

Crystal Structure Studies and Thermal Characterization of Novel 4-Hydroxychalcone Derivative

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Abstract: The derivatives of 4-hydroxychalcones were synthesized and characterized by infrared and ¹H NMR spectral studies. The grown crystal was further characterized by single crystal x-ray diffraction studies. The crystal structure of (2E)-3-(4-hydroxyphenyl)-1-phenylprop-2-en-1-one was determined using single crystal x-ray diffraction. The compound crystallizes in orthorhombic crystal class in the space group P2₁2₁2₁ with cell parameters a=5.3738(4) Å, b=12.9239(10) Å, c=17.1310(14) Å, Z=4 and V= 1189.76 Å³. The conjugated compound is slightly twisted with a dihedral angle of 25.00° between the benzene and hydroxyphenyl ring. Differential scanning calorimetric studies shows that the crystal is stable up to 186 °C.

Keywords: Crystal growth, Chalcones, Characterization, Single crystal studies

Introduction

Phenol-formaldehyde (PF) resin is one among the most widely used synthetic polymer used in day-to-day life due to its good insulating characteristics, easy cure kinetics and cost efficiency¹. It has been reported that such polymers with wide property variations can be achieved by the simple variation of reaction conditions like pH, catalyst type temperature and the molar ratio of phenolic compound /formaldehyde. Resoles are synthesized under basic conditions with an excess of formaldehyde (P/F molar ratio <1) whereas novolacs under acidic conditions and in the presence of excess of phenol (P/F molar ratio >1). They differ in their chemical composition and their properties. Resoles are heat curable and therefore highly crosslinkable. For the synthesis of phenol-formaldehyde resins, the phenol

has been used widely as it is available in bulk at a cheaper price. By varying the phenolic structure with suitable substituents, it is possible to fine tune the polymer structure with unique properties required for specific applications²⁻⁹. Chalcones are a class of compounds mostly studied for pharmacological properties^{10,11} and recently have been explored for their optical applications¹²⁻¹⁵. In the past few years chalcones have been shown to possess interesting biological properties like anti-invasive¹⁶, anticancer^{17,18}, antimalarial¹⁹, antimicrobial²⁰, antimutagenic²¹, radioprotective²², anti-inflammatory effects²³ and find use as synthetic intermediates²⁴.

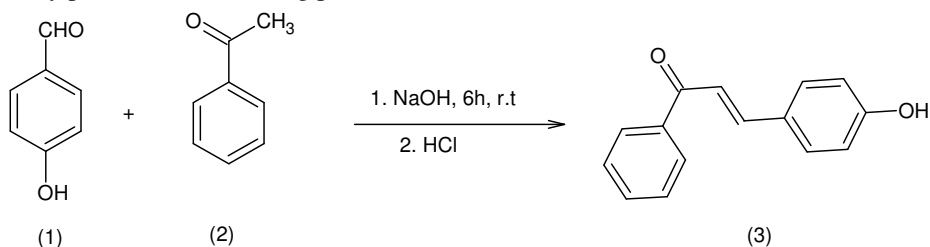
Recently we explored hydroxyphenyl compounds for their application as monomer in the synthesis of resol/novolacs type resins. The objective of the present work is to synthesize the chalcone derivative having a hydroxyl function (Scheme 1), growth of single crystals using slow evaporation technique and its characterization by IR, ¹H NMR, DSC and single crystal studies.

Experimental

The chemicals and solvents required in the synthesis were obtained from commercial sources and were used without further purification. Melting point of the compound was determined using open capillary method and is uncorrected. Thin layer chromatography was carried out using silica gel plates and ethyl acetate: hexane (1:9) solvent system. Infrared spectra were recorded using SHIMADZU- 8400S FT-IR spectrometer in the wavenumber range 400-4000 cm⁻¹ by KBr pellet technique. ¹H NMR spectra was recorded using Bruker 400MHZ NMR spectrometer using CDCl₃ as solvent.

Synthesis of 4-hydroxychalcone

The required chalcone (**3**) was prepared by reacting 4-hydroxybenzaldehyde (**1**) (10 mmole) and acetophenone (**2**) (10 mmole) in a 250 mL round bottom flask using ethanol as solvent. The reaction was carried out at room temperature and with gradual addition of NaOH solution (Scheme 1). The progress of the reaction was monitored using thin layer chromatography. After continuous stirring for 6 h, the reaction was completed. The solution was then acidified using HCl (4 N) till a pH of 3 is reached. The product was collected by vacuum filtration and was further purified by crystallization from ethanol. A yellow, powdery product with a melting point of 180-186 °C (60%) was obtained²⁵.



Scheme 1. Synthesis of hydroxychalcone (**3**)

Characterization

Fourier transform infrared (FT-IR) and ¹H NMR studies

The IR spectrum of hydroxychalcone (**3**) shows characteristic wavenumber at 1651 cm⁻¹ attributable to the C=O stretch of α,β -unsaturated ketone, confirming the formation of chalcone. A broad band observed at 3350 cm⁻¹ corresponds to the presence of phenolic group.

The ^1H NMR spectra of 4-hydroxychalcone recorded using CDCl_3 as solvent and the spectra is in agreement with the structure of the title compound. Proton NMR spectrum of the compound showed a broad singlet at δ 5.72 integrating for one proton is due the presence of phenolic OH group. Other characteristic protons appeared in the range δ 6.9-8.0 integrating for eleven protons is attributable to aromatic and $-\text{CH}=\text{CH}-$ protons.

Differential scanning calorimetry studies

The thermal property of the synthesised compound was studied in the powder form by recording the differential scanning calorimeter (DSC) response curve in the temperature range $30\text{ }^\circ\text{C}$ to $200\text{ }^\circ\text{C}$, at a heating rate of $10\text{ }^\circ\text{C}/\text{min}$, in nitrogen atmosphere using SHIMADZU differential scanning calorimeter (DSC-60). The DSC plot in Figure 1 shows an endothermic peak at $186\text{ }^\circ\text{C}$, which corresponds to the melting point of the compound. Further it indicates that there are no other phase transitions before melting. The sharpness of the peak shows the good degree of crystallinity and purity of the sample.

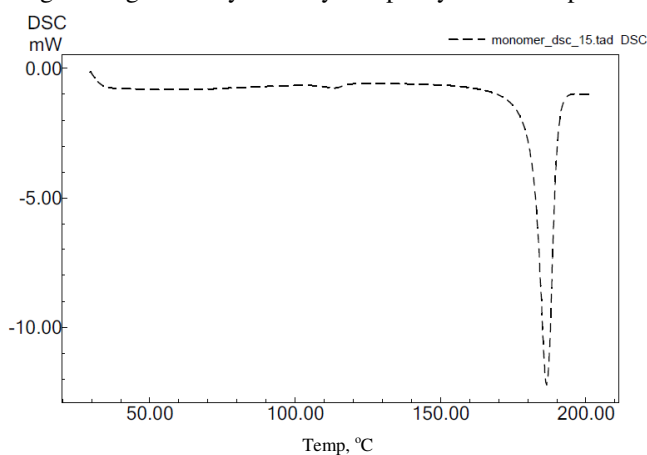


Figure 1. DSC curve for 4-hydroxychalcone

Single crystal growth and structural studies

The solubility studies in different solvents showed the compound is insoluble in water, highly soluble in *N,N*-dimethylformamide (DMF) and as moderately soluble ethyl acetate. To grow single crystals of 4-hydroxychalcone, ethyl acetate was used as solvent. A known volume of solvent was taken in a conical flask, which was kept under heat in a constant temperature bath. The finely powdered sample was added until the dissolution ceased. Then the solution was kept for slow evaporation at room temperature for 72 h. The needle type crystals initially formed after 48 h were kept further 24 h to form sufficiently bigger size crystals.

A good quality single crystal of dimension $0.35 \times 0.25 \times 0.2$ mm is used for data collection using a Bruker kappa Apex II diffractometer. The data was collected at room temperature using Mo K alpha radiation at a generator setting of 50 KV and 30 mA. Cell refinement was done using APEX2/SAINT. Data reduction was done using SAINT/XPREP. Multi-scan absorption correction method was followed with reference to SADABS. The structure was solved by SIR92 in Wingx suit²⁶ and refinements were done with SHELXL-97 in the WinGx package suite (Version 1.80.05)²⁷. The crystallographic details are provided in Table 1.

Table 1. Crystal data and structure refinement for 4-hydroxychalcone [CCDC deposition No. 905180]

Identification code	shelxl
Empirical formula	C ₁₅ H ₁₂ O ₂
Formula weight	224.25
Temperature	296(2) K
Wavelength	0.71073 Å
Crystal system, space group	Orthorhombic, P2 ₁ 2 ₁ 2 ₁
Unit cell dimensions	a = 5.3738(4) Å, b = 12.9239(10) Å, c = 17.1310(14) Å
Volume	1189.76(16) Å ³
Z, Calculated density	4, 1.252 mg/m ³
Theta range for data collection	1.97 to 28.22 deg.
Reflections collected / unique	8401 / 2908 [R(int) = 0.0204]
Completeness to theta = 28.22	99.1 %
Absorption correction	semi-empirical from equivalents
Max. and min. transmission	0.9837 and 0.9757
Refinement method	Full-matrix least-squares on F ²
Goodness-of-fit on F ²	1.054
Final R indices [I > 2σ(I)]	R1 = 0.0407, wR2 = 0.0928
R indices (all data)	R1 = 0.0769, wR2 = 0.1105

The synthesised compound exists as the most stable (*E*)-configuration, crystallizes orthorhombic system, P2₁2₁2₁ space group with Z=4. The molecular structure of 4-hydroxychalcone with thermal ellipsoid drawn at 50% probability level is shown in Figure 2. The non-centrosymmetric crystal packing of 4-hydroxychalcone is consolidated by two weak C-H...O intermolecular hydrogen bond interactions and the corresponding geometric parameters are tabulated in Table 2. Packing of the molecules when viewed along the axis a is shown in Figure 3. Anisotropic displacement parameters, hydrogen coordinates and isotropic displacement parameters can be obtained free of cost by referring to CCDC No 905180. It is interesting to note that the dihedral angle between benzene ring and hydroxyphenyl ring is 25.00°, which indicates the non-planar geometry of the crystal structure. The hydroxyphenyl ring is connected to the phenyl group through the C6-C7=C8-C9-C10 chain with the C=C bond length being 1.330 (3) Å. The analysis of weak intermolecular interactions reveals that crystalline lattice is held together by weak intermolecular C-H...O hydrogen bond. The mean plane of phenyl ring (C10-C15) is deviated from a plane (O2-C9-C10) by an angle of 9.95°. In the same way the mean plane of hydroxy phenyl ring (C1-C6) is deviated from a plane (H1O1-O1-C3) by an angle of 17.27°. The crystal structure is further stabilized by very weak aromatic stacking interactions.

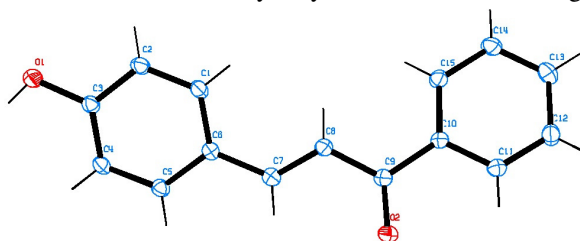
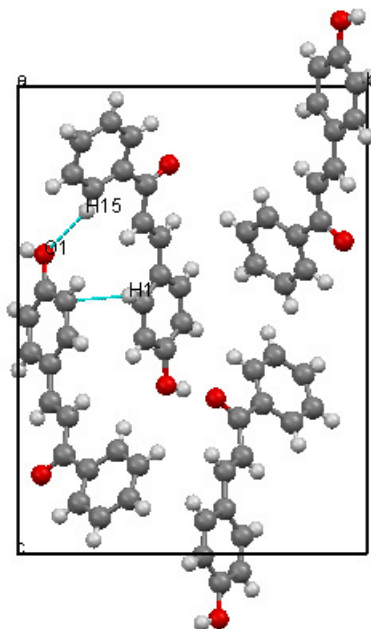
**Figure 2.** ORTEP diagram of 4-hydroxychalcone, thermal ellipsoids were drawn at 50% probability level

Table 2. Geometries of intermolecular Interactions obtained from structural analysis of 4-hydroxychalcone

Interactions	X-H (Å)	H...D (Å)	X...D (Å)	X-H...D (°)	Symmetry
C15-H15...O1	0.931(2)	2.601	3.456(2)	153.1(1)	-1/2+x, 1/2-y, 1-z
C1-H1...C2	0.930(2)	2.859	3.701(3)	151.1(1)	-1/2+x, 1/2-y, 1-z
C9-O2...H4	1.228(2)	2.713	3.812(2)	148.2(1)	1.5-x, -y, 1/2+z
C9-O2...O1	1.228(2)	2.682	3.796(2)	150.1(1)	1.5-x, -y, 1/2+z
C9-O2...H1O1	1.228(2)	1.87	2.988(2)	148.7(1)	1.5-x, -y, 1/2+z

**Figure 3.** Packing of the molecules when viewed down the a axis

Conclusion

A novel 4-hydroxychalcone is synthesized and crystals of this compound were successfully grown by the solution growth technique. The functional groups present in the synthesized crystal were identified using FTIR and ^1H NMR spectrum. Single crystal XRD studies indicate the non-centrosymmetric structure of the crystal. The crystal has high melting point indicating potential applications in device fabrication. There is ample scope for further study on optical properties and also this is a potential molecule to be explored as monomer in the synthesis of resole type resins.

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