



wwPDB X-ray Structure Validation Summary Report ⓘ

Mar 5, 2026 – 08:08 PM UTC

PDB ID : 5GJA / pdb_00005gja
Title : Crystal structure of Arabidopsis thaliana ACO2 in complex with 2-PA
Authors : Sun, X.Z.; Li, Y.X.; He, W.R.; Ji, C.G.; Xia, P.X.; Wang, Y.C.; Du, S.; Li, H.J.; Raikhel, N.; Xiao, J.Y.; Guo, H.W.
Deposited on : 2016-06-28
Resolution : 2.10 Å(reported)

This is a wwPDB X-ray Structure Validation Summary 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

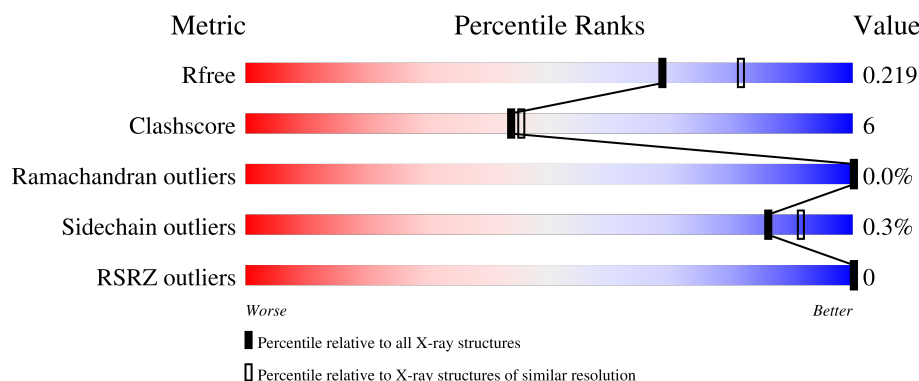
1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

X-RAY DIFFRACTION

The reported resolution of this entry is 2.10 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	6658 (2.10-2.10)
Clashscore	190562	7164 (2.10-2.10)
Ramachandran outliers	187476	7099 (2.10-2.10)
Sidechain outliers	187428	7100 (2.10-2.10)
RSRZ outliers	180081	6662 (2.10-2.10)

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	303	
1	B	303	
1	C	303	
1	D	303	
1	E	303	

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Mol	Chain	Length	Quality of chain
1	F	303	 89% 9% •
1	G	303	 89% 9% •
1	H	303	 78% 17% 5%

2 Entry composition

There are 4 unique types of molecules in this entry. The entry contains 20234 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 1-aminocyclopropane-1-carboxylate oxidase 2.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
1	A	299	Total	C	N	O	S	0	0	0
			2386	1514	395	463	14			
1	B	298	Total	C	N	O	S	0	0	0
			2378	1509	394	462	13			
1	C	298	Total	C	N	O	S	0	0	0
			2378	1509	394	462	13			
1	D	299	Total	C	N	O	S	0	0	0
			2386	1514	395	463	14			
1	E	288	Total	C	N	O	S	0	0	0
			2302	1461	381	448	12			
1	F	298	Total	C	N	O	S	0	0	0
			2378	1509	394	462	13			
1	G	298	Total	C	N	O	S	0	0	0
			2378	1509	394	462	13			
1	H	287	Total	C	N	O	S	0	0	0
			2294	1457	380	445	12			

- Molecule 2 is ZINC ION (CCD ID: ZN) (formula: Zn).

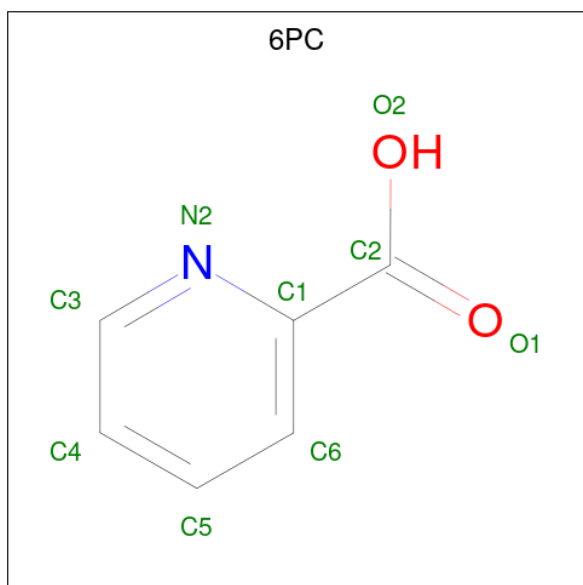
Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
2	A	1	Total	Zn	0	0
			1	1		
2	B	1	Total	Zn	0	0
			1	1		
2	C	1	Total	Zn	0	0
			1	1		
2	D	1	Total	Zn	0	0
			1	1		
2	E	1	Total	Zn	0	0
			1	1		
2	F	1	Total	Zn	0	0
			1	1		

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Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
2	G	1	Total	Zn	0	0
			1	1		
2	H	1	Total	Zn	0	0
			1	1		

- Molecule 3 is PYRIDINE-2-CARBOXYLIC ACID (CCD ID: 6PC) (formula: $C_6H_5NO_2$).



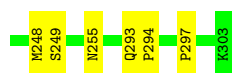
Mol	Chain	Residues	Atoms				ZeroOcc	AltConf
3	A	1	Total	C	N	O	0	0
			9	6	1	2		
3	B	1	Total	C	N	O	0	0
			9	6	1	2		
3	C	1	Total	C	N	O	0	0
			9	6	1	2		
3	D	1	Total	C	N	O	0	0
			9	6	1	2		
3	E	1	Total	C	N	O	0	0
			9	6	1	2		
3	F	1	Total	C	N	O	0	0
			9	6	1	2		
3	G	1	Total	C	N	O	0	0
			9	6	1	2		
3	H	1	Total	C	N	O	0	0
			9	6	1	2		

- Molecule 4 is water.

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
4	A	178	Total 178	O 178	0	0
4	B	156	Total 156	O 156	0	0
4	C	149	Total 149	O 149	0	0
4	D	183	Total 183	O 183	0	0
4	E	130	Total 130	O 130	0	0
4	F	178	Total 178	O 178	0	0
4	G	159	Total 159	O 159	0	0
4	H	141	Total 141	O 141	0	0

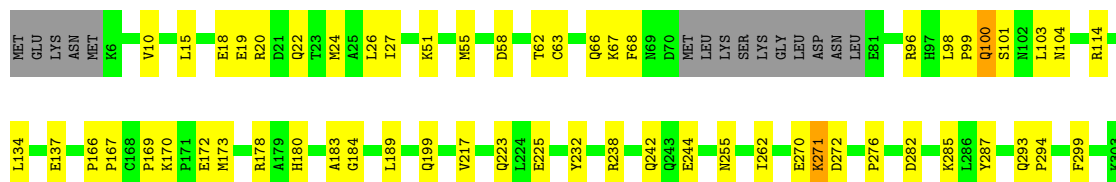
- Molecule 1: 1-aminocyclopropane-1-carboxylate oxidase 2





- Molecule 1: 1-aminocyclopropane-1-carboxylate oxidase 2

Chain E: 76% 18% 5%



- Molecule 1: 1-aminocyclopropane-1-carboxylate oxidase 2

Chain F: 89% 9% .



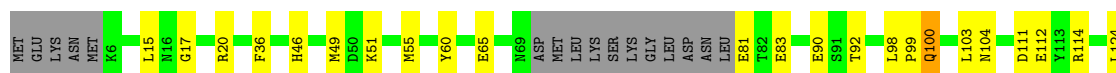
- Molecule 1: 1-aminocyclopropane-1-carboxylate oxidase 2

Chain G: 89% 9% .



- Molecule 1: 1-aminocyclopropane-1-carboxylate oxidase 2

Chain H: 78% 17% 5%



4 Data and refinement statistics

Property	Value	Source
Space group	P 1	Depositor
Cell constants a, b, c, α , β , γ	69.45Å 95.34Å 95.89Å 90.06° 89.48° 89.99°	Depositor
Resolution (Å)	48.59 – 2.10 48.59 – 2.10	Depositor EDS
% Data completeness (in resolution range)	96.9 (48.59-2.10) 92.2 (48.59-2.10)	Depositor EDS
R_{merge}	0.10	Depositor
R_{sym}	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ ¹	1.88 (at 2.10Å)	Xtriage
Refinement program	PHENIX (1.10.1_2155: ???)	Depositor
R, R_{free}	0.171 , 0.218 0.172 , 0.219	Depositor DCC
R_{free} test set	2027 reflections (1.44%)	wwPDB-VP
Wilson B-factor (Å ²)	22.1	Xtriage
Anisotropy	1.140	Xtriage
Bulk solvent k_{sol} (e/Å ³), B_{sol} (Å ²)	0.33 , 26.5	EDS
L-test for twinning ²	$\langle L \rangle = 0.51$, $\langle L^2 \rangle = 0.35$	Xtriage
Estimated twinning fraction	0.000 for h,l,-k 0.000 for h,-l,k 0.055 for h,-k,-l 0.457 for -h,k,-l 0.054 for -h,-k,l 0.000 for -h,l,k 0.000 for -h,-l,-k	Xtriage
F_o, F_c correlation	0.98	EDS
Total number of atoms	20234	wwPDB-VP
Average B, all atoms (Å ²)	37.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The analyses of the Patterson function reveals a significant off-origin peak that is 42.68 % of the origin peak, indicating pseudo-translational symmetry. The chance of finding a peak of this or larger height randomly in a structure without pseudo-translational symmetry is equal to 1.9678e-04. The detected translational NCS is most likely also responsible for the elevated intensity ratio.*

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: ZN, 6PC

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	0.34	0/2438	0.54	0/3292
1	B	0.35	0/2430	0.56	1/3282 (0.0%)
1	C	0.35	0/2430	0.60	3/3282 (0.1%)
1	D	0.36	0/2438	0.64	4/3292 (0.1%)
1	E	0.38	0/2353	0.61	0/3179
1	F	0.36	0/2430	0.60	2/3282 (0.1%)
1	G	0.33	0/2430	0.60	3/3282 (0.1%)
1	H	0.34	0/2345	0.63	1/3168 (0.0%)
All	All	0.35	0/19294	0.60	14/26059 (0.1%)

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	E	0	1

There are no bond length outliers.

The worst 5 of 14 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
1	D	170	LYS	CB-CG-CD	-12.08	83.51	111.30
1	G	16	ASN	N-CA-C	10.92	125.16	112.93
1	H	100	GLN	CA-CB-CG	-9.11	95.88	114.10
1	D	170	LYS	CG-CD-CE	8.83	131.60	111.30
1	F	55	MET	CG-SD-CE	-8.45	82.31	100.90

There are no chirality outliers.

All (1) planarity outliers are listed below:

Mol	Chain	Res	Type	Group
1	E	100	GLN	Sidechain

5.2 Too-close contacts ⓘ

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	2386	0	2338	20	0
1	B	2378	0	2329	26	1
1	C	2378	0	2329	32	0
1	D	2386	0	2338	28	0
1	E	2302	0	2242	50	0
1	F	2378	0	2329	17	0
1	G	2378	0	2329	16	0
1	H	2294	0	2238	45	0
2	A	1	0	0	0	0
2	B	1	0	0	0	0
2	C	1	0	0	0	0
2	D	1	0	0	0	0
2	E	1	0	0	0	0
2	F	1	0	0	0	0
2	G	1	0	0	0	0
2	H	1	0	0	0	0
3	A	9	0	4	0	0
3	B	9	0	4	0	0
3	C	9	0	4	0	0
3	D	9	0	4	0	0
3	E	9	0	4	0	0
3	F	9	0	4	0	0
3	G	9	0	4	0	0
3	H	9	0	4	0	0
4	A	178	0	0	2	0
4	B	156	0	0	2	0
4	C	149	0	0	7	0
4	D	183	0	0	1	0
4	E	130	0	0	4	1
4	F	178	0	0	3	0
4	G	159	0	0	1	0
4	H	141	0	0	4	0
All	All	20234	0	18504	227	1

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 6.

The worst 5 of 227 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:H:170:LYS:HE2	1:H:173:MET:HG3	1.30	1.14
1:E:18:GLU:OE2	4:E:501:HOH:O	1.97	0.82
1:H:99:PRO:O	1:H:100:GLN:HG2	1.81	0.80
1:E:20:ARG:NH1	4:E:502:HOH:O	2.13	0.80
1:B:103:LEU:HG	1:B:114:ARG:HG3	1.69	0.73

All (1) symmetry-related close contacts are listed below. The label for Atom-2 includes the symmetry operator and encoded unit-cell translations to be applied.

Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:B:6:LYS:O	4:E:501:HOH:O[1_545]	2.08	0.12

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	297/303 (98%)	294 (99%)	3 (1%)	0	100	100
1	B	296/303 (98%)	292 (99%)	4 (1%)	0	100	100
1	C	296/303 (98%)	290 (98%)	6 (2%)	0	100	100
1	D	297/303 (98%)	293 (99%)	4 (1%)	0	100	100
1	E	284/303 (94%)	280 (99%)	3 (1%)	1 (0%)	30	28
1	F	296/303 (98%)	289 (98%)	7 (2%)	0	100	100
1	G	296/303 (98%)	288 (97%)	8 (3%)	0	100	100
1	H	283/303 (93%)	279 (99%)	4 (1%)	0	100	100
All	All	2345/2424 (97%)	2305 (98%)	39 (2%)	1 (0%)	100	100

All (1) Ramachandran outliers are listed below:

Mol	Chain	Res	Type
1	E	271	LYS

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	267/271 (98%)	265 (99%)	2 (1%)	76	83
1	B	266/271 (98%)	266 (100%)	0	100	100
1	C	266/271 (98%)	265 (100%)	1 (0%)	84	89
1	D	267/271 (98%)	266 (100%)	1 (0%)	84	89
1	E	257/271 (95%)	257 (100%)	0	100	100
1	F	266/271 (98%)	265 (100%)	1 (0%)	84	89
1	G	266/271 (98%)	266 (100%)	0	100	100
1	H	256/271 (94%)	255 (100%)	1 (0%)	84	89
All	All	2111/2168 (97%)	2105 (100%)	6 (0%)	86	91

5 of 6 residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	D	62	THR
1	F	286	LEU
1	H	135	LEU
1	A	286	LEU
1	A	18	GLU

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. 5 of 41 such sidechains are listed below:

Mol	Chain	Res	Type
1	F	229	ASN
1	H	41	ASN
1	G	64	GLN
1	G	293	GLN

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Mol	Chain	Res	Type
1	H	100	GLN

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 ⓘ

Of 16 ligands modelled in this entry, 8 are monoatomic - leaving 8 for Mogul analysis.

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$
3	6PC	D	402	2	9,9,9	0.98	0	11,11,11	2.01	4 (36%)
3	6PC	H	402	2	9,9,9	1.10	0	11,11,11	1.49	2 (18%)
3	6PC	F	402	2	9,9,9	0.91	0	11,11,11	1.75	4 (36%)
3	6PC	C	402	2	9,9,9	1.11	1 (11%)	11,11,11	1.54	2 (18%)
3	6PC	B	402	2	9,9,9	0.85	0	11,11,11	1.87	4 (36%)
3	6PC	G	402	2	9,9,9	1.07	0	11,11,11	1.84	2 (18%)
3	6PC	E	402	2	9,9,9	1.03	1 (11%)	11,11,11	1.77	4 (36%)
3	6PC	A	402	2	9,9,9	1.18	1 (11%)	11,11,11	1.56	4 (36%)

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
3	6PC	D	402	2	-	0/4/4/4	0/1/1/1
3	6PC	H	402	2	-	0/4/4/4	0/1/1/1
3	6PC	F	402	2	-	0/4/4/4	0/1/1/1
3	6PC	C	402	2	-	0/4/4/4	0/1/1/1
3	6PC	B	402	2	-	0/4/4/4	0/1/1/1
3	6PC	G	402	2	-	0/4/4/4	0/1/1/1
3	6PC	E	402	2	-	0/4/4/4	0/1/1/1
3	6PC	A	402	2	-	0/4/4/4	0/1/1/1

All (3) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
3	A	402	6PC	O1-C2	2.22	1.29	1.22
3	E	402	6PC	C5-C6	-2.09	1.35	1.38
3	C	402	6PC	O1-C2	2.05	1.28	1.22

The worst 5 of 26 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
3	G	402	6PC	C3-N2-C1	3.98	122.06	116.93
3	G	402	6PC	C4-C3-N2	-3.71	117.54	123.42
3	B	402	6PC	C3-N2-C1	3.64	121.62	116.93
3	D	402	6PC	C3-N2-C1	3.36	121.26	116.93
3	C	402	6PC	C3-N2-C1	3.26	121.13	116.93

There are no chirality outliers.

There are no torsion outliers.

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 [i](#)

6.1 Protein, DNA and RNA chains [i](#)

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	299/303 (98%)	-1.65	0 100 100	15, 30, 61, 97	0
1	B	298/303 (98%)	-1.62	0 100 100	20, 35, 66, 105	0
1	C	298/303 (98%)	-1.62	0 100 100	20, 35, 67, 102	0
1	D	299/303 (98%)	-1.68	0 100 100	17, 31, 62, 100	0
1	E	288/303 (95%)	-1.59	0 100 100	20, 37, 75, 101	0
1	F	298/303 (98%)	-1.63	0 100 100	18, 32, 70, 97	0
1	G	298/303 (98%)	-1.64	0 100 100	18, 32, 70, 99	0
1	H	287/303 (94%)	-1.58	0 100 100	19, 36, 76, 104	0
All	All	2365/2424 (97%)	-1.63	0 100 100	15, 34, 69, 105	0

There are no RSRZ outliers to report.

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($\text{\AA}^2$)	Q<0.9
3	6PC	C	402	9/9	0.99	0.02	18,23,27,28	0
2	ZN	B	401	1/1	1.00	0.01	20,20,20,20	0
2	ZN	C	401	1/1	1.00	0.01	21,21,21,21	0
2	ZN	D	401	1/1	1.00	0.01	21,21,21,21	0
2	ZN	E	401	1/1	1.00	0.01	25,25,25,25	0
2	ZN	F	401	1/1	1.00	0.01	23,23,23,23	0
2	ZN	G	401	1/1	1.00	0.01	21,21,21,21	0
2	ZN	H	401	1/1	1.00	0.01	22,22,22,22	0
3	6PC	A	402	9/9	1.00	0.02	17,21,25,26	0
3	6PC	B	402	9/9	1.00	0.02	18,22,26,27	0
2	ZN	A	401	1/1	1.00	0.01	22,22,22,22	0
3	6PC	D	402	9/9	1.00	0.02	17,22,27,30	0
3	6PC	E	402	9/9	1.00	0.02	21,25,30,31	0
3	6PC	F	402	9/9	1.00	0.02	17,22,27,29	0
3	6PC	G	402	9/9	1.00	0.01	16,19,25,25	0
3	6PC	H	402	9/9	1.00	0.02	15,19,30,31	0

6.5 Other polymers [i](#)

There are no such residues in this entry.