



Full wwPDB X-ray Structure Validation Report ⓘ

Mar 9, 2026 – 04:40 AM UTC

PDB ID : 5AYP / pdb_00005ayp
Title : Crystal structure of Bacillus stearothermophilus Farnesyl pyrophosphate synthase
Authors : Makabe, K.; Kijima, T.
Deposited on : 2015-08-26
Resolution : 2.31 Å(reported)

This is a Full wwPDB X-ray Structure Validation Report for a publicly released PDB entry.

We welcome your comments at validation@mail.wwpdb.org

A user guide is available at

<https://www.wwpdb.org/validation/2017/XrayValidationReportHelp>

with specific help available everywhere you see the ⓘ symbol.

The types of validation reports are described at

<http://www.wwpdb.org/validation/2017/FAQs#types>.

The following versions of software and data (see [references ⓘ](#)) were used in the production of this report:

MolProbity	:	4-5-2 with Phenix2.0
Xtriage (Phenix)	:	2.0
EDS	:	3.0
Percentile statistics	:	20250101.v01 (using entries in the PDB archive January 1st 2025)
CCP4	:	9.0.010 (Gargrove)
Density-Fitness	:	1.0.12
Ideal geometry (proteins)	:	Engh & Huber (2001)
Ideal geometry (DNA, RNA)	:	Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP)	:	2.49

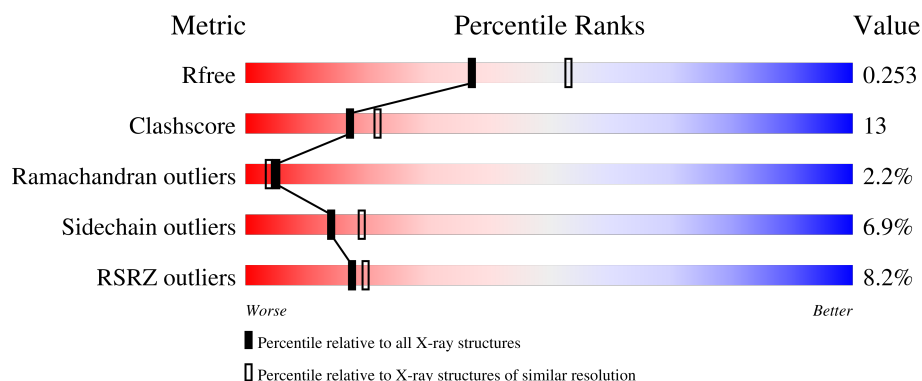
1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

X-RAY DIFFRACTION

The reported resolution of this entry is 2.31 Å.

Percentile scores (ranging between 0-100) for global validation metrics of the entry are shown in the following graphic. The table shows the number of entries on which the scores are based.



Metric	Whole archive (#Entries)	Similar resolution (#Entries, resolution range(Å))
R_{free}	180053	7754 (2.34-2.30)
Clashscore	190562	8383 (2.34-2.30)
Ramachandran outliers	187476	8303 (2.34-2.30)
Sidechain outliers	187428	8303 (2.34-2.30)
RSRZ outliers	180081	7760 (2.34-2.30)

The table below summarises the geometric issues observed across the polymeric chains and their fit to the electron density. The red, orange, yellow and green segments of the lower bar indicate the fraction of residues that contain outliers for ≥ 3 , 2, 1 and 0 types of geometric quality criteria respectively. A grey segment represents the fraction of residues that are not modelled. The numeric value for each fraction is indicated below the corresponding segment, with a dot representing fractions $\leq 5\%$. The upper red bar (where present) indicates the fraction of residues that have poor fit to the electron density. The numeric value is given above the bar.

Mol	Chain	Length	Quality of chain
1	A	297	7% 64% 17% 5% 13%
1	B	297	8% 72% 14% 11%

2 Entry composition

There are 2 unique types of molecules in this entry. The entry contains 4029 atoms, of which 0 are hydrogens and 0 are deuteriums.

In the tables below, the ZeroOcc column contains the number of atoms modelled with zero occupancy, the AltConf column contains the number of residues with at least one atom in alternate conformation and the Trace column contains the number of residues modelled with at most 2 atoms.

- Molecule 1 is a protein called Farnesyl diphosphate synthase.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
1	A	258	Total	C	N	O	S	0	0	0
			1977	1244	358	366	9			
1	B	264	Total	C	N	O	S	0	0	0
			2020	1278	357	376	9			

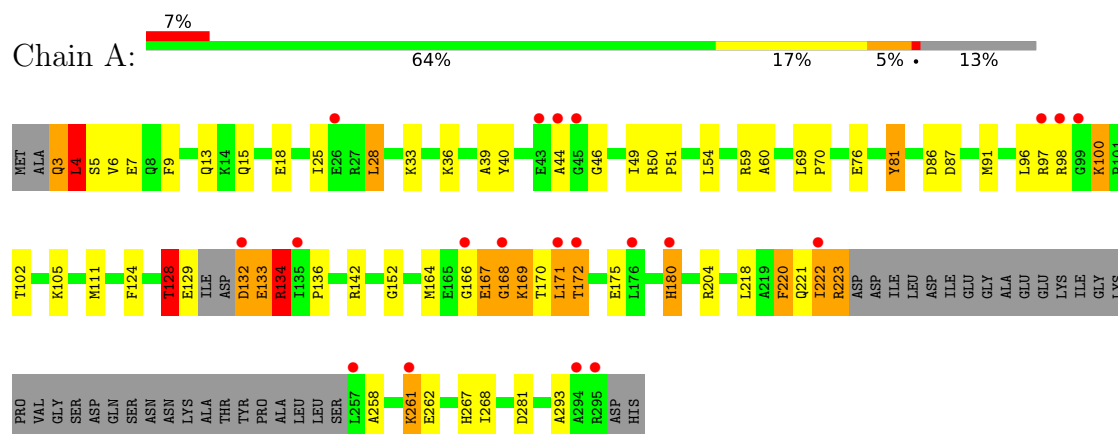
- Molecule 2 is water.

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
2	A	20	Total	O	0	0
			20	20		
2	B	12	Total	O	0	0
			12	12		

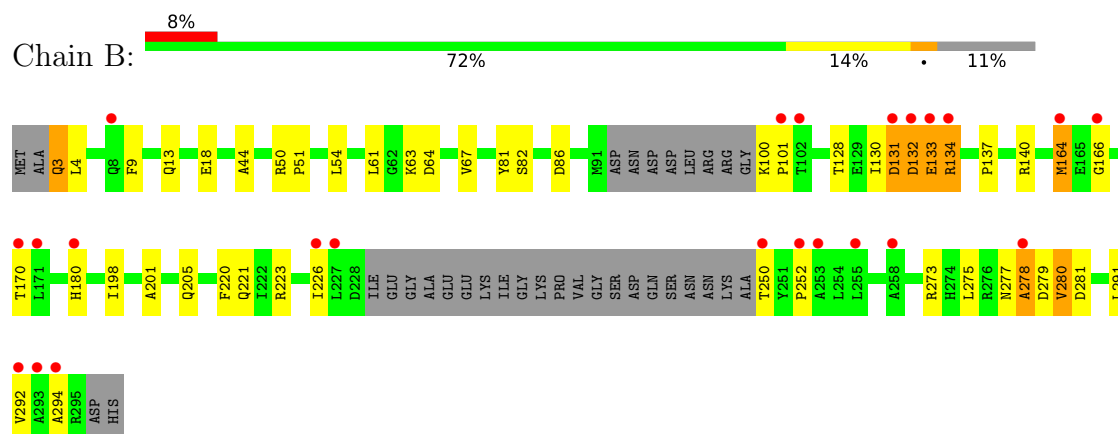
3 Residue-property plots [i](#)

These plots are drawn for all protein, RNA, DNA and oligosaccharide chains in the entry. The first graphic for a chain summarises the proportions of the various outlier classes displayed in the second graphic. The second graphic shows the sequence view annotated by issues in geometry and electron density. Residues are color-coded according to the number of geometric quality criteria for which they contain at least one outlier: green = 0, yellow = 1, orange = 2 and red = 3 or more. A red dot above a residue indicates a poor fit to the electron density ($RSRZ > 2$). Stretches of 2 or more consecutive residues without any outlier are shown as a green connector. Residues present in the sample, but not in the model, are shown in grey.

- Molecule 1: Farnesyl diphosphate synthase



- Molecule 1: Farnesyl diphosphate synthase



4 Data and refinement statistics

Property	Value	Source
Space group	P 21 21 21	Depositor
Cell constants a, b, c, α , β , γ	49.02Å 95.16Å 103.35Å 90.00° 90.00° 90.00°	Depositor
Resolution (Å)	20.00 – 2.31 20.00 – 2.31	Depositor EDS
% Data completeness (in resolution range)	99.3 (20.00-2.31) 99.6 (20.00-2.31)	Depositor EDS
R_{merge}	(Not available)	Depositor
R_{sym}	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ ¹	3.48 (at 2.30Å)	Xtriage
Refinement program	REFMAC 5.8.0049	Depositor
R, R_{free}	0.211 , 0.252 0.219 , 0.253	Depositor DCC
R_{free} test set	1120 reflections (5.10%)	wwPDB-VP
Wilson B-factor (Å ²)	35.6	Xtriage
Anisotropy	0.413	Xtriage
Bulk solvent k_{sol} (e/Å ³), B_{sol} (Å ²)	0.40 , 46.7	EDS
L-test for twinning ²	$\langle L \rangle = 0.49$, $\langle L^2 \rangle = 0.33$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
F_o, F_c correlation	0.94	EDS
Total number of atoms	4029	wwPDB-VP
Average B, all atoms (Å ²)	49.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 5.40% of the height of the origin peak. No significant pseudotranslation is detected.*

¹Intensities estimated from amplitudes.

²Theoretical values of $\langle |L| \rangle$, $\langle L^2 \rangle$ for acentric reflections are 0.5, 0.333 respectively for untwinned datasets, and 0.375, 0.2 for perfectly twinned datasets.

5 Model quality [i](#)

5.1 Standard geometry [i](#)

The Z score for a bond length (or angle) is the number of standard deviations the observed value is removed from the expected value. A bond length (or angle) with $|Z| > 5$ is considered an outlier worth inspection. RMSZ is the root-mean-square of all Z scores of the bond lengths (or angles).

Mol	Chain	Bond lengths		Bond angles	
		RMSZ	$\# Z > 5$	RMSZ	$\# Z > 5$
1	A	0.79	0/2005	0.97	6/2699 (0.2%)
1	B	0.79	0/2050	1.01	8/2765 (0.3%)
All	All	0.79	0/4055	0.99	14/5464 (0.3%)

Chiral center outliers are detected by calculating the chiral volume of a chiral center and verifying if the center is modelled as a planar moiety or with the opposite hand. A planarity outlier is detected by checking planarity of atoms in a peptide group, atoms in a mainchain group or atoms of a sidechain that are expected to be planar.

Mol	Chain	#Chirality outliers	#Planarity outliers
1	A	0	2

There are no bond length outliers.

All (14) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed($^{\circ}$)	Ideal($^{\circ}$)
1	B	280	VAL	N-CA-C	-6.31	101.12	108.82
1	A	136	PRO	CA-C-N	6.02	127.37	119.84
1	A	136	PRO	C-N-CA	6.02	127.37	119.84
1	B	132	ASP	CA-C-N	6.01	132.53	121.70
1	B	132	ASP	C-N-CA	6.01	132.53	121.70
1	A	152	GLY	CA-C-N	5.82	125.92	119.87
1	A	152	GLY	C-N-CA	5.82	125.92	119.87
1	A	46	GLY	N-CA-C	-5.30	106.23	111.85
1	B	132	ASP	N-CA-C	-5.20	105.61	111.28
1	A	128	THR	N-CA-C	5.03	117.88	111.69
1	B	280	VAL	CA-C-N	-5.03	115.86	122.85
1	B	280	VAL	C-N-CA	-5.03	115.86	122.85
1	B	280	VAL	N-CA-CB	-5.02	106.82	112.45
1	B	281	ASP	N-CA-CB	5.00	118.64	110.39

There are no chirality outliers.

All (2) planarity outliers are listed below:

Mol	Chain	Res	Type	Group
1	A	128	THR	Peptide
1	A	134	ARG	Peptide

5.2 Too-close contacts [i](#)

In the following table, the Non-H and H(model) columns list the number of non-hydrogen atoms and hydrogen atoms in the chain respectively. The H(added) column lists the number of hydrogen atoms added and optimized by MolProbity. The Clashes column lists the number of clashes within the asymmetric unit, whereas Symm-Clashes lists symmetry-related clashes.

Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
1	A	1977	0	2017	64	0
1	B	2020	0	2063	39	0
2	A	20	0	0	0	0
2	B	12	0	0	0	0
All	All	4029	0	4080	102	0

The all-atom clashscore is defined as the number of clashes found per 1000 atoms (including hydrogen atoms). The all-atom clashscore for this structure is 13.

All (102) close contacts within the same asymmetric unit are listed below, sorted by their clash magnitude.

Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:B:278:ALA:HB3	1:B:279:ASP:HA	1.24	1.13
1:B:132:ASP:HB2	1:B:133:GLU:HB2	1.48	0.94
1:B:278:ALA:HB3	1:B:279:ASP:CA	2.00	0.92
1:A:180:HIS:ND1	1:A:221:GLN:HG3	1.86	0.91
1:A:3:GLN:OE1	1:A:3:GLN:N	2.03	0.91
1:A:171:LEU:O	1:A:172:THR:OG1	1.92	0.86
1:B:132:ASP:CB	1:B:133:GLU:HB2	2.07	0.85
1:A:49:ILE:HD13	1:A:220:PHE:HZ	1.44	0.81
1:A:3:GLN:HB3	1:A:6:VAL:H	1.54	0.72
1:B:130:ILE:HG22	1:B:131:ASP:N	2.05	0.71
1:A:87:ASP:OD2	1:A:97:ARG:HD2	1.91	0.70
1:A:49:ILE:HD13	1:A:220:PHE:CZ	2.27	0.69
1:B:275:LEU:O	1:B:278:ALA:HB2	1.93	0.69
1:A:180:HIS:CE1	1:A:221:GLN:HG3	2.29	0.67
1:A:180:HIS:ND1	1:A:180:HIS:C	2.53	0.66
1:B:278:ALA:CB	1:B:279:ASP:CA	2.67	0.66

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Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:A:3:GLN:HA	1:A:4:LEU:CB	2.25	0.66
1:B:63:LYS:NZ	1:B:198:ILE:O	2.23	0.66
1:A:169:LYS:HE2	1:A:170:THR:N	2.10	0.65
1:A:218:LEU:HD13	1:A:267:HIS:CE1	2.31	0.65
1:B:130:ILE:O	1:B:131:ASP:CB	2.45	0.63
1:A:223:ARG:HG3	1:A:223:ARG:HH11	1.64	0.63
1:A:222:ILE:O	1:A:223:ARG:HG2	2.00	0.62
1:A:169:LYS:O	1:A:171:LEU:HD12	1.99	0.61
1:B:134:ARG:HG2	1:B:134:ARG:HH11	1.64	0.61
1:A:167:GLU:O	1:A:168:GLY:C	2.43	0.61
1:A:220:PHE:O	1:A:223:ARG:HD3	2.00	0.61
1:A:180:HIS:CG	1:A:221:GLN:HG3	2.36	0.60
1:A:171:LEU:O	1:A:172:THR:CB	2.50	0.59
1:B:132:ASP:CA	1:B:133:GLU:HB2	2.32	0.59
1:B:128:THR:O	1:B:140:ARG:NH2	2.35	0.58
1:A:9:PHE:CE1	1:A:59:ARG:HD2	2.38	0.58
1:A:167:GLU:O	1:A:169:LYS:N	2.37	0.57
1:A:111:MET:HE2	1:B:164:MET:HG2	1.87	0.57
1:A:258:ALA:O	1:A:261:LYS:HG3	2.05	0.56
1:A:128:THR:O	1:A:132:ASP:N	2.37	0.56
1:B:275:LEU:O	1:B:278:ALA:CB	2.53	0.56
1:A:268:ILE:HG13	1:A:293:ALA:HB2	1.88	0.56
1:A:180:HIS:HB2	1:A:221:GLN:HE21	1.71	0.55
1:A:3:GLN:CG	1:A:5:SER:HB2	2.37	0.55
1:B:273:ARG:NH2	1:B:277:ASN:OD1	2.39	0.55
1:B:223:ARG:HD2	1:B:292:VAL:HG13	1.89	0.55
1:B:130:ILE:CG2	1:B:131:ASP:N	2.70	0.54
1:A:132:ASP:OD1	1:A:132:ASP:C	2.51	0.53
1:A:172:THR:HB	1:A:175:GLU:HB2	1.91	0.53
1:A:258:ALA:O	1:A:261:LYS:CG	2.57	0.53
1:B:250:THR:HB	1:B:252:PRO:HD2	1.92	0.51
1:B:131:ASP:HB2	1:B:140:ARG:NH1	2.25	0.50
1:B:223:ARG:HA	1:B:226:ILE:HG22	1.92	0.50
1:A:51:PRO:HG3	1:A:76:GLU:HB2	1.93	0.50
1:A:9:PHE:O	1:A:13:GLN:HG2	2.12	0.50
1:B:220:PHE:O	1:B:223:ARG:HG2	2.12	0.50
1:A:133:GLU:HA	1:A:134:ARG:HH21	1.77	0.49
1:A:261:LYS:HG3	1:A:262:GLU:N	2.28	0.49
1:A:81:TYR:C	1:A:81:TYR:CD1	2.91	0.49
1:A:3:GLN:HA	1:A:4:LEU:HB3	1.95	0.48
1:B:50:ARG:HB2	1:B:51:PRO:HD3	1.95	0.48

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Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:A:180:HIS:C	1:A:180:HIS:HD1	2.21	0.48
1:A:132:ASP:O	1:A:133:GLU:O	2.32	0.48
1:B:205:GLN:HG2	1:B:278:ALA:O	2.15	0.47
1:A:25:ILE:O	1:A:28:LEU:HB2	2.15	0.47
1:A:220:PHE:C	1:A:222:ILE:H	2.22	0.47
1:B:180:HIS:CE1	1:B:221:GLN:HG2	2.50	0.47
1:B:180:HIS:CD2	1:B:221:GLN:HG2	2.49	0.47
1:A:40:TYR:OH	1:A:100:LYS:HD3	2.14	0.47
1:A:223:ARG:HD3	1:A:223:ARG:N	2.29	0.46
1:A:33:LYS:HA	1:A:36:LYS:HE3	1.96	0.46
1:A:222:ILE:C	1:A:223:ARG:HG2	2.39	0.46
1:A:3:GLN:HG2	1:A:5:SER:HB2	1.97	0.46
1:A:60:ALA:HA	1:A:281:ASP:O	2.16	0.46
1:A:3:GLN:HB3	1:A:5:SER:N	2.31	0.46
1:B:54:LEU:C	1:B:54:LEU:HD23	2.41	0.45
1:A:3:GLN:HB2	1:A:6:VAL:HG13	1.98	0.45
1:B:3:GLN:HB2	1:B:4:LEU:H	1.66	0.45
1:B:180:HIS:CG	1:B:221:GLN:HG2	2.51	0.45
1:A:54:LEU:C	1:A:54:LEU:HD23	2.41	0.45
1:A:97:ARG:HG3	1:A:102:THR:HG22	1.99	0.45
1:B:9:PHE:O	1:B:13:GLN:HG2	2.17	0.45
1:B:130:ILE:O	1:B:131:ASP:HB3	2.16	0.45
1:B:82:SER:O	1:B:86:ASP:HB2	2.17	0.44
1:A:4:LEU:HA	1:A:7:GLU:HG2	1.99	0.44
1:B:133:GLU:O	1:B:134:ARG:HB2	2.18	0.44
1:A:40:TYR:O	1:A:44:ALA:HB2	2.19	0.43
1:A:25:ILE:HG21	1:A:39:ALA:HB2	2.00	0.43
1:A:50:ARG:HB2	1:A:51:PRO:HD3	2.01	0.43
1:A:180:HIS:NE2	1:A:218:LEU:HD23	2.34	0.43
1:B:44:ALA:CB	1:B:101:PRO:HG3	2.49	0.43
1:A:164:MET:C	1:A:166:GLY:H	2.26	0.42
1:A:222:ILE:C	1:A:223:ARG:CG	2.92	0.42
1:A:96:LEU:HD23	1:A:100:LYS:C	2.45	0.42
1:A:3:GLN:N	1:A:3:GLN:CD	2.74	0.42
1:B:223:ARG:CD	1:B:292:VAL:HG13	2.49	0.42
1:A:129:GLU:O	1:A:132:ASP:HA	2.20	0.42
1:B:134:ARG:HH11	1:B:134:ARG:CG	2.31	0.42
1:B:61:LEU:HD11	1:B:201:ALA:HB2	2.01	0.41
1:B:278:ALA:CB	1:B:280:VAL:HG22	2.50	0.41
1:B:279:ASP:OD1	1:B:279:ASP:N	2.54	0.41
1:A:86:ASP:HA	1:A:91:MET:HG2	2.02	0.40

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Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:A:124:PHE:O	1:A:128:THR:HG23	2.20	0.40
1:A:69:LEU:HB3	1:A:70:PRO:HD3	2.03	0.40
1:A:3:GLN:CB	1:A:6:VAL:HG13	2.52	0.40
1:B:64:ASP:O	1:B:67:VAL:HG12	2.21	0.40

There are no symmetry-related clashes.

5.3 Torsion angles [i](#)

5.3.1 Protein backbone [i](#)

In the following table, the Percentiles column shows the percent Ramachandran outliers of the chain as a percentile score with respect to all X-ray entries followed by that with respect to entries of similar resolution.

The Analysed column shows the number of residues for which the backbone conformation was analysed, and the total number of residues.

Mol	Chain	Analysed	Favoured	Allowed	Outliers	Percentiles	
1	A	252/297 (85%)	240 (95%)	7 (3%)	5 (2%)	6	4
1	B	258/297 (87%)	244 (95%)	8 (3%)	6 (2%)	5	3
All	All	510/594 (86%)	484 (95%)	15 (3%)	11 (2%)	5	4

All (11) Ramachandran outliers are listed below:

Mol	Chain	Res	Type
1	A	4	LEU
1	A	133	GLU
1	A	172	THR
1	B	131	ASP
1	B	133	GLU
1	B	134	ARG
1	B	278	ALA
1	A	168	GLY
1	A	222	ILE
1	B	294	ALA
1	B	166	GLY

5.3.2 Protein sidechains ⓘ

In the following table, the Percentiles column shows the percent sidechain outliers of the chain as a percentile score with respect to all X-ray entries followed by that with respect to entries of similar resolution.

The Analysed column shows the number of residues for which the sidechain conformation was analysed, and the total number of residues.

Mol	Chain	Analysed	Rotameric	Outliers	Percentiles	
1	A	199/231 (86%)	179 (90%)	20 (10%)	7	8
1	B	205/231 (89%)	197 (96%)	8 (4%)	28	42
All	All	404/462 (87%)	376 (93%)	28 (7%)	14	19

All (28) residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	3	GLN
1	A	4	LEU
1	A	15	GLN
1	A	18	GLU
1	A	28	LEU
1	A	81	TYR
1	A	98	ARG
1	A	100	LYS
1	A	105	LYS
1	A	132	ASP
1	A	134	ARG
1	A	142	ARG
1	A	167	GLU
1	A	169	LYS
1	A	171	LEU
1	A	180	HIS
1	A	204	ARG
1	A	220	PHE
1	A	223	ARG
1	A	261	LYS
1	B	3	GLN
1	B	18	GLU
1	B	81	TYR
1	B	100	LYS
1	B	137	PRO
1	B	164	MET
1	B	170	THR

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Mol	Chain	Res	Type
1	B	291	LEU

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (3) such sidechains are listed below:

Mol	Chain	Res	Type
1	A	103	ASN
1	A	221	GLN
1	A	272	GLN

5.3.3 RNA [i](#)

There are no RNA molecules in this entry.

5.4 Non-standard residues in protein, DNA, RNA chains [i](#)

There are no non-standard protein/DNA/RNA residues in this entry.

5.5 Carbohydrates [i](#)

There are no oligosaccharides in this entry.

5.6 Ligand geometry [i](#)

There are no ligands in this entry.

5.7 Other polymers [i](#)

There are no such residues in this entry.

5.8 Polymer linkage issues [i](#)

There are no chain breaks in this entry.

6 Fit of model and data

6.1 Protein, DNA and RNA chains

In the following table, the column labelled ‘#RSRZ> 2’ contains the number (and percentage) of RSRZ outliers, followed by percent RSRZ outliers for the chain as percentile scores relative to all X-ray entries and entries of similar resolution. The OWAB column contains the minimum, median, 95th percentile and maximum values of the occupancy-weighted average B-factor per residue. The column labelled ‘Q< 0.9’ lists the number of (and percentage) of residues with an average occupancy less than 0.9.

Mol	Chain	Analysed	<RSRZ>	#RSRZ>2	OWAB(Å ²)	Q<0.9
1	A	258/297 (86%)	0.27	20 (7%) 19 21	30, 42, 82, 106	0
1	B	264/297 (88%)	0.39	23 (8%) 16 18	30, 45, 82, 101	0
All	All	522/594 (87%)	0.33	43 (8%) 17 20	30, 43, 82, 106	0

All (43) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	B	278	ALA	5.0
1	A	168	GLY	3.5
1	A	257	LEU	3.4
1	B	132	ASP	3.4
1	A	97	ARG	3.3
1	A	294	ALA	3.3
1	B	164	MET	3.3
1	A	180	HIS	3.2
1	B	227	LEU	3.2
1	B	131	ASP	3.1
1	B	294	ALA	3.1
1	B	171	LEU	3.0
1	A	99	GLY	3.0
1	B	102	THR	2.9
1	A	26	GLU	2.9
1	B	133	GLU	2.7
1	B	226	ILE	2.7
1	A	171	LEU	2.6
1	B	258	ALA	2.6
1	A	132	ASP	2.6
1	B	170	THR	2.6
1	B	250	THR	2.6
1	A	261	LYS	2.6
1	A	176	LEU	2.5

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Mol	Chain	Res	Type	RSRZ
1	A	222	ILE	2.5
1	B	134	ARG	2.5
1	B	166	GLY	2.4
1	A	295	ARG	2.4
1	B	255	LEU	2.4
1	B	252	PRO	2.3
1	A	45	GLY	2.3
1	B	253	ALA	2.3
1	A	172	THR	2.3
1	A	44	ALA	2.2
1	B	293	ALA	2.2
1	A	98	ARG	2.2
1	B	292	VAL	2.2
1	A	166	GLY	2.2
1	A	43	GLU	2.1
1	B	8	GLN	2.1
1	B	180	HIS	2.0
1	A	135	ILE	2.0
1	B	101	PRO	2.0

6.2 Non-standard residues in protein, DNA, RNA chains [i](#)

There are no non-standard protein/DNA/RNA residues in this entry.

6.3 Carbohydrates [i](#)

There are no oligosaccharides in this entry.

6.4 Ligands [i](#)

There are no ligands in this entry.

6.5 Other polymers [i](#)

There are no such residues in this entry.