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# A new sodium dimangnesium trivanadate, $NaMg_2V_3O_{10}$

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Key indicators: single-crystal X-ray study; $T$ = 293 K; mean $\sigma$(Mg–O) = 0.003 Å; $R$ factor = 0.033; $wR$ factor = 0.096; data-to-parameter ratio = 11.7.

A single crystal of $NaMg_2V_3O_{10}$ has been prepared by solid-state reaction at 1173 K. The $[Mg_2(V_3O_{10})]^-$ anions are built up from edge-sharing $MgO_6$ octahedra to form $[Mg_4O_{18}]$ units, which are linked to each other by trivanadate groups ($V_3O_{10}$). The $Na^+$ ions are located in the tunnel space.

## Related literature

For related literature, see: Barbier (1988); Brown & Altermatt (1985); Gopal & Calvo (1974); Krishnamachari & Calvo (1971); Mitiaev *et al.* (2004); Murashova *et al.* (1988*a*, 1988*b*); Ng & Calvo (1972); Saux & Galy (1973).

## Experimental

### *Crystal data*

$NaMg_2V_3O_{10}$
$M_r$ = 384.42
Triclinic, $P\overline{1}$
$a$ = 6.7369 (1) Å
$b$ = 6.7553 (1) Å
$c$ = 9.6222 (1) Å
$\alpha$ = 104.325 (1)°
$\beta$ = 100.604 (1)°
$\gamma$ = 101.696 (1)°
$V$ = 402.63 (1) Å$^3$
$Z$ = 2
Mo $K\alpha$ radiation
$\mu$ = 3.66 mm$^{-1}$
$T$ = 293 (2) K
0.4 × 0.07 × 0.03 mm

### *Data collection*

Enraf–Nonius CAD-4 diffractometer
Absorption correction: $\psi$ scan (North *et al.*, 1968)
$T_{min}$ = 0.871, $T_{max}$ = 0.965
(expected range = 0.809–0.896)
3118 measured reflections
1712 independent reflections
1415 reflections with $I > 2\sigma(I)$
$R_{int}$ = 0.049
2 standard reflections
frequency: 120 min
intensity decay: 0.4%

### *Refinement*

$R[F^2 > 2\sigma(F^2)]$ = 0.033
$wR(F^2)$ = 0.095
$S$ = 1.06
1712 reflections
146 parameters
$\Delta\rho_{max}$ = 0.73 e Å$^{-3}$
$\Delta\rho_{min}$ = −1.18 e Å$^{-3}$

**Table 1**
Selected bond lengths (Å).

| | | | |
|---|---|---|---|
| V1—O4 | 1.672 (3) | V2—O7 | 1.717 (3) |
| V1—O6 | 1.688 (3) | V2—O5 | 1.848 (3) |
| V1—O2 | 1.704 (3) | V3—O8 | 1.642 (3) |
| V1—O1 | 1.806 (3) | V3—O3 | 1.655 (3) |
| V2—O9 | 1.643 (3) | V3—O1$^{i}$ | 1.757 (3) |
| V2—O10 | 1.694 (3) | V3—O5$^{ii}$ | 1.827 (3) |

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

Data collection: *CAD-4 EXPRESS* (Duisenberg, 1992; Macíček & Yordanov, 1992); cell refinement: *CAD-4 EXPRESS*; data reduction: *MolEN* (Fair, 1990); program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *DIAMOND* (Brandenburg, 1998); software used to prepare material for publication: *SHELXL97*.

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: BR2067).

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# supporting information

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## A new sodium dimangnesium trivanadate, $NaMg_2V_3O_{10}$

**Brahim Ayed and Amor Haddad**

### S1. Comment

The synthesis and structural characterization of new materials characterized by mixed open frameworks of $MO_6$ octahedra and $XO_4$ tetrahedra sharing edges and/or corners delimiting tunnels where cations are located and study of their properties are an active area of research in solid state chemistry, due to their interest in the fields of catalysis, ion exchange and ion conduction. In the system $MgO–V_2O_5$, a small number of compounds have been structurally characterized now, namely, $Mg_2V_2O_7$ (Gopal & Calvo, 1974), $MgV_2O_6$ (Ng & Calvo, 1972), $Mg_3(VO_4)_2$ (Krishnamachari & Calvo, 1971) and $MgV_3O_8$ (Saux & Galy, 1973). The same is true for the inclusion of alkali elements into this system, to our knowledge, only the structure of $NaMg_4(VO_4)_3$ (Murashova *et al.*, 1988*a*), $LiMg(VO_4)$ (Barbier, 1988), $K_2MgV_2O_7$ (Murashova *et al.*, 1988*b*) and $Na_6Mg_2(V_4O_{15})$(Mitiaev *et al.*, 2004) have been determined. Extending our investigation a new magnesium trivanadate, $NaMg_2V_3O_{10}$ has been prepared by a conventional solid-state reaction and characterized by single-crystal X-ray diffraction. The structure of $NaMg_2V_3O_{10}$ consists of $MgO_6$ octahedra and $VO_4$ tetrahedral sharing corners and edges to form a three-dimensional framework. The $Na^+$ are located in the tunnels space. A projection of the structure, showing the displacement ellipsoids, is presented in Fig 1. The $Mg_2$ $(V_3O_{10})]^-$ anions are built up from edge sharing $MgO_6$ octahedra to form $[Mg_4O_{18}]$ units, which are linked to each other by trivanadate groups $(V_3O_{10})$. The $Mg_4O_{18}$ basal unit is built up by the edge linkages of four $MgO_6$ octahedra, Such a unit is formed by two kind of divalent-metal cations, one labeled as Mg1 share edge with another labelled Mg2 forming $Mg_2O_{10}$ dimers, repetition of the dimers ensured by centres of symmetry on the shared edge between two $Mg1O_6$ leads to the formation of $Mg_4O_{10}$ unit. Each trivanadate is formed by three tetrahedra, $V1O_4$, $V2O_4$ and $V3O_4$, interconnected through the corners O1 and O5. The V1, V2 and V3 tetrahedron shares the eight remaining O-atom corners with five $Mg_4O_{18}$ units forming ribbons running along the [011] direction (Fig. 2). The projection of the structure along the [001] show that the trivanadate groups and the $MgO_6$ polyhedra form six side tunnels running along [001] in which $Na^+$ cations are located (Fig3). The geometry of the $VO_4$ tetrahedra is close to that generally observed. Two groups of distances can be distinguished. The V—O bonds corresponding to the two V—O—V bridges of the $V_3O_{10}$ groups are the largest one. Consequently, the two external tetrahedra V1 and V2 present one long V—O distance and three smaller ones. Whereas the cental V3 tetrahedron has two long and two shorter. The Mg atoms are surrounded by six O atoms and the sodium cations exhibit a sixfold coordination. The bond valence sums determined using the Brown & Altermatt (1985) formulation are in the agreement with the formal charges deduced from the chemical formula: 5.088, 5.020, 5.100 from V1 to V3 respectively; 0.858 for Na; 2,188, 1.960 for Mg1 and Mg2 respectively, and ranging from 1.928 to 2.197 for the oxygen atoms.

### S2. Experimental

The starting materials for synthesizing $NaMg_2V_3O_{10}$ were $NaVO_3$, $V_2O_5$ and $Mg(NO_3)_2$.7H2O. The stoichiometric mixture was heated in air, in a platinum crucible, after a progressive heating to 873 K, the mixture was heated at 1173 K, cooled to 773 K at rate of 5 K.hr-1 and then to room temperature. The parallelepiped crystals obtained after washing with hot

water were brown. Quantitative analysis of these crystals, by electron microscope probe, revealed that they contain sodium, magnesium and vanadium.

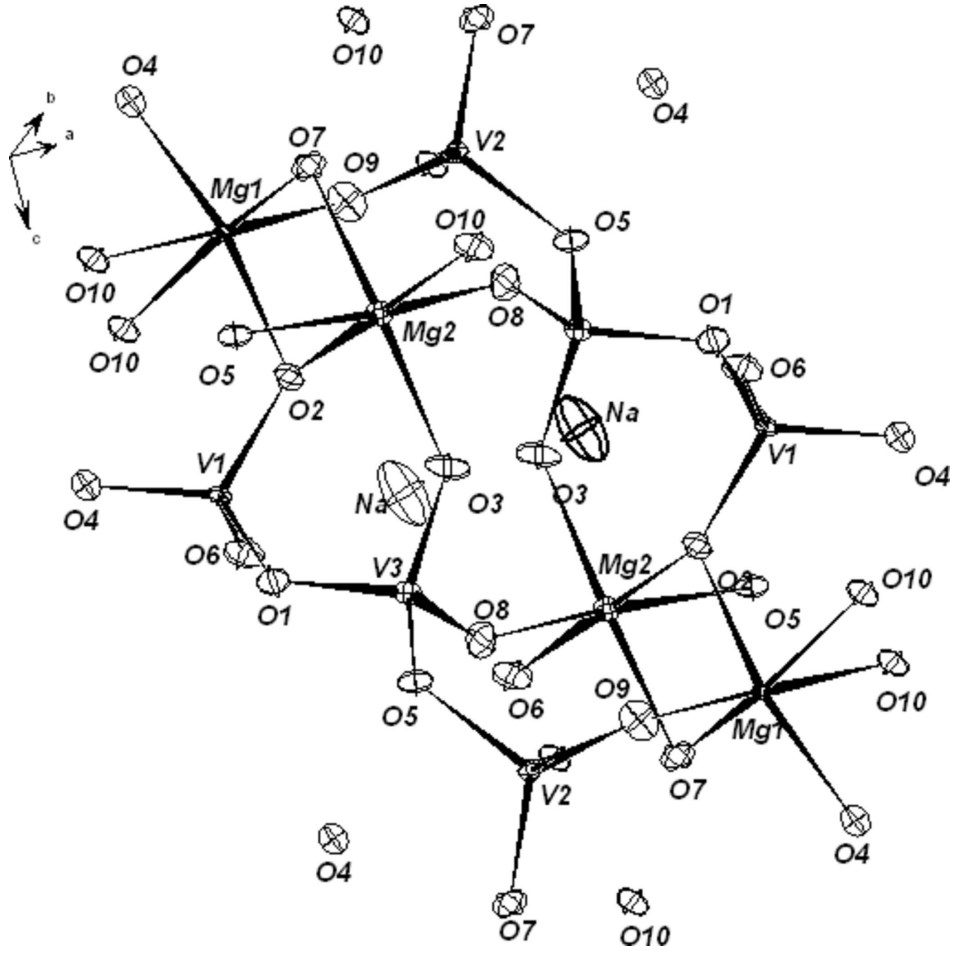


**Figure 1**

A projection of $NaMg_2V_3O_{10}$, showing the displacement ellipsoids.

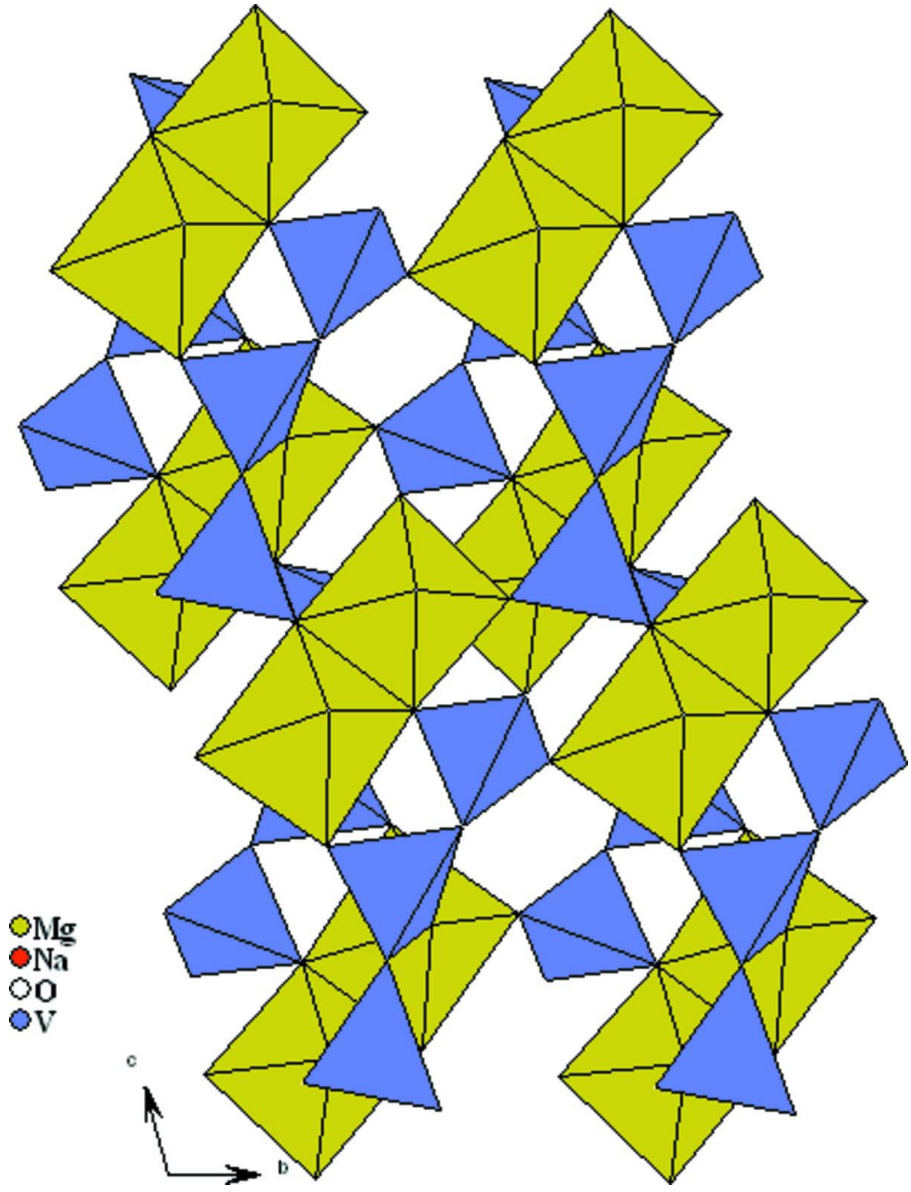


**Figure 2**

View showing the ribbons running along the [011] direction.

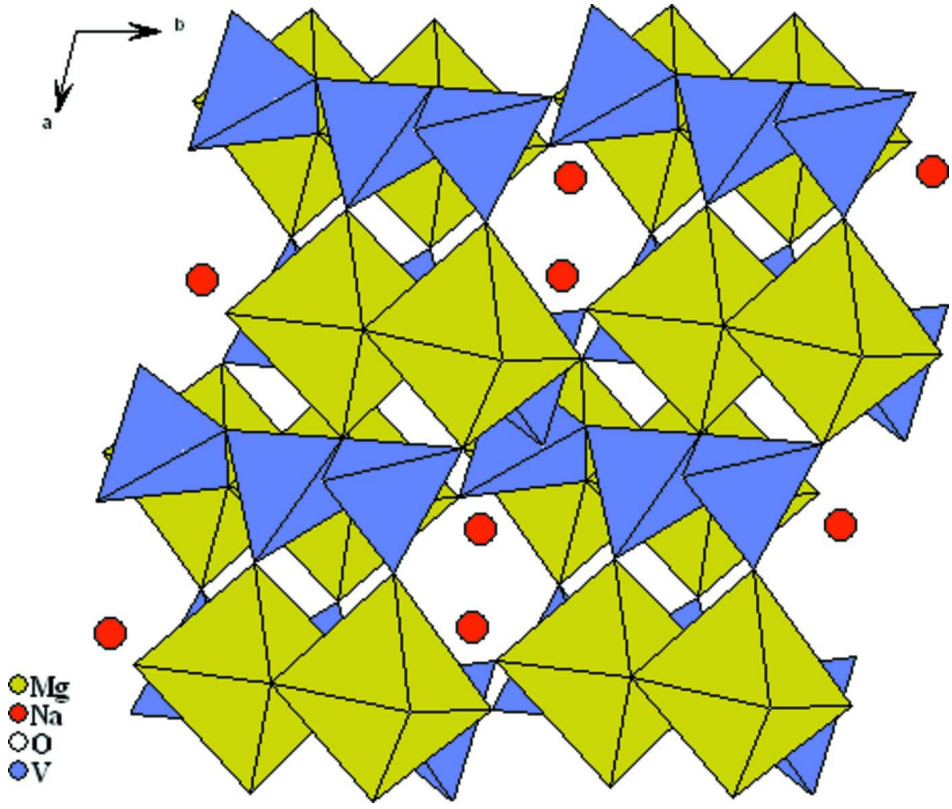


**Figure 3**

Projection of the structure of $NaMg_2V_3O_{10}$ along [001] direction.

### Sodium dimagnesium trivanadate

*Crystal data*

$NaMg_2V_3O_{10}$
$M_r$ = 384.42
Triclinic, $P\overline{1}$
Hall symbol: -P 1
$a$ = 6.7369 (1) Å
$b$ = 6.7553 (1) Å
$c$ = 9.6222 (1) Å
$\alpha$ = 104.325 (1)°
$\beta$ = 100.604 (1)°
$\gamma$ = 101.696 (1)°
$V$ = 402.63 (1) Å$^3$
$Z$ = 2
$F(000)$ = 368
$D_x$ = 3.171 Mg m$^{-3}$
Mo $K\alpha$ radiation, $\lambda$ = 0.71073 Å
Cell parameters from 25 reflections
$\theta$ = 1.5–27.0°
$\mu$ = 3.66 mm$^{-1}$
$T$ = 293 K
Parallelepiped, brown
0.4 × 0.07 × 0.03 mm

*Data collection*

Enraf–Nonius CAD-4 diffractometer
Radiation source: fine-focus sealed tube
Graphite monochromator
$\omega/2\theta$ scans
Absorption correction: $\psi$ scan (North *et al.*, 1968)
$T_{min}$ = 0.871, $T_{max}$ = 0.965
3118 measured reflections
1712 independent reflections
1415 reflections with $I > 2\sigma(I)$
$R_{int}$ = 0.049
$\theta_{max}$ = 27.0°, $\theta_{min}$ = 2.3°
$h$ = −8→8
$k$ = −8→8
$l$ = −12→12
2 standard reflections every 120 min
intensity decay: 0.4%

*Refinement*

Refinement on $F^2$
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)] = 0.033$
$wR(F^2) = 0.095$
$S = 1.06$
1712 reflections
146 parameters
0 restraints
Primary atom site location: structure-invariant direct methods
Secondary atom site location: difference Fourier map
$w = 1/[\sigma^2(F_o^2) + (0.0426P)^2 + 0.4338P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.001$
$\Delta\rho_{max} = 0.73$ e Å$^{-3}$
$\Delta\rho_{min} = -1.18$ e Å$^{-3}$
Extinction correction: *SHELXL97* (Sheldrick, 2008), $Fc^*=kFc[1+0.001xFc^2\lambda^3/\sin(2\theta)]^{-1/4}$
Extinction coefficient: 0.003 (2)

*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 (Å²)*

| | *x* | *y* | *z* | $U_{iso}$*/$U_{eq}$ |
|---|---|---|---|---|
| V1 | 0.11192 (10) | 0.04819 (10) | 0.30906 (7) | 0.00700 (18) |
| V2 | 0.23427 (10) | −0.33675 (10) | −0.04757 (7) | 0.00795 (18) |
| V3 | −0.22756 (10) | −0.42610 (10) | 0.38667 (7) | 0.00858 (19) |
| Mg1 | −0.20718 (18) | −0.18407 (18) | −0.01815 (13) | 0.0043 (3) |
| Mg2 | −0.76019 (19) | −0.4331 (2) | 0.29306 (14) | 0.0098 (3) |
| Na | 0.6408 (4) | 0.0239 (3) | 0.3640 (3) | 0.0416 (6) |
| O1 | 0.0677 (4) | 0.1930 (5) | 0.4803 (3) | 0.0156 (6) |
| O2 | 0.2277 (4) | 0.2383 (4) | 0.2402 (3) | 0.0118 (6) |
| O3 | −0.2797 (5) | −0.6006 (5) | 0.4778 (3) | 0.0172 (6) |
| O4 | −0.1271 (4) | −0.0914 (5) | 0.2063 (3) | 0.0143 (6) |
| O5 | 0.0972 (4) | −0.4778 (4) | −0.2430 (3) | 0.0118 (6) |
| O6 | 0.2690 (5) | −0.1090 (5) | 0.3424 (3) | 0.0163 (6) |
| O7 | 0.2151 (4) | −0.5009 (4) | 0.0627 (3) | 0.0130 (6) |
| O8 | −0.4437 (4) | −0.3693 (5) | 0.3187 (3) | 0.0159 (6) |
| O9 | 0.4808 (5) | −0.2374 (5) | −0.0409 (3) | 0.0188 (7) |
| O10 | 0.1292 (4) | −0.1322 (4) | 0.0086 (3) | 0.0116 (5) |

*Atomic displacement parameters (Å²)*

| | $U^{11}$ | $U^{22}$ | $U^{33}$ | $U^{12}$ | $U^{13}$ | $U^{23}$ |
|---|---|---|---|---|---|---|
| V1 | 0.0082 (3) | 0.0063 (3) | 0.0071 (3) | 0.0016 (2) | 0.0016 (2) | 0.0034 (2) |
| V2 | 0.0112 (3) | 0.0072 (3) | 0.0066 (3) | 0.0036 (2) | 0.0021 (2) | 0.0032 (2) |
| V3 | 0.0110 (3) | 0.0083 (3) | 0.0078 (3) | 0.0031 (2) | 0.0034 (2) | 0.0033 (2) |
| Mg1 | 0.0063 (6) | 0.0029 (5) | 0.0037 (6) | 0.0009 (4) | 0.0012 (4) | 0.0014 (4) |
| Mg2 | 0.0104 (7) | 0.0096 (6) | 0.0093 (6) | 0.0022 (5) | 0.0016 (5) | 0.0033 (5) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Na | 0.0371 (13) | 0.0245 (11) | 0.0622 (16) | 0.0043 (9) | 0.0221 (11) | 0.0066 (11) |
| O1 | 0.0171 (15) | 0.0156 (14) | 0.0122 (14) | 0.0003 (11) | 0.0059 (11) | 0.0020 (11) |
| O2 | 0.0143 (14) | 0.0099 (13) | 0.0114 (13) | 0.0023 (10) | 0.0029 (11) | 0.0045 (11) |
| O3 | 0.0259 (16) | 0.0128 (14) | 0.0188 (15) | 0.0092 (12) | 0.0101 (13) | 0.0087 (12) |
| O4 | 0.0123 (14) | 0.0150 (14) | 0.0136 (14) | −0.0011 (11) | 0.0024 (11) | 0.0053 (11) |
| O5 | 0.0140 (14) | 0.0133 (14) | 0.0101 (13) | 0.0054 (11) | 0.0050 (11) | 0.0043 (11) |
| O6 | 0.0184 (15) | 0.0149 (14) | 0.0198 (15) | 0.0075 (11) | 0.0059 (12) | 0.0092 (12) |
| O7 | 0.0150 (14) | 0.0129 (14) | 0.0124 (13) | 0.0059 (11) | 0.0014 (11) | 0.0057 (11) |
| O8 | 0.0124 (14) | 0.0175 (14) | 0.0190 (15) | 0.0051 (11) | 0.0034 (11) | 0.0069 (12) |
| O9 | 0.0173 (16) | 0.0167 (15) | 0.0241 (17) | 0.0046 (12) | 0.0073 (13) | 0.0074 (13) |
| O10 | 0.0127 (13) | 0.0097 (13) | 0.0142 (13) | 0.0038 (10) | 0.0041 (11) | 0.0054 (11) |

*Geometric parameters (Å, º)*

| | | | |
|---|---|---|---|
| V1—O4 | 1.672 (3) | Mg2—Mg1$^{i}$ | 3.1470 (17) |
| V1—O6 | 1.688 (3) | Mg2—V2$^{i}$ | 3.4044 (14) |
| V1—O2 | 1.704 (3) | Mg2—Na$^{iv}$ | 3.492 (3) |
| V1—O1 | 1.806 (3) | Mg2—Na$^{ii}$ | 3.575 (3) |
| V2—O9 | 1.643 (3) | Na—O3$^{viii}$ | 2.404 (4) |
| V2—O10 | 1.694 (3) | Na—O6 | 2.435 (4) |
| V2—O7 | 1.717 (3) | Na—O4$^{ix}$ | 2.477 (4) |
| V2—O5 | 1.848 (3) | Na—O8$^{ix}$ | 2.509 (4) |
| V2—Mg1 | 3.3760 (14) | Na—O6$^{x}$ | 2.665 (4) |
| V2—Mg2$^{i}$ | 3.4044 (14) | Na—O1$^{ix}$ | 2.771 (4) |
| V3—O8 | 1.642 (3) | Na—V1$^{ix}$ | 3.291 (2) |
| V3—O3 | 1.655 (3) | Na—V3$^{ix}$ | 3.380 (2) |
| V3—O1$^{ii}$ | 1.757 (3) | Na—V1$^{x}$ | 3.474 (3) |
| V3—O5$^{iii}$ | 1.827 (3) | Na—Mg2$^{ix}$ | 3.492 (3) |
| V3—Na$^{iv}$ | 3.380 (2) | Na—Na$^{x}$ | 3.543 (5) |
| V3—Na$^{v}$ | 3.582 (2) | O1—V3$^{ii}$ | 1.757 (3) |
| Mg1—O9$^{iv}$ | 2.020 (3) | O1—Na$^{iv}$ | 2.771 (4) |
| Mg1—O4 | 2.028 (3) | O2—Mg1$^{vi}$ | 2.049 (3) |
| Mg1—O2$^{vi}$ | 2.049 (3) | O2—Mg2$^{viii}$ | 2.132 (3) |
| Mg1—O7$^{iii}$ | 2.051 (3) | O3—Mg2$^{vii}$ | 2.120 (3) |
| Mg1—O10$^{vi}$ | 2.069 (3) | O3—Na$^{v}$ | 2.404 (4) |
| Mg1—O10 | 2.178 (3) | O4—Na$^{iv}$ | 2.477 (4) |
| Mg1—Mg2$^{i}$ | 3.1470 (17) | O5—V3$^{iii}$ | 1.827 (3) |
| Mg1—Mg1$^{vi}$ | 3.240 (2) | O5—Mg2$^{i}$ | 2.156 (3) |
| Mg1—V1$^{vi}$ | 3.2839 (13) | O6—Mg2$^{ix}$ | 2.082 (3) |
| Mg2—O8 | 2.043 (3) | O6—Na$^{x}$ | 2.665 (4) |
| Mg2—O6$^{iv}$ | 2.082 (3) | O7—Mg1$^{iii}$ | 2.051 (3) |
| Mg2—O7$^{iv}$ | 2.117 (3) | O7—Mg2$^{ix}$ | 2.117 (3) |
| Mg2—O3$^{vii}$ | 2.120 (3) | O8—Na$^{iv}$ | 2.509 (4) |
| Mg2—O2$^{v}$ | 2.132 (3) | O9—Mg1$^{ix}$ | 2.020 (3) |
| Mg2—O5$^{i}$ | 2.156 (3) | O10—Mg1$^{vi}$ | 2.069 (3) |
| | | | |
| O4—V1—O6 | 112.10 (15) | O10$^{vi}$—Mg1—O10 | 80.59 (12) |
| O4—V1—O2 | 113.54 (14) | O8—Mg2—O6$^{iv}$ | 88.16 (13) |

| | | | |
|---|---|---|---|
| O6—V1—O2 | 111.46 (14) | O8—Mg2—O7$^{iv}$ | 86.61 (12) |
| O4—V1—O1 | 104.42 (14) | O6$^{iv}$—Mg2—O7$^{iv}$ | 98.45 (12) |
| O6—V1—O1 | 110.07 (14) | O8—Mg2—O3$^{vii}$ | 90.45 (13) |
| O2—V1—O1 | 104.72 (14) | O6$^{iv}$—Mg2—O3$^{vii}$ | 88.10 (13) |
| O9—V2—O10 | 107.80 (14) | O7$^{iv}$—Mg2—O3$^{vii}$ | 172.73 (13) |
| O9—V2—O7 | 110.35 (15) | O8—Mg2—O2$^{v}$ | 88.64 (13) |
| O10—V2—O7 | 111.25 (14) | O6$^{iv}$—Mg2—O2$^{v}$ | 176.66 (13) |
| O9—V2—O5 | 107.91 (14) | O7$^{iv}$—Mg2—O2$^{v}$ | 80.40 (12) |
| O10—V2—O5 | 107.49 (13) | O3$^{vii}$—Mg2—O2$^{v}$ | 92.89 (12) |
| O7—V2—O5 | 111.87 (13) | O8—Mg2—O5$^{i}$ | 173.94 (13) |
| O8—V3—O3 | 109.72 (15) | O6$^{iv}$—Mg2—O5$^{i}$ | 95.28 (12) |
| O8—V3—O1$^{ii}$ | 106.39 (15) | O7$^{iv}$—Mg2—O5$^{i}$ | 87.95 (11) |
| O3—V3—O1$^{ii}$ | 106.04 (14) | O3$^{vii}$—Mg2—O5$^{i}$ | 94.64 (12) |
| O8—V3—O5$^{iii}$ | 111.97 (14) | O2$^{v}$—Mg2—O5$^{i}$ | 87.83 (11) |
| O3—V3—O5$^{iii}$ | 111.02 (14) | O3$^{viii}$—Na—O6 | 105.48 (13) |
| O1$^{ii}$—V3—O5$^{iii}$ | 111.43 (13) | O3$^{viii}$—Na—O4$^{ix}$ | 115.05 (13) |
| O9$^{iv}$—Mg1—O4 | 96.22 (13) | O6—Na—O4$^{ix}$ | 131.92 (14) |
| O9$^{iv}$—Mg1—O2$^{vi}$ | 94.40 (13) | O3$^{viii}$—Na—O8$^{ix}$ | 163.72 (16) |
| O4—Mg1—O2$^{vi}$ | 168.05 (13) | O6—Na—O8$^{ix}$ | 70.96 (12) |
| O9$^{iv}$—Mg1—O7$^{iii}$ | 93.58 (13) | O4$^{ix}$—Na—O8$^{ix}$ | 76.24 (12) |
| O4—Mg1—O7$^{iii}$ | 100.80 (12) | O3$^{viii}$—Na—O6$^{x}$ | 70.20 (12) |
| O2$^{vi}$—Mg1—O7$^{iii}$ | 83.95 (12) | O6—Na—O6$^{x}$ | 92.11 (12) |
| O9$^{iv}$—Mg1—O10$^{vi}$ | 100.55 (13) | O4$^{ix}$—Na—O6$^{x}$ | 124.66 (14) |
| O4—Mg1—O10$^{vi}$ | 88.02 (12) | O8$^{ix}$—Na—O6$^{x}$ | 93.84 (13) |
| O2$^{vi}$—Mg1—O10$^{vi}$ | 84.66 (12) | O3$^{viii}$—Na—O1$^{ix}$ | 69.27 (11) |
| O7$^{iii}$—Mg1—O10$^{vi}$ | 162.47 (13) | O6—Na—O1$^{ix}$ | 162.23 (15) |
| O9$^{iv}$—Mg1—O10 | 178.74 (12) | O4$^{ix}$—Na—O1$^{ix}$ | 62.91 (10) |
| O4—Mg1—O10 | 83.25 (12) | O8$^{ix}$—Na—O1$^{ix}$ | 109.07 (13) |
| O2$^{vi}$—Mg1—O10 | 86.24 (12) | O6$^{x}$—Na—O1$^{ix}$ | 70.12 (11) |
| O7$^{iii}$—Mg1—O10 | 85.40 (11) | | |

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