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A Study X-ray Crystal Structure of Compound 2-[Methylthio(morpholino)methylene]malononitrile, $C_9H_{11}N_3OS$

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Abstract: In this paper we reported the crystal structure of 2-[methylthio(morpholino)methylene]malononitrile ($C_9H_{11}N_3OS$). The compound was obtained by crystallization reaction between 2-(bis(methylthio)methylene)malononitrile and morpholine. The structure of compound $C_9H_{11}N_3OS$ was identified by performing X-ray diffraction analysis. Suitable crystals were grown by slow crystallisation from ethanol for 24h. The compound $C_9H_{11}N_3OS$ crystallized in an orthorhombic crystal system with a space group of *Pna21*. In the title compound, $C_9H_{11}N_3OS$, the two cyano groups and the morpholinyl ring adopt a *cis-trans* configuration of the C=C bond, showing an *Z*, *E* configuration. The morpholine ring is adopting chair conformation. In the compound $C_9H_{11}N_3OS$, the central fragment S1/N3/C2/C9, the morpholine ring O6/N3/O4/C5/C7/C8 and the 1,1-dicyanomethylen fragment N11/N13/C9/C10/C12 are almost planar. The central fragment makes dihedral angle of 23.11 (15)° with the 1,1-dicyano methylen fragment. The morpholine ring is twisted out of the plane of the central fragment as seen in the value of the C8—N3—C2—S1 torsional angle of 33.1 (3)°. The dihedral angle between the central fragment and the morpholine ring is 35.26 (12)°. In the crystal structure a weak intramolecular hydrogen bond C8—H(8 2)…S1 has been observed and intermolecular classical C(4)—H(41)...S(1), C(5—H(52)...S(1) and weak C(8)—(H81)...O(6) hydrogen bonds link the molecules into chains along the *a* axis.

Keywords: Synthesis, Single-crystal X-ray Study, R Factor = 0.0374, wR Factor = 0.0872, Data-to-parameter Ratio = 15.0

1. Introduction

The synthesis of α-cyanoketene-*N*,*S*-acetals has been a subject of great interest because of their wide applications. For example, they are important and versatile reagents in organic synthesis, and have been used in particular for the synthesis of polyfunctionalized heterocycles such as pyrazolopyrimidines and pyrazolotriazines [1-5]. On the other hand, substituted α-cyanoketene-*N*,*S*-acetals are often used in medicine due to their pronounced bactericidal, fungicidal and antiviral effects [1-7]. The synthesis of α-cyanoketene *N*,*S*-acetals has been reported by many research groups from α-cyanoketene *S*,*S*-acetals through addition–elimination reactions with strong nucleophiles such as alkylamines or weaker nucleophiles such as arylamines, under gentle or powerful conditions, in various solvents [8-12]. So, the synthesis of 2-[methylthio(morpholino)methylene]malononitrile has been reported by the study [13] from the reaction of 2-(bis(methylthio)methylene)malononitrile and morpholine under mild conditions and we report the crystal structure of this compound.

2. Results and Discussion

The method for preparing the 2-[methylthio(morpholino)methylene]malononitrile is presented in Figure 1. The starting material 2-[bis(methylthio)methylene]malononitrile was obtained easily

in high yield according to the method described by Kuwayama & Kataoka [13]. It was prepared in one pot from the reaction of malononitril with carbon disulfide in the presence of potassium carbonate followed by alkylation with methyl iodide. 2-[bis(methylthio)methylene]malononitrile was reacted with morpholine in the presence of TEA in ethanol under reflux for two hours. The solvent was evaporated in a vacuum to afford an oily viscous crude product that was purified by performing column chromatography with an ethyl acetate and hexane (1:1) eluent. The compound was obtained in high yields (98%).

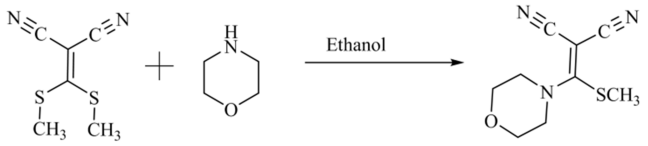

Figure 1. *Synthesis of 2-[methylthio(morpholino)methylene]malononitrile.*

The structure of 2-[methylthio(morpholino)methylene] malononitrile ($C_9H_{11}N_3OS$) was identified by X-ray diffraction analysis. The *ORTEP* plot of the compound with the numbering scheme is presented in Figure 2. Table 1 has a summary of the crystal data, X-ray data collection, data reduction and structure refinement results for compound $C_9H_{11}N_3OS$. The compound $C_9H_{11}N_3OS$ crystallized in an orthorhombic crystal system with a space group of *Pna21*.

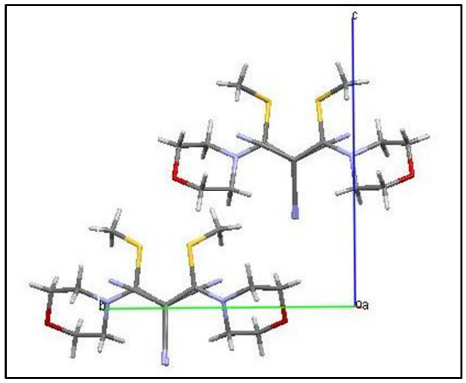

Figure 2. *The structure of 2-[methylthio(morpholino)methylene] malononitrile showing the atom numbering scheme with ellipsoids drawn at the 50% probability level.*

Table 1. *Crystal data, X-ray data collection, data reduction and structure refinement for the 2-[methylthio(morpholino)methylene]malononitrile.*

Crystal shape	**Plate-like**	**Absorption coefficient**	**2.65 (mm^{-1})**
Colour	Colourless	F (000)	440
Size mm	0.28 × 0.10 × 0.05	Theta range for data collection	4–71 (º)
		Limiting indices	
Empirical formula	$C_9H_{11}N_3OS$	h	-7→9
		k	-13→13
		l	-14→11
Molar mass	209.27 (g)	Reflections collected / unique	6069/1598,R_{int} = 0.040
Temperature	100 (K)	Completeness to theta =	1.57/0.82/25.00
Wavelength	1.54180	Max. and min. transmission	T_{min} = 0.750 T_{max} = 0.880
Crystal system	Orthorhombic	Refinement method	Full-matrix least-squares on F^2
Space group	$Pna2_1$	Data/ restraints/ parameters	1590/0/127
Unit cell dimensions			
a, b, *c* (Å)	7.6690 (3), 10.7742 (4),	Goodness-of-fit on F^2	0.88
α, β, γ(º)	12.0631 (5) 90, 90, 90		
Cell volume	996.74 (7) ($Å^3$)	Final R indices [I>2 σ (I)]	R = 0.035 wR = 0.087
Z	4	Largest diff. peak and hole	0.41 & −0.29(e $Å^{-3}$)
Calculated density ($g.cm^{-3}$)	1.394		

Selected bond distances and angles of the compound $C_9H_{11}N_3OS$ are presented in Table 2. The bond lengths and angles of the morpholine ring in the compound $C_9H_{11}N_3OS$ are within in the normal range [16]. The C2–N3 bond length is 1.336(3)Å. This bond is shorter than the normal [C–N (1.47Å)]. The C2=C9 bond length [1.401(4)Å is longer than the average C=C bond length (1.34Å) and indicates the single C–C bond character (1.455Å). Also, the C9–C10 [1.423(4)Å)] and C9–C12 [1.435(4)Å] are slightly longer than the normal [C–C (1.470)Å]. These may be due to the strong electron-donating effects of the N3 atom.

Table 2. *Selected bond lengths [Å] and angles [°] of 2-[methylthio(morpholino)methylene]malononitrile.*

Bond	**bond lengths [Å] and angles [°]**	**Bond**	**bond lengths [Å] and angles [°]**
S1–C2	1.751 (3)	C2–S1–C14	109.84 (19)
S1–C14	1.818 (3)	S1–C2–N3	110.1 (2)
C2–N3	1.336 (3)	S1–C2–C9	106.9
C2–C9	1.401 (4)	N3–C2–C9	109.9
N3–C4	1.473 (3)	C2–N3–C4	107.9
N3–C8	1.480 (3)	C2–N3–C8	110.6
C4–C5	1.518 (3)	C4–N3–C8	111.2
C4–H4	0.976	N3–C4–C5	109.8 (2)
C4–H42	0.973	C4–C5–O6	122.1 (2)
C5–O6	1.424 (3)	C4–C5–H51	121.8 (3)

Bond	bond lengths [Å] and angles [°]	Bond	bond lengths [Å] and angles [°]
C5–H51	0.956	O6–C5–H51	115.7 (2)
C5–H52	0.952	C5–O6–C7	112.7
O6–C7	1.424 (3)	O6–C7–C8	110.0
C7–C8	1.524 (3)	C7–C8–N3	106.9
C9–C10	1.423 (4)	C2–C9–C10	111.2
C9–C12	1.435 (4)	C2–C9–C12	109.4
C10–N11	1.149 (4)	C10–C9–C12	109.8
C12–N11	1.146 (4)	C9–C10–N11	108.7
		C9–C12–N13	108.0

The mean planes data for the compound and the dihedral angles between the planes are shown in Table 3. The morpholine ring is adopting chair conformation. In the compound $C_9H_{11}N_3OS$, the central fragment S1/N3/C2/C9, the morpholine ring O6/N3/O4/C5/C7/C8 and the 1,1-dicyanomethylen fragment N11/N13/C9/C10/C12 are almost planar. The maximum deviations of each plane are listed in Table 3. The morpholine ring is twisted out of the plane of the central fragment as seen in the value of the C8—N3—C2—S1 torsional angle of 33.1 (3)°. The dihedral angle between the central fragment and the morpholine ring is 35.26 (12)°. The central fragment makes dihedral angle of 23.11 (15)° with the 1,1-dicyano methylen fragment.

Table 3. *Plane deviations and angles [°] between selected planes in the structure of 2-[methylthio(morpholino)methylene]malononitrile*

Plane	Atom with greatest deviation	Angle between planes
O6/N3/O4/C5/C7/C8 (i)	O6; 0.260 (2)	i & ii = 35.26 (12)
S1/N3/C2/C9 (ii)	C2; - 0.005 (2)	i & iii = 58.33 (15)
N11/N13/C9/C10/C12 (iii)	C10; - 0.013 (2)	ii & iii = 23.11 (15)

The hydrogen bonding geometry of the compound is listed in Table 4. A weak intramolecular hydrogen bond C8—H8 2…S1 has been observed. In crystal, C—H…S and C—H…O hydrogen bonds link the molecules into chains along the *a* axis as shown in Figure 3.

Table 4. *Hydrogen bonding geometry [Å, °] for the 2-[methylthio(morpholino)methylene]malononitrile*

D—H···*A*	*D*–H	*H*···*A*	*D*···*A*	*D*–H···*A*
C(4)—H(4 1)...S(1)[i, a]	0.98	2.84	3.764 (3)	158
C(5—H(5 2)...S(1)[ii, a]	0.95	2.87	3.550 (3)	129
C(8)—(H8 1)...O(6)[iii, a]	0.98	2.54	3.422 (3)	149
C(8)—H(8 2)...S(1)[b]	0.97	2.69	3.180 (2)	112

[a] Intermolecular, [b] Intramolecular; Symmetry codes (i) 2-x,1-y,-1/2+z; (ii) 3/2-x,1/2+y,-1/2+z; (iii) 1/2+*x*,3/2-*y, z*.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å^2), Atomic displacement parameters (Å^2), and Geometric parameters (Å, °), are summarized in Table 5 and Table 6, respectively. The H atoms were all located in a difference map, but those attached to carbon atoms were repositioned geometrically. The H atoms were initially refined with soft restraints on the bond lengths and angles to regularize their geometry (C---H in the range 0.93--0.98, N---H in the range 0.86--0.89 N---H to 0.86 O---H = 0.82 A°) and U_{iso} (H) (in the range 1.2--1.5 times U_{eq} of the parent atom), after which the positions were refined with riding constraints [17]. Crystal packing of 2-[methylthio(morpholino)methylene]malononitrile viewed down the *b* axis (Figure 3).

Table 5. *Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å^2) of 2-[methylthio(morpholino)methylene]malononitrile.*

	x	y	z	Uiso*/Ueq
S1	0.88851 (8)	0.35242 (5)	0.71573 (12)	0.0204
C2	0.8761 (3)	0.3699 (2)	0.5717 (2)	0.0164
N3	0.8612 (3)	0.48166 (19)	0.5246 (2)	0.0172
C4	0.7913 (3)	0.5001 (2)	0.4121 (2)	0.0187
C5	0.6709 (3)	0.6119 (2)	0.4133 (2)	0.0207
O6	0.7553 (3)	0.72090 (16)	0.45317 (18)	0.0217
C7	0.8107 (3)	0.7024 (2)	0.5646 (2)	0.0207
C8	0.9410 (3)	0.5958 (2)	0.5704 (2)	0.0184
C9	0.8856 (3)	0.2592 (2)	0.5109 (2)	0.0182
C10	0.9469 (3)	0.2559 (2)	0.3997 (2)	0.0206
N11	1.0007 (3)	0.2513 (2)	0.3109 (2)	0.0276
C12	0.8535 (3)	0.1407 (2)	0.5614 (3)	0.0195
N13	0.8314 (3)	0.0432 (2)	0.5967 (2)	0.0285
C14	0.7346 (3)	0.4652 (3)	0.7705 (2)	0.0224
H41	0.8854	0.5141	0.3592	0.0238*
H42	0.7224	0.4282	0.3906	0.0229*

	x	y	z	Uiso*/Ueq
H51	0.5762	0.5942	0.4623	0.0233*
H52	0.6293	0.6251	0.3398	0.0239*
H71	0.8653	0.7781	0.5883	0.0238*
H72	0.7063	0.6837	0.6099	0.0243*
H82	0.9778	0.5806	0.6462	0.0229*
H81	1.0451	0.6163	0.5265	0.0231*
H142	0.6345	0.4706	0.7216	0.0354*
H141	0.7847	0.5449	0.7800	0.0359*
H143	0.7012	0.4358	0.8406	0.0358*

Table 6. *Atomic displacement parameters (Å^2) of 2-[methylthio(morpholino)methylene]malononitrile.*

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
S1	0.0285 (3)	0.0151 (3)	0.0176 (3)	−0.0005 (2)	−0.0018 (3)	0.0023 (3)
C2	0.0138 (10)	0.0172 (12)	0.0180 (13)	−0.0016 (9)	−0.0007 (9)	0.0023 (10)
N3	0.0201 (10)	0.0145 (10)	0.0171 (11)	−0.0026 (8)	0.0004 (8)	0.0009 (9)
C4	0.0215 (11)	0.0162 (11)	0.0184 (12)	−0.0011 (9)	−0.0006 (10)	0.0019 (10)
C5	0.0230 (12)	0.0200 (12)	0.0192 (14)	−0.0010 (10)	−0.0038 (10)	0.0041 (11)
O6	0.0278 (9)	0.0144 (8)	0.0229 (11)	−0.0002 (7)	−0.0033 (7)	0.0033 (7)
C7	0.0236 (12)	0.0143 (11)	0.0241 (14)	0.0009 (10)	−0.0006 (10)	0.0003 (10)
C8	0.0183 (11)	0.0150 (12)	0.0218 (13)	−0.0032 (9)	−0.0028 (10)	0.0000 (10)
C9	0.0193 (12)	0.0159 (12)	0.0194 (14)	0.0009 (9)	−0.0009 (9)	0.0007 (10)
C10	0.0231 (12)	0.0120 (11)	0.0268 (16)	0.0027 (9)	−0.0021 (10)	−0.0005 (10)
N11	0.0336 (13)	0.0219 (11)	0.0273 (14)	0.0027 (9)	0.0061 (10)	0.0002 (10)
C12	0.0209 (11)	0.0183 (14)	0.0193 (14)	0.0018 (9)	−0.0023 (10)	−0.0027 (10)
N13	0.0366 (13)	0.0158 (11)	0.0331 (15)	−0.0018 (9)	0.0021 (11)	0.0005 (10)
C14	0.0252 (12)	0.0229 (13)	0.0191 (14)	−0.0001 (10)	0.0039 (10)	−0.0018 (11)

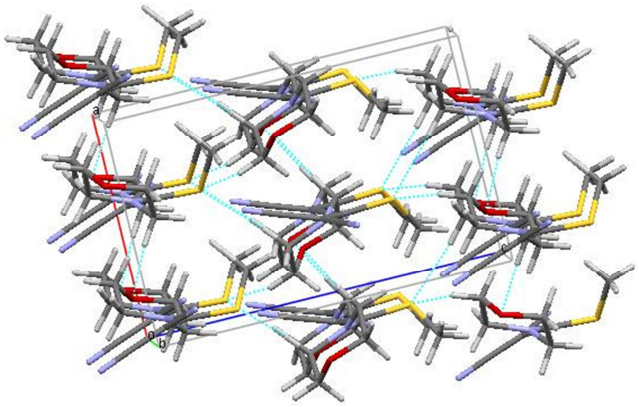

Figure 3. *An extended chains of along the a axis.*

3. Experimental

The 2-[methylthio(morpholino)methylene]malononitrile was synthesized according to a previously reported method [13] by reaction of 2-[bis(methylthio)methylene]malononitrile (0.01mol) with morpholine (0.01mol) in ethanol (20ml) under reflux for two hours. After two hours the solvent was evaporated in a vacuum to afford an oily viscous crude product that was purified by performing column chromatography with an ethyl acetate and hexane (1:1) eluent. The compound was obtained in high yields (yield 98%, m. p. 370-372k).

The crystal of $C_9H_{11}N_3O_S$ was placed in the cold stream of an Oxford Cryosystems open-flow nitrogen cryostat [14, 15] with a nominal stability of 0.1K. Data collection [14]; cell refinement [15]; data reduction [15]; program (s) used to solve structure: SIR92 [18]; program (s) used to refine structure: CRYSTALS [19]; molecular graphics: CAMERON [20]; software used to prepare material for publication: CRYSTALS [19].

4. Conclusions

In summary, we have successfully study the crystal structure of 2-[methylthio(morpholino)methylene]malononitrile. The compound was obtained by crystallization reaction between 2-[bis(methylthio)methylene]malononitrile and morpholine. A suitable crystal of 2-[methylthio(morpholino)methylene] malononitrile was grown by slow evaporation of ethanol solution of the compound for 24h. The crystal data, X-ray data collection, data reduction and structure refinement results of compounds were presented in this paper. The Compound was crystallized in an orthorhombic crystal system with a space group of *Pna21*. The morpholine ring is adopting chair conformation. The morpholine ring is twisted out of the plane of the central fragment as seen in the value of the C8—N3—C2—S1 torsional angle of 33.1 (3)°. A weak intramolecular hydrogen bond C8—H8 2…S1 has been observed in the structure of compound. Finally, this compound can be used as intermediate for the synthesis of many other heterocyclic compounds.

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