



Full wwPDB X-ray Structure Validation Report ⓘ

Mar 9, 2026 – 05:07 PM UTC

PDB ID : 6NZ9 / pdb_00006nz9
Title : Crystal structure of E. coli fumarase C bound to citrate at 1.53 angstrom resolution
Authors : Stuttgart, G.M.; May, J.F.; Bhattacharyya, B.; Weaver, T.M.
Deposited on : 2019-02-13
Resolution : 1.53 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
Mogul	:	2022.3.0, CSD as543be (2022)
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

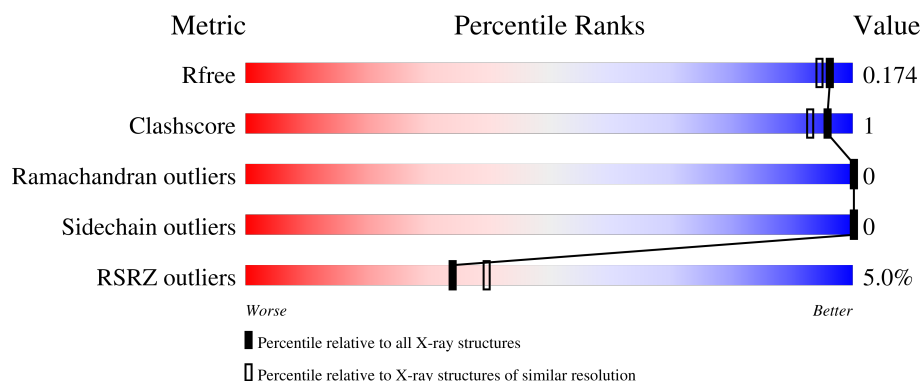
1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

X-RAY DIFFRACTION

The reported resolution of this entry is 1.53 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	5890 (1.54-1.50)
Clashscore	190562	6116 (1.54-1.50)
Ramachandran outliers	187476	6002 (1.54-1.50)
Sidechain outliers	187428	5999 (1.54-1.50)
RSRZ outliers	180081	5891 (1.54-1.50)

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	472	2% 95% • •
1	B	472	8% 93% • •

2 Entry composition

There are 3 unique types of molecules in this entry. The entry contains 7813 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.

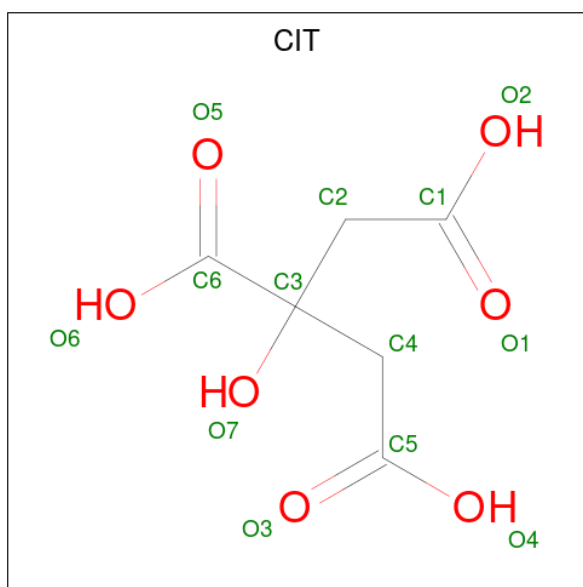
- Molecule 1 is a protein called Fumarate hydratase class II.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
1	A	456	Total	C	N	O	S	0	6	0
			3503	2187	626	667	23			
1	B	459	Total	C	N	O	S	0	7	0
			3524	2201	629	670	24			

There are 10 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	468	HIS	-	expression tag	UNP P05042
A	469	HIS	-	expression tag	UNP P05042
A	470	HIS	-	expression tag	UNP P05042
A	471	HIS	-	expression tag	UNP P05042
A	472	HIS	-	expression tag	UNP P05042
B	468	HIS	-	expression tag	UNP P05042
B	469	HIS	-	expression tag	UNP P05042
B	470	HIS	-	expression tag	UNP P05042
B	471	HIS	-	expression tag	UNP P05042
B	472	HIS	-	expression tag	UNP P05042

- Molecule 2 is CITRIC ACID (CCD ID: CIT) (formula: C₆H₈O₇).



Mol	Chain	Residues	Atoms			ZeroOcc	AltConf
2	A	1	Total	C	O	0	0
			13	6	7		
2	A	1	Total	C	O	0	0
			13	6	7		
2	B	1	Total	C	O	0	0
			13	6	7		
2	B	1	Total	C	O	0	0
			13	6	7		

- Molecule 3 is water.

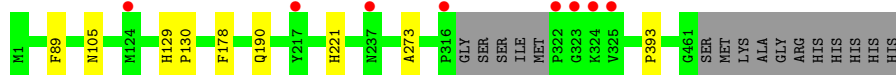
Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
3	A	396	Total	O	0	0
			396	396		
3	B	338	Total	O	0	0
			338	338		

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.

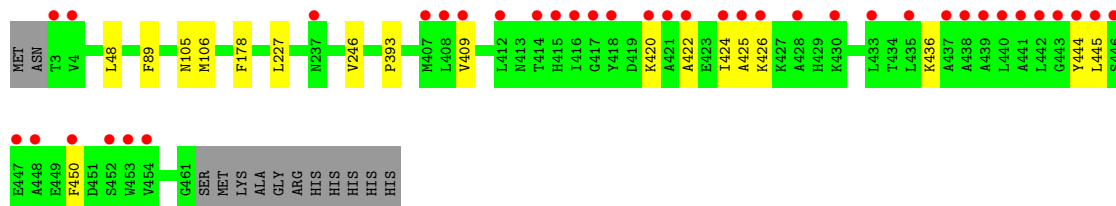
- Molecule 1: Fumarate hydratase class II

Chain A: 2% 95%



- Molecule 1: Fumarate hydratase class II

Chain B: 8% 93%



4 Data and refinement statistics

Property	Value	Source
Space group	C 2 2 21	Depositor
Cell constants a, b, c, α , β , γ	103.16Å 216.68Å 86.94Å 90.00° 90.00° 90.00°	Depositor
Resolution (Å)	45.98 – 1.53 45.98 – 1.53	Depositor EDS
% Data completeness (in resolution range)	100.0 (45.98-1.53) 100.0 (45.98-1.53)	Depositor EDS
R_{merge}	0.09	Depositor
R_{sym}	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ ¹	2.48 (at 1.52Å)	Xtriage
Refinement program	PHENIX 1.13_2998	Depositor
R, R_{free}	0.157 , 0.173 0.156 , 0.174	Depositor DCC
R_{free} test set	7329 reflections (4.99%)	wwPDB-VP
Wilson B-factor (Å ²)	16.7	Xtriage
Anisotropy	0.309	Xtriage
Bulk solvent k_{sol} (e/Å ³), B_{sol} (Å ²)	0.36 , 35.5	EDS
L-test for twinning ²	$\langle L \rangle = 0.50$, $\langle L^2 \rangle = 0.34$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
F_o, F_c correlation	0.97	EDS
Total number of atoms	7813	wwPDB-VP
Average B, all atoms (Å ²)	21.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 4.07% 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](#)

Bond lengths and bond angles in the following residue types are not validated in this section: CIT

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	0.25	0/3566	0.48	0/4829
1	B	0.24	0/3591	0.48	0/4862
All	All	0.24	0/7157	0.48	0/9691

There are no bond length outliers.

There are no bond angle outliers.

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	3503	0	3522	5	0
1	B	3524	0	3551	10	0
2	A	26	0	10	0	0
2	B	26	0	10	0	0
3	A	396	0	0	1	0
3	B	338	0	0	0	0
All	All	7813	0	7093	15	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 (15) 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:422:ALA:O	1:B:426:LYS:HD3	1.94	0.67
1:A:89:PHE:HA	1:A:105:ASN:HD21	1.60	0.66
1:B:89:PHE:HA	1:B:105:ASN:HD21	1.63	0.62
1:A:190[B]:GLN:NE2	3:A:601:HOH:O	2.33	0.62
1:B:227:LEU:HD23	1:B:246:VAL:HG21	2.00	0.43
1:B:178:PHE:CZ	1:B:393:PRO:HD3	2.53	0.43
1:B:420:LYS:HD3	1:B:444:TYR:CD2	2.54	0.43
1:A:178:PHE:CZ	1:A:393:PRO:HD3	2.54	0.42
1:B:420:LYS:O	1:B:424:ILE:HG13	2.20	0.41
1:B:445:LEU:HD13	1:B:450:PHE:HB2	2.01	0.41
1:A:221:HIS:CD2	1:A:273:ALA:HB2	2.55	0.41
1:B:409:VAL:HG21	1:B:425:ALA:HB2	2.02	0.40
1:A:129:HIS:HA	1:A:130:PRO:HD3	1.97	0.40
1:B:48:LEU:HB3	1:B:106:MET:HE3	2.03	0.40
1:B:436:LYS:HE3	1:B:450:PHE:CD1	2.56	0.40

There are no symmetry-related clashes.

5.3 Torsion angles ⓘ

5.3.1 Protein backbone ⓘ

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	458/472 (97%)	447 (98%)	11 (2%)	0	100	100
1	B	464/472 (98%)	454 (98%)	10 (2%)	0	100	100
All	All	922/944 (98%)	901 (98%)	21 (2%)	0	100	100

There are no Ramachandran outliers to report.

5.3.2 Protein sidechains [i](#)

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	374/381 (98%)	374 (100%)	0	100	100
1	B	377/381 (99%)	377 (100%)	0	100	100
All	All	751/762 (99%)	751 (100%)	0	100	100

There are no protein residues with a non-rotameric sidechain to report.

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (13) such sidechains are listed below:

Mol	Chain	Res	Type
1	A	105	ASN
1	A	163	GLN
1	A	169	GLN
1	A	211	ASN
1	A	355	ASN
1	A	384	ASN
1	B	84	GLN
1	B	105	ASN
1	B	188	HIS
1	B	329	GLN
1	B	384	ASN
1	B	399	ASN
1	B	403	ASN

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](#)

4 ligands are modelled in this entry.

In the following table, the Counts columns list the number of bonds (or angles) for which Mogul statistics could be retrieved, the number of bonds (or angles) that are observed in the model and the number of bonds (or angles) that are defined in the Chemical Component Dictionary. The Link column lists molecule types, if any, to which the group is linked. 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 $|Z| > 2$ is considered an outlier worth inspection. RMSZ is the root-mean-square of all Z scores of the bond lengths (or angles).

Mol	Type	Chain	Res	Link	Bond lengths			Bond angles		
					Counts	RMSZ	$\# Z > 2$	Counts	RMSZ	$\# Z > 2$
2	CIT	B	502	-	12,12,12	1.17	0	17,17,17	1.35	1 (5%)
2	CIT	A	501	-	12,12,12	1.12	0	17,17,17	1.44	2 (11%)
2	CIT	A	502	-	12,12,12	1.09	0	17,17,17	1.29	1 (5%)
2	CIT	B	501	-	12,12,12	1.07	0	17,17,17	1.49	1 (5%)

In the following table, the Chirals column lists the number of chiral outliers, the number of chiral centers analysed, the number of these observed in the model and the number defined in the Chemical Component Dictionary. Similar counts are reported in the Torsion and Rings columns. '-' means no outliers of that kind were identified.

Mol	Type	Chain	Res	Link	Chirals	Torsions	Rings
2	CIT	B	502	-	-	7/16/16/16	-
2	CIT	A	501	-	-	6/16/16/16	-
2	CIT	A	502	-	-	0/16/16/16	-
2	CIT	B	501	-	-	0/16/16/16	-

There are no bond length outliers.

All (5) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
2	B	501	CIT	O6-C6-C3	4.00	120.81	113.14
2	A	501	CIT	O6-C6-C3	3.61	120.07	113.14
2	B	502	CIT	O6-C6-C3	3.29	119.45	113.14
2	A	502	CIT	O6-C6-C3	2.95	118.79	113.14
2	A	501	CIT	O2-C1-C2	2.01	120.72	114.35

There are no chirality outliers.

All (13) torsion outliers are listed below:

Mol	Chain	Res	Type	Atoms
2	B	502	CIT	C4-C3-C6-O6
2	A	501	CIT	C1-C2-C3-O7
2	A	501	CIT	C2-C3-C6-O6
2	A	501	CIT	C4-C3-C6-O6
2	B	502	CIT	C2-C3-C6-O6
2	B	502	CIT	C4-C3-C6-O5
2	A	501	CIT	C2-C3-C6-O5
2	B	502	CIT	C2-C3-C6-O5
2	B	502	CIT	C1-C2-C3-O7
2	A	501	CIT	O7-C3-C6-O6
2	B	502	CIT	O7-C3-C6-O5
2	B	502	CIT	O7-C3-C6-O6
2	A	501	CIT	C4-C3-C6-O5

There are no ring outliers.

No monomer is involved in short contacts.

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	456/472 (96%)	-0.22	8 (1%) 67 73	8, 17, 29, 58	6 (1%)
1	B	459/472 (97%)	0.11	38 (8%) 17 20	8, 18, 56, 72	7 (1%)
All	All	915/944 (96%)	-0.05	46 (5%) 34 40	8, 18, 44, 72	13 (1%)

All (46) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	A	325	VAL	6.0
1	A	322	PRO	5.7
1	B	445	LEU	5.4
1	A	323	GLY	5.2
1	B	440	LEU	5.1
1	B	3	THR	4.9
1	B	424	ILE	4.7
1	B	433	LEU	4.1
1	B	453	TRP	3.9
1	B	444	TYR	3.8
1	B	441	ALA	3.7
1	B	448	ALA	3.7
1	B	442	LEU	3.6
1	B	421	ALA	3.6
1	B	422	ALA	3.6
1	B	439	ALA	3.5
1	B	452	SER	3.3
1	B	450	PHE	3.3
1	B	416	ILE	3.3
1	B	418	TYR	3.2
1	B	4	VAL	3.1
1	B	437	ALA	2.9
1	B	417	GLY	2.9
1	B	407	MET	2.8

Continued on next page...

Continued from previous page...

Mol	Chain	Res	Type	RSRZ
1	B	425	ALA	2.7
1	B	438	ALA	2.7
1	B	412	LEU	2.7
1	A	217	TYR	2.6
1	B	447	GLU	2.6
1	B	237	ASN	2.5
1	A	324	LYS	2.5
1	B	443	GLY	2.5
1	A	237	ASN	2.4
1	B	435	LEU	2.4
1	B	454	VAL	2.4
1	B	430	LYS	2.4
1	B	414	THR	2.4
1	B	446	SER	2.4
1	B	426	LYS	2.3
1	B	428	ALA	2.2
1	B	408	LEU	2.2
1	A	316	PRO	2.2
1	B	409	VAL	2.2
1	B	420	LYS	2.2
1	A	124	MET	2.1
1	B	415	HIS	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](#)

In the following table, the Atoms column lists the number of modelled atoms in the group and the number defined in the chemical component dictionary. The B-factors column lists the minimum, median, 95th percentile and maximum values of B factors of atoms in the group. The column labelled 'Q< 0.9' lists the number of atoms with occupancy less than 0.9.

Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(Å ²)	Q<0.9
2	CIT	B	502	13/13	0.73	0.16	25,37,41,43	0

Continued on next page...

Continued from previous page...

Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors($\text{\AA}^2$)	Q<0.9
2	CIT	B	501	13/13	0.90	0.10	23,27,36,41	0
2	CIT	A	501	13/13	0.92	0.08	23,26,31,32	0
2	CIT	A	502	13/13	0.92	0.10	22,25,43,49	0

6.5 Other polymers [i](#)

There are no such residues in this entry.