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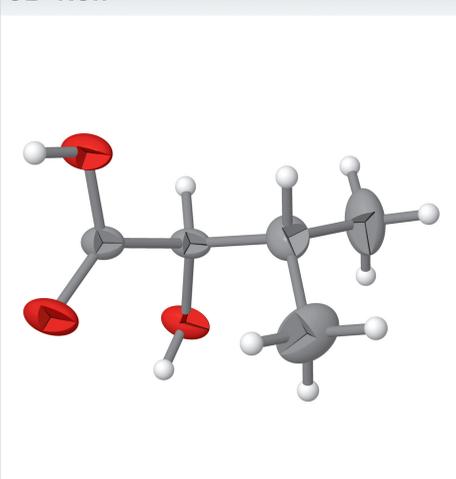
rac-Hydroxyisovaleric acid

Lukhanyo Dasi, Eric Cyriel Hosten and Richard Betz*

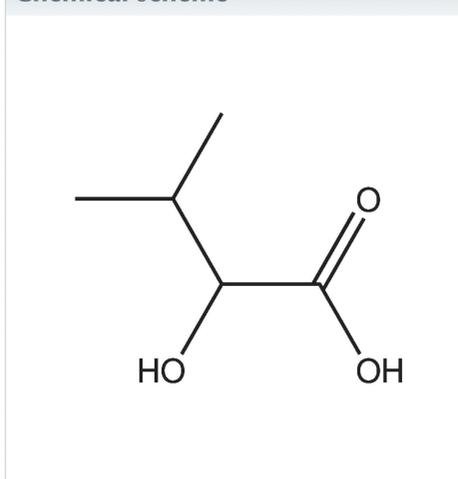
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The title compound (systematic name: *rac*-2-hydroxy-3-methylbutanoic acid), C₅H₁₀O₃, is the constitutional isomer of α -hydroxybutanoic acid. In the crystal, hydrogen bonds involving the alcoholic hydroxyl group give rise to centrosymmetric dimers that are extended to sheets perpendicular to the crystallographic *c* axis.

3D view



Chemical scheme



Structure description

The Krebs Cycle – also known as Citric Acid Cycle – is at the centre of metabolic processes in aerobic organisms. It involves a number of hydroxycarboxylic acids that constitute intriguing chelating ligands for a variety of transition metals of pharmaceutical interest (McMurry, 2008). These potential ligands classify as chelate ligands, which have found widespread use in coordination chemistry due to the increased stability of coordination compounds they can form in comparison to monodentate ligands (Gade, 1998). Hydroxycarboxylic acids are a particularly interesting class of ligands as they offer two functional groups that, depending on the experimental conditions, can either act as fully neutral, fully anionic or mixed neutral-anionic donors. Upon varying the substitution pattern on the hydrocarbon backbone, the acidity of the respective hydroxyl groups can be fine-tuned over a wide range and they may, thus, serve as probes for establishing the rules in which pK_a range coordination to various central atoms can be observed. Furthermore, the steric pretence of potential substituents may give rise to unique coordination and bonding patterns. Given the multidentate nature of hydroxycarboxylic acids encountered in the Krebs Cycle it appears prudent to investigate simpler ‘cut outs’ with a more limited number of donor sites to avoid complexer mixtures of reaction products in envisioned synthesis procedures, thus prompting the diffraction study of the title compound to allow for comparisons of metrical parameters of the free ligand and the ligand in envisioned coordination compounds. The present study falls into the ambit of our continued interest into structural aspects of *alpha*-hydroxycarboxylic acids such as 1-hydroxycyclopropanecarboxylic acid (Betz & Klüfers, 2007a), 1-hydroxycyclobutanecarboxylic acid (Betz & Klüfers, 2007b), 1-hydroxycyclopentanecarboxylic acid (Betz &

Table 1
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>
O1—H1A···O3 ⁱ	0.84	1.78	2.6143 (9)	169
O3—H3A···O2	0.84	2.32	2.7069 (10)	108
O3—H3A···O2 ⁱⁱ	0.84	2.00	2.7597 (11)	150

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

Klüfers, 2007c) or *tert*-butylglycolic acid (Betz *et al.*, 2007). Furthermore, geometrical data for glycolic acid (Ellison *et al.*, 1971; Pijper, 1971) and L-lactic acid (Schouten *et al.*, 1994; Yang *et al.*, 2021) is apparent in the literature while, to the best of our knowledge, none of the various hydroxy-*n*-butanoic acids have been subjected to diffraction studies. Only one report provides the crystal and molecular structure for *gamma*-hydroxybutanoic acid as a solvent molecule in a barium-supported tetraphenylimidodiphosphinato compound (Morales-Juarez *et al.*, 2005).

The asymmetric unit of the title compound is shown in Fig. 1 and contains one complete molecule. C—O bond lengths are found to be 1.4175 (11) Å for the alcoholic hydroxyl group and 1.2064 (12) and 1.3143 (11) Å for the carboxylic acid group and, thus, lie in the normal range reported for other hydroxycarboxylic acids whose metrical parameters have been deposited with the Cambridge Structural Database (Groom *et al.*, 2016). The alcoholic hydroxyl group adopts a staggered conformation relative to the two terminal methyl groups with the relevant C—C—O torsional angles measuring -58.32 (11) and 66.60 (12)°.

In the crystal, classical hydrogen bonds of the O—H···O type (Table 1) are apparent that involve all hydroxyl groups as donors and the oxygen atom of the alcoholic hydroxyl group and the carbonyl oxygen atom as acceptors. The hydrogen bonds supported by the alcoholic hydroxyl group as donor and the carbonyl oxygen atom as acceptor connect the individual molecules into centrosymmetric dimers, which are further extended to sheets perpendicular to the crystallographic *c* axis by means of the carboxylic acid's hydroxyl group as donor and the alcoholic hydroxyl group's oxygen atom as acceptor. In

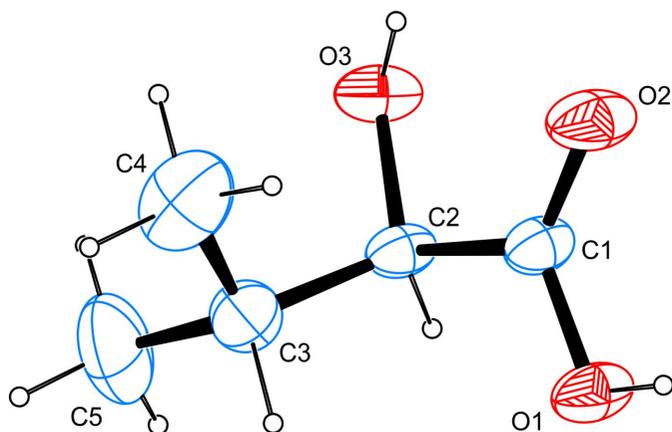


Figure 1
The molecular structure of the title compound, with atom labels and anisotropic displacement ellipsoids (drawn at 50% probability level).

Table 2
Experimental details.

Crystal data	
Chemical formula	C ₅ H ₁₀ O ₃
<i>M_r</i>	118.13
Crystal system, space group	Orthorhombic, <i>Pbca</i>
Temperature (K)	200
<i>a</i> , <i>b</i> , <i>c</i> (Å)	10.9589 (4), 9.3280 (4), 12.7255 (6)
<i>V</i> (Å ³)	1300.86 (10)
<i>Z</i>	8
Radiation type	Mo <i>K</i> α
μ (mm ⁻¹)	0.10
Crystal size (mm)	0.60 × 0.51 × 0.35
Data collection	
Diffractometer	Bruker (2010) APEXII CCD
Absorption correction	Numerical (<i>SADABS</i> , Krause <i>et al.</i> , 2015)
<i>T_{min}</i> , <i>T_{max}</i>	0.928, 0.990
No. of measured, independent and observed [<i>I</i> > 2σ(<i>I</i>)] reflections	10603, 1620, 1366
<i>R_{int}</i>	0.017
(sin θ/ <i>λ</i>) _{max} (Å ⁻¹)	0.669
Refinement	
<i>R</i> [<i>F</i> ² > 2σ(<i>F</i> ²)], <i>wR</i> (<i>F</i> ²), <i>S</i>	0.035, 0.107, 1.05
No. of reflections	1620
No. of parameters	79
H-atom treatment	H-atom parameters constrained
$\Delta\rho_{\max}$, $\Delta\rho_{\min}$ (e Å ⁻³)	0.35, -0.15

Computer programs: *APEX2* and *SAINT* (Bruker, 2010), *SHELXS97*, *SHELXL97* and *SHELXTL* (Sheldrick, 2008), *SHELXTL* (Sheldrick, 2008), *PLATON* (Spek, 2020) and *Mercury* (Macrae *et al.*, 2020).

terms of graph-set analysis (Etter *et al.*, 1990; Bernstein *et al.*, 1995), the descriptor for these hydrogen bonds is *C*₁¹(5)*R*₂²(10) on the unary level. A depiction of the hydrogen-bonding pattern is shown in Fig. 2.

Synthesis and crystallization

The compound was obtained commercially (Fluka). Crystals suitable for the diffraction studies were taken directly from the provided material.

Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2.

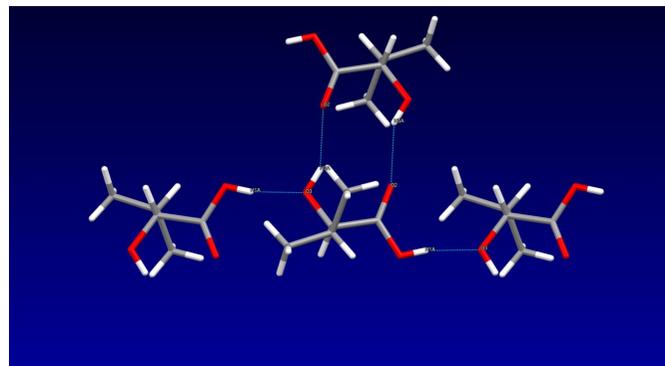


Figure 2
Intermolecular hydrogen bonds (dotted blue lines), viewed along [001].

Acknowledgements

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References

- Bernstein, J., Davis, R. E., Shimoni, L. & Chang, N.-L. (1995). *Angew. Chem. Int. Ed. Engl.* **34**, 1555–1573.
- Betz, R. & Klüfers, P. (2007*a*). *Acta Cryst.* **E63**, o3891.
- Betz, R. & Klüfers, P. (2007*b*). *Acta Cryst.* **E63**, o4032.
- Betz, R. & Klüfers, P. (2007*c*). *Acta Cryst.* **E63**, o3932.
- Betz, R., Klüfers, P. & Mangstl, M. M. (2007). *Acta Cryst.* **E63**, o4144.
- Bruker (2010). *APEX2* and *SAINT*. Bruker AXS Inc., Madison, USA.
- Ellison, R. D., Johnson, C. K. & Levy, H. A. (1971). *Acta Cryst.* **B27**, 333–344.
- Etter, M. C., MacDonald, J. C. & Bernstein, J. (1990). *Acta Cryst.* **B46**, 256–262.
- Gade, L. H. (1998). *Koordinationschemie*, ed. 1. Weinheim: Wiley-VCH.
- Groom, C. R., Bruno, I. J., Lightfoot, M. P. & Ward, S. C. (2016). *Acta Cryst.* **B72**, 171–179.
- Krause, L., Herbst-Irmer, R., Sheldrick, G. M. & Stalke, D. (2015). *J. Appl. Cryst.* **48**, 3–10.
- Macrae, C. F., Sovago, I., Cottrell, S. J., Galek, P. T. A., McCabe, P., Pidcock, E., Platings, M., Shields, G. P., Stevens, J. S., Towler, M. & Wood, P. A. (2020). *J. Appl. Cryst.* **53**, 226–235.
- McMurry, J. (2008). *Org. Chem.* 7th ed. Totnes: Thomson Learning.
- Morales-Juárez, J., Cea-Olivares, R., Moya-Cabrera, M. M., Jancik, V., García-Montalvo, V. & Toscano, R. A. (2005). *Inorg. Chem.* **44**, 6924–6926.
- Pijper, W. P. (1971). *Acta Cryst.* **B27**, 344–348.
- Schouten, A., Kanters, J. A. & van Krieken, J. (1994). *J. Mol. Struct.* **323**, 165–168.
- Sheldrick, G. M. (2008). *Acta Cryst.* **A64**, 112–122.
- Spek, A. L. (2020). *Acta Cryst.* **E76**, 1–11.
- Yang, J., Hu, C. T., Reiter, E. & Kahr, B. (2021). *CrystEngComm*, **23**, 2644–2647.

full crystallographic data

IUCrData (2024). **9**, x231093 [https://doi.org/10.1107/S2414314623010933]

rac-Hydroxyisovaleric acid

Lukhanyo Dasi, Eric Cyriel Hosten and Richard Betz

rac-2-Hydroxy-3-methylbutanoic acid*Crystal data*

$C_5H_{10}O_3$	$D_x = 1.206 \text{ Mg m}^{-3}$
$M_r = 118.13$	Mo $K\alpha$ radiation, $\lambda = 0.71073 \text{ \AA}$
Orthorhombic, <i>Pbca</i>	Cell parameters from 4732 reflections
$a = 10.9589 (4) \text{ \AA}$	$\theta = 3.2\text{--}28.1^\circ$
$b = 9.3280 (4) \text{ \AA}$	$\mu = 0.10 \text{ mm}^{-1}$
$c = 12.7255 (6) \text{ \AA}$	$T = 200 \text{ K}$
$V = 1300.86 (10) \text{ \AA}^3$	Blocks, colourless
$Z = 8$	$0.60 \times 0.51 \times 0.35 \text{ mm}$
$F(000) = 512$	

Data collection

Bruker (2010) APEXII CCD diffractometer	10603 measured reflections
Radiation source: sealed tube	1620 independent reflections
Graphite monochromator	1366 reflections with $I > 2\sigma(I)$
φ and ω scans	$R_{\text{int}} = 0.017$
Absorption correction: numerical (SADABS, Krause <i>et al.</i> , 2015)	$\theta_{\text{max}} = 28.4^\circ$, $\theta_{\text{min}} = 3.2^\circ$
$T_{\text{min}} = 0.928$, $T_{\text{max}} = 0.990$	$h = -11 \rightarrow 14$
	$k = -12 \rightarrow 12$
	$l = -16 \rightarrow 16$

Refinement

Refinement on F^2	Secondary atom site location: difference Fourier map
Least-squares matrix: full	Hydrogen site location: inferred from neighbouring sites
$R[F^2 > 2\sigma(F^2)] = 0.035$	H-atom parameters constrained
$wR(F^2) = 0.107$	$w = 1/[\sigma^2(F_o^2) + (0.0586P)^2 + 0.2192P]$
$S = 1.05$	where $P = (F_o^2 + 2F_c^2)/3$
1620 reflections	$(\Delta/\sigma)_{\text{max}} < 0.001$
79 parameters	$\Delta\rho_{\text{max}} = 0.35 \text{ e \AA}^{-3}$
0 restraints	$\Delta\rho_{\text{min}} = -0.15 \text{ e \AA}^{-3}$
Primary atom site location: structure-invariant direct methods	

Special details

Geometry. All esds (except the esd in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell esds are taken into account individually in the estimation of esds in distances, angles and torsion angles; correlations between esds in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell esds is used for estimating esds involving l.s. planes.

Refinement. The carbon-bound H atom of the methine group was placed in a calculated position1 (C–H 1.00 Å) and was included in the refinement in the riding model approximation, with $U(\text{H})$ set to $1.2U_{\text{eq}}(\text{C})$.

The H atoms of the methyl groups were allowed to rotate with a fixed angle around the C–C bond to best fit the experimental electron density (HFIX 137 in the *SHELX* program suite (Sheldrick, 2008)), with $U(\text{H})$ set to $1.5U_{\text{eq}}(\text{C})$.

The H atoms of the hydroxyl groups were allowed to rotate with a fixed angle around the C–C bond to best fit the experimental electron density (HFIX 147 in the *SHELX* program suite (Sheldrick, 2008)), with $U(\text{H})$ set to $1.5U_{\text{eq}}(\text{O})$.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å²)

	<i>x</i>	<i>y</i>	<i>z</i>	$U_{\text{iso}}^*/U_{\text{eq}}$
O1	0.62325 (6)	0.36594 (8)	0.47438 (7)	0.0378 (2)
H1A	0.695518	0.348157	0.492101	0.066 (5)*
O2	0.59660 (8)	0.13436 (8)	0.51070 (8)	0.0464 (3)
O3	0.35374 (6)	0.15502 (8)	0.47493 (7)	0.0341 (2)
H3A	0.394355	0.078645	0.474626	0.049 (4)*
C1	0.55798 (9)	0.24797 (10)	0.47994 (8)	0.0288 (2)
C2	0.42861 (8)	0.26994 (9)	0.44097 (8)	0.0266 (2)
H2	0.396479	0.360413	0.472773	0.032*
C3	0.42813 (9)	0.28752 (12)	0.32116 (8)	0.0379 (3)
H3	0.486954	0.365679	0.303082	0.046*
C4	0.47104 (15)	0.15122 (17)	0.26654 (11)	0.0592 (4)
H4A	0.472586	0.166730	0.190382	0.089*
H4B	0.414942	0.072567	0.283046	0.089*
H4C	0.553206	0.126684	0.291045	0.089*
C5	0.30193 (13)	0.3343 (2)	0.28387 (12)	0.0647 (4)
H5A	0.303823	0.351007	0.207865	0.097*
H5B	0.278457	0.422888	0.319944	0.097*
H5C	0.242457	0.258894	0.299861	0.097*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
O1	0.0214 (3)	0.0242 (4)	0.0678 (5)	−0.0016 (3)	−0.0083 (3)	0.0040 (3)
O2	0.0317 (4)	0.0245 (4)	0.0830 (6)	0.0016 (3)	−0.0136 (4)	0.0091 (4)
O3	0.0187 (3)	0.0242 (4)	0.0593 (5)	0.0019 (2)	0.0065 (3)	0.0076 (3)
C1	0.0218 (4)	0.0216 (4)	0.0431 (5)	0.0010 (3)	−0.0013 (4)	−0.0008 (3)
C2	0.0192 (4)	0.0190 (4)	0.0417 (5)	0.0006 (3)	0.0001 (4)	0.0004 (3)
C3	0.0299 (5)	0.0418 (6)	0.0421 (6)	−0.0069 (4)	−0.0015 (4)	0.0056 (4)
C4	0.0572 (8)	0.0690 (9)	0.0514 (7)	−0.0101 (7)	0.0171 (6)	−0.0167 (6)
C5	0.0441 (7)	0.0949 (12)	0.0550 (7)	0.0007 (7)	−0.0172 (6)	0.0153 (7)

Geometric parameters (Å, °)

O1—C1	1.3143 (11)	C3—C5	1.5257 (17)
O1—H1A	0.8400	C3—H3	1.0000
O2—C1	1.2064 (12)	C4—H4A	0.9800
O3—C2	1.4175 (11)	C4—H4B	0.9800
O3—H3A	0.8400	C4—H4C	0.9800
C1—C2	1.5159 (13)	C5—H5A	0.9800

C2—C3	1.5334 (14)	C5—H5B	0.9800
C2—H2	1.0000	C5—H5C	0.9800
C3—C4	1.5234 (18)		
C1—O1—H1A	109.5	C5—C3—H3	107.7
C2—O3—H3A	109.5	C2—C3—H3	107.7
O2—C1—O1	124.19 (9)	C3—C4—H4A	109.5
O2—C1—C2	123.57 (9)	C3—C4—H4B	109.5
O1—C1—C2	112.22 (8)	H4A—C4—H4B	109.5
O3—C2—C1	109.83 (7)	C3—C4—H4C	109.5
O3—C2—C3	112.46 (8)	H4A—C4—H4C	109.5
C1—C2—C3	110.06 (8)	H4B—C4—H4C	109.5
O3—C2—H2	108.1	C3—C5—H5A	109.5
C1—C2—H2	108.1	C3—C5—H5B	109.5
C3—C2—H2	108.1	H5A—C5—H5B	109.5
C4—C3—C5	112.11 (12)	C3—C5—H5C	109.5
C4—C3—C2	111.31 (10)	H5A—C5—H5C	109.5
C5—C3—C2	110.05 (9)	H5B—C5—H5C	109.5
C4—C3—H3	107.7		
O2—C1—C2—O3	17.39 (14)	O3—C2—C3—C4	-58.32 (11)
O1—C1—C2—O3	-163.81 (8)	C1—C2—C3—C4	64.49 (11)
O2—C1—C2—C3	-106.95 (12)	O3—C2—C3—C5	66.60 (12)
O1—C1—C2—C3	71.85 (10)	C1—C2—C3—C5	-170.59 (10)

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>
O1—H1A...O3 ⁱ	0.84	1.78	2.6143 (9)	169
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