



Full wwPDB X-ray Structure Validation Report ⓘ

Mar 7, 2026 – 01:01 AM UTC

PDB ID : 9EXU / pdb_00009exu
Title : Complex of a mutant of the SARS-CoV-2 main protease Mpro with the nsp4/5 substrate peptide (cocrystallization).
Authors : Battistutta, R.; Fornasier, E.; Giachin, G.
Deposited on : 2024-04-08
Resolution : 1.78 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

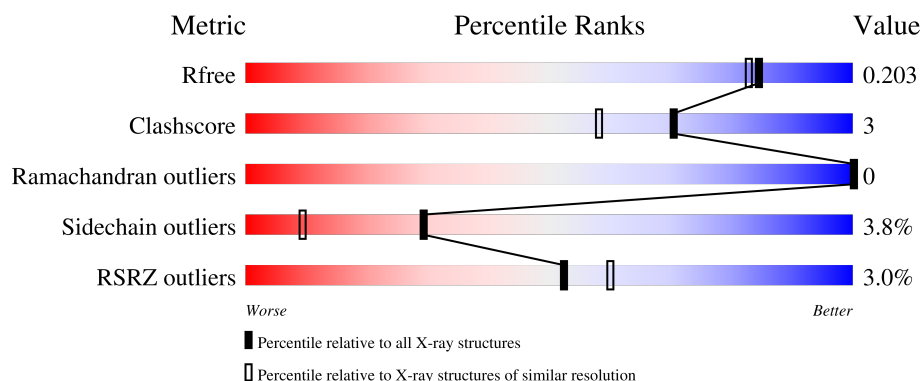
1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

X-RAY DIFFRACTION

The reported resolution of this entry is 1.78 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	1365 (1.78-1.78)
Clashscore	190562	1395 (1.78-1.78)
Ramachandran outliers	187476	1382 (1.78-1.78)
Sidechain outliers	187428	1382 (1.78-1.78)
RSRZ outliers	180081	1365 (1.78-1.78)

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	306	3% 88% 10% ..
1	B	306	3% 91% 7% ..
2	C	11	9% 91% 9%
2	D	11	9% 91% 9%

2 Entry composition

There are 3 unique types of molecules in this entry. The entry contains 5183 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 Non-structural protein 7.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
1	A	302	Total	C	N	O	S	0	0	0
			2327	1473	395	438	21			
1	B	303	Total	C	N	O	S	0	0	0
			2334	1478	396	439	21			

There are 4 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	41	ALA	HIS	conflict	UNP P0DTD1
A	145	ALA	CYS	conflict	UNP P0DTD1
B	41	ALA	HIS	conflict	UNP P0DTD1
B	145	ALA	CYS	conflict	UNP P0DTD1

- Molecule 2 is a protein called THR-SER-ALA-VAL-LEU-GLN-SER-GLY-PHE-ARG-LYS.

Mol	Chain	Residues	Atoms				ZeroOcc	AltConf	Trace
2	C	11	Total	C	N	O	0	2	0
			100	65	17	18			
2	D	10	Total	C	N	O	0	2	0
			91	59	15	17			

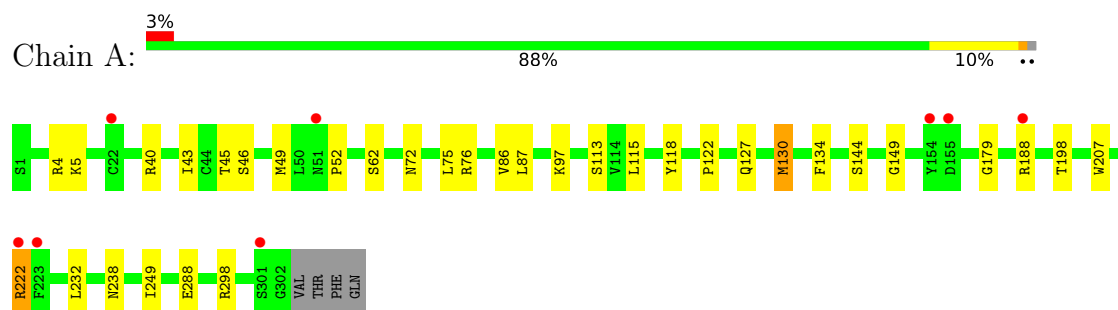
- Molecule 3 is water.

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
3	A	176	Total	O	0	0
			176	176		
3	B	141	Total	O	0	0
			141	141		
3	C	5	Total	O	0	0
			5	5		
3	D	9	Total	O	0	0
			9	9		

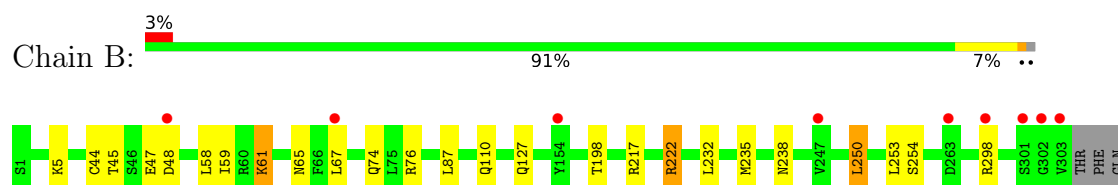
3 Residue-property plots [i](#)

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.

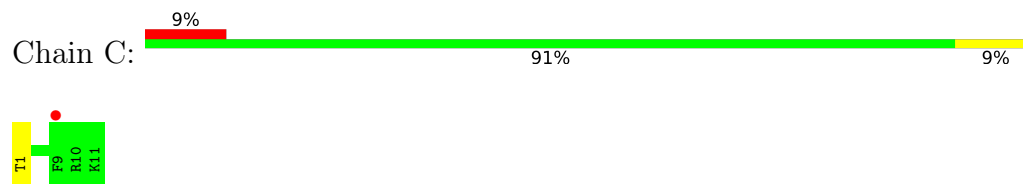
- Molecule 1: Non-structural protein 7



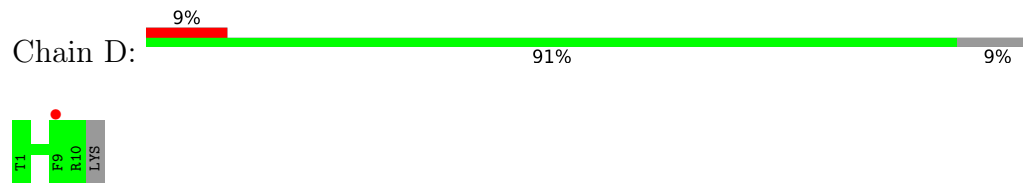
- Molecule 1: Non-structural protein 7



- Molecule 2: THR-SER-ALA-VAL-LEU-GLN-SER-GLY-PHE-ARG-LYS



- Molecule 2: THR-SER-ALA-VAL-LEU-GLN-SER-GLY-PHE-ARG-LYS



4 Data and refinement statistics

Property	Value	Source
Space group	P 1	Depositor
Cell constants a, b, c, α , β , γ	53.56Å 61.36Å 67.90Å 92.22° 109.10° 108.38°	Depositor
Resolution (Å)	46.88 – 1.78 46.88 – 1.78	Depositor EDS
% Data completeness (in resolution range)	92.9 (46.88-1.78) 93.5 (46.88-1.78)	Depositor EDS
R_{merge}	0.04	Depositor
R_{sym}	0.04	Depositor
$\langle I/\sigma(I) \rangle$ ¹	1.30 (at 1.77Å)	Xtriage
Refinement program	PHENIX 1.20.1_4487	Depositor
R, R_{free}	0.179 , 0.204 0.178 , 0.203	Depositor DCC
R_{free} test set	3407 reflections (4.61%)	wwPDB-VP
Wilson B-factor (Å ²)	37.4	Xtriage
Anisotropy	0.339	Xtriage
Bulk solvent k_{sol} (e/Å ³), B_{sol} (Å ²)	0.32 , 35.5	EDS
L-test for twinning ²	$\langle L \rangle = 0.51$, $\langle L^2 \rangle = 0.34$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
F_o, F_c correlation	0.97	EDS
Total number of atoms	5183	wwPDB-VP
Average B, all atoms (Å ²)	50.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 8.25% 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

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

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	0.82	1/2378 (0.0%)	0.88	0/3232
1	B	0.79	0/2385	0.86	0/3242
2	C	0.48	0/94	0.72	0/123
2	D	0.55	0/85	0.62	0/112
All	All	0.80	1/4942 (0.0%)	0.86	0/6709

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	1

All (1) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
1	A	130	MET	SD-CE	-6.54	1.63	1.79

There are no bond angle outliers.

There are no chirality outliers.

All (1) planarity outliers are listed below:

Mol	Chain	Res	Type	Group
1	A	222	ARG	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	2327	0	2279	22	0
1	B	2334	0	2288	11	1
2	C	100	0	99	0	0
2	D	91	0	86	0	0
3	A	176	0	0	2	0
3	B	141	0	0	3	0
3	C	5	0	0	0	0
3	D	9	0	0	0	0
All	All	5183	0	4752	33	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 3.

All (33) 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:130:MET:HE3	1:A:130:MET:HA	1.77	0.67
1:A:52:PRO:HD2	1:A:188:ARG:CD	2.29	0.62
1:B:61:LYS:HG3	1:B:65:ASN:HD22	1.65	0.60
1:A:130:MET:HE2	1:A:134:PHE:HA	1.86	0.56
1:A:46:SER:HA	1:A:49:MET:HE2	1.87	0.56
1:A:4:ARG:NH1	3:A:403:HOH:O	2.41	0.54
1:A:52:PRO:HD2	1:A:188:ARG:HG2	1.90	0.53
1:A:130:MET:HE2	1:A:134:PHE:C	2.33	0.53
1:A:86:VAL:HG13	1:A:179:GLY:HA2	1.91	0.52
1:B:198:THR:HG22	1:B:238:ASN:OD1	2.10	0.51
1:A:40:ARG:HA	1:A:87:LEU:HG	1.93	0.50
1:A:198:THR:HG22	1:A:238:ASN:OD1	2.11	0.50
1:B:222:ARG:H	1:B:222:ARG:HG3	1.45	0.48
1:B:235:MET:HE3	1:B:235:MET:HB2	1.71	0.47
1:B:298:ARG:HD2	3:B:411:HOH:O	2.15	0.46
1:A:52:PRO:HD2	1:A:188:ARG:CG	2.46	0.45
1:A:130:MET:HE2	1:A:134:PHE:CA	2.47	0.45
1:B:5:LYS:HG2	1:B:127:GLN:HB2	1.99	0.45
1:A:52:PRO:CD	1:A:188:ARG:HG2	2.48	0.44

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Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:B:110:GLN:HG3	3:B:509:HOH:O	2.17	0.44
1:A:5:LYS:HG2	1:A:127:GLN:HB2	2.01	0.43
1:B:48:ASP:HB2	3:B:410:HOH:O	2.19	0.43
1:A:52:PRO:HD2	1:A:188:ARG:HD3	2.00	0.42
1:A:118:TYR:CE1	1:A:144:SER:HB3	2.55	0.42
1:A:249:ILE:HD13	1:A:249:ILE:HG21	1.74	0.42
1:A:62:SER:OG	3:A:401:HOH:O	2.13	0.41
1:B:232:LEU:HD23	1:B:232:LEU:HA	1.95	0.41
1:A:207:TRP:CE2	1:A:288:GLU:HB3	2.55	0.41
1:B:250:LEU:HD12	1:B:250:LEU:HA	1.92	0.41
1:A:40:ARG:O	1:A:43:ILE:HG12	2.20	0.41
1:A:113:SER:O	1:A:149:GLY:HA2	2.21	0.40
1:A:115:LEU:HD11	1:A:122:PRO:HB3	2.02	0.40
1:B:58:LEU:HD12	1:B:58:LEU:HA	1.74	0.40

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:59:ILE:O	1:B:217:ARG:NH1[1_665]	2.10	0.10

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	300/306 (98%)	295 (98%)	5 (2%)	0	100	100
1	B	301/306 (98%)	296 (98%)	5 (2%)	0	100	100
2	C	11/11 (100%)	10 (91%)	1 (9%)	0	100	100
2	D	10/11 (91%)	9 (90%)	1 (10%)	0	100	100
All	All	622/634 (98%)	610 (98%)	12 (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	257/261 (98%)	249 (97%)	8 (3%)	35	14
1	B	258/261 (99%)	246 (95%)	12 (5%)	23	6
2	C	10/8 (125%)	10 (100%)	0	100	100
2	D	9/8 (112%)	9 (100%)	0	100	100
All	All	534/538 (99%)	514 (96%)	20 (4%)	29	10

All (20) residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	45	THR
1	A	72	ASN
1	A	75	LEU
1	A	76	ARG
1	A	97	LYS
1	A	222	ARG
1	A	232	LEU
1	A	298	ARG
1	B	44	CYS
1	B	45	THR
1	B	47	GLU
1	B	61	LYS
1	B	67	LEU
1	B	74	GLN
1	B	76	ARG
1	B	87	LEU
1	B	222	ARG
1	B	250	LEU
1	B	253	LEU
1	B	254	SER

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (8) such

sidechains are listed below:

Mol	Chain	Res	Type
1	A	51	ASN
1	A	83	GLN
1	A	110	GLN
1	A	274	ASN
1	B	83	GLN
1	B	142	ASN
1	B	180	ASN
1	B	244	GLN

5.3.3 RNA ⓘ

There are no RNA molecules in this entry.

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

2 non-standard protein/DNA/RNA residues 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	THC	C	1	2	8,9,10	1.09	1 (12%)	10,11,13	3.72	2 (20%)
2	THC	D	1	2	8,9,10	0.70	0	10,11,13	0.65	0

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	THC	C	1	2	-	6/9/10/12	-
2	THC	D	1	2	-	4/9/10/12	-

All (1) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
2	C	1	THC	CN-N1	2.79	1.43	1.34

All (2) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
2	C	1	THC	CM-CN-N1	-11.36	97.28	116.12
2	C	1	THC	CB-CA-C	-2.07	108.11	111.55

There are no chirality outliers.

All (10) torsion outliers are listed below:

Mol	Chain	Res	Type	Atoms
2	C	1	THC	ON-CN-N1-CA
2	C	1	THC	CM-CN-N1-CA
2	C	1	THC	N1-CA-CB-OG1
2	C	1	THC	N1-CA-CB-CG2
2	C	1	THC	C-CA-CB-OG1
2	C	1	THC	C-CA-CB-CG2
2	D	1	THC	N1-CA-CB-OG1
2	D	1	THC	N1-CA-CB-CG2
2	D	1	THC	C-CA-CB-OG1
2	D	1	THC	C-CA-CB-CG2

There are no ring outliers.

No monomer is involved in short contacts.

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 ⓘ

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	302/306 (98%)	0.33	8 (2%) 57 65	33, 46, 78, 117	0
1	B	303/306 (99%)	0.30	9 (2%) 52 60	33, 46, 72, 101	0
2	C	10/11 (90%)	0.87	1 (10%) 12 14	30, 49, 89, 96	2 (20%)
2	D	9/11 (81%)	0.58	1 (11%) 10 11	34, 41, 55, 80	2 (22%)
All	All	624/634 (98%)	0.33	19 (3%) 52 60	30, 46, 78, 117	4 (0%)

All (19) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	B	303	VAL	5.5
1	A	222	ARG	4.7
2	C	9[A]	PHE	4.4
1	B	154	TYR	3.9
1	A	154	TYR	3.7
2	D	9[A]	PHE	3.6
1	A	301	SER	3.2
1	A	188	ARG	2.9
1	B	263	ASP	2.6
1	A	51	ASN	2.3
1	B	247	VAL	2.3
1	B	48	ASP	2.3
1	B	301	SER	2.2
1	A	155	ASP	2.2
1	B	67	LEU	2.1
1	B	298	ARG	2.1
1	B	302	GLY	2.0
1	A	223	PHE	2.0
1	A	22	CYS	2.0

6.2 Non-standard residues in protein, DNA, RNA chains [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	THC	C	1	10/11	0.77	0.19	65,77,112,129	0
2	THC	D	1	10/11	0.88	0.13	52,59,67,69	0

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.