Full wwPDB X-ray Structure Validation Report (i)

Mar 18, 2024 – 12:44 PM JST

PDB ID	:	6AKH
Title	:	Pre-catalytic Ternary Complex of Human DNA Polymerase Mu with Templating Adenine and Incoming Mn-dUMPNPP
Authors	:	Chang, Y.K.; Wu, W.J.; Tsai, M.D.
Deposited on	:	2018-08-31
Resolution	:	1.75 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 (i) 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 (i)) were used in the production of this report:

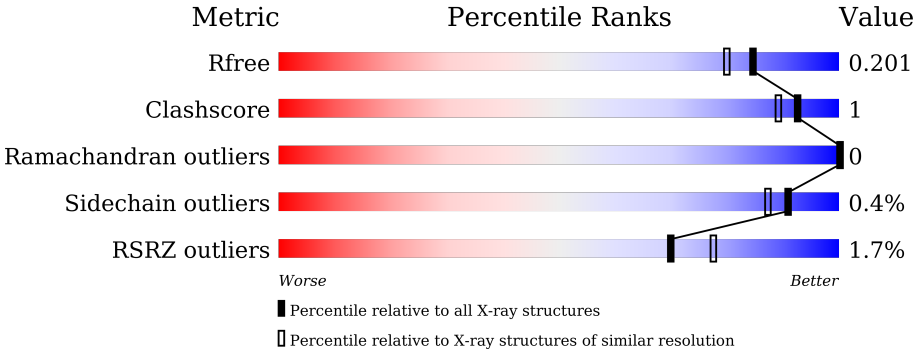
MolProbity	:	4.02b-467
Mogul	:	1.8.5 (274361), CSD as541be (2020)
Xtriage (Phenix)	:	1.13
EDS	:	2.36
buster-report	:	1.1.7 (2018)
Percentile statistics	:	20191225.v01 (using entries in the PDB archive December 25th 2019)
Refmac	:	5.8.0158
CCP4	:	7.0.044 (Gargrove)
Ideal geometry (proteins)	:	Engh & Huber (2001)
Ideal geometry (DNA, RNA)	:	Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP)	:	2.36

1 Overall quality at a glance (i)

The following experimental techniques were used to determine the structure:
X-RAY DIFFRACTION

The reported resolution of this entry is 1.75 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}	130704	2340 (1.76-1.76)
Clashscore	141614	2466 (1.76-1.76)
Ramachandran outliers	138981	2437 (1.76-1.76)
Sidechain outliers	138945	2437 (1.76-1.76)
RSRZ outliers	127900	2298 (1.76-1.76)

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 <=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	356	2%, 89%, •, 8%
2	T	9	100%
3	P	4	100%
4	D	4	100%

2 Entry composition (i)

There are 10 unique types of molecules in this entry. The entry contains 3589 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 DNA-directed DNA/RNA polymerase mu.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	S			
1	A	327	2673	1691	489	483	10	0	16	0

There are 6 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	127	GLY	-	expression tag	UNP Q9NP87
A	128	SER	-	expression tag	UNP Q9NP87
A	129	ALA	-	expression tag	UNP Q9NP87
A	130	ALA	-	expression tag	UNP Q9NP87
A	131	ALA	-	expression tag	UNP Q9NP87
A	410	GLY	-	linker	UNP Q9NP87

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

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	P			
2	T	9	182	87	36	51	8	0	0	0

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

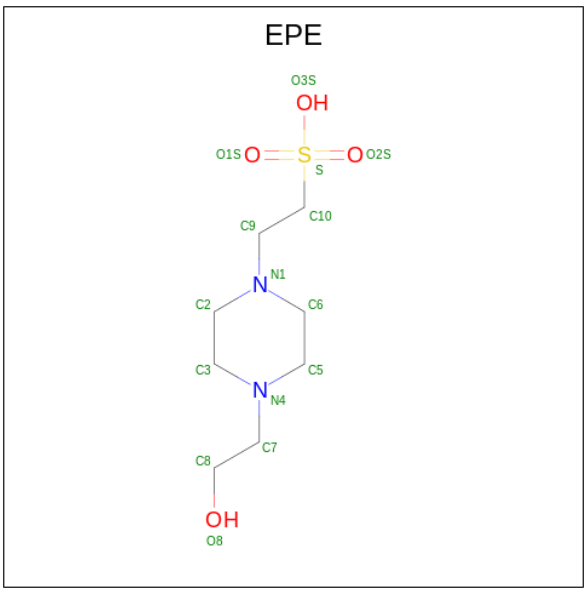
Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	P			
3	P	4	79	39	15	22	3	0	1	0

- Molecule 4 is a DNA chain called DNA (5'-D(P*GP*CP*CP*G)-3').

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	P			
4	D	4	124	57	24	37	6	0	2	0

- Molecule 5 is 4-(2-HYDROXYETHYL)-1-PIPERAZINE ETHANESULFONIC ACID

(three-letter code: EPE) (formula: $C_8H_{18}N_2O_4S$).



Mol	Chain	Residues	Atoms					ZeroOcc	AltConf
			Total	C	N	O	S		
5	A	1	11	5	2	3	1	0	0

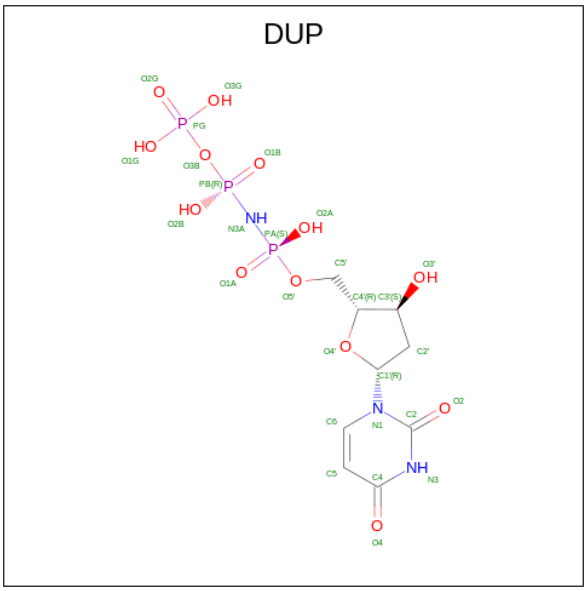
- Molecule 6 is MANGANESE (II) ION (three-letter code: MN) (formula: Mn) (labeled as "Ligand of Interest" by depositor).

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
			Total	Mn		
6	A	2	2	2	0	0

- Molecule 7 is SODIUM ION (three-letter code: NA) (formula: Na).

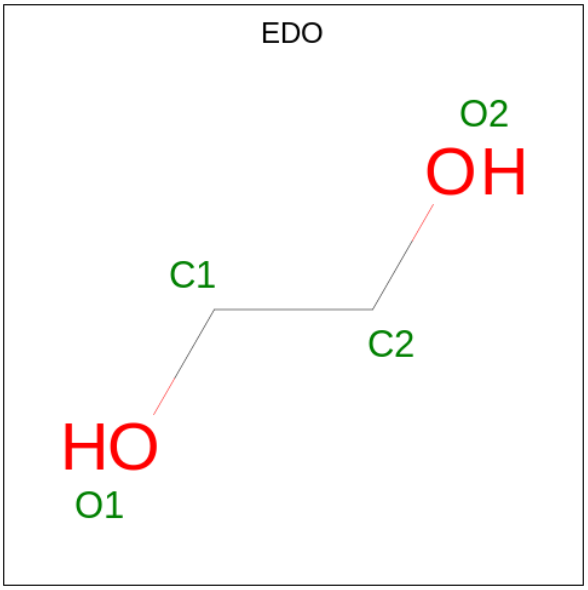
Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
			Total	Na		
7	A	1	1	1	0	0

- Molecule 8 is 2'-DEOXYURIDINE 5'-ALPHA,BETA-IMIDO-TRIPHOSPHATE (three-letter code: DUP) (formula: $C_9H_{16}N_3O_{13}P_3$) (labeled as "Ligand of Interest" by depositor).



Mol	Chain	Residues	Atoms					ZeroOcc	AltConf
			Total	C	N	O	P		
8	A	1	28	9	3	13	3	0	0

- Molecule 9 is 1,2-ETHANEDIOL (three-letter code: EDO) (formula: $C_2H_6O_2$).



Mol	Chain	Residues	Atoms			ZeroOcc	AltConf
			Total	C	O		
9	A	1	4	2	2	0	0
9	A	1	Total 4	C 2	O 2	0	0
9	A	1	Total 4	C 2	O 2	0	0

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Mol	Chain	Residues	Atoms			ZeroOcc	AltConf
			Total	C	O		
9	A	1	4	2	2	0	0
			Total	C	O		
9	A	1	4	2	2	0	0
			Total	C	O		
9	A	1	4	2	2	0	0
			Total	C	O		
9	T	1	4	2	2	0	0

- Molecule 10 is water.

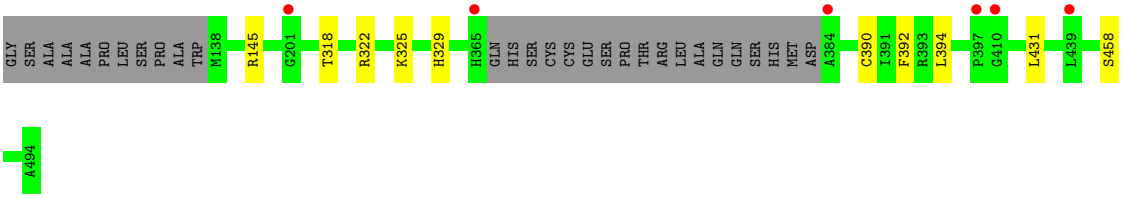
Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
			Total	O		
10	A	385	385	385	0	0
			Total	O		
10	T	42	42	42	0	0
			Total	O		
10	P	18	18	18	0	0
			Total	O		
10	D	16	16	16	0	0

3 Residue-property plots (i)

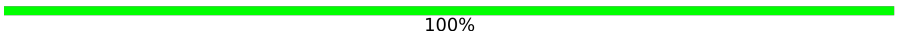
These plots are drawn for all protein, RNA, DNA and oligosaccharide chains in the entry. The first graphic for a chain summarises the proportions of the various outlier classes displayed in the second graphic. The second graphic shows the sequence view annotated by issues in geometry and electron density.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

Chain A:

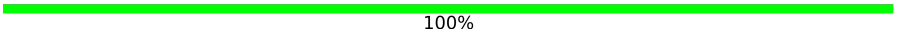


• Molecule 2: DNA (5'-D(*CP*GP*GP*CP*AP*TP*AP*CP*G)-3')

Chain T: 

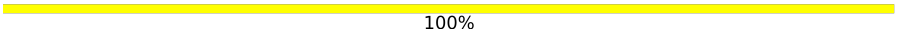
There are no outlier residues recorded for this chain.

• Molecule 3: DNA (5'-D(*CP*GP*TP*A)-3')

Chain P: 

There are no outlier residues recorded for this chain.

• Molecule 4: DNA (5'-D(P*GP*CP*CP*G)-3')

Chain D: 

4 Data and refinement statistics (i)

Property	Value	Source
Space group	P 21 21 21	Depositor
Cell constants a, b, c, α, β, γ	59.84Å 68.80Å 109.68Å 90.00° 90.00° 90.00°	Depositor
Resolution (Å)	30.00 – 1.75 28.86 – 1.75	Depositor EDS
% Data completeness (in resolution range)	99.3 (30.00-1.75) 99.3 (28.86-1.75)	Depositor EDS
R_{merge}	(Not available)	Depositor
R_{sym}	(Not available)	Depositor
$< I/\sigma(I) >$ [1]	4.88 (at 1.75Å)	Xtriage
Refinement program	REFMAC 5.8.0155	Depositor
R, R_{free}	0.164 , 0.190 0.173 , 0.201	Depositor DCC
R_{free} test set	2349 reflections (5.08%)	wwPDB-VP
Wilson B-factor (Å^2)	17.6	Xtriage
Anisotropy	0.018	Xtriage
Bulk solvent k_{sol}(e/Å^3), B_{sol}(Å^2)	0.35 , 49.5	EDS
L-test for twinning[2]	$< \|L\| > = 0.50$, $< L^2 > = 0.33$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
F_o,F_c correlation	0.96	EDS
Total number of atoms	3589	wwPDB-VP
Average B, all atoms (Å^2)	22.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 5.42% of the height of the origin peak. No significant pseudotranslation is detected.*

[1] Intensities estimated from amplitudes.

[2] Theoretical values of $< |L| >$, $< L^2 >$ 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: NA, EPE, MN, DUP, EDO

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	0.47	0/2748	0.72	3/3719 (0.1%)
2	T	0.51	0/204	0.84	0/313
3	P	0.45	0/88	0.79	0/134
4	D	0.97	1/137 (0.7%)	0.91	1/205 (0.5%)
All	All	0.50	1/3177 (0.0%)	0.74	4/4371 (0.1%)

All (1) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
4	D	1	DG	OP3-P	-10.72	1.48	1.61

All (4) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
1	A	145	ARG	NE-CZ-NH2	-7.04	116.78	120.30
4	D	2	DC	C1'-O4'-C4'	-5.55	104.55	110.10
1	A	322	ARG	NE-CZ-NH1	5.17	122.88	120.30
1	A	145	ARG	NE-CZ-NH1	5.04	122.82	120.30

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	2673	0	2626	7	0
2	T	182	0	102	0	0
3	P	79	0	46	0	0
4	D	124	0	68	2	0
5	A	11	0	9	0	0
6	A	2	0	0	0	0
7	A	1	0	0	0	0
8	A	28	0	12	0	0
9	A	24	0	36	1	0
9	T	4	0	6	0	0
10	A	385	0	0	2	0
10	D	16	0	0	0	0
10	P	18	0	0	0	0
10	T	42	0	0	0	0
All	All	3589	0	2905	9	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 (9) 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)
4:D:3[A]:DC:H4'	4:D:4[A]:DG:OP1	2.00	0.60
4:D:3[A]:DC:C4'	4:D:4[A]:DG:OP1	2.56	0.54
1:A:458:SER:H	9:A:511:EDO:H21	1.77	0.50
1:A:390[B]:CYS:SG	1:A:392:PHE:CD1	3.10	0.45
1:A:325:LYS:NZ	10:A:605:HOH:O	2.50	0.44
1:A:394:LEU:HD11	10:A:797:HOH:O	2.17	0.44
1:A:318[A]:THR:HG22	1:A:431:LEU:HD12	2.00	0.42
1:A:390[B]:CYS:SG	1:A:392:PHE:CE1	3.14	0.41

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	340/356 (96%)	330 (97%)	10 (3%)	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	281/301 (93%)	280 (100%)	1 (0%)	91	87

All (1) residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	329	HIS

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. There are no such sidechains identified.

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 monosaccharides in this entry.

5.6 Ligand geometry (i)

Of 12 ligands modelled in this entry, 3 are monoatomic - leaving 9 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	$\#\|Z\| > 2$
9	EDO	A	510	-	3,3,3	0.47	0	2,2,2	0.28	0
5	EPE	A	501	-	10,10,15	2.02	1 (10%)	11,12,20	1.88	2 (18%)
9	EDO	A	506	-	3,3,3	0.47	0	2,2,2	0.14	0
9	EDO	T	101	-	3,3,3	0.43	0	2,2,2	0.33	0
8	DUP	A	505	6	25,29,29	1.84	4 (16%)	30,45,45	1.47	4 (13%)
9	EDO	A	511	-	3,3,3	0.26	0	2,2,2	0.12	0
9	EDO	A	507	-	3,3,3	0.47	0	2,2,2	0.10	0
9	EDO	A	509	-	3,3,3	0.48	0	2,2,2	0.25	0
9	EDO	A	508	-	3,3,3	0.41	0	2,2,2	0.49	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
9	EDO	A	510	-	-	1/1/1/1	-
5	EPE	A	501	-	-	4/8/8/19	-
9	EDO	A	506	-	-	0/1/1/1	-
9	EDO	T	101	-	-	0/1/1/1	-
8	DUP	A	505	6	-	5/16/34/34	0/2/2/2
9	EDO	A	511	-	-	0/1/1/1	-
9	EDO	A	507	-	-	0/1/1/1	-
9	EDO	A	509	-	-	1/1/1/1	-
9	EDO	A	508	-	-	0/1/1/1	-

All (5) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
8	A	505	DUP	PB-O1B	6.74	1.56	1.46

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Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
5	A	501	EPE	C10-S	-6.14	1.68	1.77
8	A	505	DUP	PB-N3A	3.32	1.72	1.63
8	A	505	DUP	PA-N3A	3.00	1.71	1.63
8	A	505	DUP	PB-O2B	-2.03	1.51	1.56

All (6) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
5	A	501	EPE	O3S-S-C10	5.05	113.94	105.77
8	A	505	DUP	O1B-PB-N3A	-3.85	106.10	111.77
8	A	505	DUP	O1A-PA-N3A	-3.44	106.71	111.77
5	A	501	EPE	O1S-S-C10	-2.64	103.74	106.92
8	A	505	DUP	C2'-C1'-N1	-2.08	109.46	114.27
8	A	505	DUP	O3G-PG-O1G	2.04	115.45	107.64

There are no chirality outliers.

All (11) torsion outliers are listed below:

Mol	Chain	Res	Type	Atoms
8	A	505	DUP	PB-N3A-PA-O5'
8	A	505	DUP	PA-N3A-PB-O1B
8	A	505	DUP	PB-O3B-PG-O1G
8	A	505	DUP	PB-O3B-PG-O3G
5	A	501	EPE	C2-C3-N4-C7
5	A	501	EPE	C9-C10-S-O3S
5	A	501	EPE	C10-C9-N1-C2
5	A	501	EPE	C9-C10-S-O2S
9	A	510	EDO	O1-C1-C2-O2
8	A	505	DUP	PB-O3B-PG-O2G
9	A	509	EDO	O1-C1-C2-O2

There are no ring outliers.

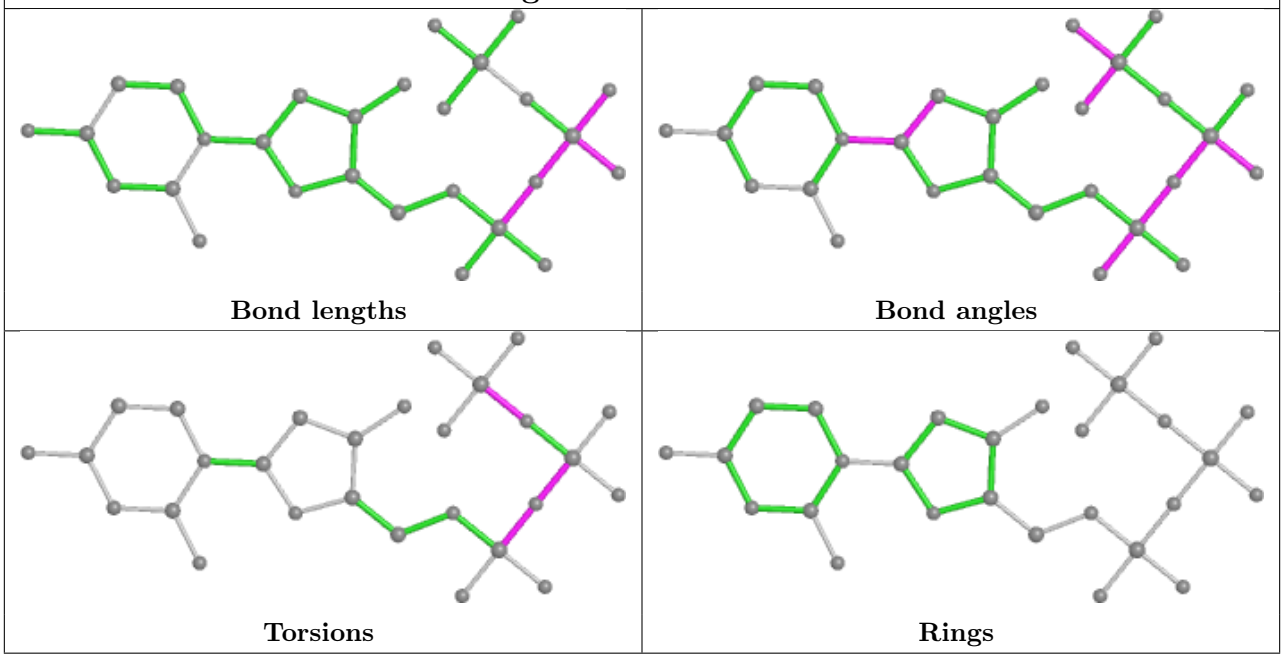
1 monomer is involved in 1 short contact:

Mol	Chain	Res	Type	Clashes	Symm-Clashes
9	A	511	EDO	1	0

The following is a two-dimensional graphical depiction of Mogul quality analysis of bond lengths, bond angles, torsion angles, and ring geometry for all instances of the Ligand of Interest. In addition, ligands with molecular weight > 250 and outliers as shown on the validation Tables will also be included. For torsion angles, if less then 5% of the Mogul distribution of torsion angles is

within 10 degrees of the torsion angle in question, then that torsion angle is considered an outlier. Any bond that is central to one or more torsion angles identified as an outlier by Mogul will be highlighted in the graph. For rings, the root-mean-square deviation (RMSD) between the ring in question and similar rings identified by Mogul is calculated over all ring torsion angles. If the average RMSD is greater than 60 degrees and the minimal RMSD between the ring in question and any Mogul-identified rings is also greater than 60 degrees, then that ring is considered an outlier. The outliers are highlighted in purple. The color gray indicates Mogul did not find sufficient equivalents in the CSD to analyse the geometry.

Ligand DUP A 505



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	327/356 (91%)	-0.01	6 (1%)	68	76	9, 19, 34, 56	0
2	T	9/9 (100%)	-0.36	0	100	100	13, 18, 27, 31	0
3	P	4/4 (100%)	-0.49	0	100	100	14, 16, 17, 20	0
4	D	4/4 (100%)	-0.36	0	100	100	18, 18, 20, 25	0
All	All	344/373 (92%)	-0.03	6 (1%)	70	77	9, 19, 34, 56	0

All (6) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	A	397	PRO	4.4
1	A	384	ALA	3.3
1	A	201	GLY	3.2
1	A	365	HIS	3.1
1	A	439	LEU	2.1
1	A	410	GLY	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 monosaccharides 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,

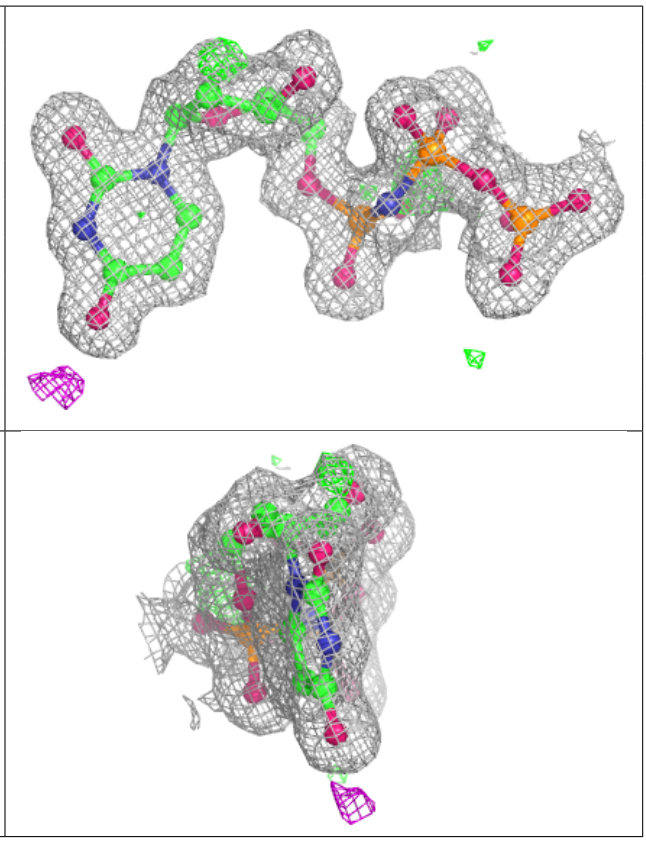
median, 95th percentile and maximum values of B factors of atoms in the group. The column labelled 'Q< 0.9' lists the number of atoms with occupancy less than 0.9.

Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(Å^2)	Q<0.9
9	EDO	A	509	4/4	0.63	0.20	51,52,52,52	0
9	EDO	A	510	4/4	0.85	0.14	48,50,50,52	0
9	EDO	A	511	4/4	0.86	0.24	15,19,22,25	0
9	EDO	T	101	4/4	0.88	0.16	33,37,38,38	0
9	EDO	A	507	4/4	0.90	0.15	27,30,31,33	0
9	EDO	A	506	4/4	0.92	0.16	29,33,36,36	0
9	EDO	A	508	4/4	0.95	0.13	21,23,24,27	0
5	EPE	A	501	11/15	0.97	0.19	25,33,48,49	0
8	DUP	A	505	28/28	0.99	0.09	8,10,13,13	0
7	NA	A	504	1/1	0.99	0.06	16,16,16,16	0
6	MN	A	503	1/1	1.00	0.05	9,9,9,9	0
6	MN	A	502	1/1	1.00	0.06	9,9,9,9	0

The following is a graphical depiction of the model fit to experimental electron density of all instances of the Ligand of Interest. In addition, ligands with molecular weight > 250 and outliers as shown on the geometry validation Tables will also be included. Each fit is shown from different orientation to approximate a three-dimensional view.

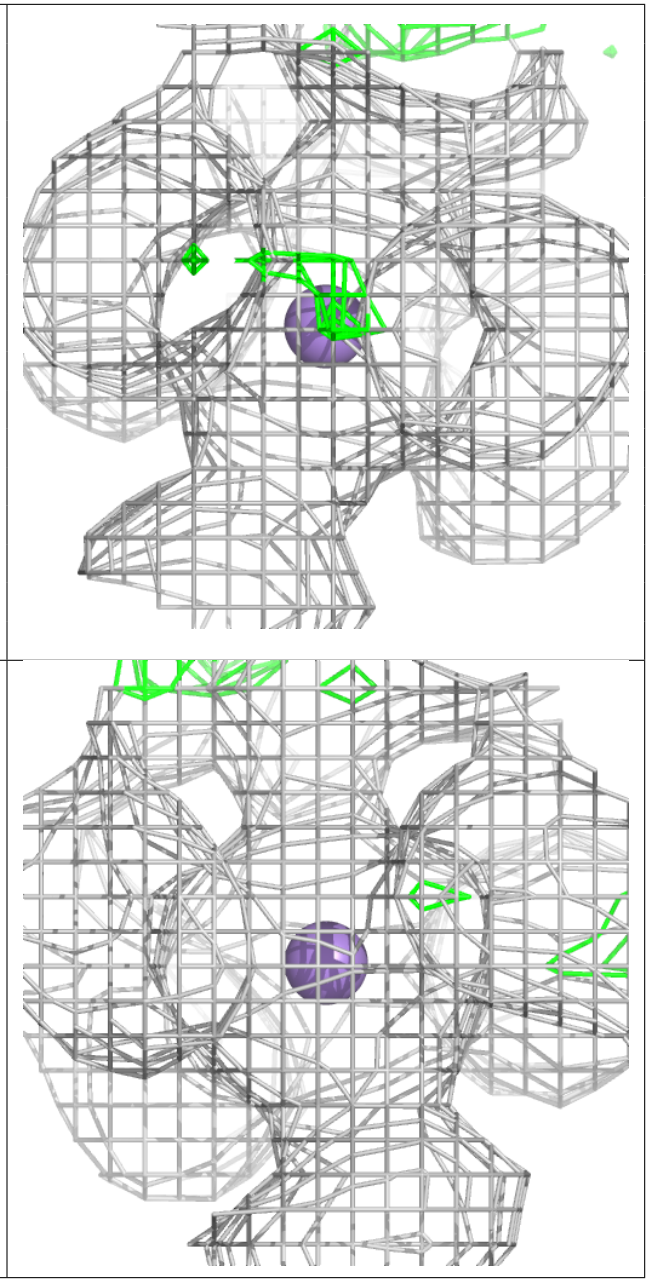
Electron density around DUP A 505:

$2mF_o$-DF_c (at 0.7 rmsd) in gray
mF_o-DF_c (at 3 rmsd) in purple (negative) and green (positive)



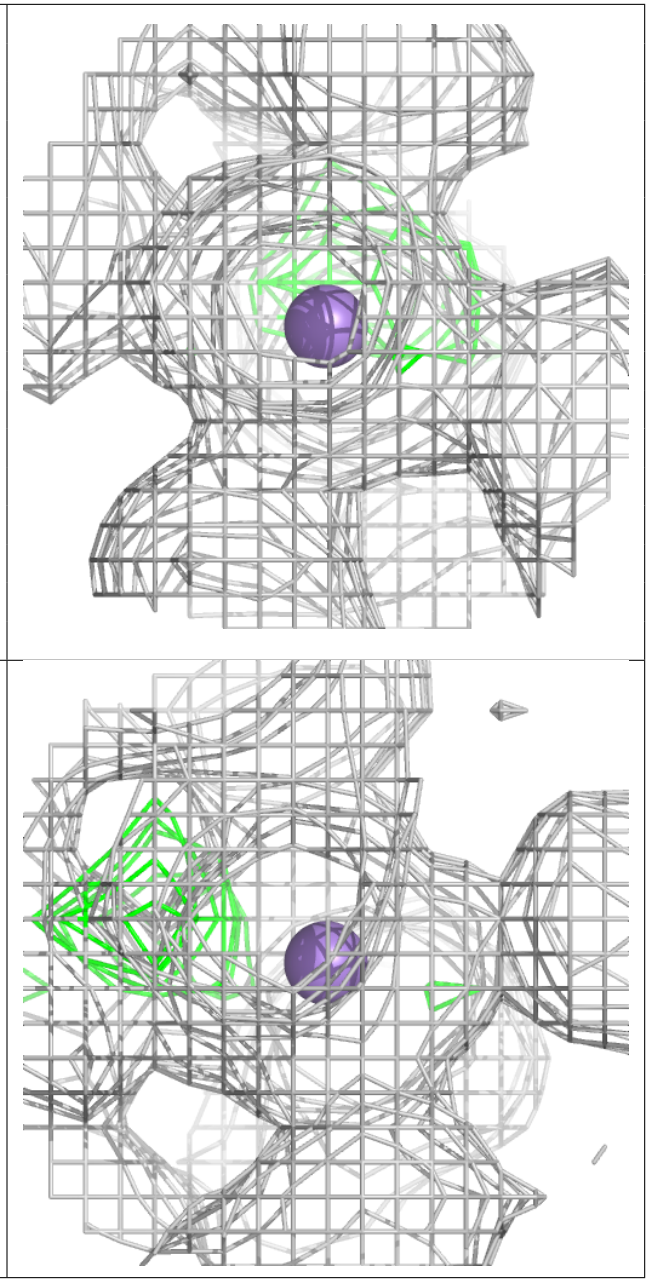
Electron density around MN A 503:

$2mF_o$-DF_c (at 0.7 rmsd) in gray
mF_o-DF_c (at 3 rmsd) in purple (negative)
and green (positive)



Electron density around MN A 502:

$2mF_o$-DF_c (at 0.7 rmsd) in gray
mF_o-DF_c (at 3 rmsd) in purple (negative)
and green (positive)



6.5 Other polymers (i)

There are no such residues in this entry.