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## catena-Poly[[diaqualithium]- $\mu$ -[*rac-cis*-2-carboxycyclohexane-1-carboxylato- $\kappa^2$ O<sup>1</sup>:O<sup>2</sup>]]

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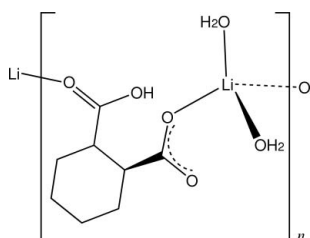
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Key indicators: single-crystal X-ray study;  $T = 200$  K; mean  $\sigma(\text{C}-\text{C}) = 0.002$  Å;  $R$  factor = 0.045;  $wR$  factor = 0.134; data-to-parameter ratio = 15.3.

In the structure of the title compound,  $[\text{Li}(\text{C}_8\text{H}_{11}\text{O}_4)(\text{H}_2\text{O})_2]_n$ , the distorted tetrahedral  $\text{LiO}_4$  coordination sphere comprises two water molecules and two carboxyl O-atom donors from separate bridging *cis*-2-carboxycyclohexane-1-carboxylate monoanions [ $\text{Li}-\text{O} = 1.887(4)-1.946(3)$  Å], giving chain substructures which extend along [010]. Water–water and water–carboxyl  $\text{O}-\text{H}\cdots\text{O}$  hydrogen bonds stabilize these chain structures and provide interchain links, resulting in a two-dimensional layered structure extending parallel to (100).

### Related literature

For the structure of an  $\text{Ni}^{\text{II}}$  complex derived from racemic *cis*-cyclohexane-1,2-dicarboxylic acid, see: Zheng *et al.* (2008) and for the structure of the corresponding  $\text{Sr}^{2+}$  complex, see: Robertson & Harrison (2010). For the structure of lithium 3,5-dinitrobenzoate, see: Yang & Ng (2007) and for lithium hydrogenterephthalate pseudopolymorphs, see: Küppers (1978); Gonschorek & Küppers (1975); Adiwidjaja & Küppers (1978).



### Experimental

#### Crystal data

$[\text{Li}(\text{C}_8\text{H}_{11}\text{O}_4)(\text{H}_2\text{O})_2]$   
 $M_r = 214.14$

Monoclinic,  $P2_1/c$   
 $a = 16.2749(5)$  Å

$b = 5.4568(2)$  Å  
 $c = 12.0438(5)$  Å  
 $\beta = 97.533(3)^\circ$   
 $V = 1060.37(7)$  Å<sup>3</sup>  
 $Z = 4$

Mo  $K\alpha$  radiation  
 $\mu = 0.11$  mm<sup>-1</sup>  
 $T = 200$  K  
 $0.30 \times 0.25 \times 0.20$  mm

#### Data collection

Oxford Diffraction Gemini-S CCD-detector diffractometer  
Absorption correction: multi-scan (*CrysAlis PRO*; Oxford Diffraction, 2010)  
 $T_{\text{min}} = 0.97$ ,  $T_{\text{max}} = 0.99$

5758 measured reflections  
2084 independent reflections  
1550 reflections with  $I > 2\sigma(I)$   
 $R_{\text{int}} = 0.023$

#### Refinement

$R[F^2 > 2\sigma(F^2)] = 0.045$   
 $wR(F^2) = 0.134$   
 $S = 1.04$   
2084 reflections

136 parameters  
H-atom parameters constrained  
 $\Delta\rho_{\text{max}} = 0.82$  e Å<sup>-3</sup>  
 $\Delta\rho_{\text{min}} = -0.39$  e Å<sup>-3</sup>

**Table 1**

Hydrogen-bond geometry (Å, °).

$D-\text{H}\cdots A$	$D-\text{H}$	$\text{H}\cdots A$	$D\cdots A$	$D-\text{H}\cdots A$
$\text{O1W}-\text{H11W}\cdots\text{O11}^{\text{i}}$	0.99	1.77	2.739 (2)	163
$\text{O1W}-\text{H12W}\cdots\text{O1W}^{\text{ii}}$	0.90	2.26	3.164 (3)	180
$\text{O2W}-\text{H21W}\cdots\text{O12}^{\text{iii}}$	0.90	1.89	2.7913 (19)	179
$\text{O2W}-\text{H22W}\cdots\text{O11}^{\text{iv}}$	0.87	2.13	2.936 (2)	153
$\text{O2W}-\text{H22W}\cdots\text{O12}^{\text{iv}}$	0.87	2.54	3.228 (2)	136
$\text{O22}-\text{H22}\cdots\text{O11}^{\text{v}}$	0.90	1.70	2.5958 (17)	174

Symmetry codes: (i)  $x, -y + \frac{1}{2}, z + \frac{1}{2}$ ; (ii)  $-x, y - \frac{1}{2}, -z + \frac{3}{2}$ ; (iii)  $-x, -y + 1, -z + 1$ ; (iv)  $x, y + 1, z$ ; (v)  $x, -y - \frac{1}{2}, z + \frac{1}{2}$ .

Data collection: *CrysAlis PRO* (Oxford Diffraction, 2010); cell refinement: *CrysAlis PRO*; data reduction: *CrysAlis PRO*; program(s) used to solve structure: *SIR92* (Altomare *et al.*, 1994); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008) within *WinGX* (Farrugia, 1999); molecular graphics: *PLATON* (Spek, 2009); software used to prepare material for publication: *PLATON*.

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Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: NG5258).

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## supporting information

*Acta Cryst.* (2011). E67, m1658 [https://doi.org/10.1107/S1600536811045077]

**catena-Poly[[diaqualithium]- $\mu$ -[*rac-cis*-(2-carboxycyclohexane-1-carboxylato- $\kappa^2O^1:O^2$ )]]**

**Graham Smith, Urs D. Wermuth and Michael L. Williams**

**S1. Comment**

The structures of metal complexes with *cis*-cyclohexane-1,2-dicarboxylic acid (*cis*-CHDC) are not common in the crystallographic literature with examples largely involving metals of the first-row transition series, *e.g.* Ni<sup>II</sup> (Zheng *et al.*, 2008), and also with Sr (Robertson & Harrison, 2010). In these complexes the *cis*-CHDC ligand is usually in the dianionic form. Our 1:1 stoichiometric reaction of *cis*-CHDC anhydride with lithium carbonate in 50% ethanol–water solution provided minor crystals of the title compound, [C<sub>8</sub>H<sub>11</sub>LiO<sub>4</sub>(H<sub>2</sub>O)<sub>2</sub>]<sub>n</sub> in which the ligand is in the monoanionic form and the structure is reported here.

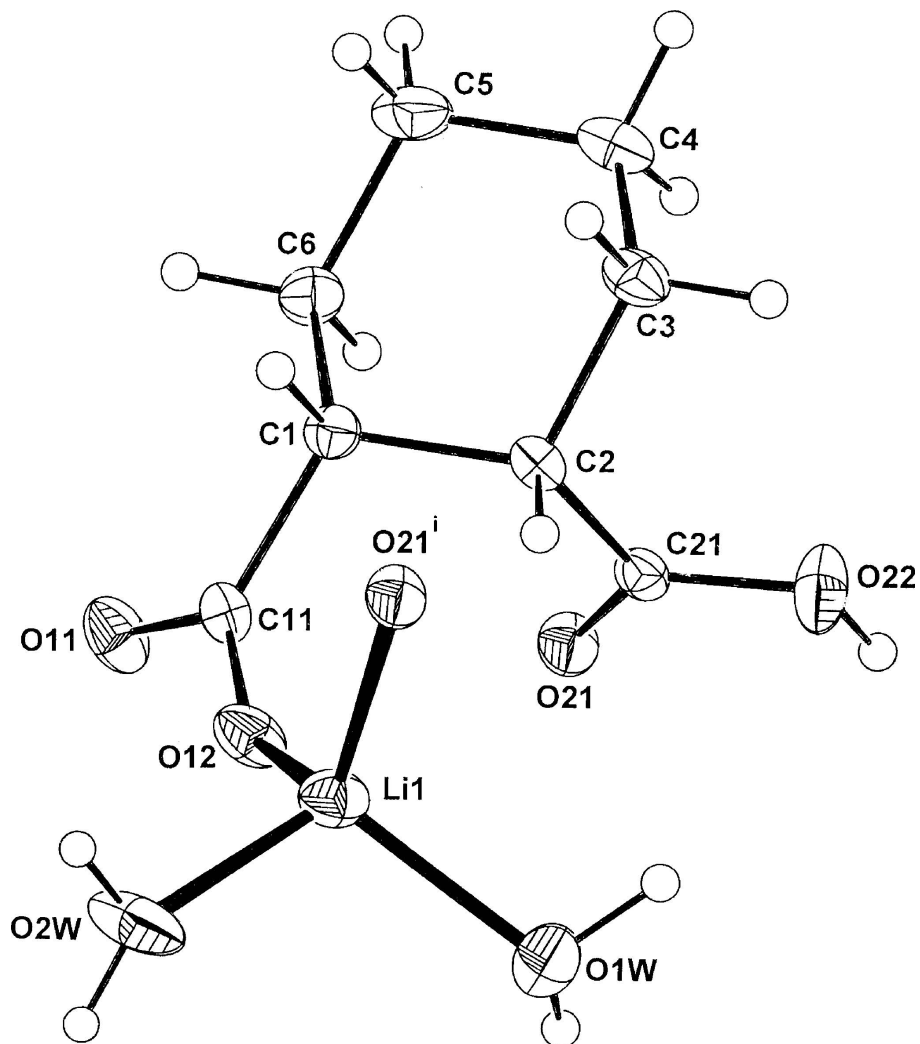
In this complex (Fig. 1), the LiO<sub>4</sub> stereochemistry is distorted tetrahedral, involving two water molecules and two O-donors from separate carboxyl groups of the monoanions in a bridging mode [Li—O range, 1.887 (4)–1.946 (3) Å]. This coordination mode is usual for Li carboxylate complexes, *e.g.*, the analogous pseudopolymorphs of lithium hydrogen phthalate (the monohydrate, the dihydrate and the methanol monosolvate: Gonschorek & Küppers, 1975; Küppers, 1978; Adiwidjaja & Küppers, 1978) and with lithium 3,5-dinitrobenzoate (Yang & Ng, 2007). In the title compound, the complex units form one-dimensional chain substructures which extend along [010] (Fig. 2). Within the chains, water–water and water–carboxyl hydrogen bonds, including a three-centre O—H $\cdots$ O<sub>carboxyl</sub> cyclic interaction involving O2*W* and infinite water chains involving O1*W* (Table 1), stabilize the structure. In addition, a strong carboxylic acid–carboxyl O—H $\cdots$ O hydrogen bond and water–carboxyl hydrogen bonds from both water donors link the chains, resulting in a two-dimensional layered structure extending parallel to (100) (Fig. 3).

**S2. Experimental**

The title compound was synthesized by heating under reflux for 10 min. a solution of 1 mmol of cyclohexane-1,2-dicarboxylic anhydride and 1 mmol of lithium carbonate in 50 ml of 1:1 ethanol–water. After concentration to *ca* 30 ml the filtered solution was allowed to evaporate at room temperature, giving finally a residual viscous oil in which minor well-formed colourless crystals of the title compound were found.

**S3. Refinement**

Hydrogen atoms involved in hydrogen-bonding interactions were located by difference-Fourier methods and their positional parameters were allowed to ride with  $U_{\text{iso}}(\text{H}) = 1.5U_{\text{eq}}(\text{O})$ . Other hydrogen atoms were included in the refinement at calculated positions [C—H = 0.97–0.98 Å] with  $U_{\text{iso}}(\text{H}) = 1.5U_{\text{eq}}(\text{C})$ . The residual positive electron density in the refinement (0.823 e Å<sup>-3</sup>) is unusually large for this structure and is located 1.02 Å from H12*W*.



**Figure 1**

Molecular configuration and atom naming scheme for the complex unit in the title compound with displacement ellipsoids drawn at the 40% probability level. For symmetry code (i), see Table 1.

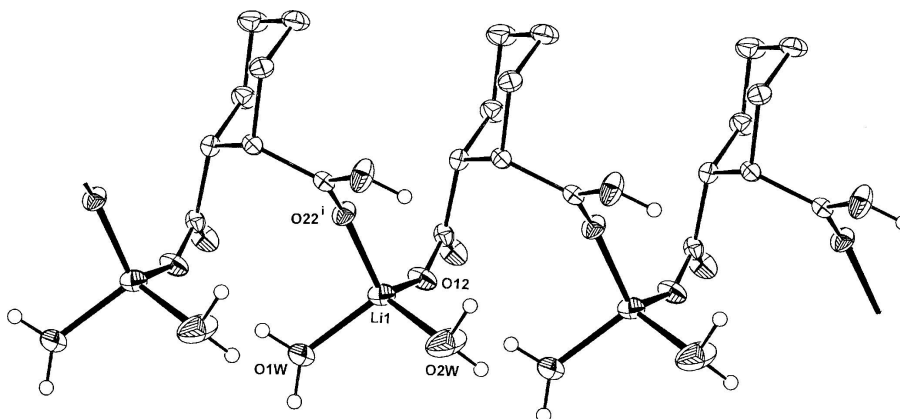


Figure 2

The hydrogen-bonded complex chain substructure of the title compound and its extension along [010]. Hydrogen bonds are shown as dashed lines and non-associative H atoms are omitted.

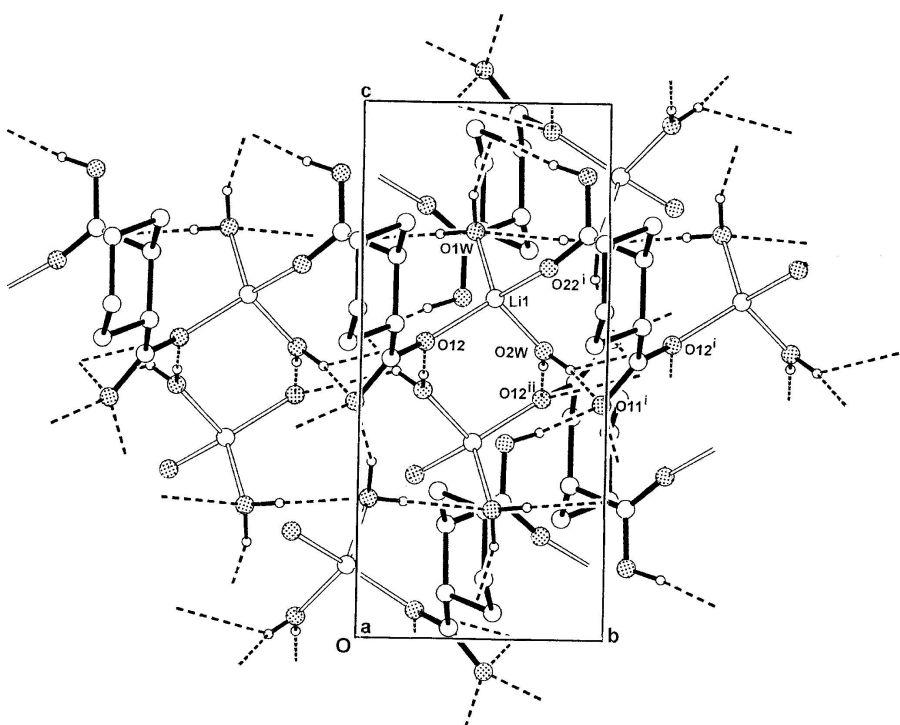


Figure 3

A view down the *a* axis of the unit cell showing the sheet structure extending parallel to (100). For symmetry codes, see Table 1.

*catena*-Poly[[diaqualithium]- $\mu$ -[*rac-cis*-(2-carboxycyclohexane-1-carboxylato- $\kappa^2$ O<sup>1</sup>:O<sup>2</sup>)]

*Crystal data*

[Li(C<sub>8</sub>H<sub>11</sub>O<sub>4</sub>)(H<sub>2</sub>O)<sub>2</sub>]

*M<sub>r</sub>* = 214.14

Monoclinic, *P*2<sub>1</sub>/*c*

Hall symbol: -*P* 2ybc

*a* = 16.2749 (5) Å

*b* = 5.4568 (2) Å

*c* = 12.0438 (5) Å

$\beta$  = 97.533 (3)°

*V* = 1060.37 (7) Å<sup>3</sup>

*Z* = 4

$F(000) = 456$   
 $D_x = 1.341 \text{ Mg m}^{-3}$   
 Mo  $K\alpha$  radiation,  $\lambda = 0.71073 \text{ \AA}$   
 Cell parameters from 2836 reflections  
 $\theta = 3.2\text{--}28.7^\circ$

$\mu = 0.11 \text{ mm}^{-1}$   
 $T = 200 \text{ K}$   
 Block, colourless  
 $0.30 \times 0.25 \times 0.20 \text{ mm}$

*Data collection*

Oxford Diffraction Gemini-S CCD-detector  
 diffractometer  
 Radiation source: Enhance (Mo) X-ray source  
 Graphite monochromator  
 Detector resolution:  $16.077 \text{ pixels mm}^{-1}$   
 $\omega$  scans  
 Absorption correction: multi-scan  
 (*CrysAlis PRO*; Oxford Diffraction, 2010)  
 $T_{\min} = 0.97, T_{\max} = 0.99$

5758 measured reflections  
 2084 independent reflections  
 1550 reflections with  $I > 2\sigma(I)$   
 $R_{\text{int}} = 0.023$   
 $\theta_{\max} = 26.0^\circ, \theta_{\min} = 3.4^\circ$   
 $h = -19 \rightarrow 20$   
 $k = -6 \rightarrow 6$   
 $l = -13 \rightarrow 14$

*Refinement*

Refinement on  $F^2$   
 Least-squares matrix: full  
 $R[F^2 > 2\sigma(F^2)] = 0.045$   
 $wR(F^2) = 0.134$   
 $S = 1.04$   
 2084 reflections  
 136 parameters  
 0 restraints  
 Primary atom site location: structure-invariant  
 direct methods

Secondary atom site location: difference Fourier  
 map  
 Hydrogen site location: inferred from  
 neighbouring sites  
 H-atom parameters constrained  
 $w = 1/[\sigma^2(F_o^2) + (0.085P)^2]$   
 where  $P = (F_o^2 + 2F_c^2)/3$   
 $(\Delta/\sigma)_{\max} < 0.001$   
 $\Delta\rho_{\max} = 0.82 \text{ e \AA}^{-3}$   
 $\Delta\rho_{\min} = -0.39 \text{ e \AA}^{-3}$

*Special details*

**Geometry.** Bond distances, angles *etc.* have been calculated using the rounded fractional coordinates. All su's are estimated from the variances of the (full) variance-covariance matrix. The cell e.s.d.'s are taken into account in the estimation of distances, angles and torsion angles

**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 ( $\text{\AA}^2$ )*

	$x$	$y$	$z$	$U_{\text{iso}}^*/U_{\text{eq}}$
O1W	0.04966 (10)	0.4570 (4)	0.75941 (13)	0.0617 (7)
O2W	0.03531 (8)	0.7437 (3)	0.53796 (16)	0.0527 (6)
O11	0.17016 (8)	-0.0191 (2)	0.43846 (11)	0.0318 (5)
O12	0.13158 (8)	0.2623 (2)	0.55259 (11)	0.0297 (4)
O21	0.19747 (8)	-0.2424 (2)	0.69312 (11)	0.0265 (4)
O22	0.23639 (9)	-0.0915 (2)	0.86385 (11)	0.0366 (5)
C1	0.27299 (10)	0.1392 (3)	0.58486 (14)	0.0208 (5)
C2	0.27190 (10)	0.1422 (3)	0.71265 (14)	0.0198 (5)
C3	0.36052 (11)	0.1758 (3)	0.77421 (16)	0.0270 (6)
C4	0.41960 (11)	-0.0170 (4)	0.73895 (17)	0.0331 (6)
C5	0.42078 (12)	-0.0142 (4)	0.61278 (18)	0.0362 (7)
C6	0.33353 (11)	-0.0509 (3)	0.54969 (16)	0.0265 (6)

C11	0.18554 (11)	0.1254 (3)	0.52073 (14)	0.0211 (5)
C21	0.23163 (10)	-0.0844 (3)	0.75461 (14)	0.0204 (5)
Li1	0.10696 (18)	0.5409 (6)	0.6350 (3)	0.0278 (9)
H1	0.29500	0.29900	0.56620	0.0310*
H2	0.23920	0.28440	0.73030	0.0300*
H11W	0.09160	0.44600	0.82710	0.0930*
H12W	0.02120	0.31460	0.75400	0.0930*
H21W	-0.01870	0.74220	0.50990	0.0790*
H22	0.21350	-0.23120	0.88480	0.0550*
H22W	0.06250	0.85130	0.50340	0.0790*
H31	0.38070	0.33750	0.75810	0.0410*
H32	0.35930	0.16460	0.85440	0.0410*
H41	0.47500	0.01400	0.77660	0.0500*
H42	0.40260	-0.17780	0.76160	0.0500*
H51	0.45690	-0.14350	0.59240	0.0540*
H52	0.44290	0.14110	0.59100	0.0540*
H61	0.33560	-0.03770	0.46980	0.0400*
H62	0.31400	-0.21400	0.56480	0.0400*

*Atomic displacement parameters ( $\text{\AA}^2$ )*

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{12}$	$U^{13}$	$U^{23}$
O1W	0.0409 (9)	0.1113 (15)	0.0325 (9)	-0.0244 (10)	0.0032 (7)	0.0115 (9)
O2W	0.0242 (8)	0.0398 (9)	0.0898 (14)	-0.0014 (7)	-0.0090 (7)	0.0226 (9)
O11	0.0366 (8)	0.0306 (8)	0.0258 (8)	0.0077 (6)	-0.0050 (6)	-0.0094 (6)
O12	0.0245 (7)	0.0301 (7)	0.0325 (8)	0.0082 (6)	-0.0034 (5)	-0.0086 (6)
O21	0.0291 (7)	0.0253 (7)	0.0244 (7)	-0.0085 (6)	0.0005 (5)	-0.0021 (5)
O22	0.0573 (10)	0.0320 (8)	0.0197 (8)	-0.0171 (7)	0.0016 (6)	0.0011 (6)
C1	0.0213 (9)	0.0184 (9)	0.0227 (10)	-0.0009 (8)	0.0029 (7)	0.0018 (7)
C2	0.0199 (9)	0.0170 (9)	0.0214 (9)	0.0011 (7)	-0.0018 (7)	-0.0017 (7)
C3	0.0224 (9)	0.0258 (10)	0.0309 (11)	-0.0058 (8)	-0.0038 (7)	-0.0010 (8)
C4	0.0187 (9)	0.0363 (11)	0.0420 (13)	0.0012 (9)	-0.0042 (8)	0.0001 (9)
C5	0.0211 (10)	0.0431 (13)	0.0451 (13)	0.0046 (9)	0.0071 (8)	-0.0002 (10)
C6	0.0239 (9)	0.0295 (10)	0.0268 (10)	0.0048 (8)	0.0061 (7)	-0.0006 (8)
C11	0.0250 (9)	0.0194 (9)	0.0180 (9)	0.0014 (8)	-0.0004 (7)	0.0010 (7)
C21	0.0184 (8)	0.0210 (9)	0.0210 (9)	0.0039 (7)	0.0000 (7)	0.0004 (7)
Li1	0.0223 (15)	0.0305 (17)	0.0303 (17)	-0.0018 (14)	0.0029 (12)	-0.0068 (13)

*Geometric parameters ( $\text{\AA}$ ,  $^\circ$ )*

O1W—Li1	1.921 (4)	C2—C3	1.544 (2)
O2W—Li1	1.896 (4)	C2—C21	1.517 (2)
O12—Li1	1.887 (4)	C3—C4	1.523 (3)
O21—Li1 <sup>i</sup>	1.946 (3)	C4—C5	1.522 (3)
O11—C11	1.265 (2)	C5—C6	1.533 (3)
O12—C11	1.251 (2)	C1—H1	0.9800
O21—C21	1.222 (2)	C2—H2	0.9800
O22—C21	1.308 (2)	C3—H31	0.9700

O1W—H11W	0.9900	C3—H32	0.9700
O1W—H12W	0.9000	C4—H41	0.9700
O2W—H21W	0.9000	C4—H42	0.9700
O2W—H22W	0.8700	C5—H51	0.9700
O22—H22	0.9000	C5—H52	0.9700
C1—C2	1.542 (2)	C6—H61	0.9700
C1—C11	1.530 (2)	C6—H62	0.9700
C1—C6	1.528 (2)		
C11—O12—Li1	148.04 (15)	C1—C2—H2	108.00
C21—O21—Li1 <sup>i</sup>	155.44 (16)	C21—C2—H2	108.00
Li1—O1W—H11W	108.00	C2—C3—H32	109.00
Li1—O1W—H12W	116.00	C2—C3—H31	109.00
H11W—O1W—H12W	107.00	C4—C3—H32	109.00
Li1—O2W—H21W	136.00	H31—C3—H32	108.00
Li1—O2W—H22W	112.00	C4—C3—H31	109.00
H21W—O2W—H22W	111.00	C3—C4—H41	109.00
C21—O22—H22	110.00	C5—C4—H41	109.00
C2—C1—C6	112.09 (14)	C5—C4—H42	109.00
C2—C1—C11	111.90 (13)	C3—C4—H42	109.00
C6—C1—C11	114.69 (14)	H41—C4—H42	108.00
C1—C2—C3	110.39 (14)	C6—C5—H52	109.00
C1—C2—C21	112.71 (14)	H51—C5—H52	108.00
C3—C2—C21	110.74 (14)	C6—C5—H51	109.00
C2—C3—C4	111.61 (15)	C4—C5—H51	109.00
C3—C4—C5	111.25 (17)	C4—C5—H52	109.00
C4—C5—C6	111.18 (16)	C1—C6—H61	109.00
C1—C6—C5	111.27 (15)	C1—C6—H62	109.00
O12—C11—C1	117.38 (15)	C5—C6—H61	109.00
O11—C11—O12	122.52 (16)	H61—C6—H62	108.00
O11—C11—C1	120.10 (15)	C5—C6—H62	109.00
O21—C21—C2	123.74 (15)	O1W—Li1—O12	112.12 (18)
O21—C21—O22	123.43 (15)	O1W—Li1—O21 <sup>ii</sup>	106.63 (18)
O22—C21—C2	112.83 (14)	O2W—Li1—O21 <sup>ii</sup>	104.03 (17)
C11—C1—H1	106.00	O12—Li1—O21 <sup>ii</sup>	118.41 (16)
C6—C1—H1	106.00	O2W—Li1—O12	107.57 (19)
C2—C1—H1	106.00	O1W—Li1—O2W	107.32 (16)
C3—C2—H2	108.00		
Li1—O12—C11—O11	-161.8 (3)	C11—C1—C6—C5	176.49 (15)
Li1—O12—C11—C1	17.7 (4)	C2—C1—C11—O11	-135.69 (16)
C11—O12—Li1—O1W	-115.3 (3)	C2—C1—C11—O12	44.8 (2)
C11—O12—Li1—O2W	126.9 (3)	C6—C1—C11—O11	-6.6 (2)
C11—O12—Li1—O21 <sup>ii</sup>	9.5 (4)	C6—C1—C11—O12	173.93 (15)
Li1 <sup>i</sup> —O21—C21—O22	51.7 (4)	C1—C2—C3—C4	-54.63 (19)
Li1 <sup>i</sup> —O21—C21—C2	-127.4 (3)	C21—C2—C3—C4	70.90 (19)
C21—O21—Li1 <sup>i</sup> —O1W <sup>i</sup>	-32.5 (4)	C1—C2—C21—O21	-5.8 (2)
C21—O21—Li1 <sup>i</sup> —O2W <sup>i</sup>	80.8 (4)	C1—C2—C21—O22	174.98 (14)

C21—O21—Li1 <sup>i</sup> —O12 <sup>i</sup>	-159.9 (3)	C3—C2—C21—O21	-130.05 (17)
C6—C1—C2—C3	53.79 (18)	C3—C2—C21—O22	50.76 (19)
C6—C1—C2—C21	-70.61 (18)	C2—C3—C4—C5	56.5 (2)
C11—C1—C2—C3	-175.75 (13)	C3—C4—C5—C6	-56.5 (2)
C11—C1—C2—C21	59.85 (18)	C4—C5—C6—C1	55.4 (2)
C2—C1—C6—C5	-54.49 (19)		

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

*Hydrogen-bond geometry (Å, °)*

<i>D</i> —H $\cdots$ <i>A</i>	<i>D</i> —H	H $\cdots$ <i>A</i>	<i>D</i> $\cdots$ <i>A</i>	<i>D</i> —H $\cdots$ <i>A</i>
O1 <i>W</i> —H11 <i>W</i> $\cdots$ O11 <sup>iii</sup>	0.99	1.77	2.739 (2)	163
O1 <i>W</i> —H12 <i>W</i> $\cdots$ O1 <i>W</i> <sup>iv</sup>	0.90	2.26	3.164 (3)	180
O2 <i>W</i> —H21 <i>W</i> $\cdots$ O12 <sup>v</sup>	0.90	1.89	2.7913 (19)	179
O2 <i>W</i> —H22 <i>W</i> $\cdots$ O11 <sup>ii</sup>	0.87	2.13	2.936 (2)	153
O2 <i>W</i> —H22 <i>W</i> $\cdots$ O12 <sup>ii</sup>	0.87	2.54	3.228 (2)	136
O22—H22 $\cdots$ O11 <sup>vi</sup>	0.90	1.70	2.5958 (17)	174
C3—H32 $\cdots$ O22	0.97	2.45	2.819 (2)	102

Symmetry codes: (ii)  $x, y+1, z$ ; (iii)  $x, -y+1/2, z+1/2$ ; (iv)  $-x, y-1/2, -z+3/2$ ; (v)  $-x, -y+1, -z+1$ ; (vi)  $x, -y-1/2, z+1/2$ .