponds to the two shortest K—O distances, *viz.* 2.7559 (15) and 2.8612 (15) Å. In the second pair with a K—K distance of 4.365 (7) Å, the four O(5) atoms at the vertices of the pseudo-square face (O—O separation 2.995 (2) and 3.139 (7) Å with O(5)—O(5)—O(5) angles of 90°), the respective K—O bonds lengths are 2.8612 (15) and 3.2790 (17) Å. The polyhedra surrounding three potassium cations engaged in two successive pairs (one long and one short) form a cluster within they share a common O(5)—O(5) edge with a contact distance of 2.995 (2) Å. This potassium-oxygen polyhedra packing also prevails in the Ga and Mn cyclooctaphosphate analogues but the K—O distances spread over larger ranges, *viz.* from 2.754 (28) Å to 3.359 (28) Å and from 2.738 (2) to 3.506 (2) Å, respectively. Thus the respective coordinations of the potassium cations can be regarded as being [6 + 4] and [8 + 2] for Ga and Mn cyclooctaphosphate.

A careful examination of the geometry of the $M^{\text{III}}\text{O}_6$ octahedra in this structural type shows that the distortion index (bond length) (Momma & Izumi, 2008) increases from Al to Mn (0.0117 for Al, 0.0202 for Ga and 0.0574 for Mn). The AlO_6 octahedron is only very slightly distorted with two shorter Al—O distances of 1.8523 (12) Å and four others very close to 1.90 Å (1.9013 (12) ($\times 2$) and 1.9021 (11) ($\times 2$) Å). The significant larger distortion of the MnO_6 octahedron is probably due to the Jahn-Teller effect associated with the d^4 electronic configuration of Mn^{III} (Murashova & Chudinova, 1999).

Besides the structural family to which the title compound belongs, only another sodium and silver- containing cyclo-octaphosphate, $\text{Ag}_9\text{NaP}_8\text{O}_{24}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, exhibits a ring anion with internal $2/m$ symmetry among the presently known cyclooctaphosphates (Durif, 1995, 2005). However, despite the common internal symmetry, the shape of the 8-membered ring anion present in this structure is very different from that of the title compound as shown in Fig. 4.

S2. Experimental

Single-crystals of the title compound were obtained by solid state reaction, from the reagents K_2CO_3 , Al_2O_3 and $(\text{NH}_4)_2\text{H}_2\text{PO}_4$ in the molar ratio $\text{K} / \text{P} / \text{Al} = 57 / 34 / 9$. The mixture has progressively been heated up to 873 K over a period of 12 h. Then the temperature was slowly decreased down to 723 K at the rate of 5 K h^{-1} and maintained at this value for 12 h. Then a new cooling step down to 573 K at the rate of 5 K h^{-1} was carried out before the furnace was switched off. Single-crystals of $\text{K}_2\text{Al}_2\text{P}_8\text{O}_{24}$ were extracted from the batch by washing with hot water in order to remove the excess of P_2O_5 . A translucent colorless needle of the title compound was used for the structure refinement.

S3. Refinement

The highest residual peak in the final difference Fourier map was located 0.74 \AA from atom P2 and the deepest hole was located 0.69 \AA from atom P1.

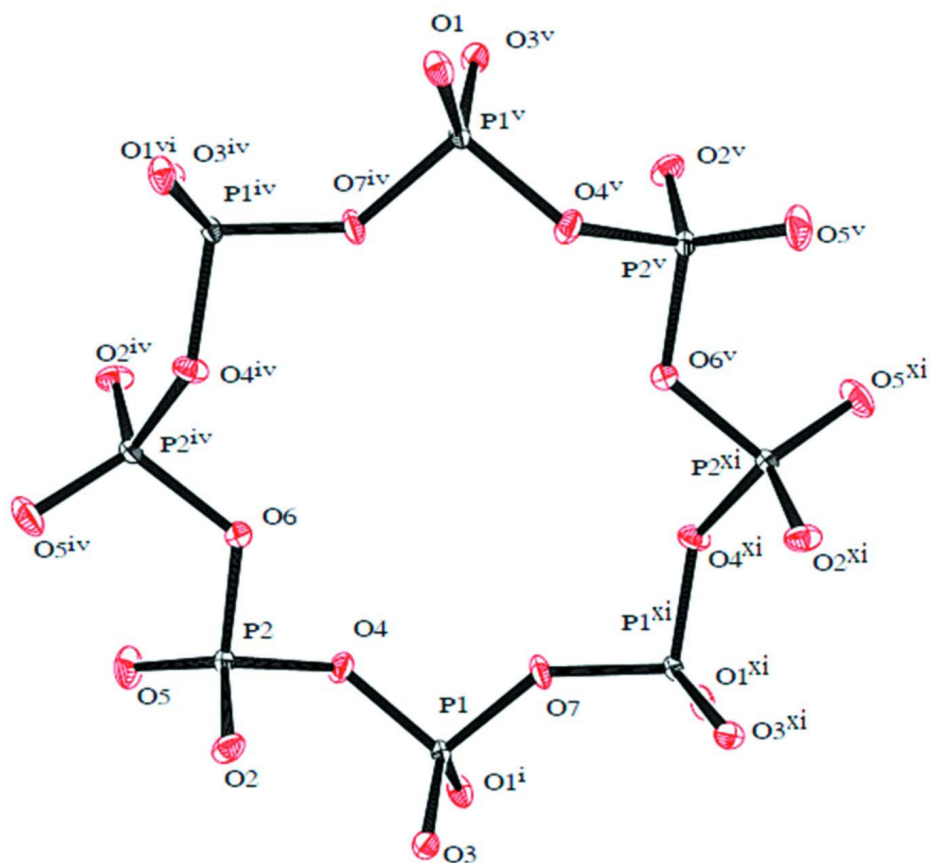


Figure 1

ORTEP-3 view (Farrugia, 1997) of the centrosymmetric $(\text{P}_8\text{O}_{24})^{8-}$ ring anion. Displacement ellipsoids are drawn at the 50% probability level. Symmetry codes: (i) $-x, -y + 1, -z + 1$; (iv) $-x, y, -z$; (v) $-x, -y + 1, -z$; (vi) $x - 1/2, -y + 1/2, z$; (ix) $-x + 1/2, -y + 1/2, -z + 1$; (xi) $x, -y, z$.

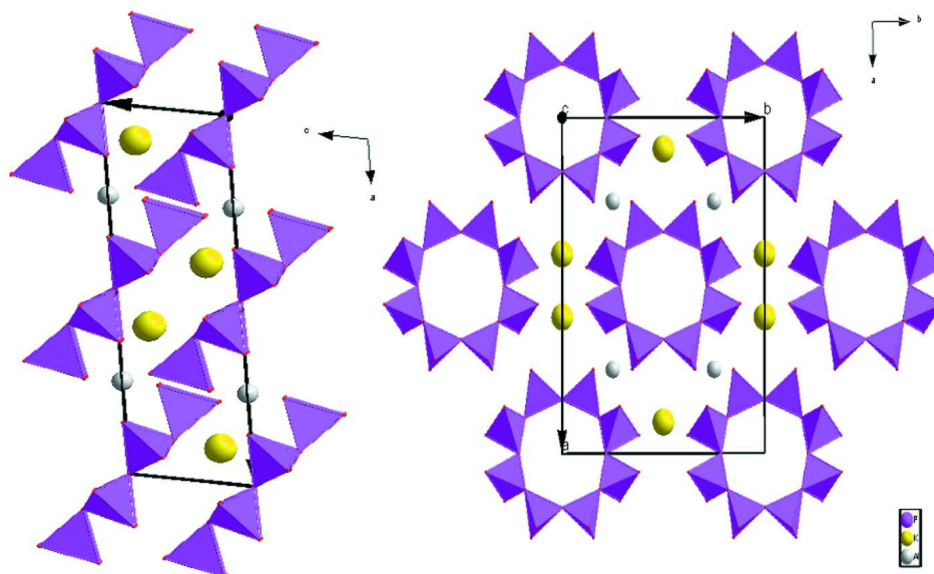


Figure 2

Projections of the 8-membered ring anions $P_8O_{24}^{8-}$ along $[010]$ (left) and $[001]$ (right).

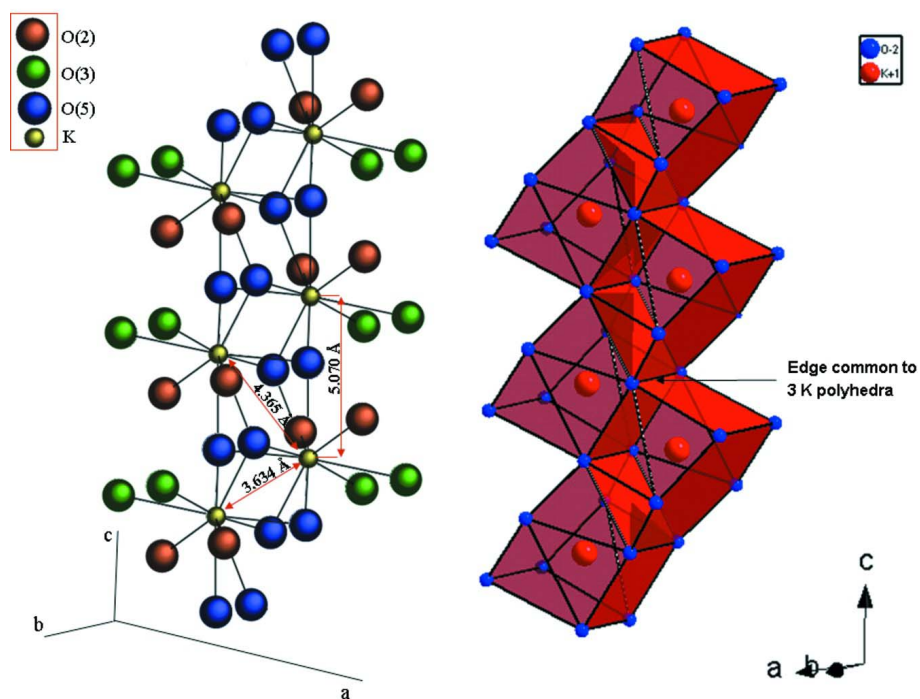
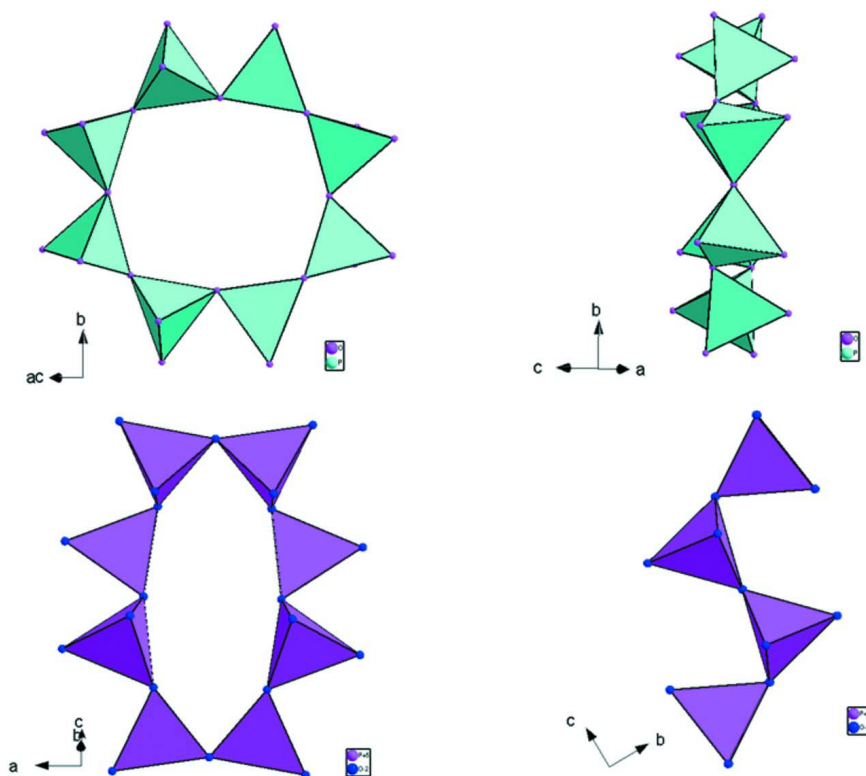


Figure 3

Partial view showing the packing of the $K-O$ polyhedra along the c axis in the ball and stick (left) and polyhedral (right) representation.


Figure 4

Comparison of the 8-membered ring anions $\text{P}_8\text{O}_{24}^{8-}$ (both with internal $2/m$ symmetry) in $\text{K}_2\text{Al}_2\text{P}_8\text{O}_{24}$ (top) and $\text{Ag}_9\text{NaP}_8\text{O}_{24}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ (bottom).

Dipotassium dialuminium cyclooctaphosphate

Crystal data

$\text{K}_2\text{Al}_2\text{P}_8\text{O}_{24}$

$M_r = 763.92$

Monoclinic, $C2/m$

Hall symbol: $-C 2y$

$a = 16.598 (2) \text{ \AA}$

$b = 12.2150 (17) \text{ \AA}$

$c = 5.0705 (7) \text{ \AA}$

$\beta = 100.315 (4)^\circ$

$V = 1011.4 (2) \text{ \AA}^3$

$Z = 2$

$F(000) = 752$

$D_x = 2.508 \text{ Mg m}^{-3}$

Mo $K\alpha$ radiation, $\lambda = 0.71073 \text{ \AA}$

Cell parameters from 3017 reflections

$\theta = 3.3\text{--}37.7^\circ$

$\mu = 1.31 \text{ mm}^{-1}$

$T = 296 \text{ K}$

Needle, colourless

$0.30 \times 0.10 \times 0.08 \text{ mm}$

Data collection

Bruker APEXII CCD

diffractometer

Radiation source: fine-focus sealed tube

Graphite monochromator

Detector resolution: $8.3333 \text{ pixels mm}^{-1}$

ω and φ scans

Absorption correction: multi-scan

(*SADABS*; Bruker, 2008)

$T_{\min} = 0.562$, $T_{\max} = 0.748$

9643 measured reflections

2844 independent reflections

2252 reflections with $I > 2\sigma(I)$

$R_{\text{int}} = 0.047$

$\theta_{\max} = 38.7^\circ$, $\theta_{\min} = 4.1^\circ$

$h = -29 \rightarrow 28$

$k = -18 \rightarrow 20$

$l = -8 \rightarrow 8$

Refinement

Refinement on F^2
 Least-squares matrix: full
 $R[F^2 > 2\sigma(F^2)] = 0.042$
 $wR(F^2) = 0.124$
 $S = 1.07$
 2844 reflections
 87 parameters
 0 restraints

Primary atom site location: structure-invariant
 direct methods
 Secondary atom site location: difference Fourier
 map
 $w = 1/[\sigma^2(F_o^2) + (0.0738P)^2 + 0.0398P]$
 where $P = (F_o^2 + 2F_c^2)/3$
 $(\Delta/\sigma)_{\max} < 0.001$
 $\Delta\rho_{\max} = 1.40 \text{ e } \text{\AA}^{-3}$
 $\Delta\rho_{\min} = -1.04 \text{ e } \text{\AA}^{-3}$

Special details

Geometry. All e.s.d.'s (except the e.s.d. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell e.s.d.'s are taken into account individually in the estimation of e.s.d.'s in distances, angles and torsion angles; correlations between e.s.d.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell e.s.d.'s is used for estimating e.s.d.'s involving l.s. planes.

Refinement. Refinement of F^2 against ALL reflections. The weighted R -factor wR and goodness of fit S are based on F^2 , conventional R -factors R are based on F , with F set to zero for negative F^2 . The threshold expression of $F^2 > \sigma(F^2)$ is used only for calculating R -factors(gt) etc. and is not relevant to the choice of reflections for refinement. R -factors based on F^2 are statistically about twice as large as those based on F , and R -factors based on ALL data will be even larger.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (\AA^2)

	x	y	z	$U_{\text{iso}}^*/U_{\text{eq}}$
K	-0.09371 (4)	0.5000	0.25194 (13)	0.02290 (13)
Al	0.2500	0.2500	0.0000	0.00771 (13)
P1	0.19023 (2)	0.12098 (3)	0.46962 (8)	0.00720 (9)
P2	0.07782 (2)	0.27631 (3)	0.16477 (8)	0.00835 (9)
O1	0.28060 (8)	0.36965 (10)	0.2366 (2)	0.0118 (2)
O2	0.14059 (7)	0.28394 (11)	-0.0132 (2)	0.0132 (2)
O3	0.24968 (7)	0.15349 (10)	0.2942 (2)	0.0105 (2)
O4	0.10711 (7)	0.18408 (11)	0.3873 (2)	0.0122 (2)
O5	0.05469 (9)	0.37739 (12)	0.2866 (3)	0.0184 (3)
O6	0.0000	0.21471 (15)	0.0000	0.0140 (3)
O7	0.16028 (11)	0.0000	0.3993 (3)	0.0125 (3)

Atomic displacement parameters (\AA^2)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
K	0.0299 (3)	0.0147 (3)	0.0240 (3)	0.000	0.0046 (2)	0.000
Al	0.0085 (3)	0.0083 (3)	0.0064 (3)	0.0001 (2)	0.0016 (2)	0.0006 (2)
P1	0.00956 (16)	0.00518 (17)	0.00672 (15)	0.00032 (12)	0.00110 (11)	0.00033 (11)
P2	0.00850 (17)	0.00632 (18)	0.01023 (16)	0.00094 (12)	0.00164 (12)	0.00031 (12)
O1	0.0186 (5)	0.0084 (5)	0.0078 (4)	-0.0009 (4)	0.0006 (4)	-0.0006 (3)
O2	0.0095 (5)	0.0177 (6)	0.0130 (5)	0.0020 (4)	0.0033 (4)	0.0049 (4)
O3	0.0104 (5)	0.0111 (5)	0.0105 (5)	0.0011 (4)	0.0037 (3)	0.0033 (4)
O4	0.0108 (5)	0.0125 (6)	0.0138 (5)	0.0033 (4)	0.0034 (4)	0.0051 (4)
O5	0.0247 (6)	0.0105 (6)	0.0198 (6)	0.0053 (5)	0.0030 (5)	-0.0045 (5)
O6	0.0096 (7)	0.0092 (8)	0.0217 (8)	0.000	-0.0011 (6)	0.000
O7	0.0177 (7)	0.0051 (7)	0.0129 (7)	0.000	-0.0021 (5)	0.000

Geometric parameters (Å, °)

K—O5 ⁱ	2.7559 (15)	Al—O3	1.9021 (11)
K—O5 ⁱⁱ	2.7559 (15)	P1—O1 ^{ix}	1.4861 (12)
K—O5	2.8612 (15)	P1—O3	1.4956 (12)
K—O5 ⁱⁱⁱ	2.8612 (15)	P1—O4	1.5701 (13)
K—O2 ^{iv}	2.9493 (14)	P1—O7	1.5794 (8)
K—O2 ^v	2.9493 (13)	P2—O5	1.4622 (14)
K—O3 ^{vi}	3.2431 (13)	P2—O2	1.4983 (12)
K—O3 ^{vii}	3.2431 (13)	P2—O6	1.5957 (10)
K—O5 ^{iv}	3.2790 (17)	P2—O4	1.6070 (13)
K—O5 ^v	3.2790 (17)	P2—K ^v	3.4928 (7)
K—P2 ^{iv}	3.4927 (7)	O1—P1 ^{ix}	1.4861 (12)
K—P2 ^v	3.4927 (7)	O2—K ^v	2.9494 (13)
Al—O2 ^{viii}	1.8523 (12)	O3—K ^x	3.2431 (13)
Al—O2	1.8523 (12)	O5—K ⁱ	2.7559 (15)
Al—O1 ^{viii}	1.9013 (12)	O5—K ^v	3.2790 (17)
Al—O1	1.9013 (12)	O6—P2 ^{iv}	1.5957 (10)
Al—O3 ^{viii}	1.9021 (11)	O7—P1 ^{xi}	1.5793 (8)
O5 ⁱ —K—O5 ⁱⁱ	65.84 (6)	O5—K—P2 ^v	106.81 (4)
O5 ⁱ —K—O5	99.41 (4)	O5 ⁱⁱⁱ —K—P2 ^v	58.01 (3)
O5 ⁱⁱ —K—O5	66.08 (6)	O2 ^{iv} —K—P2 ^v	119.65 (3)
O5 ⁱ —K—O5 ⁱⁱⁱ	66.08 (6)	O2 ^v —K—P2 ^v	25.13 (2)
O5 ⁱⁱ —K—O5 ⁱⁱⁱ	99.41 (4)	O3 ^{vi} —K—P2 ^v	129.83 (3)
O5—K—O5 ⁱⁱⁱ	63.13 (6)	O3 ^{vii} —K—P2 ^v	74.69 (2)
O5 ⁱ —K—O2 ^{iv}	147.08 (5)	O5 ^{iv} —K—P2 ^v	78.81 (3)
O5 ⁱⁱ —K—O2 ^{iv}	82.35 (4)	O5 ^v —K—P2 ^v	24.68 (2)
O5—K—O2 ^{iv}	73.61 (4)	P2 ^{iv} —K—P2 ^v	102.94 (2)
O5 ⁱⁱⁱ —K—O2 ^{iv}	130.89 (4)	O2 ^{viii} —Al—O2	180.0
O5 ⁱ —K—O2 ^v	82.35 (4)	O2 ^{viii} —Al—O1 ^{viii}	90.00 (6)
O5 ⁱⁱ —K—O2 ^v	147.08 (5)	O2—Al—O1 ^{viii}	89.99 (6)
O5—K—O2 ^v	130.89 (4)	O2 ^{viii} —Al—O1	89.99 (6)
O5 ⁱⁱⁱ —K—O2 ^v	73.61 (4)	O2—Al—O1	90.01 (6)
O2 ^{iv} —K—O2 ^v	126.97 (6)	O1 ^{viii} —Al—O1	180.00 (5)
O5 ⁱ —K—O3 ^{vi}	109.11 (4)	O2 ^{viii} —Al—O3 ^{viii}	91.53 (5)
O5 ⁱⁱ —K—O3 ^{vi}	72.48 (4)	O2—Al—O3 ^{viii}	88.47 (5)
O5—K—O3 ^{vi}	112.63 (4)	O1 ^{viii} —Al—O3 ^{viii}	91.12 (5)
O5 ⁱⁱⁱ —K—O3 ^{vi}	171.88 (4)	O1—Al—O3 ^{viii}	88.88 (5)
O2 ^{iv} —K—O3 ^{vi}	49.77 (3)	O2 ^{viii} —Al—O3	88.47 (5)
O2 ^v —K—O3 ^{vi}	112.88 (4)	O2—Al—O3	91.52 (5)
O5 ⁱ —K—O3 ^{vii}	72.48 (4)	O1 ^{viii} —Al—O3	88.88 (5)
O5 ⁱⁱ —K—O3 ^{vii}	109.11 (4)	O1—Al—O3	91.12 (5)
O5—K—O3 ^{vii}	171.88 (4)	O3 ^{viii} —Al—O3	180.0
O5 ⁱⁱⁱ —K—O3 ^{vii}	112.63 (4)	O1 ^{ix} —P1—O3	116.38 (7)
O2 ^{iv} —K—O3 ^{vii}	112.88 (4)	O1 ^{ix} —P1—O4	109.98 (7)
O2 ^v —K—O3 ^{vii}	49.77 (3)	O3—P1—O4	110.70 (7)
O3 ^{vi} —K—O3 ^{vii}	70.64 (5)	O1 ^{ix} —P1—O7	109.34 (8)

O5 ⁱ —K—O5 ^{iv}	154.67 (6)	O3—P1—O7	109.20 (8)
O5 ⁱⁱ —K—O5 ^{iv}	114.04 (5)	O4—P1—O7	99.98 (8)
O5—K—O5 ^{iv}	61.04 (5)	O5—P2—O2	117.73 (9)
O5 ⁱⁱⁱ —K—O5 ^{iv}	89.66 (4)	O5—P2—O6	111.73 (8)
O2 ^{iv} —K—O5 ^{iv}	47.65 (3)	O2—P2—O6	107.39 (6)
O2 ^v —K—O5 ^{iv}	98.27 (4)	O5—P2—O4	111.39 (8)
O3 ^{vi} —K—O5 ^{iv}	94.08 (3)	O2—P2—O4	108.11 (7)
O3 ^{vii} —K—O5 ^{iv}	126.82 (4)	O6—P2—O4	98.73 (7)
O5 ⁱ —K—O5 ^v	114.04 (5)	O5—P2—K ^v	69.45 (6)
O5 ⁱⁱ —K—O5 ^v	154.67 (6)	O2—P2—K ^v	56.71 (5)
O5—K—O5 ^v	89.66 (4)	O6—P2—K ^v	101.18 (5)
O5 ⁱⁱⁱ —K—O5 ^v	61.04 (5)	O4—P2—K ^v	157.99 (5)
O2 ^{iv} —K—O5 ^v	98.27 (4)	P1 ^{ix} —O1—Al	133.95 (8)
O2 ^v —K—O5 ^v	47.65 (3)	P2—O2—Al	138.36 (8)
O3 ^{vi} —K—O5 ^v	126.82 (4)	P2—O2—K ^v	98.17 (6)
O3 ^{vii} —K—O5 ^v	94.08 (3)	Al—O2—K ^v	113.58 (5)
O5 ^{iv} —K—O5 ^v	54.36 (5)	P1—O3—Al	136.54 (8)
O5 ⁱ —K—P2 ^{iv}	155.10 (4)	P1—O3—K ^x	120.51 (6)
O5 ⁱⁱ —K—P2 ^{iv}	93.25 (3)	Al—O3—K ^x	101.05 (4)
O5—K—P2 ^{iv}	58.01 (3)	P1—O4—P2	132.20 (8)
O5 ⁱⁱⁱ —K—P2 ^{iv}	106.81 (4)	P2—O5—K ⁱ	141.08 (8)
O2 ^{iv} —K—P2 ^{iv}	25.13 (2)	P2—O5—K	134.77 (8)
O2 ^v —K—P2 ^{iv}	119.65 (3)	K ⁱ —O5—K	80.59 (4)
O3 ^{vi} —K—P2 ^{iv}	74.69 (2)	P2—O5—K ^v	85.87 (6)
O3 ^{vii} —K—P2 ^{iv}	129.83 (3)	K ⁱ —O5—K ^v	114.04 (5)
O5 ^{iv} —K—P2 ^{iv}	24.68 (2)	K—O5—K ^v	90.34 (4)
O5 ^v —K—P2 ^{iv}	78.81 (3)	P2—O6—P2 ^{iv}	123.73 (12)
O5 ⁱ —K—P2 ^v	93.25 (3)	P1 ^{xi} —O7—P1	138.66 (12)
O5 ⁱⁱ —K—P2 ^v	155.10 (4)		

Symmetry codes: (i) $-x, -y+1, -z+1$; (ii) $-x, y, -z+1$; (iii) $x, -y+1, z$; (iv) $-x, y, -z$; (v) $-x, -y+1, -z$; (vi) $x-1/2, -y+1/2, z$; (vii) $x-1/2, y+1/2, z$; (viii) $-x+1/2, -y+1/2, -z$; (ix) $-x+1/2, -y+1/2, -z+1$; (x) $x+1/2, y-1/2, z$; (xi) $x, -y, z$.