



Full wwPDB X-ray Structure Validation Report ⓘ

Apr 25, 2026 – 04:47 PM EDT

PDB ID : 4MQS / pdb_00004mq
Title : Structure of active human M2 muscarinic acetylcholine receptor bound to the agonist iperoxo
Authors : Kruse, A.C.; Ring, A.M.; Manglik, A.; Hu, J.; Hu, K.; Eitel, K.; Huebner, H.; Pardon, E.; Valant, C.; Sexton, P.M.; Christopoulos, A.; Felder, C.C.; Gmeiner, P.; Steyaert, J.; Weis, W.I.; Garcia, K.C.; Wess, J.; Kobilka, B.K.
Deposited on : 2013-09-16
Resolution : 3.50 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

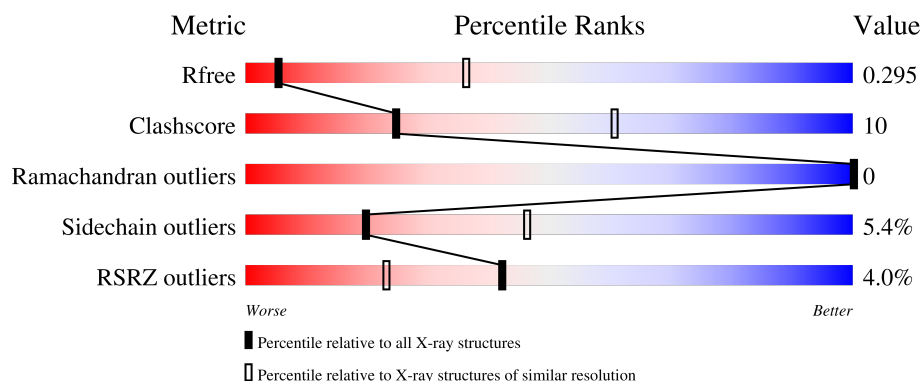
1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

X-RAY DIFFRACTION

The reported resolution of this entry is 3.50 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	1085 (3.54-3.46)
Clashscore	190562	1140 (3.54-3.46)
Ramachandran outliers	187476	1113 (3.54-3.46)
Sidechain outliers	187428	1114 (3.54-3.46)
RSRZ outliers	180081	1084 (3.54-3.46)

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	351	2% 56% 21% • 21%
2	B	125	8% 84% 10% • •

2 Entry composition

There are 3 unique types of molecules in this entry. The entry contains 3034 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 Muscarinic acetylcholine receptor M2.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
1	A	277	Total	C	N	O	S	0	0	0
			2128	1431	323	357	17			

There are 31 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	-16	ASP	-	expression tag	UNP P08172
A	-15	TYR	-	expression tag	UNP P08172
A	-14	LYS	-	expression tag	UNP P08172
A	-13	ASP	-	expression tag	UNP P08172
A	-12	ASP	-	expression tag	UNP P08172
A	-11	ASP	-	expression tag	UNP P08172
A	-10	GLU	-	expression tag	UNP P08172
A	-9	ASN	-	expression tag	UNP P08172
A	-8	LEU	-	expression tag	UNP P08172
A	-7	TYR	-	expression tag	UNP P08172
A	-6	PHE	-	expression tag	UNP P08172
A	-5	GLN	-	expression tag	UNP P08172
A	-4	GLY	-	expression tag	UNP P08172
A	-3	LEU	-	expression tag	UNP P08172
A	-2	GLU	-	expression tag	UNP P08172
A	0	ASP	ASN	engineered mutation	UNP P08172
A	1	ASP	ASN	engineered mutation	UNP P08172
A	4	ASP	ASN	engineered mutation	UNP P08172
A	7	ASP	ASN	engineered mutation	UNP P08172
A	17	LEU	-	insertion	UNP P08172
A	18	GLU	-	insertion	UNP P08172
A	373	THR	ALA	engineered mutation	UNP P08172
A	374	ARG	LYS	engineered mutation	UNP P08172
A	467	HIS	-	expression tag	UNP P08172
A	468	HIS	-	expression tag	UNP P08172
A	469	HIS	-	expression tag	UNP P08172
A	470	HIS	-	expression tag	UNP P08172

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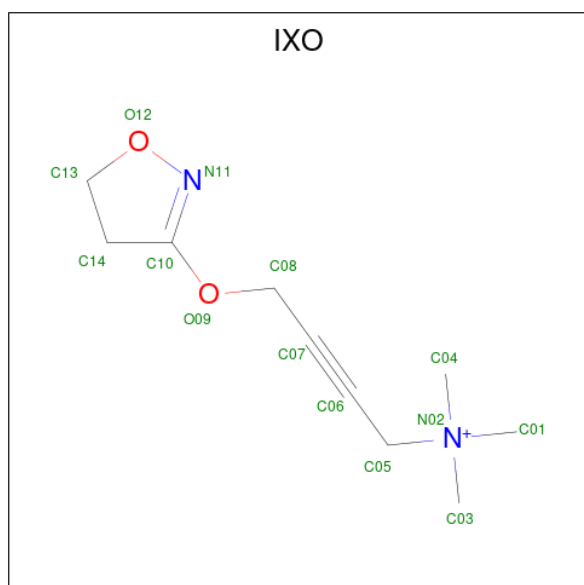
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Chain	Residue	Modelled	Actual	Comment	Reference
A	471	HIS	-	expression tag	UNP P08172
A	472	HIS	-	expression tag	UNP P08172
A	473	HIS	-	expression tag	UNP P08172
A	474	HIS	-	expression tag	UNP P08172

- Molecule 2 is a protein called Nanobody 9-8.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
2	B	121	Total	C	N	O	S	0	0	0
			892	550	149	189	4			

- Molecule 3 is 4-(4,5-dihydro-1,2-oxazol-3-yloxy)-N,N,N-trimethylbut-2-yn-1-aminium (CCD ID: IXO) (formula: C₁₀H₁₇N₂O₂).

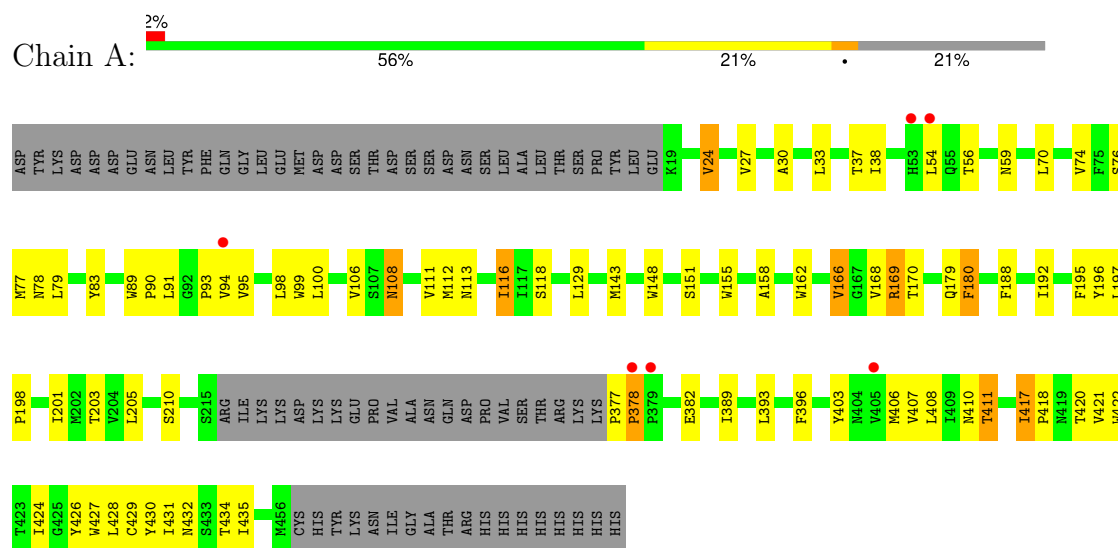


Mol	Chain	Residues	Atoms				ZeroOcc	AltConf
3	A	1	Total	C	N	O	0	0
			14	10	2	2		

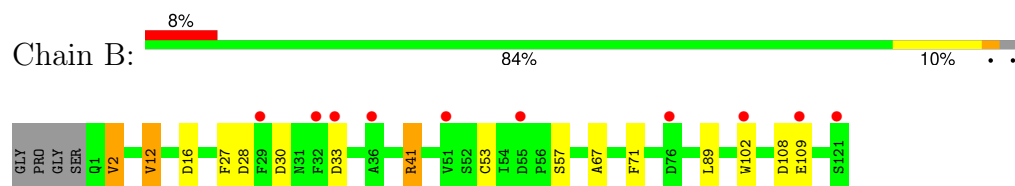
3 Residue-property plots [i](#)

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: Muscarinic acetylcholine receptor M2



• Molecule 2: Nanobody 9-8



4 Data and refinement statistics

Property	Value	Source
Space group	P 21 21 21	Depositor
Cell constants a, b, c, α , β , γ	62.90Å 78.13Å 163.48Å 90.00° 90.00° 90.00°	Depositor
Resolution (Å)	32.52 – 3.50 32.52 – 3.50	Depositor EDS
% Data completeness (in resolution range)	96.1 (32.52-3.50) 92.2 (32.52-3.50)	Depositor EDS
R_{merge}	0.19	Depositor
R_{sym}	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ ¹	1.15 (at 3.32Å)	Xtriage
Refinement program	PHENIX (phenix.refine: dev_1241)	Depositor
R, R_{free}	0.249 , 0.298 0.252 , 0.295	Depositor DCC
R_{free} test set	1189 reflections (9.38%)	wwPDB-VP
Wilson B-factor (Å ²)	83.8	Xtriage
Anisotropy	0.502	Xtriage
Bulk solvent k_{sol} (e/Å ³), B_{sol} (Å ²)	0.27 , 77.0	EDS
L-test for twinning ²	$\langle L \rangle = 0.43$, $\langle L^2 \rangle = 0.26$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
F_o, F_c correlation	0.89	EDS
Total number of atoms	3034	wwPDB-VP
Average B, all atoms (Å ²)	117.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 6.45% 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: IXO

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	0.35	0/2191	0.82	5/3018 (0.2%)
2	B	0.32	0/911	0.78	1/1242 (0.1%)
All	All	0.34	0/3102	0.81	6/4260 (0.1%)

There are no bond length outliers.

All (6) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
1	A	378	PRO	CB-CA-C	-8.78	100.21	110.92
1	A	378	PRO	N-CA-C	8.57	121.15	110.70
1	A	378	PRO	CA-C-N	5.69	126.95	119.84
1	A	378	PRO	C-N-CA	5.69	126.95	119.84
2	B	2	VAL	N-CA-C	5.12	116.34	108.71
1	A	417	ILE	N-CA-C	5.02	113.36	107.89

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	2128	0	2111	51	0
2	B	892	0	784	9	0
3	A	14	0	17	1	0

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Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
All	All	3034	0	2912	58	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 10.

All (58) 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:A:77:MET:HE2	1:A:430:TYR:HB3	1.64	0.79
1:A:162:TRP:HD1	1:A:179:GLN:HG3	1.57	0.70
1:A:108:ASN:HD21	1:A:112:MET:HE2	1.58	0.68
2:B:53:CYS:HB2	2:B:102:TRP:HH2	1.60	0.66
1:A:166:VAL:HG12	1:A:168:VAL:H	1.67	0.59
2:B:67:ALA:HB1	2:B:71:PHE:CD2	2.37	0.59
2:B:33:ASP:O	2:B:57:SER:OG	2.18	0.59
1:A:111:VAL:HG22	1:A:396:PHE:HE2	1.70	0.57
1:A:108:ASN:OD1	1:A:155:TRP:NE1	2.39	0.56
1:A:38:ILE:HG21	1:A:74:VAL:HB	1.88	0.55
1:A:38:ILE:HG22	1:A:70:LEU:HD12	1.88	0.55
1:A:118:SER:HB3	1:A:205:LEU:HD11	1.89	0.54
1:A:129:LEU:HD21	2:B:53:CYS:HB3	1.89	0.54
1:A:33:LEU:HD21	1:A:431:ILE:HG22	1.89	0.54
1:A:418:PRO:HG2	1:A:421:VAL:HB	1.91	0.53
1:A:76:SER:HA	1:A:99:TRP:HE1	1.73	0.53
1:A:203:THR:HG22	1:A:393:LEU:HD13	1.91	0.52
2:B:12:VAL:HG13	2:B:16:ASP:HB2	1.91	0.52
1:A:90:PRO:HG2	1:A:91:LEU:HD12	1.91	0.52
1:A:403:TYR:HB3	1:A:429:CYS:SG	2.50	0.52
1:A:188:PHE:CE1	1:A:408:LEU:HG	2.45	0.51
1:A:91:LEU:HB3	1:A:95:VAL:HG11	1.92	0.51
1:A:95:VAL:HA	1:A:98:LEU:HB2	1.92	0.51
1:A:37:THR:HG23	1:A:434:THR:HA	1.96	0.47
1:A:74:VAL:O	1:A:78:ASN:ND2	2.36	0.47
1:A:54:LEU:O	1:A:59:ASN:ND2	2.47	0.47
1:A:410:ASN:HB2	1:A:417:ILE:HD12	1.96	0.47
1:A:93:PRO:HB3	1:A:169:ARG:CZ	2.45	0.47
1:A:91:LEU:HB3	1:A:95:VAL:CG1	2.46	0.46
1:A:406:MET:HE1	1:A:422:TRP:HA	1.98	0.46
1:A:197:LEU:HB3	1:A:198:PRO:HD3	1.97	0.46
1:A:192:ILE:HA	1:A:196:TYR:HD2	1.81	0.46
2:B:2:VAL:HG11	2:B:27:PHE:CE1	2.50	0.45

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Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:A:210:SER:HB3	1:A:389:ILE:HD12	1.99	0.45
1:A:108:ASN:HB3	1:A:151:SER:HB3	1.99	0.45
1:A:195:PHE:C	1:A:198:PRO:HD2	2.41	0.44
1:A:70:LEU:O	1:A:74:VAL:HG12	2.18	0.44
1:A:30:ALA:HB1	1:A:427:TRP:CH2	2.53	0.43
1:A:195:PHE:HB2	3:A:501:IXO:H113	1.99	0.43
1:A:420:THR:O	1:A:424:ILE:HG13	2.17	0.43
1:A:188:PHE:CE1	1:A:411:THR:HG21	2.54	0.43
1:A:158:ALA:O	1:A:162:TRP:HB2	2.19	0.43
1:A:106:VAL:HG12	1:A:148:TRP:HZ3	1.83	0.43
1:A:24:VAL:O	1:A:27:VAL:HG12	2.19	0.42
1:A:79:LEU:HD23	1:A:89:TRP:HH2	1.84	0.42
1:A:432:ASN:HA	1:A:435:ILE:HG12	2.01	0.42
1:A:406:MET:CE	1:A:422:TRP:HA	2.50	0.41
1:A:83:TYR:CD1	1:A:89:TRP:HB2	2.56	0.41
1:A:377:PRO:HA	1:A:378:PRO:HD3	1.97	0.41
1:A:180:PHE:C	1:A:180:PHE:HD1	2.29	0.41
1:A:116:ILE:HG12	1:A:143:MET:HB3	2.02	0.41
2:B:28:ASP:C	2:B:30:ASP:H	2.29	0.41
1:A:378:PRO:HB2	1:A:382:GLU:HB3	2.02	0.41
1:A:201:ILE:O	1:A:205:LEU:HG	2.21	0.41
1:A:100:LEU:HD23	1:A:100:LEU:HA	1.85	0.40
2:B:41:ARG:O	2:B:41:ARG:HG2	2.20	0.40
1:A:111:VAL:HG22	1:A:396:PHE:CE2	2.54	0.40
1:A:56:THR:HG21	2:B:109:GLU:HB3	2.03	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	273/351 (78%)	264 (97%)	9 (3%)	0	100 100

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Mol	Chain	Analysed	Favoured	Allowed	Outliers	Percentiles	
2	B	119/125 (95%)	116 (98%)	3 (2%)	0	100	100
All	All	392/476 (82%)	380 (97%)	12 (3%)	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	224/312 (72%)	211 (94%)	13 (6%)	18	44
2	B	91/101 (90%)	87 (96%)	4 (4%)	25	51
All	All	315/413 (76%)	298 (95%)	17 (5%)	20	46

All (17) residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	24	VAL
1	A	94	VAL
1	A	108	ASN
1	A	113	ASN
1	A	116	ILE
1	A	166	VAL
1	A	169	ARG
1	A	170	THR
1	A	180	PHE
1	A	407	VAL
1	A	411	THR
1	A	426	TYR
1	A	428	LEU
2	B	12	VAL
2	B	41	ARG
2	B	89	LEU
2	B	108	ASP

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (2) such sidechains are listed below:

Mol	Chain	Res	Type
2	B	80	ASN
2	B	113	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 ⓘ

1 ligand is 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	$\# Z > 2$
3	IXO	A	501	-	13,14,14	4.09	8 (61%)	12,18,18	1.45	2 (16%)

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	IXO	A	501	-	-	4/9/16/16	0/1/1/1

All (8) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
3	A	501	IXO	C10-N11	11.77	1.41	1.29
3	A	501	IXO	O12-N11	-5.05	1.37	1.43
3	A	501	IXO	C07-C06	3.91	1.28	1.19
3	A	501	IXO	C14-C13	-3.31	1.45	1.52
3	A	501	IXO	C08-C07	2.73	1.56	1.46
3	A	501	IXO	O09-C10	2.37	1.37	1.34
3	A	501	IXO	C05-N02	-2.24	1.43	1.50
3	A	501	IXO	C03-N02	-2.00	1.44	1.50

All (2) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
3	A	501	IXO	C08-O09-C10	3.81	120.39	115.48
3	A	501	IXO	O09-C08-C07	2.92	117.09	109.36

There are no chirality outliers.

All (4) torsion outliers are listed below:

Mol	Chain	Res	Type	Atoms
3	A	501	IXO	C05-C06-C07-C08
3	A	501	IXO	C07-C08-O09-C10
3	A	501	IXO	C06-C07-C08-O09
3	A	501	IXO	N02-C05-C06-C07

There are no ring outliers.

1 monomer is involved in 1 short contact:

Mol	Chain	Res	Type	Clashes	Symm-Clashes
3	A	501	IXO	1	0

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	277/351 (78%)	0.21	6 (2%) 62 37	62, 106, 148, 169	0
2	B	121/125 (96%)	0.63	10 (8%) 17 11	95, 134, 179, 201	0
All	All	398/476 (83%)	0.34	16 (4%) 42 23	62, 116, 164, 201	0

All (16) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	A	53	HIS	3.3
2	B	76	ASP	3.1
1	A	379	PRO	3.0
2	B	36	ALA	3.0
1	A	54	LEU	2.7
2	B	51	VAL	2.6
1	A	378	PRO	2.6
2	B	29	PHE	2.6
2	B	55	ASP	2.5
2	B	121	SER	2.5
2	B	109	GLU	2.5
2	B	32	PHE	2.3
1	A	94	VAL	2.2
1	A	405	VAL	2.2
2	B	102	TRP	2.2
2	B	33	ASP	2.1

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	IXO	A	501	14/14	0.91	0.18	73,103,125,136	0

6.5 Other polymers [i](#)

There are no such residues in this entry.