



Full wwPDB X-ray Structure Validation Report ⓘ

Mar 6, 2026 – 06:32 PM UTC

PDB ID : 4APA / pdb_00004apa
Title : Crystal structure of Mycobacterium tuberculosis fumarase (Rv1098c) S318A
in apo form
Authors : Bellinzoni, M.; Haouz, A.; Mechaly, A.E.; Alzari, P.M.
Deposited on : 2012-03-31
Resolution : 2.04 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

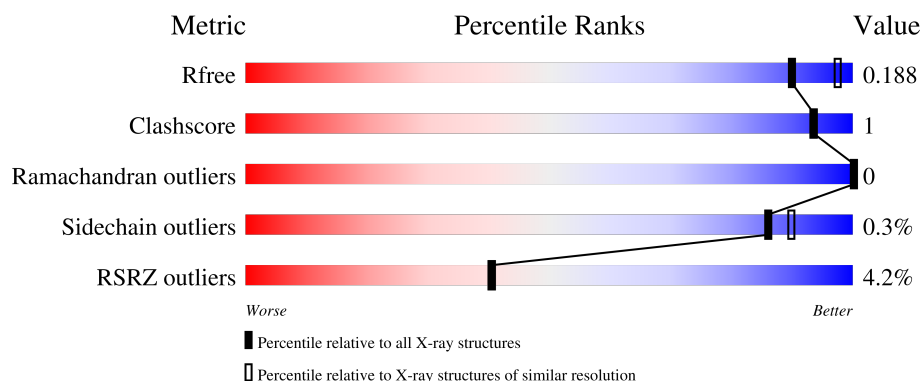
1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

X-RAY DIFFRACTION

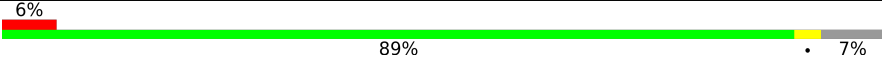
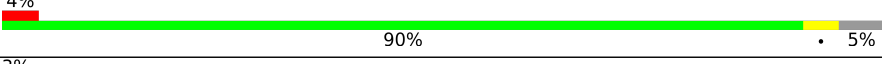
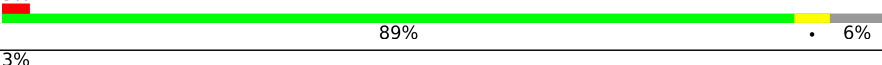
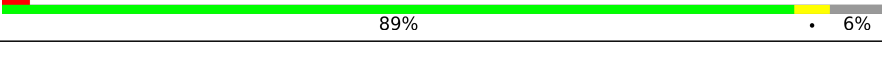
The reported resolution of this entry is 2.04 Å.

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	2260 (2.04-2.04)
Clashscore	190562	2333 (2.04-2.04)
Ramachandran outliers	187476	2318 (2.04-2.04)
Sidechain outliers	187428	2318 (2.04-2.04)
RSRZ outliers	180081	2260 (2.04-2.04)

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	474	 6% 89% 5% 0% 0%
1	B	474	 4% 90% 5% 0% 0%
1	C	474	 3% 89% 6% 0% 0%
1	D	474	 3% 89% 6% 0% 0%

2 Entry composition

There are 2 unique types of molecules in this entry. The entry contains 13702 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 FUMARATE HYDRATASE CLASS II.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
1	A	440	Total	C	N	O	S	0	1	0
			3175	1976	573	616	10			
1	B	449	Total	C	N	O	S	0	0	0
			3278	2046	589	632	11			
1	C	445	Total	C	N	O	S	0	0	0
			3244	2025	587	622	10			
1	D	444	Total	C	N	O	S	0	0	0
			3207	2003	575	619	10			

There are 8 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	1	GLY	-	expression tag	UNP O53446
A	318	ALA	SER	engineered mutation	UNP O53446
B	1	GLY	-	expression tag	UNP O53446
B	318	ALA	SER	engineered mutation	UNP O53446
C	1	GLY	-	expression tag	UNP O53446
C	318	ALA	SER	engineered mutation	UNP O53446
D	1	GLY	-	expression tag	UNP O53446
D	318	ALA	SER	engineered mutation	UNP O53446

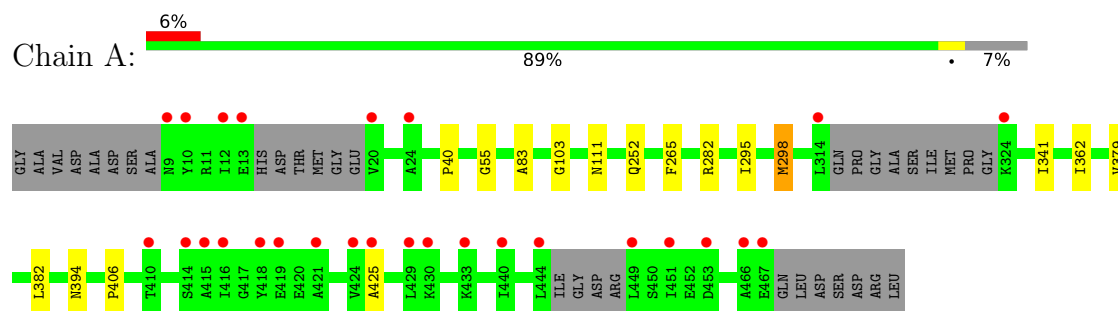
- Molecule 2 is water.

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
2	A	212	Total	O	0	0
			212	212		
2	B	156	Total	O	0	0
			156	156		
2	C	227	Total	O	0	0
			227	227		
2	D	203	Total	O	0	0
			203	203		

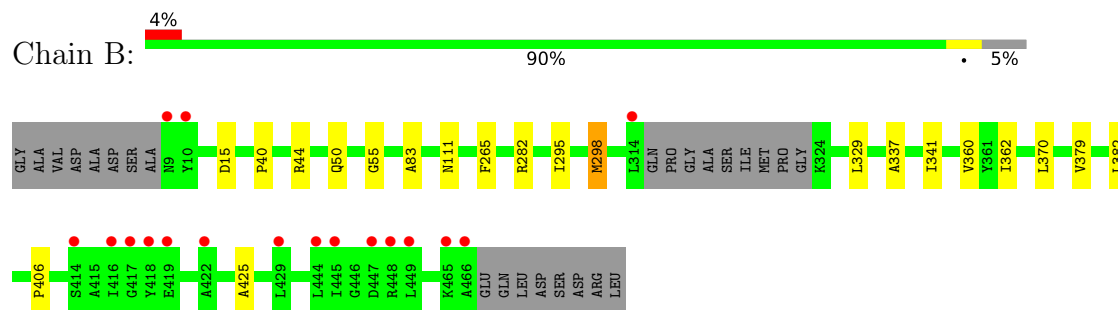
3 Residue-property plots

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.

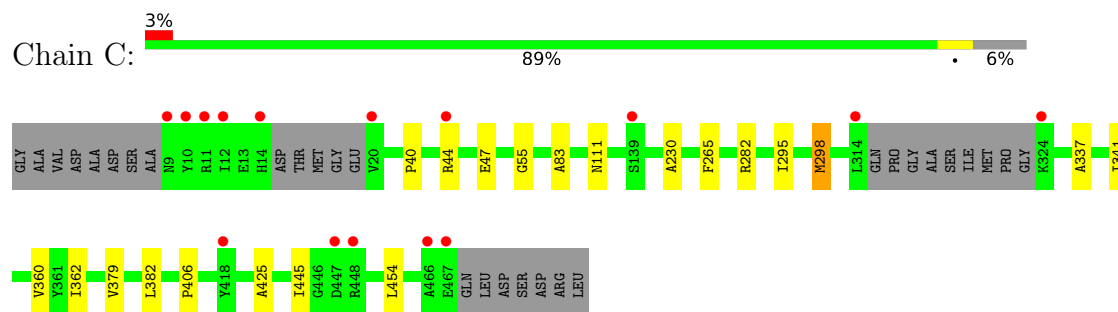
• Molecule 1: FUMARATE HYDRATASE CLASS II



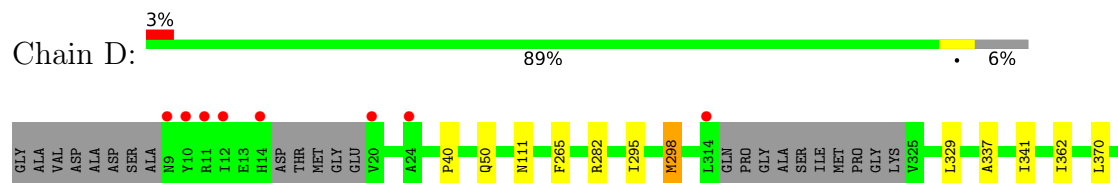
• Molecule 1: FUMARATE HYDRATASE CLASS II

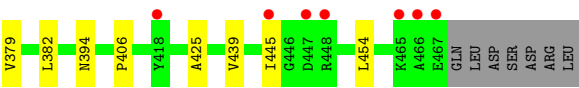


• Molecule 1: FUMARATE HYDRATASE CLASS II



• Molecule 1: FUMARATE HYDRATASE CLASS II





4 Data and refinement statistics

Property	Value	Source
Space group	C 1 2 1	Depositor
Cell constants a, b, c, α , β , γ	268.27Å 97.14Å 96.44Å 90.00° 104.54° 90.00°	Depositor
Resolution (Å)	43.41 – 2.04 43.41 – 2.04	Depositor EDS
% Data completeness (in resolution range)	97.2 (43.41-2.04) 97.9 (43.41-2.04)	Depositor EDS
R_{merge}	0.08	Depositor
R_{sym}	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ ¹	2.10 (at 2.05Å)	Xtriage
Refinement program	BUSTER 2.11.2	Depositor
R, R_{free}	0.165 , 0.179 0.171 , 0.188	Depositor DCC
R_{free} test set	7424 reflections (4.97%)	wwPDB-VP
Wilson B-factor (Å ²)	25.9	Xtriage
Anisotropy	0.532	Xtriage
Bulk solvent k_{sol} (e/Å ³), B_{sol} (Å ²)	0.35 , 42.7	EDS
L-test for twinning ²	$\langle L \rangle = 0.47$, $\langle L^2 \rangle = 0.30$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
F_o, F_c correlation	0.96	EDS
Total number of atoms	13702	wwPDB-VP
Average B, all atoms (Å ²)	34.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 5.96% 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

5.1 Standard geometry

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	0.87	1/3219 (0.0%)	1.24	6/4389 (0.1%)
1	B	0.86	1/3324 (0.0%)	1.23	4/4529 (0.1%)
1	C	0.88	1/3287 (0.0%)	1.22	6/4475 (0.1%)
1	D	0.89	1/3250 (0.0%)	1.22	5/4431 (0.1%)
All	All	0.88	4/13080 (0.0%)	1.23	21/17824 (0.1%)

All (4) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
1	A	298	MET	SD-CE	-6.69	1.62	1.79
1	B	298	MET	SD-CE	-6.28	1.63	1.79
1	D	298	MET	SD-CE	-6.08	1.64	1.79
1	C	298	MET	SD-CE	-5.99	1.64	1.79

All (21) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
1	C	362	ILE	N-CA-CB	6.16	115.25	110.45
1	B	362	ILE	N-CA-CB	6.03	115.16	110.45
1	D	111	ASN	CA-CB-CG	5.86	118.46	112.60
1	D	362	ILE	N-CA-CB	5.84	115.01	110.45
1	C	111	ASN	CA-CB-CG	5.78	118.38	112.60
1	A	111	ASN	CA-CB-CG	5.65	118.25	112.60
1	A	362	ILE	N-CA-CB	5.59	114.81	110.45
1	C	265	PHE	CA-CB-CG	-5.50	108.30	113.80
1	B	111	ASN	CA-CB-CG	5.46	118.06	112.60
1	D	394	ASN	CA-C-N	5.41	127.85	120.77
1	D	394	ASN	C-N-CA	5.41	127.85	120.77
1	D	265	PHE	CA-CB-CG	-5.38	108.42	113.80
1	C	47	GLU	CA-C-N	5.26	127.59	120.38
1	C	47	GLU	C-N-CA	5.26	127.59	120.38
1	A	394	ASN	CA-C-N	5.23	127.62	120.77
1	A	394	ASN	C-N-CA	5.23	127.62	120.77

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Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
1	B	15	ASP	CA-CB-CG	5.19	117.79	112.60
1	A	103	GLY	N-CA-C	5.12	120.08	114.40
1	A	265	PHE	CA-CB-CG	-5.08	108.72	113.80
1	B	265	PHE	CA-CB-CG	-5.06	108.74	113.80
1	C	230	ALA	N-CA-C	5.05	116.47	111.07

There are no chirality outliers.

There are no planarity outliers.

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	3175	0	3117	7	0
1	B	3278	0	3265	12	0
1	C	3244	0	3242	11	0
1	D	3207	0	3174	10	0
2	A	212	0	0	1	0
2	B	156	0	0	1	0
2	C	227	0	0	2	0
2	D	203	0	0	0	0
All	All	13702	0	12798	35	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 1.

All (35) 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:40:PRO:HD2	1:C:382:LEU:HD11	1.86	0.57
1:C:445:ILE:HD11	1:C:454:LEU:HD22	1.88	0.56
1:B:50:GLN:HG2	1:B:370:LEU:CD1	2.36	0.55
1:D:445:ILE:HD11	1:D:454:LEU:HD22	1.89	0.55
1:B:382:LEU:HD11	1:C:40:PRO:HD2	1.88	0.54
1:B:44:ARG:HG3	1:C:44:ARG:HH22	1.73	0.53
1:C:282:ARG:HG2	1:C:341:ILE:HD13	1.92	0.51

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Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:A:40:PRO:HD2	1:D:382:LEU:HD11	1.93	0.49
1:B:282:ARG:HG2	1:B:341:ILE:HD13	1.94	0.49
1:A:282:ARG:HG2	1:A:341:ILE:HD13	1.95	0.48
1:D:282:ARG:HG2	1:D:341:ILE:HD13	1.93	0.48
1:D:295:ILE:HA	1:D:298:MET:HE3	1.96	0.48
1:B:50:GLN:HG2	1:B:370:LEU:HD13	1.95	0.48
1:B:295:ILE:HA	1:B:298:MET:HE3	1.97	0.47
1:A:295:ILE:HA	1:A:298:MET:HE3	1.97	0.46
1:C:295:ILE:HA	1:C:298:MET:HE3	1.97	0.46
1:A:382:LEU:HD11	1:D:40:PRO:HD2	1.98	0.46
1:B:360:VAL:HG22	2:B:2138:HOH:O	2.17	0.44
1:C:44:ARG:HG2	2:C:2188:HOH:O	2.18	0.43
1:D:406:PRO:HB3	1:D:425:ALA:HB1	1.99	0.43
1:A:406:PRO:HB3	1:A:425:ALA:HB1	2.01	0.43
1:B:55:GLY:O	1:B:83:ALA:HB1	2.18	0.42
1:C:360:VAL:HG22	2:C:2180:HOH:O	2.19	0.42
1:A:252[B]:GLN:NE2	2:A:2030:HOH:O	2.52	0.42
1:C:337:ALA:O	1:C:341:ILE:HG12	2.20	0.42
1:C:406:PRO:HB3	1:C:425:ALA:HB1	2.02	0.42
1:C:55:GLY:O	1:C:83:ALA:HB1	2.20	0.41
1:B:406:PRO:HB3	1:B:425:ALA:HB1	2.02	0.41
1:A:55:GLY:O	1:A:83:ALA:HB1	2.20	0.41
1:D:50:GLN:HG2	1:D:370:LEU:CD1	2.50	0.41
1:D:337:ALA:O	1:D:341:ILE:HG12	2.21	0.41
1:B:329:LEU:HD23	1:B:329:LEU:HA	1.93	0.40
1:D:329:LEU:HD23	1:D:329:LEU:HA	1.97	0.40
1:B:337:ALA:O	1:B:341:ILE:HG12	2.21	0.40
1:D:439:VAL:HG11	1:D:454:LEU:HD13	2.03	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	433/474 (91%)	423 (98%)	10 (2%)	0	100	100
1	B	445/474 (94%)	435 (98%)	10 (2%)	0	100	100
1	C	439/474 (93%)	429 (98%)	10 (2%)	0	100	100
1	D	438/474 (92%)	428 (98%)	10 (2%)	0	100	100
All	All	1755/1896 (93%)	1715 (98%)	40 (2%)	0	100	100

There are no Ramachandran outliers to report.

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	313/362 (86%)	312 (100%)	1 (0%)	86	90
1	B	330/362 (91%)	329 (100%)	1 (0%)	86	90
1	C	325/362 (90%)	324 (100%)	1 (0%)	86	90
1	D	318/362 (88%)	317 (100%)	1 (0%)	86	90
All	All	1286/1448 (89%)	1282 (100%)	4 (0%)	86	90

All (4) residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	379	VAL
1	B	379	VAL
1	C	379	VAL
1	D	379	VAL

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (22) such sidechains are listed below:

Mol	Chain	Res	Type
1	A	31	GLN
1	A	38	ASN
1	A	339	GLN

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Mol	Chain	Res	Type
1	A	353	ASN
1	A	368	ASN
1	B	178	HIS
1	B	339	GLN
1	B	368	ASN
1	B	413	ASN
1	C	252	GLN
1	C	268	GLN
1	C	339	GLN
1	C	343	ASN
1	C	353	ASN
1	C	368	ASN
1	C	413	ASN
1	D	252	GLN
1	D	310	GLN
1	D	339	GLN
1	D	343	ASN
1	D	368	ASN
1	D	394	ASN

5.3.3 RNA ⓘ

There are no RNA molecules in this entry.

5.4 Non-standard residues in protein, DNA, RNA chains ⓘ

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

5.5 Carbohydrates ⓘ

There are no oligosaccharides in this entry.

5.6 Ligand geometry ⓘ

There are no ligands in this entry.

5.7 Other polymers ⓘ

There are no such residues in this entry.

5.8 Polymer linkage issues ⓘ

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	440/474 (92%)	0.02	27 (6%) 27 27	19, 31, 77, 93	1 (0%)
1	B	449/474 (94%)	-0.03	17 (3%) 44 44	20, 33, 69, 106	0
1	C	445/474 (93%)	-0.29	15 (3%) 48 48	18, 27, 52, 110	0
1	D	444/474 (93%)	-0.20	15 (3%) 48 48	19, 27, 59, 101	0
All	All	1778/1896 (93%)	-0.12	74 (4%) 40 40	18, 29, 67, 110	1 (0%)

All (74) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	C	14	HIS	7.6
1	B	466	ALA	7.4
1	D	14	HIS	6.8
1	D	12	ILE	6.2
1	A	444	LEU	6.1
1	A	467	GLU	5.6
1	D	314	LEU	5.4
1	B	314	LEU	5.1
1	C	9	ASN	5.0
1	C	20	VAL	4.9
1	A	414	SER	4.7
1	D	467	GLU	4.4
1	C	314	LEU	4.4
1	D	9	ASN	4.3
1	A	314	LEU	4.3
1	C	447	ASP	4.3
1	A	418	TYR	4.3
1	A	449	LEU	4.1
1	B	445	ILE	4.0
1	A	20	VAL	3.8
1	A	9	ASN	3.8

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Mol	Chain	Res	Type	RSRZ
1	C	467	GLU	3.8
1	D	20	VAL	3.8
1	A	10	TYR	3.7
1	B	447	ASP	3.6
1	A	416	ILE	3.6
1	C	10	TYR	3.6
1	D	418	TYR	3.5
1	D	447	ASP	3.5
1	B	418	TYR	3.4
1	A	419	GLU	3.3
1	D	10	TYR	3.3
1	A	421	ALA	3.2
1	C	324	LYS	3.2
1	C	11	ARG	3.1
1	B	429	LEU	3.1
1	C	418	TYR	3.0
1	A	440	ILE	3.0
1	A	430	LYS	3.0
1	A	24	ALA	3.0
1	A	12	ILE	3.0
1	A	451	ILE	3.0
1	D	466	ALA	2.9
1	A	415	ALA	2.9
1	B	419	GLU	2.9
1	B	9	ASN	2.8
1	B	448	ARG	2.8
1	C	466	ALA	2.8
1	C	139	SER	2.8
1	D	11	ARG	2.8
1	A	466	ALA	2.8
1	B	414	SER	2.7
1	B	465	LYS	2.7
1	B	10	TYR	2.7
1	D	24	ALA	2.6
1	D	448	ARG	2.5
1	A	324	LYS	2.4
1	A	433	LYS	2.4
1	C	12	ILE	2.4
1	A	425	ALA	2.4
1	C	448	ARG	2.3
1	D	445	ILE	2.3
1	A	424	VAL	2.2

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Mol	Chain	Res	Type	RSRZ
1	B	422	ALA	2.2
1	A	429	LEU	2.2
1	B	416	ILE	2.2
1	C	44	ARG	2.2
1	B	417	GLY	2.1
1	A	453	ASP	2.1
1	B	444	LEU	2.1
1	A	410	THR	2.1
1	A	13	GLU	2.0
1	B	449	LEU	2.0
1	D	465	LYS	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.