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1-Methyl-5-nitroimidazolium chloride

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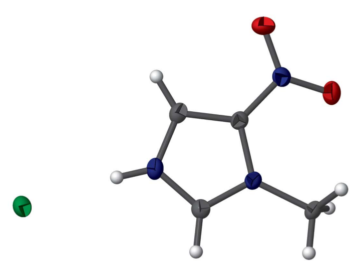
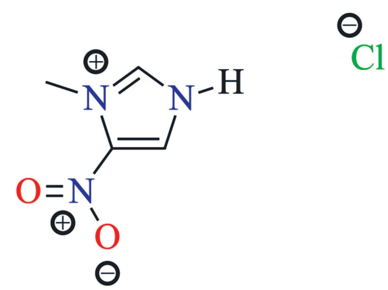
The title salt, $C_4H_6N_3O_2^+\cdot Cl^-$, exhibits multiple hydrogen-bonding interactions involving the nitroimidazolium cation and the chloride anion. Strong hydrogen bonds between the amine hydrogen atom and the chloride anion link the ionic moieties. Of note, with respect to H$\cdots$Cl interactions, the central aromatic hydrogen atom displays a shorter interaction than the other aromatic hydrogen atom. Finally, interactions are observed between the nitro moiety and methyl H atoms. While no π–π stacking is observed, anion-π interactions are present. The crystal was refined as a two-component twin.

3D view



Chemical scheme



Structure description

The study of nitroimidazole-based compounds remains of interest due to their appearance on the World Health Organization's list of essential drugs (Purgato & Barbui, 2012). Among the numerous functionalized derivatives of imidazoles, 5-nitroimidazoles have long been known to be effective antibiotics (Leiros *et al.*, 2004). Recently, however, 5-nitroimidazole-based compounds have received renewed attention for the potential treatment of a slew of infectious diseases such as leishmaniasis and tuberculosis (Ang *et al.*, 2017). A previous report by Bowden & Izadi (1998) analyzed the antibacterial activities of various derivatives of metronidazole, a compound bearing a 5-nitroimidazole core. In their work, several derivatives of metronidazole were chemically modified and studied with the intent of overcoming some of the disadvantages of 5-nitroimidazole-based pharmaceuticals (Bowden & Izadi, 1998). Furthermore, Miyamoto and coworkers reported the synthesis of a new class of nitroimidazole derivatives to combat drug-resistant strains of infections (Miyamoto *et al.*, 2013). Hence, with the renewed interest in

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

D—H···A	D—H	H···A	D···A	D—H···A
N3—H3···Cl1	0.856 (19)	2.160 (19)	3.0141 (11)	175.4 (15)
C4—H4···Cl1^{i}	0.95	2.78	3.6161 (12)	147
C2—H2···Cl1^{ii}	0.95	2.62	3.4723 (12)	150
C6—H6B···Cl1^{ii}	0.98	2.85	3.7519 (13)	154
C6—H6C···Cl1^{iii}	0.98	2.84	3.6617 (13)	142

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

these compounds, fundamental structural analysis of nitroimidazoles is of importance to the advancement of drug development.

Herein we report the crystal structure of 1-methyl-5-nitroimidazolium chloride (Fig. 1). While the overall crystalline forces are dominated by the Coulombic interactions between ion pairs, non-covalent interactions will still play a role in the formation of the crystal (Gavezzotti, 2010). The amine hydrogen atom, H3, exhibits the shortest hydrogen bond with the chloride anion with a distance of 2.160 (19) Å (Table 1). The 2-position of imidazolium cations is known to be relatively acidic (Noack *et al.*, 2010). As such, the central aromatic hydrogen (H2) tends to form shorter interactions with anions when compared with the other aromatic H atoms on the heterocyclic cores (Dupont, 2004). This trend is observed within this structure as well with H2 displaying a shorter interaction with the anion (2.62 Å) than the other aromatic hydrogen H4 (2.78 Å). As has been observed in related systems, the halide anions surround the cation in distinctive locations facilitating interactions with nearly all atoms of the heterocyclic core (Hunt *et al.*, 2006; Sanchora *et al.*, 2019; Matthews *et al.*, 2015). For example, the chloride anion interacts with the methyl H atoms (H6*A*, H6*B*, and H6*C*) at distances of 3.14, 2.85, and 2.84 Å, respectively.

Nitro moieties are capable of exhibiting a diverse set of non-covalent interactions (Bauzá *et al.*, 2019; Sikorski & Trzybiński, 2013). Within the title structure, both nitro O atoms (O1 and O2) participate in interactions with methyl H atoms H6*A* and H6*B* at distances of 2.56 and 2.90 Å, respectively. No short interactions with the aromatic H atoms are observed with the nitro group. The nitro moiety is nearly coplanar to the imidazole ring, with an N4—C5—C4—N3 torsion angle of 6.71 (10)^{o}. As demonstrated by Bauzá *et al.*, π-holes are present in nitroaromatics, forming an important set of potential interactions (Bauzá *et al.*, 2015). For the title compound, the chloride anion is interacting with both faces of the π-hole of the nitro moiety at distances of 3.33 (10) and 3.37 (10) Å. The packing is shown in Fig. 2.

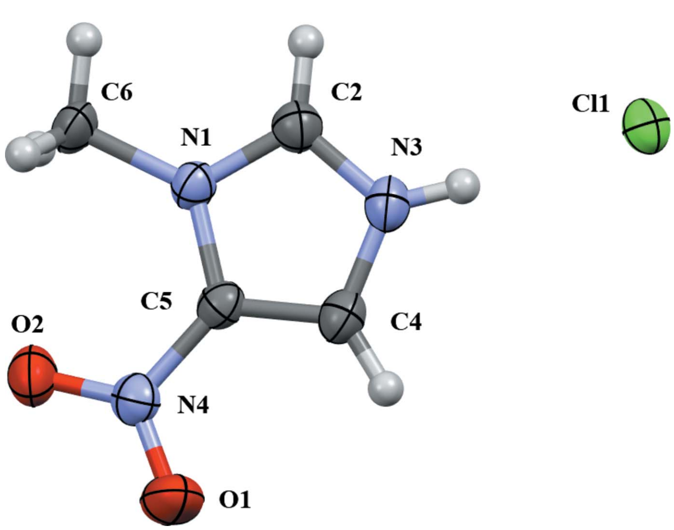


Figure 1
Constituents of the title salt showing the atom-labeling scheme and 50% probability ellipsoids.

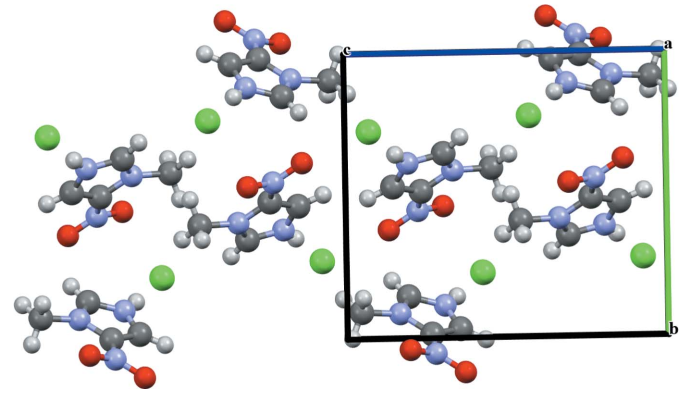


Figure 2
Packing diagram of the title salt.

Synthesis and crystallization

The title compound is a hydrolysis product from the synthetic procedure described below, analogous to our previously reported synthesis of 2,3-dimethyl-1*H*-imidazol-3-ium chloride (Anderson *et al.*, 2020).

In brief, 5-nitroimidazole and trityl chloride were dissolved in separate 50 ml beakers with toluene. The reactants were then combined in a single-necked 100 ml round-bottom flask equipped with a magnetic stir bar and left to stir for 2 days at room temperature. The solvent was removed under vacuum leaving a white solid residue. This solid was washed twice with tetrahydrofuran and recovered *via* vacuum filtration. Crystals were grown at room temperature by vapor diffusion with acetonitrile as the solvent and tetrahydrofuran as the anti-solvent. Colorless crystals of the hydrolyzed byproduct reported herein were observed within one week.

Refinement

For full experimental details including crystal data, data collection and structure refinement details, refer to Table 2.

The structure emulates a double the volume orthorhombic *C*-centered cell and is twinned by this symmetry (180° rotation around the real space *a* axis or around the reciprocal direction [$\bar{2}$01]). Refinement with the transformation matrix 1 0 0, 0 −1 0, −1 0 −1 yielded a 0.555 (1) to 0.445 (1) twinning ratio.

Table 2
Experimental details.

Crystal data	
Chemical formula	$C_4H_6N_3O_2^+\cdot Cl^-$
M_r	163.57
Crystal system, space group	Monoclinic, $P2_1/c$
Temperature (K)	150
a, b, c (Å)	6.3498 (5), 9.8991 (9), 11.5969 (10)
β (°)	105.817 (3)
V (Å^3)	701.35 (10)
Z	4
Radiation type	Mo $K\alpha$
μ (mm^{-1})	0.49
Crystal size (mm)	0.35 × 0.15 × 0.12
Data collection	
Diffractometer	Bruker AXS D8 Quest diffractometer with PhotonII charge-integrating pixel array detector (CPAD)
Absorption correction	Multi-scan (*SADABS*; Krause *et al.*, 2015)
T_{min}, T_{max}	0.659, 0.747
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	12789, 2681, 2556
R_{int}	0.037
$(\sin \theta/\lambda)_{max}$ (Å^{-1})	0.771
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.026, 0.072, 1.08
No. of reflections	2681
No. of parameters	97
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e Å^{-3})	0.35, −0.24

Computer programs: *APEX3* (Bruker, 2019), *SAINT* (Bruker, 2019), *SHELXS97* (Sheldrick, 2008), *SHELXL2018/3* (Sheldrick, 2015) *ShelXle* (Hübschle *et al.*, 2011), *OLEX2* (Dolomanov *et al.*, 2009), *publCIF* (Westrip, 2010), and *enCIFer* (Allen *et al.*, 2004). For the Cambridge Structural Database (CSD), see Groom *et al.* (2016).

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full crystallographic data

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Crystal data

$C_4H_6N_3O_2^+\cdot Cl^-$
$M_r = 163.57$
Monoclinic, $P2_1/c$
$a = 6.3498$ (5) Å
$b = 9.8991$ (9) Å
$c = 11.5969$ (10) Å
$\beta = 105.817$ (3)°
$V = 701.35$ (10) Å^3
$Z = 4$
$F(000) = 336$
$D_x = 1.549$ Mg m^{-3}
Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å
Cell parameters from 9893 reflections
$\theta = 2.8$–33.2°
$\mu = 0.49$ mm^{-1}
$T = 150$ K
Rod, colourless
0.35 × 0.15 × 0.12 mm

Data collection

Bruker AXS D8 Quest diffractometer with PhotonII charge-integrating pixel array detector (CPAD)
Detector resolution: 7.4074 pixels mm^{-1}
ω and phi scans
Absorption correction: multi-scan (SADABS; Krause *et al.*, 2015)
$T_{min} = 0.659$, $T_{max} = 0.747$
12789 measured reflections
2681 independent reflections
2556 reflections with $I > 2\sigma(I)$
$R_{int} = 0.037$
$\theta_{max} = 33.3°$, $\theta_{min} = 2.8°$
$h = -8 \rightarrow 9$
$k = -15 \rightarrow 14$
$l = -16 \rightarrow 17$

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)] = 0.026$
$wR(F^2) = 0.072$
$S = 1.08$
2681 reflections
97 parameters
0 restraints
Primary atom site location: structure-invariant direct methods
Secondary atom site location: difference Fourier map
Hydrogen site location: mixed
H atoms treated by a mixture of independent and constrained refinement
$w = 1/[\sigma^2(F_o^2) + (0.039P)^2 + 0.1001P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} = 0.001$
$\Delta\rho_{max} = 0.35$ e Å^{-3}
$\Delta\rho_{min} = -0.24$ e Å^{-3}

Special details

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

Refinement. Refined as a two-component twin. H atoms attached to carbon atoms were positioned geometrically and constrained to ride on their parent atoms. C—H bond distances were constrained to 0.95 Å for aromatic C—H moieties with $U_{iso}(H) = 1.2 \times U_{eq}(C)$, and to 0.98 Å for CH_3 moieties with $U_{iso}(H) = 1.5 \times U_{eq}(C)$. The N—H proton on N3 was located as residual electron density and allowed to refine freely.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å²)

	x	*y*	*z*	U_{iso}*/U_{eq}
Cl1	0.75167 (5)	0.72586 (3)	0.07499 (2)	0.02027 (7)
O1	−0.1250 (2)	0.37864 (11)	0.13424 (9)	0.0313 (2)
O2	−0.14844 (16)	0.45993 (11)	0.30478 (8)	0.02609 (19)
N3	0.42357 (17)	0.61303 (11)	0.19454 (9)	0.02019 (19)
H3	0.512 (3)	0.6439 (18)	0.1567 (14)	0.019 (4)*
N1	0.25774 (17)	0.58619 (10)	0.33532 (8)	0.01734 (17)
N4	−0.05494 (18)	0.44564 (10)	0.22517 (8)	0.01998 (18)
C5	0.14730 (19)	0.51334 (11)	0.23575 (9)	0.01723 (18)
C4	0.2514 (2)	0.53027 (13)	0.14779 (10)	0.0202 (2)
H4	0.211185	0.491815	0.069785	0.024*
C2	0.4252 (2)	0.64545 (12)	0.30717 (10)	0.0202 (2)
H2	0.530167	0.702184	0.358999	0.024*
C6	0.2176 (2)	0.59302 (13)	0.45524 (10)	0.0224 (2)
H6A	0.081178	0.642222	0.449455	0.034*
H6B	0.339456	0.640052	0.510943	0.034*
H6C	0.205596	0.501290	0.484604	0.034*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
Cl1	0.02085 (12)	0.01942 (11)	0.02158 (11)	−0.00029 (9)	0.00752 (10)	0.00269 (9)
O1	0.0386 (6)	0.0293 (5)	0.0243 (4)	−0.0130 (4)	0.0060 (4)	−0.0054 (3)
O2	0.0224 (4)	0.0351 (5)	0.0225 (4)	−0.0009 (4)	0.0090 (3)	0.0033 (3)
N3	0.0207 (4)	0.0232 (5)	0.0186 (4)	0.0012 (4)	0.0086 (4)	0.0026 (3)
N1	0.0206 (4)	0.0166 (4)	0.0161 (4)	−0.0004 (3)	0.0071 (3)	−0.0011 (3)
N4	0.0217 (4)	0.0195 (4)	0.0182 (4)	−0.0011 (4)	0.0045 (3)	0.0033 (3)
C5	0.0194 (5)	0.0169 (4)	0.0152 (4)	0.0010 (4)	0.0044 (4)	0.0010 (3)
C4	0.0223 (5)	0.0229 (5)	0.0160 (4)	0.0016 (4)	0.0060 (4)	0.0014 (4)
C2	0.0214 (5)	0.0200 (5)	0.0199 (5)	−0.0011 (4)	0.0068 (4)	−0.0001 (4)
C6	0.0306 (6)	0.0232 (5)	0.0162 (4)	−0.0047 (4)	0.0110 (4)	−0.0038 (4)

Geometric parameters (Å, º)

O1—N4	1.2223 (14)	N4—C5	1.4239 (16)
O2—N4	1.2343 (13)	C5—C4	1.3687 (16)
N3—H3	0.856 (19)	C4—H4	0.9500
N3—C4	1.3553 (16)	C2—H2	0.9500
N3—C2	1.3423 (15)	C6—H6A	0.9800
N1—C5	1.3797 (14)	C6—H6B	0.9800
N1—C2	1.3307 (16)	C6—H6C	0.9800

N1—C6	1.4822 (14)

C4—N3—H3	125.4 (11)	N3—C4—C5	106.06 (10)
C2—N3—H3	125.5 (11)	N3—C4—H4	127.0
C2—N3—C4	108.98 (10)	C5—C4—H4	127.0
C5—N1—C6	129.12 (10)	N3—C2—H2	125.1
C2—N1—C5	106.44 (10)	N1—C2—N3	109.79 (11)
C2—N1—C6	124.29 (10)	N1—C2—H2	125.1
O1—N4—O2	124.85 (12)	N1—C6—H6A	109.5
O1—N4—C5	115.92 (10)	N1—C6—H6B	109.5
O2—N4—C5	119.21 (10)	N1—C6—H6C	109.5
N1—C5—N4	123.97 (10)	H6A—C6—H6B	109.5
C4—C5—N1	108.73 (10)	H6A—C6—H6C	109.5
C4—C5—N4	126.94 (10)	H6B—C6—H6C	109.5

O1—N4—C5—N1	−175.66 (11)	C4—N3—C2—N1	−0.17 (14)
O1—N4—C5—C4	11.97 (18)	C2—N3—C4—C5	0.12 (14)
O2—N4—C5—N1	5.77 (16)	C2—N1—C5—N4	−173.64 (11)
O2—N4—C5—C4	−166.59 (12)	C2—N1—C5—C4	−0.08 (13)
N1—C5—C4—N3	−0.02 (13)	C6—N1—C5—N4	10.81 (18)
N4—C5—C4—N3	173.29 (11)	C6—N1—C5—C4	−175.63 (11)
C5—N1—C2—N3	0.15 (13)	C6—N1—C2—N3	175.98 (10)

Hydrogen-bond geometry (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N3—H3···Cl1	0.856 (19)	2.160 (19)	3.0141 (11)	175.4 (15)
C4—H4···Cl1^{i}	0.95	2.78	3.6161 (12)	147
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C6—H6*C*···Cl1^{iii}	0.98	2.84	3.6617 (13)	142

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