

# 1,4-Diazoniabicyclo[2.2.2]octane tetrachloridozincate monohydrate

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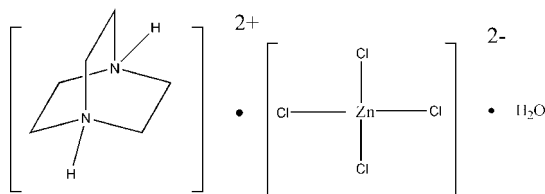
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Key indicators: single-crystal X-ray study;  $T = 291$  K; mean  $\sigma(\text{C}-\text{C}) = 0.009$  Å;  $R$  factor = 0.046;  $wR$  factor = 0.121; data-to-parameter ratio = 19.8.

In the title compound,  $(\text{C}_6\text{H}_{14}\text{N}_2)[\text{ZnCl}_4]\cdot\text{H}_2\text{O}$ , the crystal packing is governed by an extensive three-dimensional network of  $\text{N}-\text{H}\cdots\text{Cl}$ ,  $\text{N}-\text{H}\cdots\text{O}$  and  $\text{O}-\text{H}\cdots\text{Cl}$  hydrogen bonds. The zinc(II) metal centre has a slightly distorted tetrahedral coordination geometry.

## Related literature

For the applications of ferroelectric materials, see: Fu *et al.* (2007); Dawber *et al.* (2005); Haertling (1999); Scott (2007). For the properties and structure of a related diazabicyclo[2.2.2]octane (dabco) salt, see: Szafranski *et al.* (2002).



## Experimental

### Crystal data

$(\text{C}_6\text{H}_{14}\text{N}_2)[\text{ZnCl}_4]\cdot\text{H}_2\text{O}$   
 $M_r = 339.40$   
Orthorhombic,  $P2_12_12_1$   
 $a = 8.4483$  (17) Å

$b = 11.705$  (2) Å  
 $c = 12.976$  (3) Å  
 $V = 1283.2$  (5) Å<sup>3</sup>  
 $Z = 4$

Mo  $K\alpha$  radiation  
 $\mu = 2.72$  mm<sup>-1</sup>

$T = 291$  K  
 $0.30 \times 0.28 \times 0.26$  mm

### Data collection

Rigaku Mercury2 diffractometer  
Absorption correction: multi-scan  
(*CrystalClear*; Rigaku, 2005)  
 $T_{\min} = 0.462$ ,  $T_{\max} = 0.495$

11890 measured reflections  
2510 independent reflections  
2166 reflections with  $I > 2\sigma(I)$   
 $R_{\text{int}} = 0.053$

### Refinement

$R[F^2 > 2\sigma(F^2)] = 0.046$   
 $wR(F^2) = 0.121$   
 $S = 1.03$   
2510 reflections  
127 parameters  
H-atom parameters constrained

$\Delta\rho_{\max} = 0.89$  e Å<sup>-3</sup>  
 $\Delta\rho_{\min} = -0.48$  e Å<sup>-3</sup>  
Absolute structure: Flack (1983),  
1050 Friedel pairs  
Flack parameter: 0.07 (3)

**Table 1**  
Hydrogen-bond geometry (Å, °).

| $D-\text{H}\cdots A$                                       | $D-\text{H}$ | $\text{H}\cdots A$ | $D\cdots A$ | $D-\text{H}\cdots A$ |
|--|--------------|--------------------|-------------|----------------------|
| $\text{N}2-\text{H}2\text{C}\cdots\text{O}1$               | 0.91         | 1.96               | 2.809 (8)   | 154                  |
| $\text{N}1-\text{H}1\text{C}\cdots\text{Cl}1^{\text{i}}$   | 0.91         | 2.64               | 3.338 (5)   | 134                  |
| $\text{N}1-\text{H}1\text{C}\cdots\text{Cl}3^{\text{i}}$   | 0.91         | 2.80               | 3.383 (5)   | 123                  |
| $\text{O}1-\text{H}1\text{D}\cdots\text{Cl}3^{\text{ii}}$  | 0.85         | 2.82               | 3.410 (7)   | 129                  |
| $\text{O}1-\text{H}1\text{E}\cdots\text{Cl}1^{\text{iii}}$ | 0.85         | 2.75               | 3.454 (7)   | 141                  |

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

Data collection: *CrystalClear* (Rigaku, 2005); cell refinement: *CrystalClear*; data reduction: *CrystalClear*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *SHELXTL* (Sheldrick, 2008); software used to prepare material for publication: *SHELXTL*.

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: RZ2310).

## References

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Fu, D.-W., Song, Y.-M., Wang, G.-X., Ye, Q., Xiong, R.-G., Akutagawa, T., Nakamura, T., Chan, P. W. H. & Huang, S. D. (2007). *J. Am. Chem. Soc.* **129**, 5346–5347.  
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**supplementary materials**

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## 1,4-Diazoniabicyclo[2.2.2]octane tetrachloridozincate monohydrate

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### Comment

Ferroelectric materials continue to attract much attention due to their potential applications in memory devices (Fu *et al.*, 2007; Dawber *et al.*, 2005; Haertling, 1999; Scott, 2007). Among these materials, diazabicyclo[2.2.2]octane (dabco) salts with inorganic tetrahedral anions having potassium dihydrophosphate-type (KDP-type) structure have been found to exhibit exceptional dielectric properties (Szafranski *et al.*, 2002). As a contribution to this field, the crystal structure of the title compound is reported here.

The asymmetric unit of the title compound (Fig. 1), contains a doubly protonated  $C_6H_{14}N_2^{2+}$  dication, a  $ZnCl_4^{2-}$  dianion and a water molecule. The zinc(II) metal displays a slightly distorted tetrahedral coordination geometry. In the cation, the protonated N1 atom interacts *via* a bifurcated hydrogen bond with two Cl atoms of a neighbouring anion, while the N2 atom is hydrogen-bonded to a water molecule (Table 1). The water molecule acts as double hydrogen-bond donor to Cl atoms, resulting in an extensive three-dimensional H-bonding network (Fig. 2).

### Experimental

Single crystals of the title compound suitable for X-ray analysis were obtained by slow evaporation at room temperature of a HCl solution (0.5 M) containing diazabicyclo[2.2.2]octane (112 mg) and  $ZnCl_2 \cdot 2H_2O$  (172 mg) in an approximate 1:1 molar ratio.

### Refinement

All H atoms were placed in calculated positions, with O—H = 0.85 Å, N—H = 0.91 Å, C—H = 0.97 Å, and refined using a riding model approximation, with  $U_{iso} = 1.2U_{eq}(C, N)$  or  $1.5U_{eq}(O)$ .

### Figures

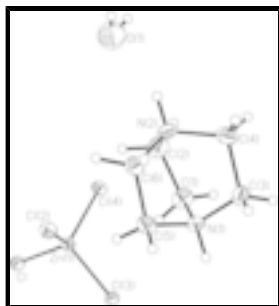


Fig. 1. The molecular structure of the title compound, showing the atomic numbering scheme with 30% probability displacement ellipsoids.

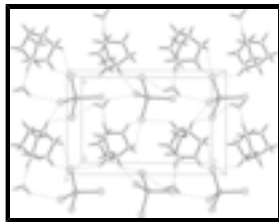


Fig. 2. Packing diagram of the title compound viewed along the *b* axis. H-bonding interactions are shown as dashed lines.

## 1,4-Diazoniabicyclo[2.2.2]octane tetrachloridozincate monohydrate

### Crystal data

(C<sub>6</sub>H<sub>14</sub>N<sub>2</sub>)[ZnCl<sub>4</sub>]·H<sub>2</sub>O

*M<sub>r</sub>* = 339.40

Orthorhombic, *P*2<sub>1</sub>2<sub>1</sub>2<sub>1</sub>

Hall symbol: P 2ac 2ab

*a* = 8.4483 (17) Å

*b* = 11.705 (2) Å

*c* = 12.976 (3) Å

*V* = 1283.2 (5) Å<sup>3</sup>

*Z* = 4

*F*<sub>000</sub> = 688

*D<sub>x</sub>* = 1.757 Mg m<sup>-3</sup>

Mo *K*α radiation

λ = 0.71073 Å

Cell parameters from 11517 reflections

θ = 3.1–27.5°

μ = 2.72 mm<sup>-1</sup>

*T* = 291 K

Block, colourless

0.30 × 0.28 × 0.26 mm

### Data collection

Rigaku Mercury2  
diffractometer

Radiation source: fine-focus sealed tube

Monochromator: graphite

Detector resolution: 13.6612 pixels mm<sup>-1</sup>

*T* = 298 K

ω scans

Absorption correction: multi-scan  
(CrystalClear; Rigaku, 2005)

*T*<sub>min</sub> = 0.462, *T*<sub>max</sub> = 0.495

11890 measured reflections

2510 independent reflections

2166 reflections with *I* > 2σ(*I*)

*R*<sub>int</sub> = 0.053

θ<sub>max</sub> = 26.0°

θ<sub>min</sub> = 3.1°

*h* = -10→10

*k* = -14→14

*l* = -16→16

### Refinement

Refinement on *F*<sup>2</sup>

Least-squares matrix: full

*R*[*F*<sup>2</sup> > 2σ(*F*<sup>2</sup>)] = 0.046

*wR*(*F*<sup>2</sup>) = 0.121

*S* = 1.03

2510 reflections

127 parameters

Hydrogen site location: inferred from neighbouring sites

H-atom parameters constrained

*w* = 1/[σ<sup>2</sup>(*F*<sub>o</sub><sup>2</sup>) + (0.0665*P*)<sup>2</sup> + 1.4482*P*]

where *P* = (*F*<sub>o</sub><sup>2</sup> + 2*F*<sub>c</sub><sup>2</sup>)/3

(Δ/σ)<sub>max</sub> = 0.001

Δρ<sub>max</sub> = 0.89 e Å<sup>-3</sup>

Δρ<sub>min</sub> = -0.48 e Å<sup>-3</sup>

Extinction correction: none

Primary atom site location: structure-invariant direct methods Absolute structure: Flack (1983), 1050 Friedel pairs  
 Secondary atom site location: difference Fourier map Flack parameter: 0.07 (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 ( $\text{\AA}^2$ )*

|     | <i>x</i>     | <i>y</i>      | <i>z</i>     | $U_{\text{iso}}^*/U_{\text{eq}}$ |
|-----|--------------|---------------|--------------|----------------------------------|
| C1  | 0.2122 (7)   | 0.3775 (6)    | 0.3733 (5)   | 0.0434 (17)                      |
| H1A | 0.1610       | 0.3189        | 0.4143       | 0.052*                           |
| H1B | 0.2347       | 0.4422        | 0.4177       | 0.052*                           |
| C2  | 0.3645 (8)   | 0.3316 (7)    | 0.3286 (5)   | 0.0489 (18)                      |
| H2A | 0.3676       | 0.2490        | 0.3347       | 0.059*                           |
| H2B | 0.4547       | 0.3632        | 0.3650       | 0.059*                           |
| C3  | 0.1700 (9)   | 0.5158 (6)    | 0.2364 (5)   | 0.0415 (16)                      |
| H3A | 0.1655       | 0.5809        | 0.2826       | 0.050*                           |
| H3B | 0.1064       | 0.5330        | 0.1761       | 0.050*                           |
| C4  | 0.3402 (8)   | 0.4934 (6)    | 0.2046 (6)   | 0.0474 (18)                      |
| H4A | 0.3568       | 0.5167        | 0.1336       | 0.057*                           |
| H4B | 0.4123       | 0.5361        | 0.2482       | 0.057*                           |
| C5  | 0.0884 (7)   | 0.3177 (5)    | 0.2132 (5)   | 0.0371 (15)                      |
| H5A | 0.0055       | 0.3356        | 0.1641       | 0.045*                           |
| H5B | 0.0602       | 0.2477        | 0.2487       | 0.045*                           |
| C6  | 0.2468 (8)   | 0.3030 (5)    | 0.1574 (4)   | 0.0405 (14)                      |
| H6A | 0.2745       | 0.2227        | 0.1536       | 0.049*                           |
| H6B | 0.2394       | 0.3328        | 0.0878       | 0.049*                           |
| Cl1 | 0.20057 (18) | -0.18534 (13) | 1.07634 (13) | 0.0420 (4)                       |
| Cl2 | 0.2573 (2)   | -0.03346 (13) | 0.81713 (10) | 0.0444 (4)                       |
| Cl3 | 0.03672 (18) | 0.09791 (13)  | 1.03379 (13) | 0.0371 (4)                       |
| Cl4 | 0.47943 (19) | 0.06684 (14)  | 1.03500 (14) | 0.0414 (4)                       |
| N1  | 0.1070 (6)   | 0.4132 (4)    | 0.2888 (4)   | 0.0308 (11)                      |
| H1C | 0.0103       | 0.4303        | 0.3156       | 0.037*                           |
| N2  | 0.3689 (6)   | 0.3664 (5)    | 0.2161 (5)   | 0.0444 (15)                      |
| H2C | 0.4659       | 0.3493        | 0.1899       | 0.053*                           |
| O1  | 0.6587 (8)   | 0.2561 (5)    | 0.1794 (5)   | 0.086 (2)                        |
| H1D | 0.6849       | 0.2659        | 0.1167       | 0.128*                           |
| H1E | 0.7293       | 0.2845        | 0.2184       | 0.128*                           |
| Zn1 | 0.24738 (9)  | -0.01799 (5)  | 0.99321 (4)  | 0.0333 (2)                       |

## supplementary materials

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

|     | $U^{11}$   | $U^{22}$   | $U^{33}$   | $U^{12}$    | $U^{13}$    | $U^{23}$    |
|-----|------------|------------|------------|-------------|-------------|-------------|
| C1  | 0.043 (4)  | 0.054 (4)  | 0.033 (3)  | 0.007 (3)   | -0.009 (3)  | -0.004 (3)  |
| C2  | 0.042 (4)  | 0.052 (4)  | 0.052 (4)  | 0.006 (3)   | -0.020 (3)  | -0.008 (4)  |
| C3  | 0.044 (4)  | 0.031 (3)  | 0.050 (4)  | 0.005 (3)   | 0.005 (3)   | 0.003 (3)   |
| C4  | 0.036 (4)  | 0.054 (4)  | 0.053 (4)  | -0.011 (3)  | 0.012 (3)   | -0.010 (4)  |
| C5  | 0.038 (3)  | 0.037 (4)  | 0.037 (3)  | -0.003 (3)  | -0.004 (3)  | 0.003 (3)   |
| C6  | 0.034 (3)  | 0.043 (3)  | 0.045 (3)  | -0.007 (3)  | -0.007 (3)  | -0.018 (3)  |
| C11 | 0.0443 (9) | 0.0383 (8) | 0.0435 (8) | 0.0001 (7)  | 0.0069 (6)  | 0.0048 (7)  |
| C12 | 0.0477 (9) | 0.0536 (9) | 0.0318 (7) | -0.0048 (9) | 0.0041 (8)  | -0.0058 (6) |
| C13 | 0.0322 (8) | 0.0407 (8) | 0.0384 (9) | 0.0023 (6)  | 0.0004 (7)  | -0.0041 (7) |
| C14 | 0.0368 (8) | 0.0459 (8) | 0.0414 (9) | -0.0079 (7) | -0.0055 (7) | 0.0029 (8)  |
| N1  | 0.022 (2)  | 0.042 (3)  | 0.029 (3)  | 0.004 (2)   | 0.0009 (19) | -0.002 (2)  |
| N2  | 0.022 (3)  | 0.051 (3)  | 0.061 (4)  | 0.003 (2)   | 0.004 (2)   | -0.018 (3)  |
| O1  | 0.067 (4)  | 0.083 (5)  | 0.106 (5)  | 0.004 (4)   | -0.014 (4)  | -0.001 (4)  |
| Zn1 | 0.0317 (3) | 0.0375 (3) | 0.0307 (3) | -0.0011 (3) | 0.0009 (3)  | 0.0002 (3)  |

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

|            |           |            |             |
|------------|-----------|------------|-------------|
| C1—N1      | 1.472 (7) | C5—C6      | 1.531 (9)   |
| C1—C2      | 1.510 (9) | C5—H5A     | 0.9700      |
| C1—H1A     | 0.9700    | C5—H5B     | 0.9700      |
| C1—H1B     | 0.9700    | C6—N2      | 1.482 (8)   |
| C2—N2      | 1.515 (9) | C6—H6A     | 0.9700      |
| C2—H2A     | 0.9700    | C6—H6B     | 0.9700      |
| C2—H2B     | 0.9700    | C11—Zn1    | 2.2710 (17) |
| C3—N1      | 1.479 (8) | C12—Zn1    | 2.2936 (15) |
| C3—C4      | 1.519 (9) | C13—Zn1    | 2.2989 (17) |
| C3—H3A     | 0.9700    | C14—Zn1    | 2.2635 (17) |
| C3—H3B     | 0.9700    | N1—H1C     | 0.9100      |
| C4—N2      | 1.514 (9) | N2—H2C     | 0.9100      |
| C4—H4A     | 0.9700    | O1—H1D     | 0.8499      |
| C4—H4B     | 0.9700    | O1—H1E     | 0.8500      |
| C5—N1      | 1.496 (8) |            |             |
| N1—C1—C2   | 109.2 (5) | C6—C5—H5B  | 110.2       |
| N1—C1—H1A  | 109.8     | H5A—C5—H5B | 108.5       |
| C2—C1—H1A  | 109.8     | N2—C6—C5   | 108.0 (5)   |
| N1—C1—H1B  | 109.8     | N2—C6—H6A  | 110.1       |
| C2—C1—H1B  | 109.8     | C5—C6—H6A  | 110.1       |
| H1A—C1—H1B | 108.3     | N2—C6—H6B  | 110.1       |
| C1—C2—N2   | 107.2 (5) | C5—C6—H6B  | 110.1       |
| C1—C2—H2A  | 110.3     | H6A—C6—H6B | 108.4       |
| N2—C2—H2A  | 110.3     | C1—N1—C3   | 110.8 (5)   |
| C1—C2—H2B  | 110.3     | C1—N1—C5   | 109.9 (5)   |
| N2—C2—H2B  | 110.3     | C3—N1—C5   | 110.1 (5)   |
| H2A—C2—H2B | 108.5     | C1—N1—H1C  | 108.7       |

|            |           |             |            |
|------------|-----------|-------------|------------|
| N1—C3—C4   | 109.0 (5) | C3—N1—H1C   | 108.7      |
| N1—C3—H3A  | 109.9     | C5—N1—H1C   | 108.7      |
| C4—C3—H3A  | 109.9     | C6—N2—C4    | 109.2 (5)  |
| N1—C3—H3B  | 109.9     | C6—N2—C2    | 110.1 (5)  |
| C4—C3—H3B  | 109.9     | C4—N2—C2    | 110.8 (5)  |
| H3A—C3—H3B | 108.3     | C6—N2—H2C   | 108.9      |
| N2—C4—C3   | 107.1 (5) | C4—N2—H2C   | 108.9      |
| N2—C4—H4A  | 110.3     | C2—N2—H2C   | 108.9      |
| C3—C4—H4A  | 110.3     | H1D—O1—H1E  | 109.5      |
| N2—C4—H4B  | 110.3     | Cl4—Zn1—Cl1 | 114.55 (7) |
| C3—C4—H4B  | 110.3     | Cl4—Zn1—Cl2 | 103.99 (7) |
| H4A—C4—H4B | 108.5     | Cl1—Zn1—Cl2 | 114.29 (6) |
| N1—C5—C6   | 107.6 (5) | Cl4—Zn1—Cl3 | 110.90 (6) |
| N1—C5—H5A  | 110.2     | Cl1—Zn1—Cl3 | 105.40 (6) |
| C6—C5—H5A  | 110.2     | Cl2—Zn1—Cl3 | 107.63 (7) |
| N1—C5—H5B  | 110.2     |             |            |

*Hydrogen-bond geometry* (Å, °)

| <i>D</i> —H... <i>A</i>     | <i>D</i> —H | H... <i>A</i> | <i>D</i> ... <i>A</i> | <i>D</i> —H... <i>A</i> |
|-----------------------------|-------------|---------------|-----------------------|-------------------------|
| N2—H2C...O1                 | 0.91        | 1.96          | 2.809 (8)             | 154                     |
| N1—H1C...Cl1 <sup>i</sup>   | 0.91        | 2.64          | 3.338 (5)             | 134                     |
| N1—H1C...Cl3 <sup>i</sup>   | 0.91        | 2.80          | 3.383 (5)             | 123                     |
| O1—H1D...Cl3 <sup>ii</sup>  | 0.85        | 2.82          | 3.410 (7)             | 129                     |
| O1—H1E...Cl1 <sup>iii</sup> | 0.85        | 2.75          | 3.454 (7)             | 141                     |

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

Fig. 1

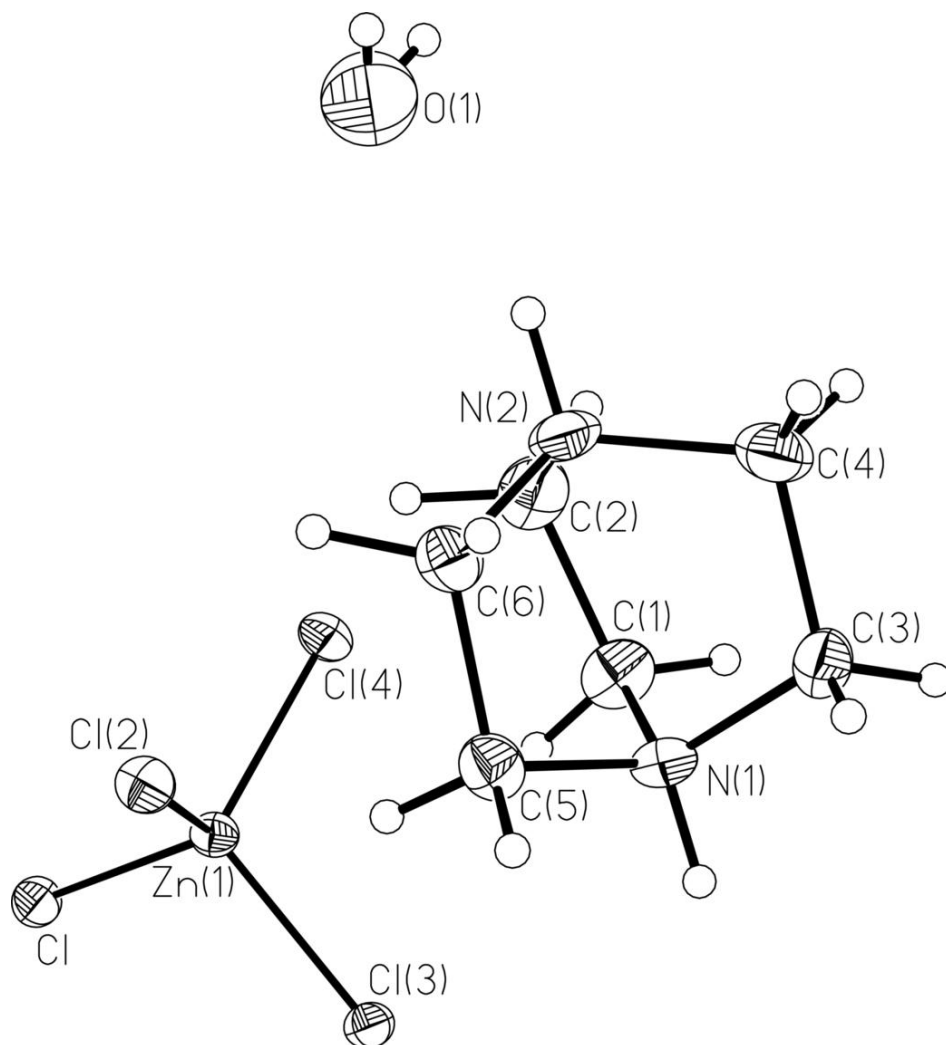




Fig. 2

