X-ray powder diffraction data for nicotine 3,5-dihydroxybenzoate dihydrate, $C_{10}H_{15}N_2{\cdot}C_7H_5O_4{\cdot}2H_2O$

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(Received 24 September 2020; accepted 3 January 2021)

Nicotine 3,5-dihydroxybenzoate dihydrate is a nicotine salt and can be used as compositions in tobacco products. X-ray powder diffraction data, unit-cell parameters, and space group for nicotine 3,5-dihydroxybenzoate, $C_{10}H_{15}N_2{\cdot}C_7H_5O_4{\cdot}2H_2O$, are reported [$a = 8.424(1)$ Å, $b = 13.179(8)$ Å, $c = 8.591(1)$ Å, $\alpha = 90°$, $\beta = 102.073(8)°$, $\gamma = 90°$, unit-cell volume $V = 932.765(3)$ Å^3, $Z = 2$, $\rho_{cal} = 1.256$ g·cm^{-3}, and space group $P2_1$] at room temperature. All measured lines were indexed and are consistent with the $P2_1$ space group. © *The Author(s), 2021. Published by Cambridge University Press on behalf of International Centre for Diffraction Data*. [doi:10.1017/S0885715621000014]

Key words: x-ray powder diffraction, nicotine 3,5-dihydroxybenzoate dihydrate

I. INTRODUCTION

Electronic cigarettes are becoming more and more popular. Nicotine salts are important parts of e-liquids and meet the need for more effective and appealing e-cigarette products to provide satisfying alternatives to smoking (Grant *et al.*, 2019). 3,5-Dihydroxybenzoic acid is synthesized from benzoic acid, and the value of LD_{50} intravenous in mouse is 2 g kg^{-1} (Adams and Cobb, 1967), generally considered safe. The lattice parameters (100 K single-crystal structure determination) and powder diffraction pattern for nicotine 3,5-dihydroxybenzoate were given by Dull *et al.* (2015, 2017) (US9738622B2; WO2015183801A1). However, hydrates are usually the more stable form. As far as we know, the crystal structure of nicotine 3,5-dihydroxybenzoate dihydrate has not been reported. In this study, nicotine 3,5-dihydroxybenzoate dihydrate was synthesized. The single-crystal X-ray diffraction and detailed X-ray powder diffraction data of nicotine 3,5-dihydroxybenzoate dihydrate were measured at room temperature and are reported here.

II. EXPERIMENTAL

A. Sample preparation

0.95 g of 3,5-dihydroxybenzoic acid was dissolved in 5 ml of ethanol. 1.01 g of nicotine was added in 40 °C. The ultrasound reaction took 4 h at 40 °C. The solution was left at room temperature and dark. After 2 months, the crystals of nicotine 3,5-dihydroxybenzoate dihydrate were obtained. Then, part of yellowish blocky crystals were dried and ground into powders. The powders were collected after passing through 200 mesh sieve.

B. Powder diffraction data collection and reduction

X-ray powder diffraction measurement was performed at room temperature using an Empyrean diffractometer (PANalytical Co., Ltd., Netherlands) with a PIXcel3D detector and Cu$K\alpha$ radiation (generator setting: 40 kV and 40 mA). The diffraction data were collected over the angular range from 4 to 50° 2θ with a step size of 0.013° 2θ and a counting time of 30 ms step^{-1}. The powder XRD pattern is shown in Figure 1.

The software package Material Studio 8.0 (Accelrys Co., Ltd., San Diego, CA, USA) was used to process the data in the Analytical & Testing Center (Sichuan University, Chengdu, China). The X-ray powder diffraction pattern was pretreated by subtracting the background, smoothing, and stripping off the $K\alpha_2$ component by Material Studio. The automatic indexing results, obtained by X-Cell algorithm (Neumann, 2003),

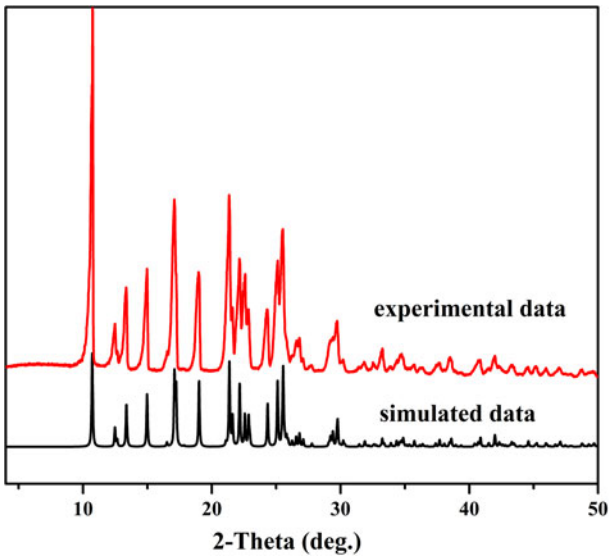

Figure 1. XRD pattern of nicotine 3,5-dihydroxybenzoate dihydrate using Cu-$K\alpha$ radiation (red line) and the simulated pattern of ours (black line).

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were then refined using the Pawley method (Pawley, 1981), which involves the assignment of Miller indices (h, k, l) to each observed peak in the experimental powder XRD pattern. No unindexed lines were observed.

C. Single-crystal X-ray diffraction

The single-crystal X-ray diffraction data for nicotine 3,5-dihydroxybenzoate dihydrate were collected on an Xcalibur, Eos diffractometer. The crystal was kept at 293.15 K during data collection. The structure was solved with Olex2 (Dolomanov *et al.*, 2009), a structure solution program using intrinsic phasing, and refined with the ShelXL (Sheldrick, 2008) refinement package using least squares minimization (Sheldrick, 2015). There are no holes and unaccounted positive electron density in the difference map.

III. RESULTS

The Pawley refinement results confirmed that the title compound is monoclinic with space group $P2_1$ and unit-cell parameters: $a = 8.424(1)$ Å, $b = 13.179(8)$ Å, $c = 8.591(1)$ Å, $\alpha = 90°$, $\beta = 102.073(8)°$, $\gamma = 90°$, unit-cell volume $V = 932.765(3)$ Å^3, $Z = 2$, and $\rho_{cal} = 1.256$ g·cm^{-3}. The values of $2\theta_{obs}$, d_{obs}, I_{obs}, h, k, l, $2\theta_{cal}$, d_{cal}, $\Delta 2\theta$ are listed in Table I. The Smith-Snyder figure of merit, $F_{(30)} = 62$, characterizes these results as highly reliable. In addition, the average magnitude of $\Delta 2\theta$ is 0.016 and Nposs is 30 when the value of n

TABLE I. Indexed X-ray powder diffraction data for nicotine 3,5-dihydroxybenzoate dihydrate. The d-values were calculated using Cu$K\alpha_1$ radiation (λ = 1.5405981 Å.

$2\theta_{obs}$ (°)	d_{obs} (Å)	I_{obs}	h	k	l	$2\theta_{cal}$ (°)	d_{cal} (Å)	$\Delta 2\theta$
10.7339	8.2395	100	0	0	1	10.7307	8.2378	−0.0032
12.4802	7.0902	15	1	1	0	12.4843	7.0843	0.0041
12.6509	6.9949	8	0	1	1	12.6615	6.9855	0.0106
13.3600	6.6252	23	1	0	−1	13.3759	6.6140	0.0160
14.9750	5.9141	28	1	1	−1	14.9743	5.9114	−0.0007
16.5375	5.3587	8	1	0	1	16.5590	5.3491	0.0215
17.0890	5.1870	44	1	2	0	17.0867	5.1851	−0.0023
17.2334	5.1438	26	0	2	1	17.2175	5.1460	−0.0159
18.9797	4.6743	27	1	2	−1	18.9948	4.6683	0.0151
21.3432	4.1617	45	1	2	1	21.3771	4.1531	0.0340
21.6189	4.1093	18	2	0	−1	21.6265	4.1058	0.0076
22.1441	4.0130	30	2	1	0 **(M)**	22.1932	4.0022	0.0491
22.5905	3.9347	26	0	1	2	22.5982	3.9314	0.0077
22.8269	3.8945	18	1	3	0	22.8234	3.8931	−0.0035
24.3106	3.6600	18	1	3	−1	24.3017	3.6595	−0.0089
25.1247	3.5433	30	2	2	0	25.1199	3.5421	−0.0048
25.4792	3.4948	37	0	2	2	25.4810	3.4928	0.0018
25.5186	3.4894	37	2	2	−1	25.5405	3.4848	0.0219
26.2539	3.3934	7	1	3	1	26.2277	3.3950	−0.0262
26.5822	3.3522	11	2	1	1	26.6092	3.3472	0.0271
29.2082	3.0565	11	0	4	1 **(M)**	29.1659	3.0593	−0.0423
29.3920	3.0378	11	2	3	0	29.3941	3.0361	0.0021
29.6940	3.0076	15	0	3	2	29.7070	3.0048	0.0129
29.7334	3.0037	15	2	3	−1	29.7586	2.9997	0.0252
29.9960	2.9780	6	1	3	−2	29.9909	2.9770	−0.0051
30.1798	2.9603	6	2	2	−2	30.2122	2.9557	0.0324
31.4666	2.8421	5	3	0	−1	31.4921	2.8384	0.0254
31.8737	2.8067	5	1	4	1	31.8725	2.8054	−0.0012
32.5564	2.7494	5	0	0	3	32.5822	2.7459	0.0257
33.1604	2.7007	8	1	3	2	33.1322	2.7016	−0.0282
34.3947	2.6065	6	3	2	−1	34.3722	2.6069	−0.0224
34.7492	2.5808	8	3	0	−2	34.7374	2.5803	−0.0118
34.8411	2.5742	7	2	4	−1 **(M)**	34.8847	2.5698	0.0436
35.6552	2.5172	5	1	5	0	35.6686	2.5151	0.0134
35.7471	2.5110	5	0	5	1	35.7347	2.5106	−0.0124
36.1935	2.4810	4	2	2	2	36.2173	2.4782	0.0238
36.4167	2.4663	4	1	0	3 **(M)**	36.4586	2.4624	0.0418
37.4146	2.4028	5	3	2	−2	37.3970	2.4027	−0.0177
37.6510	2.3882	6	2	4	1	37.6636	2.3863	0.0126
37.8742	2.3747	4	1	4	2	37.8526	2.3748	−0.0216
38.2025	2.3550	4	1	3	−3	38.2012	2.3540	−0.0013
38.5044	2.3373	7	3	2	1	38.5239	2.3350	0.0195
38.6489	2.3288	6	0	3	3	38.6351	2.3285	−0.0138
40.6841	2.2169	6	2	5	−1	40.6395	2.2182	−0.0446
40.8285	2.2094	6	2	3	−3	40.8062	2.2095	−0.0223
40.8548	2.2081	6	3	0	−3 **(M)**	40.8996	2.2047	0.0448

Continued

https://doi.org/10.1017/S0885715621000014 Published online by Cambridge University Press

TABLE I. Continued

$2\theta_{obs}$ (°)	d_{obs} (Å)	I_{obs}	h	k	l	$2\theta_{cal}$ (°)	d_{cal} (Å)	$\Delta 2\theta$
41.4982	2.1753	4	3	1	−3	41.4938	2.1745	−0.0043
41.5638	2.1720	4	3	3	1	41.5661	2.1708	0.0023
41.9971	2.1506	7	3	4	−1	41.9772	2.1505	−0.0199
42.3385	2.1340	5	3	4	0	42.3215	2.1338	−0.0170
43.2445	2.0914	5	3	1	2	43.2089	2.0920	−0.0356
43.3495	2.0866	5	1	6	−1	43.3691	2.0847	0.0196
43.4808	2.0806	5	2	1	3	43.4899	2.0792	0.0091
44.4919	2.0356	4	0	1	4	44.4893	2.0348	−0.0026
44.5575	2.0328	4	3	4	−2	44.5637	2.0315	0.0062
45.1484	2.0075	5	2	2	3	45.1703	2.0056	0.0219
45.9756	1.9733	4	1	4	3	45.9739	1.9724	−0.0016
46.8028	1.9403	4	4	0	1	46.7796	1.9403	−0.0232
46.9735	1.9337	4	3	5	−1	47.0054	1.9315	0.0319
47.0785	1.9296	4	4	3	−1	47.1008	1.9278	0.0223
48.7592	1.8670	4	4	0	−3	48.7242	1.8673	−0.0350
49.2450	1.8497	3	4	1	−3	49.2429	1.8489	−0.0021
49.4157	1.8437	3	3	5	−2	49.3838	1.8439	−0.0319
49.5339	1.8396	3	2	3	−4	49.5440	1.8383	0.0101
49.7177	1.8332	3	3	4	−3	49.7175	1.8323	−0.0002

(**M**), Multiple indexing of a given observed line.

is 30. The results were in good agreement with single-crystal data [$a = 8.4365(6)$ Å, $b = 13.1486(11)$ Å, $c = 8.6019(5)$ Å, $\alpha = 90°$, $\beta = 101.976(6)°$, $\gamma = 90°$, unit-cell volume $V = 933.42(12)$ Å^3, $Z = 2$, and $\rho_{cal} = 1.254$ g·cm^{-3}]. The principal acquisition parameters and structure refinement values for single-crystal nicotine 3,5-dihydroxybenzoate dihydrate compound are listed in Supplementary Table SI. The structural formula of 3,5-dihydroxybenzoate dihydrate is shown in Figure 2. The minimum repeating unit contains one nicotine ion, one 3,5-dihydroxybenzoate ion, and two water molecules. The nicotine ion is linked to the 3,5-dihydroxybenzoate ion by an ionic bond. One of the water molecules is attached to the

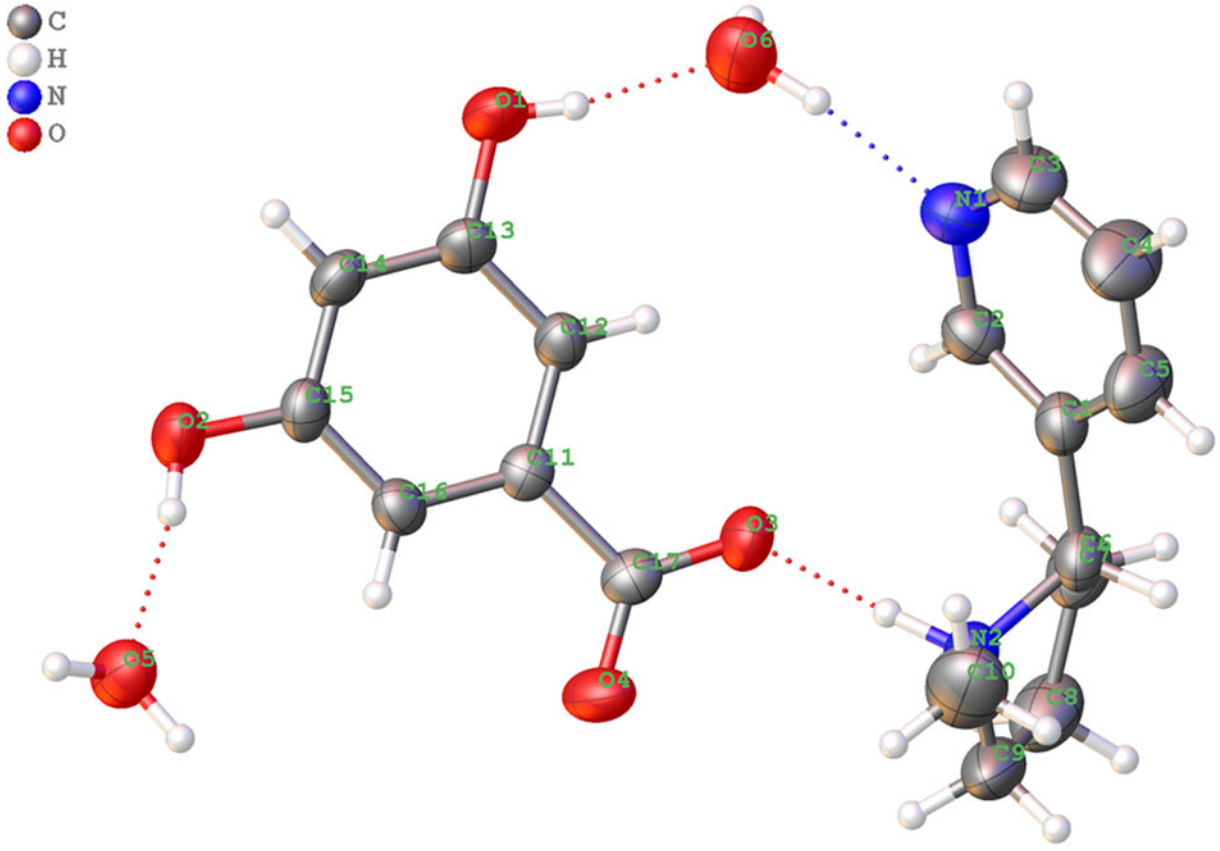

Figure 2. Structural formula of nicotine 3,5-dihydroxybenzoate dihydrate. Gray for carbon atoms, white for hydrogen atoms, blue for nitrogen atoms, and red for oxygen atoms.

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3,5-dihydroxybenzoate ion by a hydrogen bond O2–H2B . . . O5. The other water molecule is attached to the nicotine ion by a hydrogen bond O6–H6A . . . N1 and to the 3,5-dihydroxybenzoate ion by a hydrogen bond O1–H1 . . . O6. The water content of the sample was determined by a Karl Fischer coulometer. The measured value of 9.407% is close to the theoretical value (10.225%). Crystallographic data for nicotine 3,5-dihydroxybenzoate dihydrate were deposited with the Cambridge Crystallographic Data Center (CCDC) with a supplementary publication number of CCDC-2031502. The comparison of the experimental powder XRD pattern with the simulated pattern of ours is shown in Figure 1. The simulated XRD pattern was calculated using Mercury software based on the single-crystal data. Results showed that both single-crystal and powder diffraction methods are consistent with each other.

SUPPLEMENTARY MATERIAL

The supplementary material for this article can be found at https://doi.org/10.1017/S0885715621000014.

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