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Study of Polymorphic Behaviour of 2,2'-Dichloro benzil Using Dynamic Thermal and X-Ray Diffraction Technique

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2,2'-Dichloro benzil (**1**) was synthesized and its two polymorphic forms were obtained by recrystallization from the solvents acetone/chloroform and ethanol. The polymorphism present in the compound was confirmed by combined results of differential scanning calorimetry and single crystal X-ray crystallography. Each molecule crystallizes with one molecule in the asymmetric unit and the molecular conformations are quite different for both. The polymorph **1a** crystallizes as monoclinic *c2/c* space group in the solvent ethanol and the polymorph **1b** crystallizes as monoclinic *P21/c* space group in the solvent THF. X-ray crystal structures of conformational polymorphs were analyzed to understand the interplay of molecular conformation and intermolecular lattice energy in the crystallization and stability of polymorphs.

Keywords: X-ray diffraction, Single crystal growth, Organic compounds, Conformational polymorphism.

INTRODUCTION

Many crystal forms could be obtained for organic compounds. The present scope in academic and industrial research work is focused on polymorphism [1,2]. Due to the existence of different structures in crystal, the compound shows variable physical and chemical properties for different solid forms. Polymorphism behaviour is found to exist in many compounds, while the intricacy still remains for developing some polymorphs [3-5]. The structural property correlation could be obtained by the presence of polymorphic structures which is a useful device. The remarkable effect on the corresponding solid materials is noted from the different intermolecular interactions taking place in the molecule [6].

Various polymorphs has been obtained by different crystallization methods. In some of the crystallization methods two different polymorphs were also obtained by single crystallization method. The formation of new polymorphs could be identified by using different solvents, various rates of crystallization and depending on different temperatures [7,8]. The formation, change in conformation and stability of the molecule were discussed. The organic molecule crystallization depends on the perceptive cohesive force of hydrogen bonding [9,10]. The packing of crystal shows noteworthy in weak hydrogen bonding [11,12]. Due to the importance of drug designing, patenting and pharmaceutical drug discovery it

enlightens the pathway for polymorphic importance in industries [13,14].

The photo-physical property and intermolecular interactions were found to exist in polymorphic crystal **1a** and **1b**. Thus the synthesis, crystal structures and photo-physical properties of the two polymorphs were studied by TG-DTA analysis. The single crystal X-ray diffraction results applied to the forms **1a** and **1b** were also reported.

EXPERIMENTAL

Synthesis and crystal growth of polymorph: 2,2'-Dichloro benzil (**1**) was synthesized in two steps (Scheme-I). The first step involves the benzoin condensation. 4 g of KCN was dissolved in 75 mL of water in a 1 L flask. To this was added 14 g (0.05 mol) of 2,2'-dichloro benzaldehyde and 75 mL of 95 % ethanol. The mixture formed a solution at the boiling temperature and was refluxed for 1.5 h. Steam was then passed through the solution until all the alcohol and nearly all the unchanged aldehyde were removed. The condensed water was decanted from the product and later set away to crystallise. The product was then pressed as free as possible from oily material on a suction funnel and washed with cold alcohol. In this way about 10 g of crude product was obtained. The crude mixture was dissolved in hot alcohol and allowed to crystallize slowly. 2,2'-Dichloro benzoin crystallizes out as colourless,

hexagonal crystals. From the benzoin, about 1 g was taken and treated with conc. nitric acid by heating in a water bath inside a fume cupboard for about 3 h until it is free from the smell of nitrates. It is then cooled and the obtained benzil is recrystallized using hot ethanol. Pure crystals of benzil **1a** separate out (**Scheme-I**). The yield is about 70-80 %. The melting point of the benzil was found to be 80.2 °C. The other polymorph **1b** of the crystal is obtained by recrystallization using THF. The melting point of the benzil was found to be 113.8 °C. The molecular formula and structure of benzil was determined by IR, NMR and mass spectral analysis. The thermal behaviour of crystal was analyzed using thermogravimetric analysis. The structure of the crystal was confirmed by single crystal XRD analysis for compound **1a** and **1b**.

Crystal structure determination: Single crystal X-ray diffraction data were collected at room temperature (25(2) °C), using monochromatized MoK α radiation (0.71073 Å), on a Bruker axis kappa apex2 CCD diffractometer for forms **1a** and **1b**. The structures were solved using program SIR92 [15] and refined using the full-matrix LS procedure with SHELXL-97 [16].

TG-DTA studies were carried out with a NETZSCH STA 409 C/CD instrument. Samples weighing 3-5 mg were heated in opened platinum pans at a rate of 10 K/min under nitrogen gas flow of 40 mL/min.

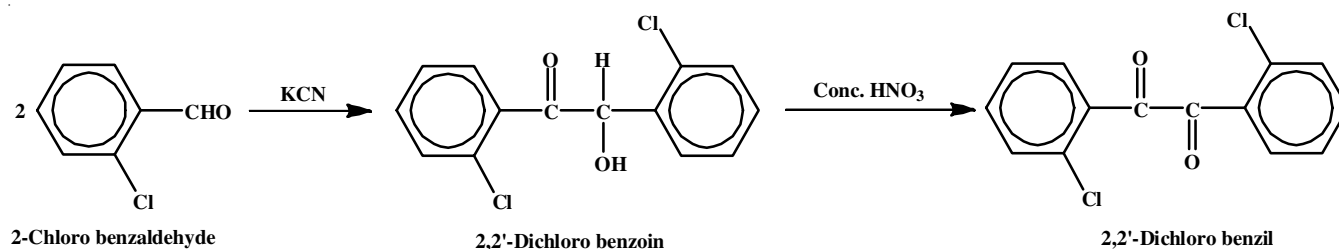
IR spectra were recorded on a Perkin Elmer Spectrum RX I spectrometer with KBr discs in the 4000-450 cm⁻¹ region. For diffuse reflectance analysis, samples weighing approximately 2 mg were mixed with 200 mg KBr by means of an agate mortar and pestle and placed in sample cups for fast sampling.

FT-RAMAN spectrometer is a Bruker 110/S spectrometer with a multi RAM, stand alone model. The spectral range is 4000-50 cm⁻¹. The laser source is Nd:YAG 1064 nm. The spectrometer has a large sample compartment to accommodate different sample formats, from powder to liquid in vials.

RESULTS AND DISCUSSION

Synthesis and characterization: The polymorph **1a** and **1b** were obtained by recrystallization using ethanol and THF respectively. The melting point of the benzil **1a** and **1b** were found to be 80.2 and 113.8 °C respectively. Both polymorphs are insoluble in water, but soluble in ethanol, chloroform and acetone. Crystals of both compounds were found to be yellow cubes. Compound **1a** crystallizes in monoclinic *c2/c* space group and **1b** in monoclinic *P21/c* space group.

Crystal structures: The structures of polymorph **1a** and **1b** were determined and the crystallographic data *viz.*, selected bond distances, bond, torsion angles and refinement are presented in Table-1.



Scheme-I: Preparation of 2,2'-dichloro benzil

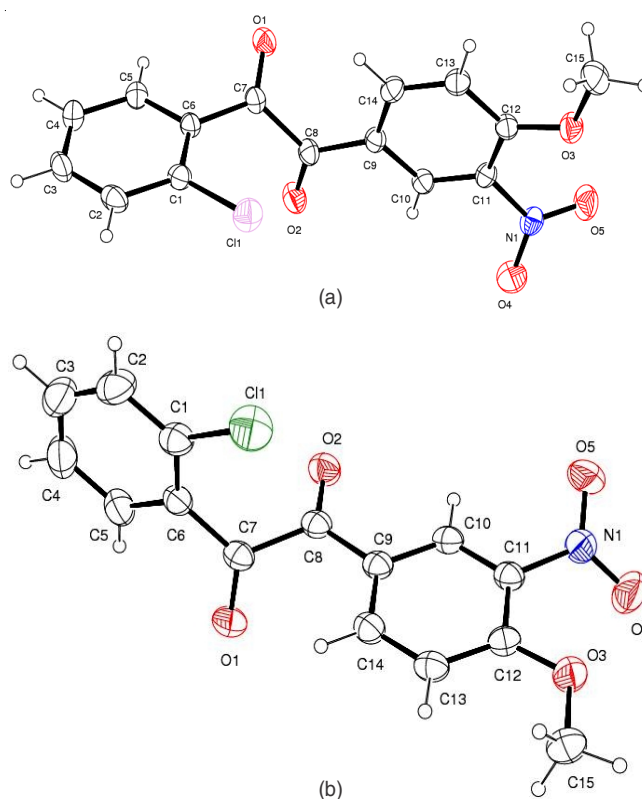


Fig. 1. Ortep diagram of polymorph **1a** and polymorph **1b**

The polymorph **1a** crystallizes in monoclinic *c2/c* space group and the other polymorph **1b** was found to crystallize in the monoclinic space group *P21/c*. Thus, the molecules exhibit conformational polymorphism as the conformations of the molecule are described by the different sequence of torsion angles listed in Table-1. The title compound contains two ring systems, *viz.* chloro phenyl moiety. The torsional angle for the C=O groups were found to be C(1)-C(6)-C(7)-O(1) 144.84(15), C(5)-C(6)-C(7)-O(1) -35.29(19) and C(1)-C(6)-C(7)-O(1) 167.7(2), C(5)-C(6)-C(7)-O(1) -12.1(3) for **1a** and **1b** respectively. The torsional angles between Cl(1)-C(1)-C(2)-C(3) -177.81(12) and Cl(1)-C(1)-C(2)-C(3) -178.27(17) for **1a** and **1b** shows a wide difference denoting the presence of polymorphism. ORTEP diagram of the complex is presented in Fig. 1 and crystal packing diagram is illustrated in Fig. 2.

Polymorphic structures stabilized by strong C=O interactions and close packing were considered. The compound 2,2'-dichloro benzil has distance angle scatter plots of C=O bonds extracted from the Cambridge Structural Database indicate that the polymorphs with a large number of symmetry independent molecules (high *Z'*) generally have better interactions when compared with the polymorphs with lower

TABLE-1
CRYSTAL DATA AND SUMMARY OF DATA
COLLECTION AND REFINEMENT DETAILS

Crystal data	Compound 1a	Compound 1b
Empirical formula	C ₁₅ H ₁₀ NO ₅ Cl	C ₁₅ H ₁₀ NO ₅ Cl
Formula weight (g mol ⁻¹)	319.69	319.69
Temperature (K)	293(2)	293(2)
Wavelength (Å)	0.71073	0.71073
Crystal system	Triclinic	Monoclinic
Space group	P-1	P21/c
a (Å)	7.8559(2)	8.541(5)
b (Å)	8.1003(2)	14.903(5)
c (Å)	12.4961(3)	11.135(5)
α (°)	74.8930(10)	90.000(5)
β (°)	74.8090(10)	92.779(5)
γ (°)	68.5930(10)	90.000(5)
Volume (Å ³)	702.32(3)	1415.7(11)
Z	2	4
D _{calc} (Mg m ⁻³)	1.512	1.500
Absorption coefficient (mm ⁻¹)	0.296	0.294
F(000)	328	656
Crystal size (mm)	0.30 × 0.20 × 0.20	0.30 × 0.20 × 0.20
θ Range for data collection (°)	2.75 - 29.64	2.28 - 25.00
Limiting indices	-10 ≤ h ≤ 10 -11 ≤ k ≤ 10 -12 ≤ l ≤ 17	-10 ≤ h ≤ 10 -17 ≤ k ≤ 1 -13 ≤ l ≤ 13
Reflections collected/ independent [R(int)]	17487/3937 [0.0207]	12500/2488 [0.0226]
Completeness to θ = 29.64°	99.6 %	100.0 %
Maximum and minimum transmission	0.951 and 0.892	0.9643 and 0.9056
Data/restraints/parameters	3937/0/200	2488/0/200
Goodness-of-fit on F ²	1.059	1.040
Final R indices [I > 2σ(I)]	R1 = 0.0423 wR2 = 0.1198	R1 = 0.0342 wR2 = 0.0889
R indices (all data)	R1 = 0.0537 wR2 = 0.1283	R1 = 0.0450 wR2 = 0.0987
Largest diff. peak and hole (Å ⁻³)	0.484 and -0.408	0.282 and -0.275

Z' values with the implication that these symmetry independent molecules have different independent conformations.

IR analysis: The IR analysis for the compound **1a** and **1b** shows difference in the finger print region from 1100-400 cm⁻¹, which shows the existence of polymorphism in the title compound (Fig. 3). The analysis also gives the existence of -C=O group at 1604, 1584 & 1685 and 1591 cm⁻¹ for polymorphic structure **1a** and **1b**, respectively.

Thermal analysis: The TG-DTA curve 4a and 4b shows the melting point at 80.2 °C for the polymorph **1a** and that of 113.8 °C (Fig. 4) for the form **1b**, respectively. The difference in the temperature could be associated with the different crystal morphology of forms **1a** and **1b**.

Raman analysis: The Raman spectrum of the two polymorphs **1a** and **1b** are different in the C-H stretching region at about 3076, 1609 and 802 cm⁻¹ and many small pattern differences in the Raman spectra below 1700 cm⁻¹ which indicates the presence of polymorphism (Fig. 5).

Conclusion

The polymorphic crystal structure shows the presence of high energy conformers. The crystal shows effective closed packing structure and strong hydrogen bonding between them leading to high energy conformers. The existence of flexible torsions in polymorphic molecule is obtained by the destabilization of conformers in the crystal which shows enormous interest in the field of pharmaceutical drugs [14,17].

Appendix A. Supplementary material: CCDC 817058 and 879618 contain the supplementary crystallographic data for **1a** and **1b**, respectively. These data can be obtained free of charge via <http://www.ccdc.cam.ac.uk/conts/retrieving.html>, or from the Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: (+44) 1223-336-033; or e-mail: deposit@ccdc.cam.ac.uk.

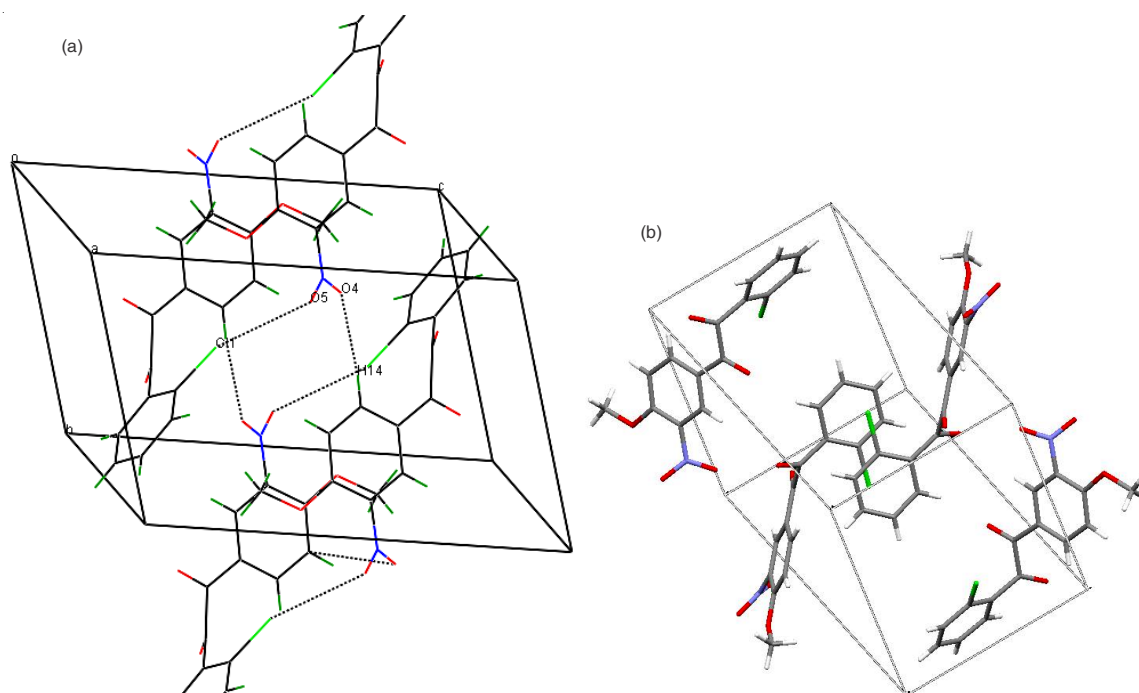
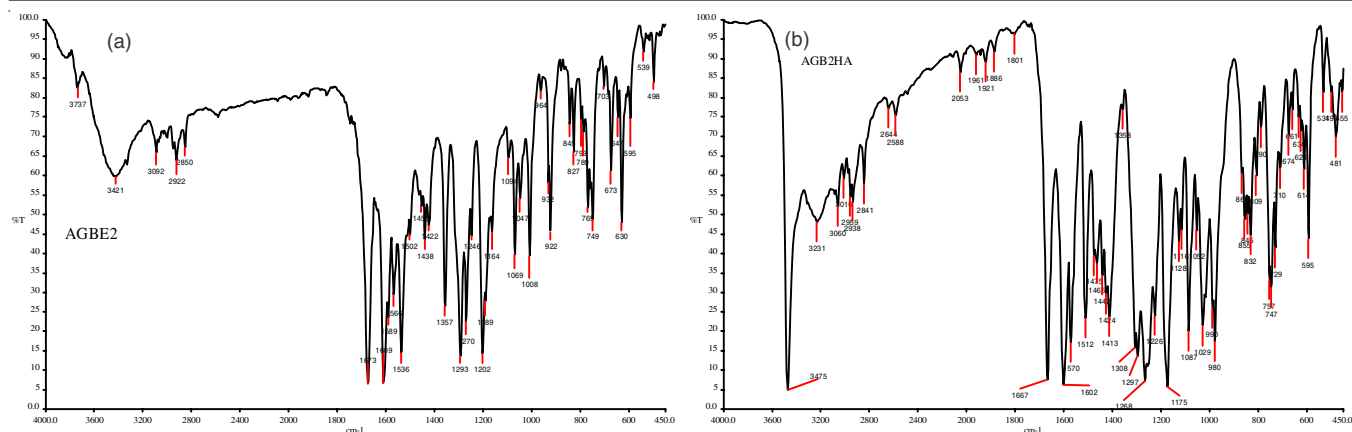
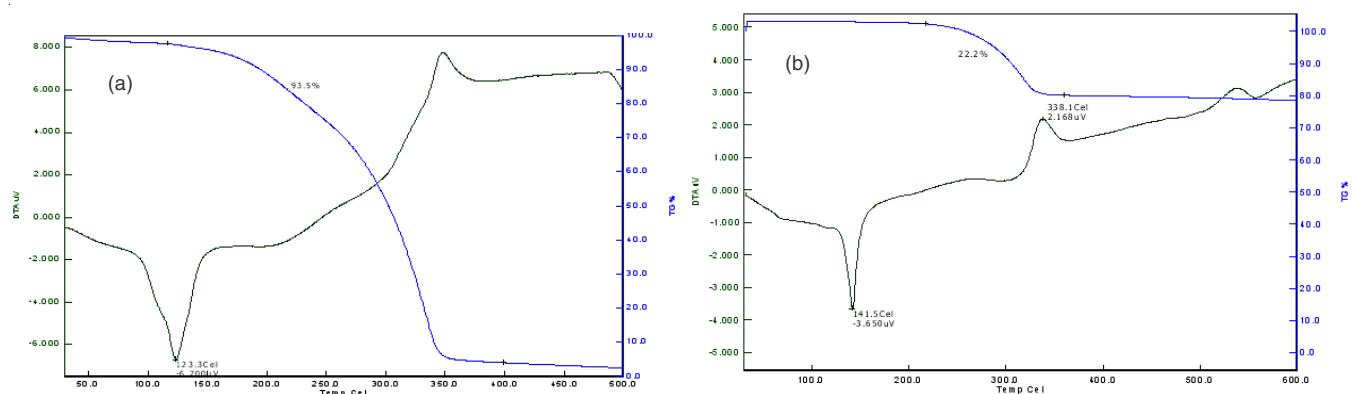
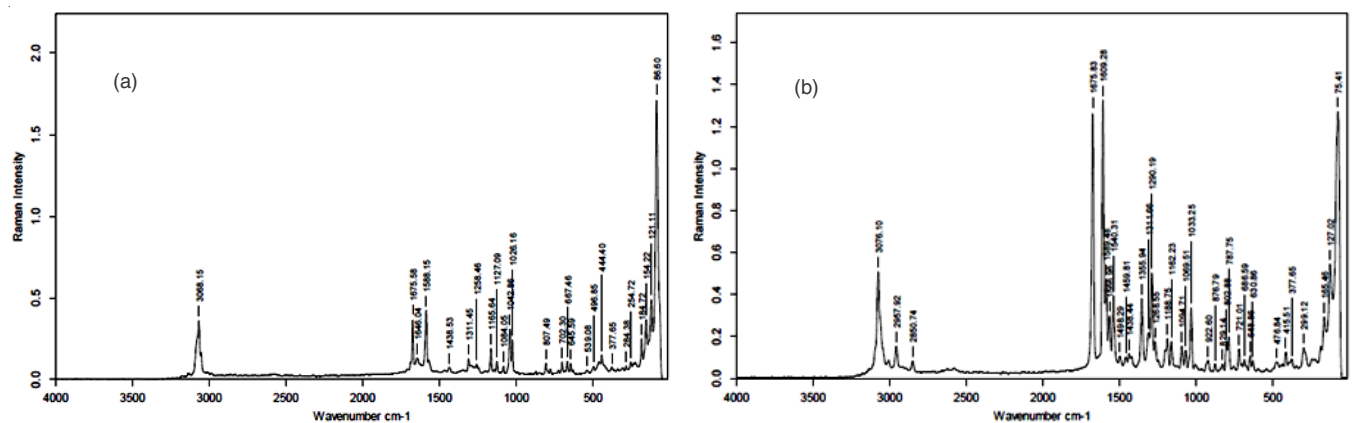


Fig. 2. Crystal packing diagram of polymorph **1a** and polymorph **1b**

Fig. 3. IR spectra of polymorph **1a** and **1b**Fig. 4. TG-DTA curves of polymorph **1a** and **1b**Fig. 5. Raman spectra of polymorph **1a** and **1b**

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