



Full wwPDB X-ray Structure Validation Report ⓘ

Sep 14, 2026 – 04:13 PM EDT

PDB ID : 9Z4Y / pdb_00009z4y
Title : Human APE1 D210N with Mg and substrate tetrahydrofuran-containing DNA
Authors : Tsutakawa, S.E.; Tainer, J.A.; Arvai, A.
Deposited on : 2025-11-11
Resolution : 2.05 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 : 9.0.015 (Gargrove)
Density-Fitness : 1.0.12
Ideal geometry (proteins) : Engh & Huber (2001)
Ideal geometry (DNA, RNA) : Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP) : 2.50

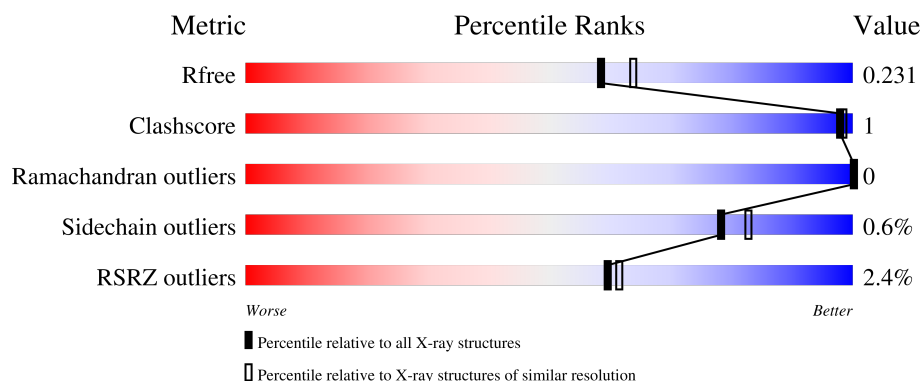
1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

X-RAY DIFFRACTION

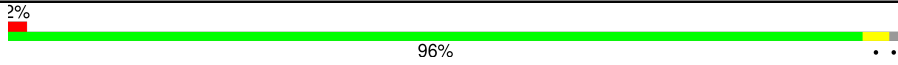
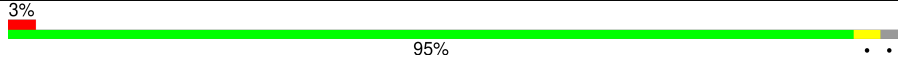
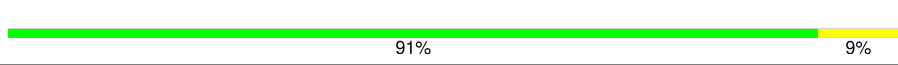
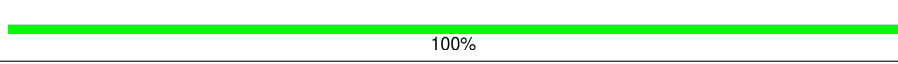
The reported resolution of this entry is 2.05 Å.

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	279	 2% 96%
1	D	279	 3% 95%
2	B	11	 91% 9%
2	E	11	 9% 82% 9% 9%
3	C	11	 100%

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Mol	Chain	Length	Quality of chain
3	F	11	 91%9%

2 Entry composition [i](#)

There are 6 unique types of molecules in this entry. The entry contains 10504 atoms, of which 4812 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 DNA repair nuclease/redox regulator APEX1, mitochondrial.

Mol	Chain	Residues	Atoms						ZeroOcc	AltConf	Trace
1	A	276	Total	C	H	N	O	S	0	0	0
			4363	1404	2165	381	404	9			
1	D	274	Total	C	H	N	O	S	0	0	0
			4345	1394	2165	379	398	9			

There are 2 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	210	ASN	ASP	engineered mutation	UNP P27695
D	210	ASN	ASP	engineered mutation	UNP P27695

- Molecule 2 is a DNA chain called DNA (5'-D(*GP*CP*TP*AP*CP*(3DR)P*GP*AP*TP*CP*G)-3').

Mol	Chain	Residues	Atoms						ZeroOcc	AltConf	Trace
2	B	11	Total	C	H	N	O	P	0	0	0
			335	102	122	38	63	10			
2	E	10	Total	C	H	N	O	P	0	0	0
			301	92	110	33	57	9			

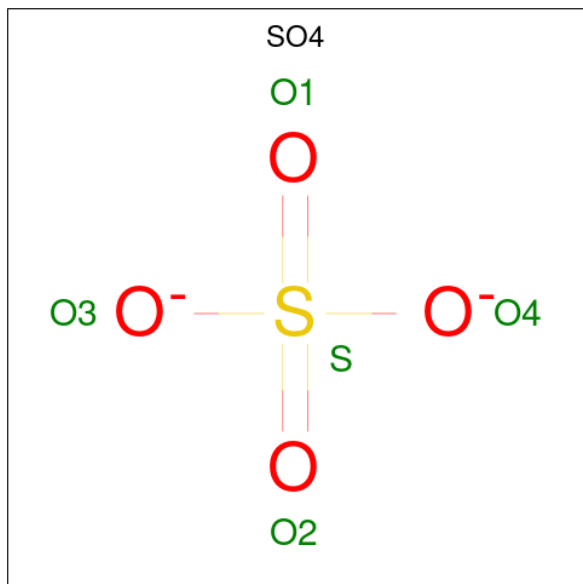
- Molecule 3 is a DNA chain called DNA (5'-D(*CP*GP*AP*TP*CP*GP*GP*TP*AP*GP*C)-3').

Mol	Chain	Residues	Atoms						ZeroOcc	AltConf	Trace
3	C	11	Total	C	H	N	O	P	0	0	0
			349	107	125	43	64	10			
3	F	11	Total	C	H	N	O	P	0	0	0
			349	107	125	43	64	10			

- Molecule 4 is MAGNESIUM ION (CCD ID: MG) (formula: Mg).

Mol	Chain	Residues	Atoms	ZeroOcc	AltConf
4	A	2	Total Mg 2 2	0	0
4	B	1	Total Mg 1 1	0	0
4	D	2	Total Mg 2 2	0	0

- Molecule 5 is SULFATE ION (CCD ID: SO4) (formula: O₄S).



Mol	Chain	Residues	Atoms	ZeroOcc	AltConf
5	A	1	Total O S 5 4 1	0	0
5	A	1	Total O S 5 4 1	0	0
5	D	1	Total O S 5 4 1	0	0
5	D	1	Total O S 5 4 1	0	0

- Molecule 6 is water.

Mol	Chain	Residues	Atoms	ZeroOcc	AltConf
6	A	178	Total O 178 178	0	0
6	B	14	Total O 14 14	0	0
6	C	24	Total O 24 24	0	0

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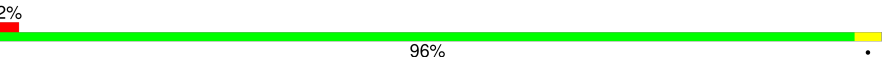
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Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
6	D	188	Total 188	O 188	0	0
6	E	16	Total 16	O 16	0	0
6	F	17	Total 17	O 17	0	0

3 Residue-property plots

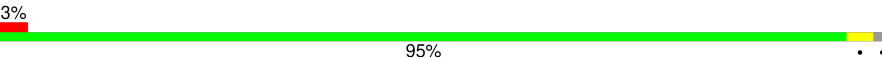
These plots are drawn for all protein, RNA, DNA and oligosaccharide chains in the entry. The first graphic for a chain summarises the proportions of the various outlier classes displayed in the second graphic. The second graphic shows the sequence view annotated by issues in geometry and electron density. 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: DNA repair nuclease/redox regulator APEX1, mitochondrial

Chain A: 



- Molecule 1: DNA repair nuclease/redox regulator APEX1, mitochondrial

Chain D: 



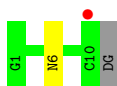
- Molecule 2: DNA (5'-D(*GP*CP*TP*AP*CP*(3DR)P*GP*AP*TP*CP*G)-3')

Chain B: 

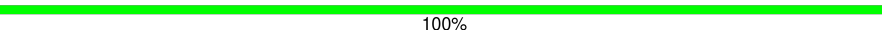


- Molecule 2: DNA (5'-D(*GP*CP*TP*AP*CP*(3DR)P*GP*AP*TP*CP*G)-3')

Chain E: 



- Molecule 3: DNA (5'-D(*CP*GP*AP*TP*CP*GP*GP*TP*AP*GP*C)-3')

Chain C: 

There are no outlier residues recorded for this chain.

- Molecule 3: DNA (5'-D(*CP*GP*AP*TP*CP*GP*GP*TP*AP*GP*C)-3')

Chain F: 



4 Data and refinement statistics

Property	Value	Source
Space group	P 1 21 1	Depositor
Cell constants a, b, c, α , β , γ	47.02Å 128.53Å 64.76Å 90.00° 96.41° 90.00°	Depositor
Resolution (Å)	35.95 – 2.05 35.95 – 2.05	Depositor EDS
% Data completeness (in resolution range)	92.9 (35.95-2.05) 87.9 (35.95-2.05)	Depositor EDS
R_{merge}	(Not available)	Depositor
R_{sym}	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ ¹	1.97 (at 2.05Å)	Xtriage
Refinement program	PHENIX 1.21.2_5419	Depositor
R, R_{free}	0.185 , 0.231 0.185 , 0.231	Depositor DCC
R_{free} test set	2212 reflections (4.65%)	wwPDB-VP
Wilson B-factor (Å ²)	25.7	Xtriage
Anisotropy	0.013	Xtriage
Bulk solvent k_{sol} (e/Å ³), B_{sol} (Å ²)	0.38 , 40.7	EDS
L-test for twinning ²	$\langle L \rangle = 0.49$, $\langle L^2 \rangle = 0.32$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
F_o, F_c correlation	0.94	EDS
Total number of atoms	10504	wwPDB-VP
Average B, all atoms (Å ²)	35.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 4.21% 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: MG, 3DR, SO4

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	0.26	0/2256	0.41	0/3058
1	D	0.28	0/2237	0.43	0/3031
2	B	0.30	0/225	0.56	0/343
2	E	0.34	0/200	0.58	0/304
3	C	0.26	0/251	0.52	0/386
3	F	0.30	0/251	0.49	0/386
All	All	0.27	0/5420	0.44	0/7508

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	2198	2165	2175	3	0
1	D	2180	2165	2163	4	0
2	B	213	122	122	0	0
2	E	191	110	111	0	0
3	C	224	125	125	0	0
3	F	224	125	125	1	0
4	A	2	0	0	0	0

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Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
4	B	1	0	0	0	0
4	D	2	0	0	0	0
5	A	10	0	0	0	0
5	D	10	0	0	0	0
6	A	178	0	0	0	0
6	B	14	0	0	0	0
6	C	24	0	0	0	0
6	D	188	0	0	0	0
6	E	16	0	0	0	0
6	F	17	0	0	0	0
All	All	5692	4812	4821	7	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 (7) 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:76:ILE:HD12	1:A:105:PRO:HG2	1.80	0.62
1:D:122:PRO:HG2	1:D:125:LYS:HB2	1.96	0.46
1:D:174:ASN:ND2	1:D:212:ASN:HD21	2.13	0.46
1:D:126:GLU:HB3	3:F:22:DC:H4'	1.99	0.44
1:A:174:ASN:ND2	1:A:212:ASN:HD21	2.17	0.43
1:A:133:LEU:CD2	1:A:160:ALA:HB2	2.50	0.42
1:D:292:LEU:N	1:D:293:PRO:HD2	2.35	0.42

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	274/279 (98%)	266 (97%)	8 (3%)	0	100	100
1	D	270/279 (97%)	261 (97%)	9 (3%)	0	100	100
All	All	544/558 (98%)	527 (97%)	17 (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	236/238 (99%)	234 (99%)	2 (1%)	73	77
1	D	234/238 (98%)	233 (100%)	1 (0%)	84	88
All	All	470/476 (99%)	467 (99%)	3 (1%)	78	83

All (3) residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	68	ASN
1	A	280	TRP
1	D	68	ASN

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (7) such sidechains are listed below:

Mol	Chain	Res	Type
1	A	68	ASN
1	A	212	ASN
1	A	226	ASN
1	A	229	ASN
1	A	289	HIS
1	D	116	HIS
1	D	212	ASN

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	3DR	B	6	2	8,11,12	1.72	1 (12%)	7,14,17	1.32	0
2	3DR	E	6	2	8,11,12	1.53	1 (12%)	7,14,17	1.29	1 (14%)

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	3DR	B	6	2	-	0/3/15/16	0/1/1/1
2	3DR	E	6	2	-	0/3/15/16	0/1/1/1

All (2) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
2	B	6	3DR	O5'-C5'	-4.02	1.32	1.44
2	E	6	3DR	O5'-C5'	-3.67	1.33	1.44

All (1) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
2	E	6	3DR	O3'-C3'-C2'	-2.23	106.21	111.43

There are no chirality outliers.

There are no torsion outliers.

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](#)

Of 9 ligands modelled in this entry, 5 are monoatomic - leaving 4 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	$\# Z > 2$
5	SO4	D	403	-	4,4,4	0.62	0	6,6,6	0.25	0
5	SO4	A	403	-	4,4,4	0.70	0	6,6,6	0.21	0
5	SO4	D	404	-	4,4,4	0.69	0	6,6,6	0.22	0
5	SO4	A	404	-	4,4,4	0.69	0	6,6,6	0.21	0

There are no bond length outliers.

There are no bond angle outliers.

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

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	276/279 (98%)	0.04	5 (1%) 67 69	18, 33, 59, 76	0
1	D	274/279 (98%)	-0.01	8 (2%) 53 55	17, 29, 55, 75	0
2	B	10/11 (90%)	0.04	0 100 100	33, 40, 54, 61	0
2	E	9/11 (81%)	0.36	1 (11%) 10 10	29, 40, 54, 75	0
3	C	11/11 (100%)	0.09	0 100 100	35, 45, 58, 60	0
3	F	11/11 (100%)	0.36	0 100 100	31, 45, 70, 70	0
All	All	591/602 (98%)	0.03	14 (2%) 59 61	17, 32, 60, 76	0

All (14) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	D	126	GLU	3.6
1	A	126	GLU	3.0
1	D	112	PRO	2.9
1	D	44	LEU	2.8
1	D	148	ASP	2.8
1	D	151	HIS	2.7
1	D	125	LYS	2.7
2	E	10	DC	2.6
1	D	43	ALA	2.5
1	A	43	ALA	2.4
1	A	109	GLN	2.2
1	A	125	LYS	2.2
1	D	318	LEU	2.0
1	A	57	GLY	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($\text{\AA}^2$)	Q<0.9
2	3DR	E	6	11/12	0.96	0.08	25,30,36,39	0
2	3DR	B	6	11/12	0.97	0.06	23,30,34,34	0

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
5	SO4	A	404	5/5	0.84	0.18	47,51,61,63	0
4	MG	D	401	1/1	0.88	0.17	39,39,39,39	0
4	MG	A	401	1/1	0.89	0.18	40,40,40,40	0
4	MG	B	401	1/1	0.92	0.21	44,44,44,44	0
4	MG	D	402	1/1	0.93	0.14	43,43,43,43	0
5	SO4	D	404	5/5	0.94	0.11	38,41,47,49	0
5	SO4	D	403	5/5	0.96	0.07	31,32,37,37	0
5	SO4	A	403	5/5	0.96	0.11	32,37,41,42	0
4	MG	A	402	1/1	0.97	0.10	39,39,39,39	0

6.5 Other polymers [i](#)

There are no such residues in this entry.