research communications

Crystal structure of 2-chloro-5-(3-hydroxy-3-methylbut-1-yn-1-yl)pyrimidine

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In the title compound, $C_9H_9ClN_2O$, the ethynylpyrimidine moiety displays an almost planar geometry. In the crystal, molecules are linked by O—H⋯N and C—H$_{pyrimidine}$⋯O hydrogen bonds, forming a three-dimensional supramolecular architecture.

1. Chemical context

The title compound, featuring a blocked acetylenic group and a chloro-substituted pyrimidine ring, is an interesting synthetic intermediate for the preparation of application-oriented solid materials including both porous coordination polymers (MacGillivray, 2010) and metal-organic frameworks (Noro & Kitagawa, 2010). Deprotection of the acetylenic functional group and transformation of the chloro substituent, e.g. into thiol or amino groups, should result in molecular building blocks for the formation of corresponding aggregate structures (Hübscher et al., 2015; Günthel et al., 2015; Hübscher et al., 2017). Aside from this experimental preparative relevance, substituted 3-hydroxyalkynes are also of considerable interest due to their structural capacity in supramolecular interactions, giving rise to particular modes of aggregation and behavior in the solid state (Toda et al., 1983, 1985; Bourne et al., 1994). In combination with heterocyclic nitrogen donors and chlorine substitution, as in the present title compound, a structural study involving competition aspects with regard to hydrogen bonding (Wang & Zheng, 2015) and potential halogen (Mukherjee et al., 2014) or π-electron assisted (Tiekink & Zukerman-Schpector, 2012) interactions should be a promising field of inquiry for crystal engineering (Desiraju et al., 2012) being subject to the contacts emanating from a variety of functional groups. Thus, in this respect, the title compound could serve as a worthwhile test substance.
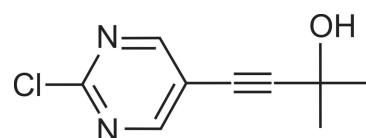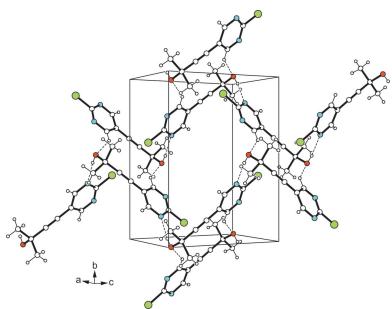
2. Structural commentary

A perspective view of the molecular structure of the title compound is depicted in Fig. 1. The ethynylpyrimidine moiety of the molecule is almost planar with the largest atomic distances from the mean plane being 0.015 (1) Å for atom C1

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

$D-H\cdots A$	$D-H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
C8—H8$A\cdots$Cl1^{i}	0.98	2.99	3.7911 (14)	140
C4—H4$\cdots$O1^{ii}	0.95	2.45	3.1963 (15)	136
C2—H2$\cdots$O1^{iii}	0.95	2.60	3.2816 (14)	129
O1—H1$\cdots$N2^{iv}	0.84	2.05	2.8881 (13)	172

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

and 0.013 (1) Å for atom C4. The OH group adopts a staggered arrangement with respect to the ethynyl unit and the methyl group C9, the C6—C7—O1–H1 torsion angle being 57.0°.

3. Supramolecular features

An O—H$\cdots\pi_{C\equiv C}$ hydrogen-bond type intermolecular interaction mode typical of 3-hydroxyalkyne structure units (Desiraju & Steiner, 1999) is not present here, apparently in favor of a stronger O—H$\cdots$N hydrogen bond involving the hydroxy group and a pyrimidine nitrogen atom (N2). Aside from this, C—H$_{\text{pyrimidine}}\cdots$O hydrogen bonds are found to yield a three-dimensional supramolecular architecture (Table 1, Fig. 2). No other types of directed intermolecular contacts, including those involving the Cl atom or π–arene stacking, are observed. Hence, this shows that in the presence of a strong donor center such as a nitrogen atom, competing with the acetylenic moiety, the common O—H$\cdots\pi_{C\equiv C}$ hydrogen bonding is suppressed, which could be a useful finding in relation to aspects of crystal engineering.

4. Database survey

The title compound represents the first example of a 5-(3-hydroxy-3-methylbut-1-yn-1-yl)pyrimidine. A search in the Cambridge Structural Database (CSD, Version 5.38, update February 2017; Groom et al., 2016) for compounds containing the 4-ethynylpyrimidine fragment excluding metal complexes
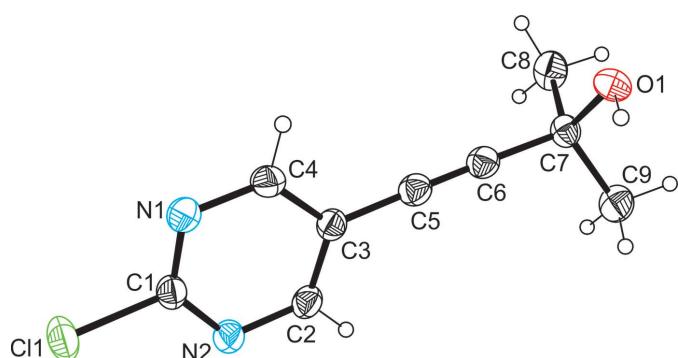

Figure 2
Packing excerpt of the title compound. Hydrogen bonds are shown as dashed lines.

and co-crystals revealed nine hits. Of particular interest is the crystal structure of 5,5'-ethyne-1,2-diylbis(2-chloropyrimidine) (refcode: PUMHIQ; Hübscher et al., 2015). In this case, the absence of a strongly coordinating donor/acceptor substituent results in poor molecular association, which is restricted to $\pi_{\text{pyrimidine}}\cdots\pi_{\text{ethyne}}$ stacking interactions.

5. Synthesis and crystallization

The title compound was prepared from 2-hydroxy-5-iodopyrimidine (Pérez-Palado et al., 2007) and 2-methyl-3-butyn-2-ol (MEBYNOL) via a Shonogashira–Hagihara cross-coupling reaction (Sonogashira et al., 1975) as follows. 2-Chloro-5-iodopyrimidine (2.0 g, 8.4 mmol) and MEBYNOL (0.7 g, 8.7 mmol) were dissolved in a degassed mixture of dry diisopropylamine and THF (60 ml each). To this solution, the catalyst being composed of triphenylphosphine (2 mol%), copper(I) and iodide (3 mol-%) and trans-dichlorobis(triphenylphosphine)palladium(II) (2 mol%) was added. The mixture was stirred at room temperature away from light for 12 h, then filtered over Celite and evaporated. Crystallization from n-hexane gave colourless crystals of the title compound on slow evaporation of the solvent (yield 1.1 g, 70%; m.p. 455 K). ^{1}H NMR (CDCl$_3$): δ_H 8.64 (2H, s, pyr-H), 2.67 (1H, s, OH), 1.64 (6H, s, Me). ^{13}C NMR (CDCl$_3$): δ_C 161.1 (pyrC-4), 159.4 (pyrC-2), 117.8 (pyrC-5), 102.4 (pyr-C$\equiv$C), 74.1 (pyr-C$\equiv$C), 65.5 (C$_{\text{quat.}}$), 31.1 (CH$_3$). IR (KBr) $\nu_{\text{max.}}$ 2240 (C$\equiv$C). GC–MS: calculated for C$_9$H$_9$N$_2$OCl (196.04), found 196 $[M]^{+}$. Analysis calculated for C$_9$H$_9$N$_2$OCl: C, 54.97; H, 4.61; N, 14.25; found: C, 54.81; H, 4.56; N, 14.05%. Colourless crystals suitable for X-ray diffraction were obtained by slow evaporation of solvent from a chloroform solution.

Figure 1
Perspective view of the molecular structure of the title compound including the atom-numbering scheme. Displacement parameters are drawn at the 50% probability level.

Table 2
Experimental details.

Crystal data	
Chemical formula	$C_9H_9ClN_2O$
M_r	196.63
Crystal system, space group	Monoclinic, $P2_1/n$
Temperature (K)	153
a, b, c (Å)	7.5555 (3), 13.0278 (7), 9.7397 (5)
β (°)	91.767 (2)
V (Å^3)	958.24 (8)
Z	4
Radiation type	Mo $K\alpha$
μ (mm^{-1})	0.36
Crystal size (mm)	$0.60 \times 0.60 \times 0.20$
Data collection	
Diffractometer	Bruker X8 *APEX2* CCD detector
Absorption correction	Multi-scan (*SADABS*; Bruker, 2008)
T_{min}, T_{max}	0.814, 0.932
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	8464, 1988, 1795
R_{int}	0.021
$(\sin \theta/\lambda)_{max}$ (Å^{-1})	0.628
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.027, 0.074, 1.07
No. of reflections	1988
No. of parameters	121
H-atom treatment	H-atom parameters constrained
$\Delta\rho_{max}, \Delta\rho_{min}$ (e Å^{-3})	0.22, −0.26

Computer programs: *APEX2* and *SAINT* (Bruker, 2008), *SHELXS97* and *SHELXTL* (Sheldrick, 2008), *SHELXL2015* (Sheldrick, 2015) and *ORTEP-3 for Windows* (Farrugia, 2012).

6. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2. H atoms were included in calculated positions (C—H = 0.95, 0.98 Å; O—H = 0.84 Å) and allowed to ride on their parent atoms with U_{iso}(H) = $1.5U_{eq}$(C,O) for methyl and hydroxy H atoms and $1.2U_{eq}$(C) for aryl H atoms.

Funding information

References

Bourne, S. A., Caira, M. R., Nassimbeni, L. R., Sakamoto, M., Tanaka, K. & Toda, F. (1994). *J. Chem. Soc. Perkin Trans. 2*, pp. 1899–1900.
Bruker (2008). *APEX2*, *SAINT* and *SADABS*. Bruker AXS Inc., Madison, Wisconsin, USA.
Desiraju, G. R. & Steiner, T. (1999). *The Weak Hydrogen Bond*. IUCr Monographs on Crystallography, Vol. 9, ch. 3, p. 164. Oxford University Press.
Desiraju, G. R. , Vittal, G. G. & Ramonau, A. (2012). In *Crystal Engineering*. London: Imperial College Press.
Farrugia, L. J. (2012). *J. Appl. Cryst.* **45**, 849–854.
Groom, C. R., Bruno, I. J., Lightfoot, M. P. & Ward, S. C. (2016). *Acta Cryst.* B**72**, 171–179.
Günthel, M., Hübscher, J., Dittrich, R., Weber, E., Joseph, I. & Mertens, F. (2015). *J. Polym. Sci. Part B Polym. Phys.* **53**, 335–344.
Hübscher, J., Seichter, W., Gruber, T., Kortus, J. & Weber, E. (2015). *J. Heterocycl. Chem.* **52**, 1062–1074.
Hübscher, J., Seichter, W. & Weber, E. (2017). *CrystEngComm*, **19**, 3026–3036.
MacGillivray, L. R. (2010). In *Metal-Organic Frameworks*. Hoboken: Wiley.
Mukherjee, A., Tothadi, S. & Desiraju, G. R. (2014). *Acc. Chem. Res.* **47**, 2514–2524.
Noro, S.-I. & Kitagawa, S. (2010). *The Supramolecular Chemistry of Organic Hybrid Materials*, edited by K. Rurack & R. Martinez-Mánez, pp. 235–269. Chichester: Wiley.
Pérez-Balado, C., Ormerod, D., Aelterman, W. & Mertens, N. (2007). *Org. Process Res. Dev.* **11**, 237–240.
Sheldrick, G. M. (2008). *Acta Cryst.* A**64**, 112–122.
Sheldrick, G. M. (2015). *Acta Cryst.* C**71**, 3–8.
Sonogashira, K., Tohda, Y. & Hagihara, N. (1975). *Tetrahedron Lett.* **16**, 4467–4470.
Tiekink, E. R. T. & Zukerman-Schpector, J. (2012). In *The Importance of Pi-Interactions in Crystal Engineering. Frontiers in Crystal Engineering*. Chichester: Wiley.
Toda, F., Tanaka, K., Ueda, H. & Oshima, T. (1983). *J. Chem. Soc. Chem. Commun.* pp. 743–744.
Toda, F., Tanaka, K., Ueda, H. & Ōshima, T. (1985). *Isr. J. Chem.* **25**, 338–345.
Wang, L.-C. & Zheng, Q.-Y. (2015). In *Hydrogen Bonded Supramolecular Structures. Lecture Notes in Supramolecular Chemistry*, edited by Z.-T. Li & L. Z. Wu, Vol. 87, pp. 69–113. Berlin, Heidelberg: Springer.

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Computing details

Data collection: *APEX2* (Bruker, 2008); cell refinement: *SAINT* (Bruker, 2008); data reduction: *SAINT* (Bruker, 2008); program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL2015* (Sheldrick, 2015); molecular graphics: *ORTEP-3 for Windows* (Farrugia, 2012); software used to prepare material for publication: *SHELXTL* (Sheldrick, 2008).

2-Chloro-5-(3-hydroxy-3-methylbut-1-yn-1-yl)pyrimidine

Crystal data

$C_9H_9ClN_2O$	$F(000) = 408$
$M_r = 196.63$	$D_x = 1.363$ Mg m^{-3}
Monoclinic, $P2_1/n$	Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å
$a = 7.5555$ (3) Å	Cell parameters from 5586 reflections
$b = 13.0278$ (7) Å	$\theta = 2.6–29.2°$
$c = 9.7397$ (5) Å	$\mu = 0.36$ mm^{-1}
$\beta = 91.767$ (2)°	$T = 153$ K
$V = 958.24$ (8) Å^3	Block, colourless
$Z = 4$	$0.60 \times 0.60 \times 0.20$ mm

Data collection

Bruker X8 APEX2 CCD detector diffractometer	1988 independent reflections
φ and ω scans	1795 reflections with $I > 2\sigma(I)$
Absorption correction: multi-scan (SADABS; Bruker, 2008)	$R_{int} = 0.021$
	$\theta_{max} = 26.5°$, $\theta_{min} = 2.6°$
$T_{min} = 0.814$, $T_{max} = 0.932$	$h = -9 \rightarrow 9$
8464 measured reflections	$k = -15 \rightarrow 16$
	$l = -10 \rightarrow 12$

Refinement

Refinement on F^2	Hydrogen site location: inferred from neighbouring sites
Least-squares matrix: full	H-atom parameters constrained
$R[F^2 > 2\sigma(F^2)] = 0.027$	
$wR(F^2) = 0.074$	$w = 1/[\sigma^2(F_o^2) + (0.0363P)^2 + 0.3033P]$
$S = 1.07$	where $P = (F_o^2 + 2F_c^2)/3$
1988 reflections	$(\Delta/\sigma)_{max} < 0.001$
121 parameters	$\Delta\rho_{max} = 0.22$ e Å^{-3}
0 restraints	$\Delta\rho_{min} = -0.26$ e Å^{-3}

Special details

Experimental. The melting point was measured using a microscope heating stage (Thermovar, Reichert–Jung). The NMR spectra were obtained on a Bruker Avance 500.1 (^{1}H) and 125.8 MHz (^{13}C) with TMS as internal standard (δ in ppm). The IR spectrum was determined on a Nicolet FT–IR 510 spectrometer as KBr pellet (wavenumber is given in cm^{-1}). The mass spectrum was recorded on a Hewlett–Packard 5890 Series II/MS 5989A. Elemental analysis was carried out with a Hanau vario MICRO cube.

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.

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

	x	*y*	*z*	U_{iso}*/U_{eq}
Cl1	0.23192 (4)	0.39748 (3)	0.09166 (3)	0.03135 (12)
O1	0.40922 (11)	−0.02601 (6)	0.82873 (9)	0.0229 (2)
H1	0.4836	0.0217	0.8368	0.034*
N1	0.33701 (13)	0.23553 (8)	0.22655 (10)	0.0237 (2)
N2	0.14057 (13)	0.34952 (8)	0.33846 (10)	0.0227 (2)
C1	0.23671 (15)	0.31831 (9)	0.23470 (12)	0.0205 (2)
C2	0.14420 (15)	0.28822 (9)	0.44881 (12)	0.0219 (3)
H2	0.0768	0.3066	0.5258	0.026*
C3	0.24367 (15)	0.19835 (9)	0.45432 (12)	0.0196 (2)
C4	0.34057 (16)	0.17568 (9)	0.33843 (12)	0.0228 (3)
H4	0.4117	0.1155	0.3389	0.027*
C5	0.24486 (15)	0.13360 (10)	0.57316 (12)	0.0222 (3)
C6	0.24267 (15)	0.08049 (9)	0.67312 (12)	0.0221 (3)
C7	0.23766 (15)	0.01625 (9)	0.79857 (12)	0.0205 (2)
C8	0.11447 (17)	−0.07507 (11)	0.77342 (14)	0.0292 (3)
H8A	0.1610	−0.1182	0.7004	0.044*
H8B	−0.0037	−0.0503	0.7457	0.044*
H8C	0.1070	−0.1154	0.8580	0.044*
C9	0.17864 (17)	0.08197 (11)	0.91878 (13)	0.0281 (3)
H9A	0.1825	0.0408	1.0030	0.042*
H9B	0.0574	0.1062	0.9003	0.042*
H9C	0.2581	0.1410	0.9300	0.042*

Atomic displacement parameters (Å^2)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
Cl1	0.03714 (19)	0.0336 (2)	0.02359 (18)	0.00504 (13)	0.00606 (13)	0.01072 (12)
O1	0.0209 (4)	0.0193 (4)	0.0288 (5)	0.0002 (3)	0.0028 (3)	0.0023 (3)
N1	0.0271 (5)	0.0234 (5)	0.0209 (5)	0.0017 (4)	0.0062 (4)	−0.0002 (4)
N2	0.0255 (5)	0.0229 (5)	0.0197 (5)	0.0039 (4)	0.0020 (4)	0.0003 (4)
C1	0.0221 (5)	0.0213 (6)	0.0180 (6)	−0.0013 (4)	0.0010 (4)	0.0017 (4)
C2	0.0238 (6)	0.0246 (6)	0.0174 (6)	0.0019 (5)	0.0031 (4)	−0.0024 (5)
C3	0.0211 (5)	0.0200 (6)	0.0176 (6)	−0.0021 (4)	0.0003 (4)	−0.0005 (4)
C4	0.0265 (6)	0.0194 (6)	0.0228 (6)	0.0024 (5)	0.0043 (5)	−0.0004 (5)
C5	0.0228 (6)	0.0224 (6)	0.0215 (6)	0.0003 (5)	0.0033 (5)	−0.0015 (5)

C6	0.0231 (6)	0.0222 (6)	0.0213 (6)	0.0007 (5)	0.0041 (5)	−0.0007 (5)
C7	0.0202 (5)	0.0224 (6)	0.0189 (6)	−0.0001 (4)	0.0032 (4)	0.0023 (5)
C8	0.0298 (6)	0.0314 (7)	0.0264 (6)	−0.0090 (5)	0.0016 (5)	0.0032 (5)
C9	0.0287 (6)	0.0330 (7)	0.0230 (6)	0.0040 (5)	0.0075 (5)	0.0000 (5)

Geometric parameters (Å, º)

Cl1—C1	1.7329 (12)	C4—H4	0.9500
O1—C7	1.4304 (14)	C5—C6	1.1950 (18)
O1—H1	0.8400	C6—C7	1.4824 (16)
N1—C1	1.3219 (16)	C7—C8	1.5257 (17)
N1—C4	1.3396 (16)	C7—C9	1.5280 (17)
N2—C1	1.3265 (16)	C8—H8A	0.9800
N2—C2	1.3386 (15)	C8—H8B	0.9800
C2—C3	1.3914 (17)	C8—H8C	0.9800
C2—H2	0.9500	C9—H9A	0.9800
C3—C4	1.3958 (17)	C9—H9B	0.9800
C3—C5	1.4320 (16)	C9—H9C	0.9800
C7—O1—H1	109.5	O1—C7—C8	106.10 (10)
C1—N1—C4	115.04 (10)	C6—C7—C8	109.81 (10)
C1—N2—C2	115.51 (10)	O1—C7—C9	110.02 (9)
N1—C1—N2	128.63 (11)	C6—C7—C9	109.31 (10)
N1—C1—Cl1	115.79 (9)	C8—C7—C9	111.65 (10)
N2—C1—Cl1	115.58 (9)	C7—C8—H8A	109.5
N2—C2—C3	122.05 (11)	C7—C8—H8B	109.5
N2—C2—H2	119.0	H8A—C8—H8B	109.5
C3—C2—H2	119.0	C7—C8—H8C	109.5
C2—C3—C4	116.30 (11)	H8A—C8—H8C	109.5
C2—C3—C5	121.11 (11)	H8B—C8—H8C	109.5
C4—C3—C5	122.59 (11)	C7—C9—H9A	109.5
N1—C4—C3	122.47 (11)	C7—C9—H9B	109.5
N1—C4—H4	118.8	H9A—C9—H9B	109.5
C3—C4—H4	118.8	C7—C9—H9C	109.5
C6—C5—C3	178.65 (13)	H9A—C9—H9C	109.5
C5—C6—C7	178.79 (13)	H9B—C9—H9C	109.5
O1—C7—C6	109.91 (9)		
C4—N1—C1—N2	0.20 (19)	N2—C2—C3—C4	0.30 (17)
C4—N1—C1—Cl1	179.40 (9)	N2—C2—C3—C5	−179.66 (11)
C2—N2—C1—N1	−0.89 (19)	C1—N1—C4—C3	0.82 (17)
C2—N2—C1—Cl1	179.91 (8)	C2—C3—C4—N1	−1.05 (18)
C1—N2—C2—C3	0.58 (17)	C5—C3—C4—N1	178.91 (11)

Hydrogen-bond geometry (Å, º)

D—H⋯A	D—H	H⋯A	D⋯A	D—H⋯A
C8—H8A⋯Cl1[i]	0.98	2.99	3.7911 (14)	140

C4—H4···O1ⁱⁱ	0.95	2.45	3.1963 (15)	136
C2—H2···O1ⁱⁱⁱ	0.95	2.60	3.2816 (14)	129
O1—H1···N2ⁱᵛ	0.84	2.05	2.8881 (13)	172

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