

L-Phenylalanine–benzoic acid (1/1)

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Key indicators

Single-crystal X-ray study
T = 293 K
Mean $\sigma(\text{C}-\text{C}) = 0.009 \text{ \AA}$
R factor = 0.071
wR factor = 0.187
Data-to-parameter ratio = 7.1For details of how these key indicators were
automatically derived from the article, see
<http://journals.iucr.org/e>.

In the title compound, $\text{C}_9\text{H}_{11}\text{NO}_2 \cdot \text{C}_7\text{H}_6\text{O}_2$, the amino acid molecule exists as a zwitterion and the carboxylic acid molecule is in an unionized state. There is a strong $\text{O}-\text{H} \cdots \text{O}$ intermolecular hydrogen bond between the phenylalanine and benzoic acid molecules, and these molecular pairs form hydrogen-bonded double layers.

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Comment

L-Phenylalanine is an essential amino acid commonly found in proteins. It has a variety of important physiological roles to play in animals and is also known to form innumerable complexes with inorganic salts, besides forming a few proton transfer complexes with carboxylic acids. Recently, the crystal structures of complexes of phenylalanine with maleic acid [Cambridge Structural Database (Version 5.26, update 2 of May 2005; Allen, 2002) refcodes EDAXIQ and VAGVIJ (Alagar *et al.*, 2001; Alagar, Subha Nandhini *et al.*, 2003)], fumaric acid (OJEPEY; Alagar, Krishnakumar *et al.*, 2003), trichloroacetic acid (IJERAQ; Rajagopal *et al.*, 2003) and malonic acid (RALRUS; Alagar *et al.*, 2005) were elucidated in our laboratory. It is important to note that the crystal structure of L-phenylalanine itself has yet to be reported. Previous studies on phenylalanine report only the unit-cell dimensions (Khawas & Murthi, 1968; Khawas, 1970, 1971) and the crystal structure of the D-isomer with a high *R* factor of 15% (Weissbuch *et al.*, 1990). Benzoic acid, an aromatic carboxylic acid, occurs naturally in certain plants; it is also used as a potential antimicrobial agent and was among the first organic crystal structures to be examined by the X-ray method (Bragg, 1921, 1922). Previous work on benzoic acid reports the crystal structure derived from two-dimensional intensities (Sim *et al.*, 1955) and a re-refinement using three-dimensional intensity data (Bruno & Randaccio, 1980). Salicylic acid itself and 2-*O*-acetylsalicylic acid, also known as aspirin, are some of the important derivatives of benzoic acid. The present paper deals with the crystal structure of the title compound, (I), a hydrogen-bonded adduct of an aromatic amino acid, L-phenylalanine, with an aromatic carboxylic acid, benzoic acid.

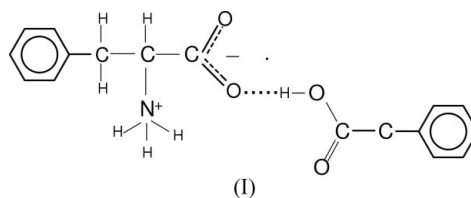


Fig. 1 shows the molecular structure of (I), with the atom-numbering scheme and 50% probability displacement ellip-

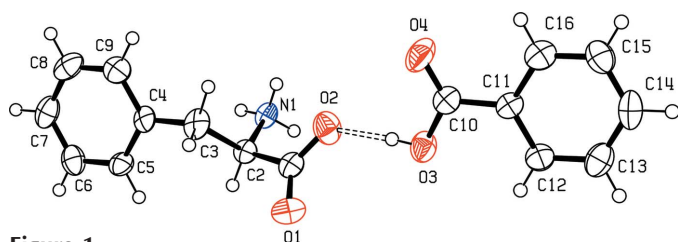


Figure 1
The molecular structure of (I), with the atom-numbering scheme and 50% probability displacement ellipsoids. Dashed lines indicate a hydrogen bond.

soids. The amino acid molecule exists as a zwitterion, an uncommon ionization state in the crystal structures of amino-carboxylic acid complexes. Usually, owing to the favoured proton transfer from the carboxylic acid to the amino acid in these complexes, the former exists in the anionic state and the latter in the cationic state. A similar zwitterionic state for the amino acid molecule is observed in *L*-phenylalanine fumaric acid. However, it is interesting to note that the zwitterionic and the cationic forms occur simultaneously in the crystal structures of *L*-phenylalanine with formic acid (JOTKIM; Görbitz & Etter, 1992) and RALRUS. The twist of the carboxylate group of the phenylalanine molecule described by $\psi^1 = -153.1$ (5) $^\circ$ and $\psi^2 = 30.5$ (7) $^\circ$ is similar to that observed in *L*-phenylalanine fumaric acid (OJEPEY) [$\psi^1 = -164.1$ (2) and -138.6 (2) $^\circ$, $\psi^2 = 17.8$ (4) and 41.1 (3) $^\circ$, for the two molecules]. This twist of the carboxylate group in (I) may be attributed to the participation of atom O1 in an energetically favoured strong intermolecular hydrogen bond with benzoic acid (see Table 2), leading to the formation of an adduct. The phenylalanine molecule exhibits a *gauche* conformation with a χ^1 value of 71.9 (7) $^\circ$, which agrees well with those observed in LPHEFOR with $\chi^1 = 72.3$ (4) and 70.8 (4) $^\circ$ for the zwitterion and the cation, respectively. These values are significantly different from those observed in EDAXIQ [-59.3 (2) $^\circ$], VAGVIJ [85.7 (2) $^\circ$], IJERAQ [-55.2 (5) and -65.2 (5) $^\circ$], OJEPEY [-69.4 (3) and 166.3 (2) $^\circ$] and RALRUS [66.9 (4) and 61.7 (4) $^\circ$]. The value of $\chi^{21} = -129.4$ (6) $^\circ$ describing the side-chain conformation agrees with that observed in VAGVIJ and IJERAQ and differs significantly from those in LPHEFOR, EDAXIQ, OJEPEY and RALRUS. The benzoic acid molecule exists in the unionized state with atoms O3 and O4 of the carboxylic acid group deviating only negligibly from the plane defined by the C atoms.

Fig. 2 shows the packing of molecules of (I), viewed down the *a* axis. There are no direct hydrogen-bonded interactions among the benzoic acid molecules. The phenylalanine and benzoic acid molecules form hydrogen-bonded double layers linked together by N—H...O and O—H...O hydrogen bonds and extend parallel to the *b* axis. The N—H...O hydrogen bonds include two characteristic head-to-tail types, one between translationally related and the other between screw-related phenylalanine molecules. The other N—H...O hydrogen bond is between the amino group of phenylalanine and the carboxylic acid group of benzoic acid. In addition, there is an O—H...O hydrogen bond present, as discussed

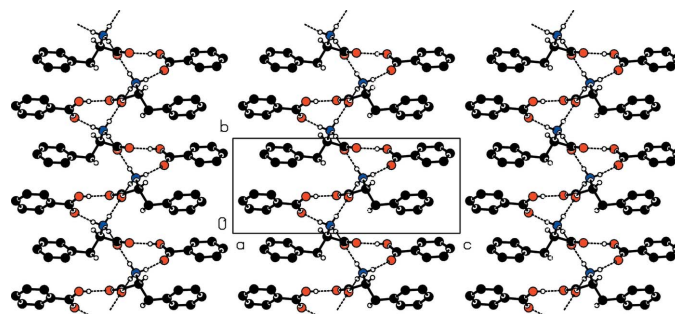


Figure 2
Packing of molecules of (I), viewed down the *a* axis. Dashed lines indicate hydrogen bonds. Aromatic H atoms have been omitted.

above. The double layers are flanked alternately, on either side, by the hydrophobic side chains of phenylalanine and the aromatic rings of benzoic acid, leading to hydrophilic and hydrophobic zones. No significant C—H...O hydrogen-bonding, C—H... π or π - π interactions were observed. A comparison with the aggregation patterns observed in other phenylalanine-carboxylic acid complexes reveals that non-existence of direct hydrogen-bonded interactions between carboxylic acids, aggregation of individual molecules in a double-layered arrangement, and formation of alternating hydrophobic and hydrophilic zones are characteristic features of these crystal structures.

Experimental

The crystals of (I) were prepared by slow evaporation of a supersaturated aqueous solution containing *L*-phenylalanine and benzoic acid, in 1:1 stoichiometric ratio.

Crystal data

$C_9H_{11}NO_2 \cdot C_7H_6O_2$
 $M_r = 287.31$
Monoclinic, $P2_1$
 $a = 5.419$ (2) Å
 $b = 7.438$ (2) Å
 $c = 17.814$ (3) Å
 $\beta = 92.94$ (2) $^\circ$
 $V = 717.1$ (3) Å³
 $Z = 2$
 $D_x = 1.331$ Mg m⁻³
 $D_m = 1.32$ (2) Mg m⁻³

D_m measured by flotation in xylene and carbon tetrachloride
Mo $K\alpha$ radiation
Cell parameters from 25 reflections
 $\theta = 9.6$ – 14.1 $^\circ$
 $\mu = 0.10$ mm⁻¹
 $T = 293$ (2) K
Block, colourless
 $0.22 \times 0.20 \times 0.18$ mm

Data collection

Nonius MACH3 diffractometer
 ω - 2θ scans
Absorption correction: ψ scan (North *et al.*, 1968)
 $T_{min} = 0.98$, $T_{max} = 0.99$
1749 measured reflections
1364 independent reflections
925 reflections with $I > 2\sigma(I)$

$R_{int} = 0.039$
 $\theta_{max} = 25.0$ $^\circ$
 $h = 0 \rightarrow 6$
 $k = -1 \rightarrow 8$
 $l = -21 \rightarrow 21$
2 standard reflections
frequency: 60 min
intensity decay: none

Refinement

Refinement on F^2
 $R[F^2 > 2\sigma(F^2)] = 0.071$
 $wR(F^2) = 0.187$
 $S = 1.12$
1364 reflections
193 parameters

H-atom parameters constrained
 $w = 1/[\sigma^2(F_o^2) + (0.1183P)^2]$
where $P = (F_o^2 + 2F_c^2)/3$
 $(\Delta/\sigma)_{max} < 0.001$
 $\Delta\rho_{max} = 0.50$ e Å⁻³
 $\Delta\rho_{min} = -0.36$ e Å⁻³

Table 1

Selected geometric parameters (Å, °).

O1—C1	1.248 (7)	C1—C2	1.530 (8)
O2—C1	1.245 (7)	C2—C3	1.535 (8)
O3—C10	1.298 (7)	C3—C4	1.489 (9)
O4—C10	1.218 (7)	C10—C11	1.479 (8)
N1—C2	1.495 (7)		
O2—C1—O1	126.6 (5)	C5—C4—C3	121.4 (5)
O2—C1—C2	115.5 (5)	O4—C10—O3	123.5 (5)
O1—C1—C2	117.8 (5)	O4—C10—C11	121.8 (6)
N1—C2—C1	110.2 (4)	O3—C10—C11	114.7 (5)
N1—C2—C3	110.7 (5)	C12—C11—C16	118.6 (5)
C1—C2—C3	108.8 (5)	C12—C11—C10	123.1 (5)
C4—C3—C2	117.6 (5)	C16—C11—C10	118.3 (5)
C9—C4—C3	121.7 (5)		
O2—C1—C2—N1	30.5 (7)	N1—C2—C3—C4	71.9 (7)
O1—C1—C2—N1	-153.1 (5)	C1—C2—C3—C4	-166.8 (5)
O2—C1—C2—C3	-91.2 (7)	C2—C3—C4—C9	-129.4 (6)
O1—C1—C2—C3	85.3 (6)	C2—C3—C4—C5	52.8 (8)

Table 2

Hydrogen-bond geometry (Å, °).

<i>D</i> —H... <i>A</i>	<i>D</i> —H	H... <i>A</i>	<i>D</i> ... <i>A</i>	<i>D</i> —H... <i>A</i>
O3—H3...O2	0.82	1.71	2.524 (5)	176
N1—H1A...O4 ⁱ	0.89	1.92	2.790 (6)	167
N1—H1B...O1 ⁱⁱ	0.89	1.96	2.842 (6)	170
N1—H1C...O1 ⁱⁱⁱ	0.89	2.15	3.026 (6)	168

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

The absolute configuration of L-phenylalanine benzoic acid was not established by the analysis but is known from the configuration of the starting reagents. The H atoms were placed at calculated positions and were allowed to ride on their respective parent atoms, with C—H = 0.93–0.98 Å, O—H = 0.82 Å and N—H = 0.89 Å, and with $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{C})$ and $1.5U_{\text{eq}}(\text{N}, \text{O})$. In the absence of significant anomalous scattering effects, Friedel pairs were merged.

Data collection: *CAD-4 EXPRESS* (Enraf–Nonius, 1994); cell refinement: *XCAD4* (Harms & Wocadlo, 1996); data reduction: *XCAD4*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 1990); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *PLATON* (Spek, 2003); software used to prepare material for publication: *SHELXL97*.

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References

- Alagar, M., Krishnakumar, R. V. & Natarajan, S. (2001). *Acta Cryst.* **E57**, o968–o970.
- Alagar, M., Krishnakumar, R. V., Parimala Devi, P. & Natarajan, S. (2005). *Acta Cryst.* **E61**, o992–o994.
- Alagar, M., Krishnakumar, R. V., Rajagopal, K., Subha Nandhini, M. & Natarajan, S. (2003). *Acta Cryst.* **E59**, o952–o954.
- Alagar, M., Subha Nandhini, M., Krishnakumar, M., Mostad, A. & Natarajan, S. (2003). *Acta Cryst.* **E59**, o209–o211.
- Allen, F. H. (2002). *Acta Cryst.* **B58**, 380–388.
- Bragg, W. H. (1921). *Proc. Phys. Soc.* **34**, 33–50.
- Bragg, W. H. (1922). *J. Chem. Soc.* pp. 2766–2787.
- Bruno, G. & Randaccio, L. (1980). *Acta Cryst.* **B36**, 1711–1712.
- Enraf–Nonius (1994). *CAD-4 EXPRESS*. Version 5.1/1.2. Enraf–Nonius, Delft, The Netherlands.
- Görbitz, C. H. & Etter, M. C. (1992). *Acta Cryst.* **C48**, 1317–1320.
- Harms, K. & Wocadlo, S. (1996). *XCAD4*. University of Marburg, Germany.
- Khawas, B. (1970). *Acta Cryst.* **B26**, 1919–1922.
- Khawas, B. (1971). *Acta Cryst.* **B27**, 1517–1520.
- Khawas, B. & Murthi, G. S. R. K. (1968). *Indian J. Phys.* **42**, 175–181.
- Rajagopal, K., Krishnakumar, R. V., Subha Nandhini, M., Cameron, T. S. & Natarajan, S. (2003). *Acta Cryst.* **E59**, o1084–o1086.
- Sheldrick, G. M. (1990). *Acta Cryst.* **A46**, 467–473.
- Sheldrick, G. M. (1997). *SHELXL97*. University of Göttingen, Germany.
- Sim, G. A., Robertson, J. M. & Goodwin, T. H. (1955). *Acta Cryst.* **8**, 157–164.
- Spek, A. L. (2003). *J. Appl. Cryst.* **36**, 7–13.
- Weissbuch, I., Frolow, F., Addadi, L., Lahav, M. & Leiserowitz, L. (1990). *J. Am. Chem. Soc.* **112**, 7718–7724.