wwPDB X-ray Structure Validation Summary Report (i)

Sep 16, 2023 – 06:11 PM EDT

PDB ID	:	4PLH
Title	:	Crystal structure of ancestral apicomplexan malate dehydrogenase with oxamate.
Authors	:	Boucher, J.I.; Jacobowitz, J.R.; Beckett, B.C.; Classen, S.; Theobald, D.L.
Deposited on	:	2014-05-16
Resolution	:	1.90 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 (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:

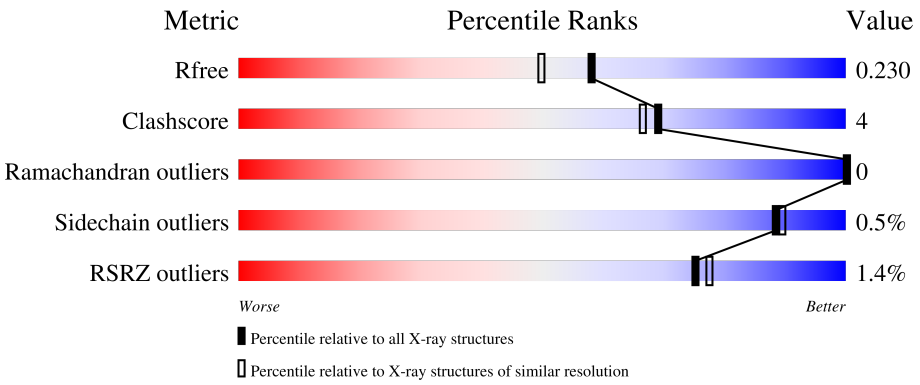
MolProbity	:	4.02b-467
Mogul	:	1.8.5 (274361), CSD as541be (2020)
Xtriage (Phenix)	:	1.13
EDS	:	2.35.1
buster-report	:	1.1.7 (2018)
Percentile statistics	:	20191225.v01 (using entries in the PDB archive December 25th 2019)
Refmac	:	5.8.0158
CCP4	:	7.0.044 (Gargrove)
Ideal geometry (proteins)	:	Engh & Huber (2001)
Ideal geometry (DNA, RNA)	:	Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP)	:	2.35.1

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 1.90 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	6207 (1.90-1.90)
Clashscore	141614	6847 (1.90-1.90)
Ramachandran outliers	138981	6760 (1.90-1.90)
Sidechain outliers	138945	6760 (1.90-1.90)
RSRZ outliers	127900	6082 (1.90-1.90)

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	326	89% 6% •
1	B	326	2% 87% 9% •
1	C	326	% 88% 5% 6%
1	D	326	2% 89% 8% •

2 Entry composition (i)

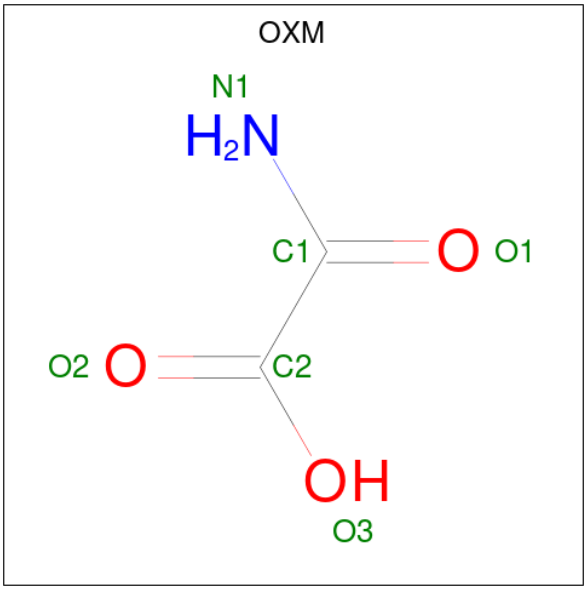
There are 5 unique types of molecules in this entry. The entry contains 10216 atoms, of which 0 are hydrogens and 0 are deuteriums.

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 malate dehydrogenase.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	S			
1	A	313	2368	1507	391	457	13	0	0	0
1	B	313	2367	1503	393	455	16	0	2	0
1	C	305	2324	1487	384	438	15	0	5	0
1	D	316	2437	1550	402	470	15	0	12	0

- Molecule 2 is OXAMIC ACID (three-letter code: OXM) (formula: $C_2H_3NO_3$).



Mol	Chain	Residues	Atoms				ZeroOcc	AltConf
			Total	C	N	O		
2	A	1	6	2	1	3	0	0
2	B	1	6	2	1	3	0	0

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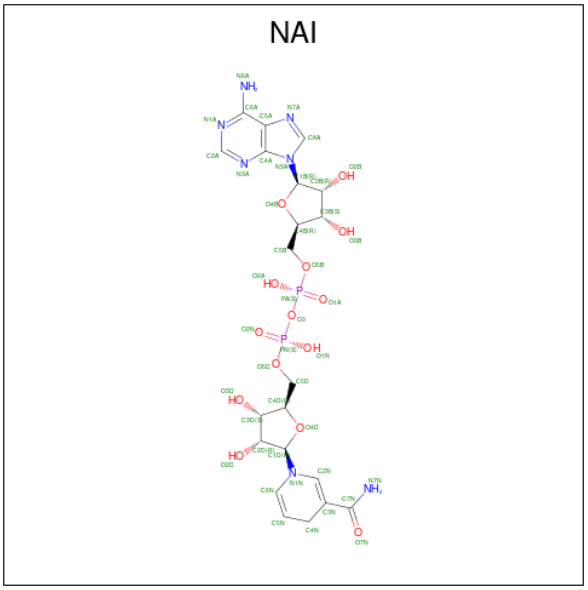
Mol	Chain	Residues	Atoms				ZeroOcc	AltConf
			Total	C	N	O		
2	C	1	6	2	1	3	0	0
			Total	C	N	O		
2	D	1	6	2	1	3	0	0

- Molecule 3 is SODIUM ION (three-letter code: NA) (formula: Na).

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
			Total	Na		
3	A	1	1	1	0	0
			Total	Na		
3	D	1	1	1	0	0

- Molecule 4 is 1,4-DIHYDRONICOTINAMIDE ADENINE DINUCLEOTIDE (three-letter code: NAI) (formula: $C_{21}H_{29}N_7O_{14}P_2$).



Mol	Chain	Residues	Atoms					ZeroOcc	AltConf
			Total	C	N	O	P		
4	A	1	44	21	7	14	2	0	0
			Total	C	N	O	P		
4	B	1	44	21	7	14	2	0	0
			Total	C	N	O	P		
4	C	1	44	21	7	14	2	0	0
			Total	C	N	O	P		
4	D	1	44	21	7	14	2	0	0

- Molecule 5 is water.

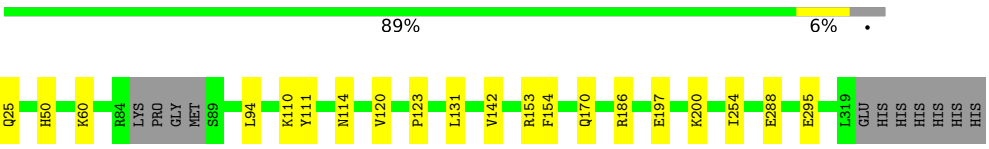
Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
			Total	O		
5	A	124	124	124	0	0
			Total	O		
5	B	128	128	128	0	0
			Total	O		
5	C	120	120	120	0	0
			Total	O		
5	D	146	146	146	0	0

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.

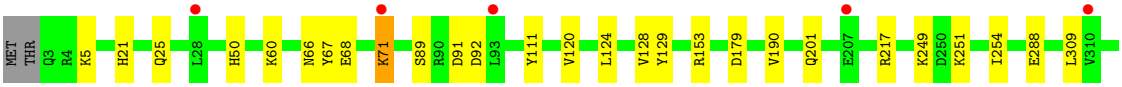
• Molecule 1: malate dehydrogenase

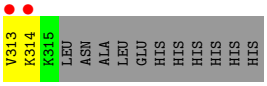
Chain A:



• Molecule 1: malate dehydrogenase

Chain B:





• Molecule 1: malate dehydrogenase

Chain C:

• Molecule 1: malate dehydrogenase

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	89.42Å 104.57Å 142.46Å 90.00° 90.00° 90.00°	Depositor
Resolution (Å)	45.14 – 1.90 45.14 – 1.73	Depositor EDS
% Data completeness (in resolution range)	99.9 (45.14-1.90) 95.2 (45.14-1.73)	Depositor EDS
R_{merge}	(Not available)	Depositor
R_{sym}	(Not available)	Depositor
$< I/\sigma(I) >$ [1]	1.03 (at 1.73Å)	Xtriage
Refinement program	PHENIX (phenix.refine: 1.8.4_1496)	Depositor
R, R_{free}	0.180 , 0.228 0.182 , 0.230	Depositor DCC
R_{free} test set	2000 reflections (1.50%)	wwPDB-VP
Wilson B-factor (Å^2)	22.8	Xtriage
Anisotropy	0.247	Xtriage
Bulk solvent k_{sol}(e/Å^3), B_{sol}(Å^2)	0.39 , 46.0	EDS
L-test for twinning[2]	$< \|L\| > = 0.49$, $< L^2 > = 0.32$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
F_o,F_c correlation	0.96	EDS
Total number of atoms	10216	wwPDB-VP
Average B, all atoms (Å^2)	36.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 3.91% 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: NAI, NA, OXM

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	0.48	0/2403	0.59	1/3253 (0.0%)
1	B	0.49	0/2410	0.60	0/3267
1	C	0.48	0/2373	0.59	1/3210 (0.0%)
1	D	0.50	0/2488	0.59	1/3373 (0.0%)
All	All	0.49	0/9674	0.59	3/13103 (0.0%)

There are no bond length outliers.

All (3) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
1	D	131	LEU	CA-CB-CG	-6.62	100.08	115.30
1	A	4	ARG	NE-CZ-NH1	-5.35	117.63	120.30
1	C	131	LEU	CA-CB-CG	-5.09	103.60	115.30

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	2368	0	2398	16	0
1	B	2367	0	2381	29	0
1	C	2324	0	2381	14	0
1	D	2437	0	2446	22	0

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Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
2	A	6	0	2	0	0
2	B	6	0	2	0	0
2	C	6	0	2	0	0
2	D	6	0	2	0	0
3	A	1	0	0	0	0
3	D	1	0	0	0	0
4	A	44	0	27	1	0
4	B	44	0	27	1	0
4	C	44	0	27	2	0
4	D	44	0	27	2	0
5	A	124	0	0	2	1
5	B	128	0	0	1	1
5	C	120	0	0	1	0
5	D	146	0	0	3	0
All	All	10216	0	9722	71	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 4.

The worst 5 of 71 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:B:71:LYS:N	1:B:71:LYS:HD3	1.79	0.90
1:B:71:LYS:HE3	1:B:111:TYR:CD1	2.10	0.86
1:B:67:TYR:O	1:B:71:LYS:NZ	2.13	0.81
1:D:218[B]:ASN:OD1	5:D:501:HOH:O	2.08	0.70
1:D:281:ASN:ND2	5:D:502:HOH:O	2.32	0.62

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)
5:A:507:HOH:O	5:B:507:HOH:O[3_545]	2.02	0.18

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	309/326 (95%)	300 (97%)	9 (3%)	0	100	100
1	B	313/326 (96%)	305 (97%)	8 (3%)	0	100	100
1	C	306/326 (94%)	301 (98%)	5 (2%)	0	100	100
1	D	326/326 (100%)	316 (97%)	10 (3%)	0	100	100
All	All	1254/1304 (96%)	1222 (97%)	32 (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	259/277 (94%)	258 (100%)	1 (0%)	91	91
1	B	258/277 (93%)	256 (99%)	2 (1%)	81	82
1	C	254/277 (92%)	253 (100%)	1 (0%)	91	91
1	D	265/277 (96%)	264 (100%)	1 (0%)	91	91
All	All	1036/1108 (94%)	1031 (100%)	5 (0%)	88	89

All (5) residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	154	PHE
1	B	71	LYS

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Mol	Chain	Res	Type
1	B	91	ASP
1	C	93	LEU
1	D	288	GLU

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (4) such sidechains are listed below:

Mol	Chain	Res	Type
1	A	114	ASN
1	B	25	GLN
1	B	201	GLN
1	D	25	GLN

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 10 ligands modelled in this entry, 2 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	$\#\|Z\| > 2$
2	OXM	D	401	-	5,5,5	2.35	1 (20%)	4,6,6	1.29	1 (25%)

Mol	Type	Chain	Res	Link	Bond lengths			Bond angles		
					Counts	RMSZ	$\#\|Z\| > 2$	Counts	RMSZ	$\#\|Z\| > 2$
2	OXM	C	401	-	5,5,5	2.28	1 (20%)	4,6,6	0.76	0
4	NAI	D	403	3	42,48,48	1.05	2 (4%)	47,73,73	1.24	4 (8%)
4	NAI	A	403	3	42,48,48	1.04	2 (4%)	47,73,73	1.24	6 (12%)
4	NAI	B	402	-	42,48,48	0.99	2 (4%)	47,73,73	1.28	7 (14%)
2	OXM	B	401	-	5,5,5	2.31	1 (20%)	4,6,6	1.32	1 (25%)
2	OXM	A	401	-	5,5,5	1.87	1 (20%)	4,6,6	1.08	0
4	NAI	C	402	-	42,48,48	1.00	2 (4%)	47,73,73	1.17	4 (8%)

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	OXM	D	401	-	-	3/3/4/4	-
2	OXM	C	401	-	-	3/3/4/4	-
4	NAI	D	403	3	-	5/25/72/72	0/5/5/5
4	NAI	A	403	3	-	5/25/72/72	0/5/5/5
4	NAI	B	402	-	-	5/25/72/72	0/5/5/5
2	OXM	B	401	-	-	3/3/4/4	-
2	OXM	A	401	-	-	3/3/4/4	-
4	NAI	C	402	-	-	5/25/72/72	0/5/5/5

The worst 5 of 12 bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
2	D	401	OXM	C1-C2	-4.75	1.49	1.55
2	B	401	OXM	C1-C2	-4.71	1.49	1.55
2	C	401	OXM	C1-C2	-4.54	1.49	1.55
4	D	403	NAI	C6N-C5N	4.46	1.41	1.33
4	A	403	NAI	C6N-C5N	4.14	1.40	1.33

The worst 5 of 23 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
4	B	402	NAI	N3A-C2A-N1A	-4.01	122.41	128.68
4	D	403	NAI	N3A-C2A-N1A	-3.96	122.50	128.68
4	A	403	NAI	N3A-C2A-N1A	-3.80	122.74	128.68
4	C	402	NAI	N3A-C2A-N1A	-3.67	122.94	128.68

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Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
4	D	403	NAI	C2A-N1A-C6A	2.91	123.73	118.75

There are no chirality outliers.

5 of 32 torsion outliers are listed below:

Mol	Chain	Res	Type	Atoms
2	A	401	OXM	N1-C1-C2-O2
2	A	401	OXM	N1-C1-C2-O3
2	A	401	OXM	O1-C1-C2-O2
2	B	401	OXM	N1-C1-C2-O2
2	B	401	OXM	N1-C1-C2-O3

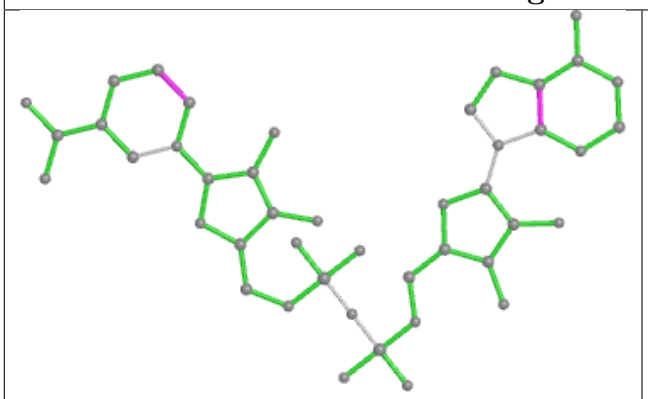
There are no ring outliers.

4 monomers are involved in 6 short contacts:

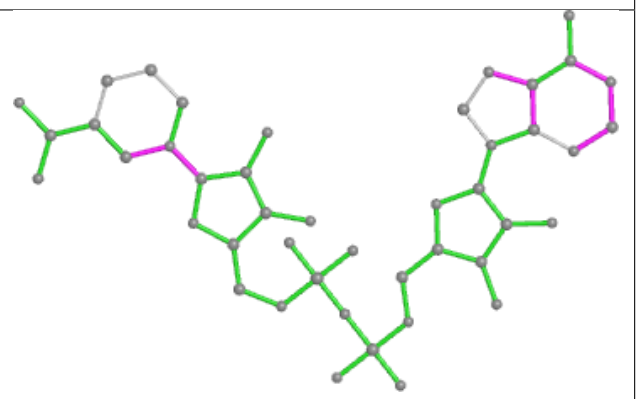
Mol	Chain	Res	Type	Clashes	Symm-Clashes
4	D	403	NAI	2	0
4	A	403	NAI	1	0
4	B	402	NAI	1	0
4	C	402	NAI	2	0

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.

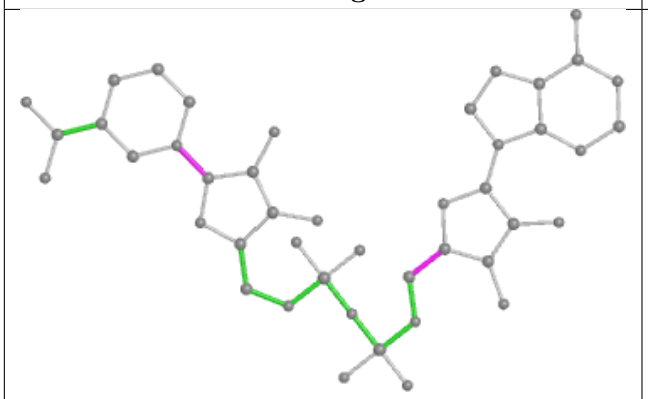
Ligand NAI D 403



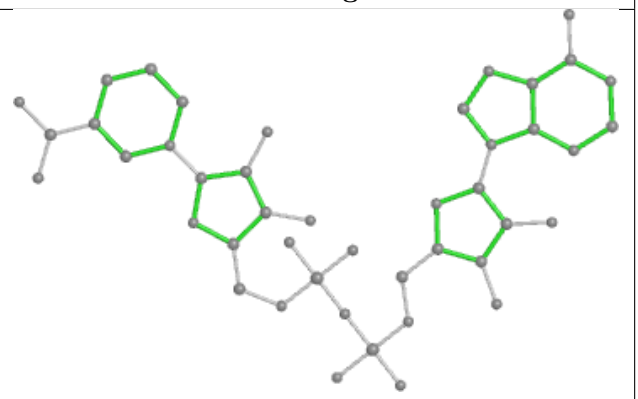
Bond lengths



Bond angles

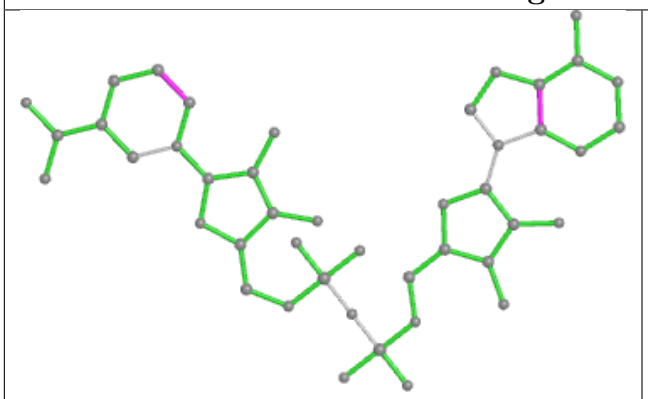


Torsions

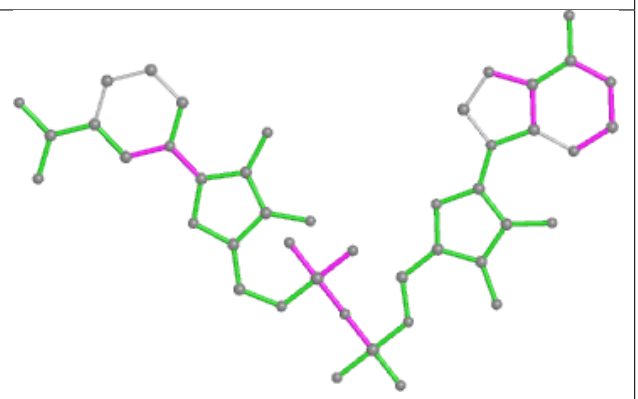


Rings

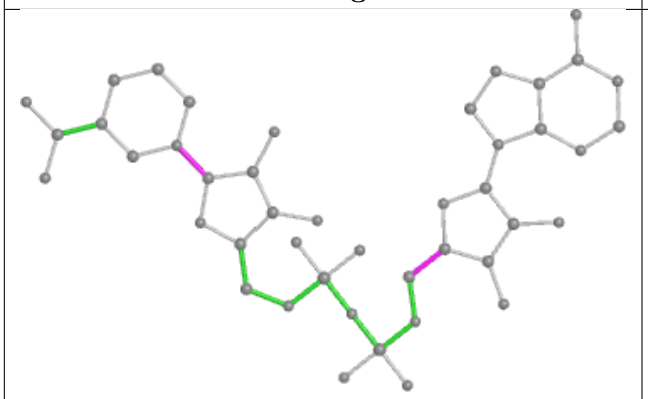
Ligand NAI A 403



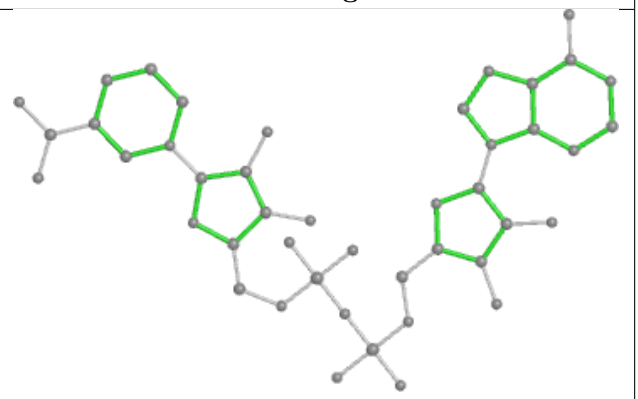
Bond lengths



Bond angles

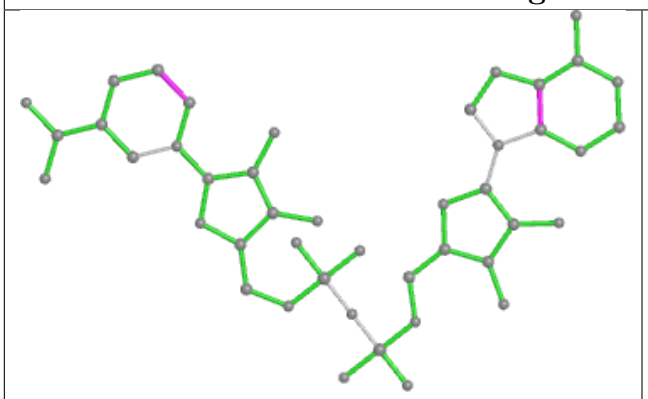


Torsions

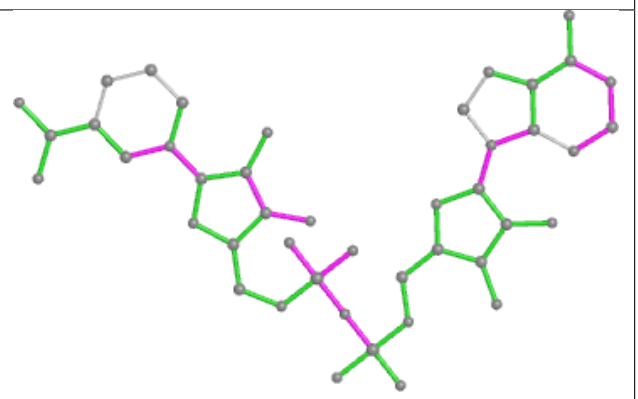


Rings

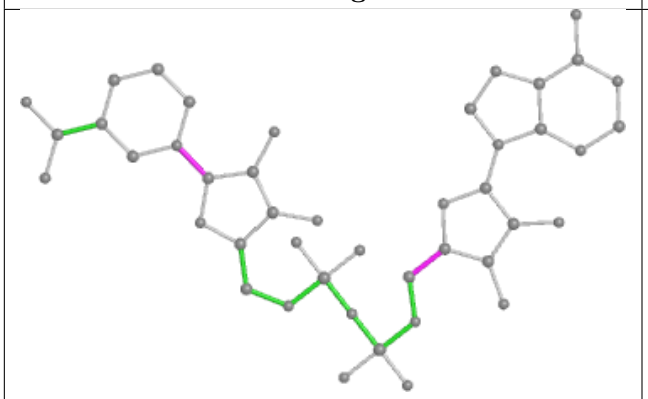
Ligand NAI B 402



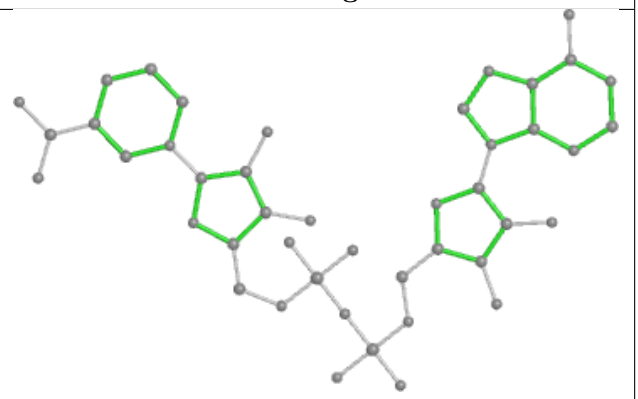
Bond lengths



Bond angles

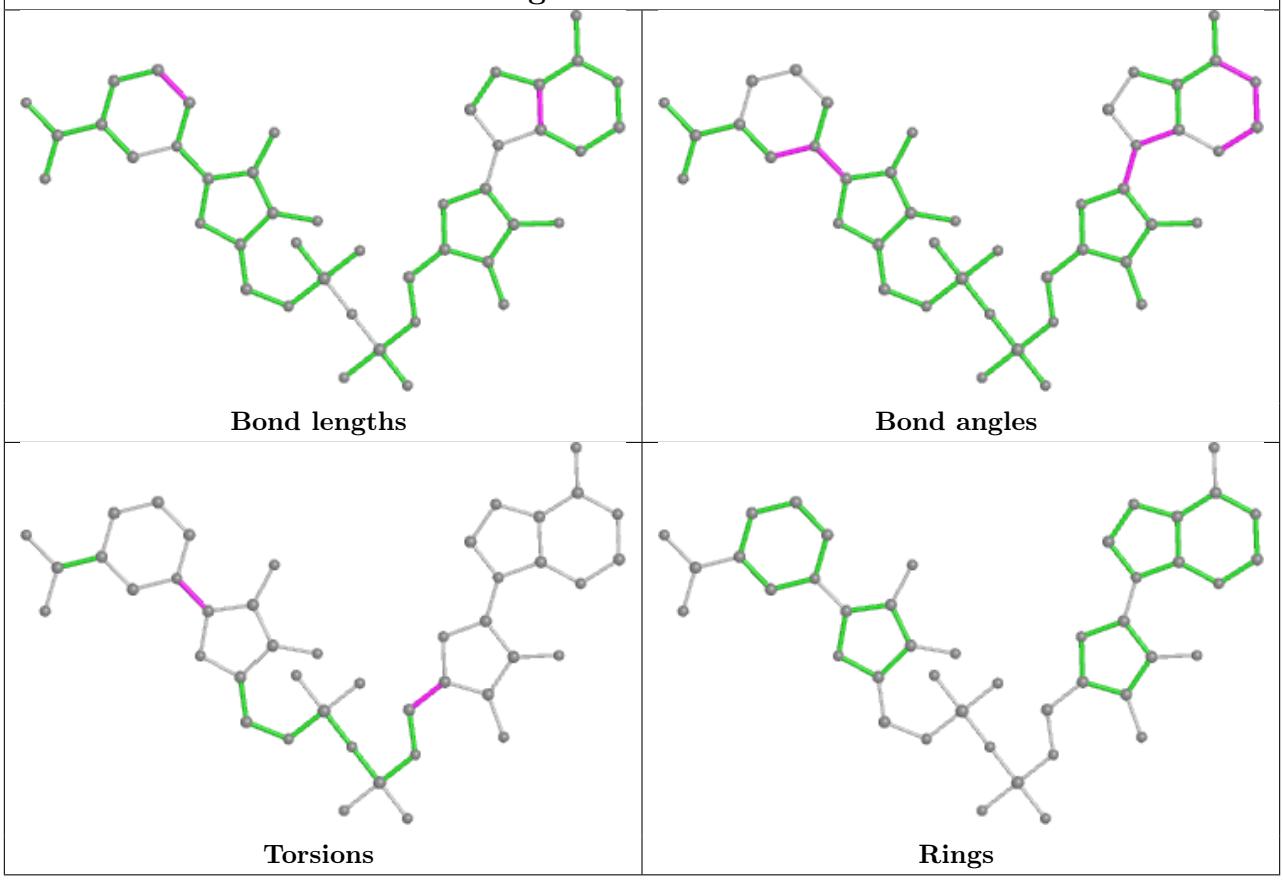


Torsions



Rings

Ligand NAI C 402



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	313/326 (96%)	-0.22	0	100	100	23, 34, 53, 66	0
1	B	313/326 (96%)	-0.02	7 (2%)	62	64	24, 36, 55, 71	0
1	C	305/326 (93%)	-0.16	4 (1%)	77	79	23, 35, 53, 71	0
1	D	316/326 (96%)	-0.12	6 (1%)	66	69	22, 34, 51, 75	0
All	All	1247/1304 (95%)	-0.13	17 (1%)	75	77	22, 35, 53, 75	0

The worst 5 of 17 RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	C	93	LEU	3.9
1	B	71	LYS	2.9
1	D	88[A]	MET	2.7
1	B	313	VAL	2.6
1	B	93	LEU	2.5

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)

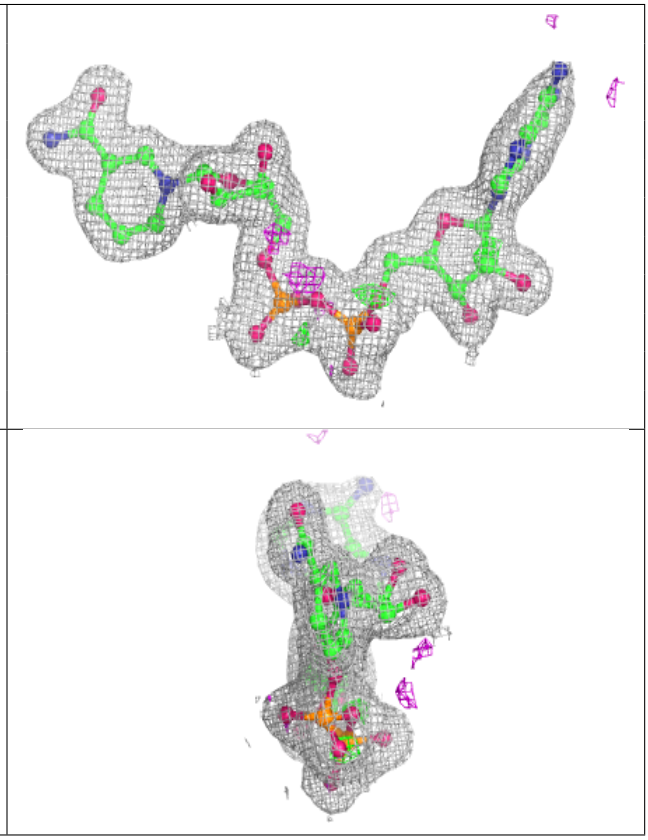
In the following table, the Atoms column lists the number of modelled atoms in the group and the number defined in the chemical component dictionary. The B-factors column lists the minimum, median, 95th percentile and maximum values of B factors of atoms in the group. The column labelled 'Q< 0.9' lists the number of atoms with occupancy less than 0.9.

Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(Å^2)	Q<0.9
2	OXM	D	401	6/6	0.85	0.19	27,45,48,57	0
2	OXM	A	401	6/6	0.86	0.23	24,50,59,73	0
2	OXM	C	401	6/6	0.88	0.34	26,55,64,65	0
2	OXM	B	401	6/6	0.89	0.23	29,47,64,64	0
4	NAI	B	402	44/44	0.96	0.10	25,29,43,50	0
4	NAI	D	403	44/44	0.96	0.08	26,29,37,41	0
4	NAI	C	402	44/44	0.97	0.07	27,32,44,51	0
4	NAI	A	403	44/44	0.98	0.07	24,29,33,39	0
3	NA	D	402	1/1	0.98	0.11	33,33,33,33	0
3	NA	A	402	1/1	0.99	0.08	31,31,31,31	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.

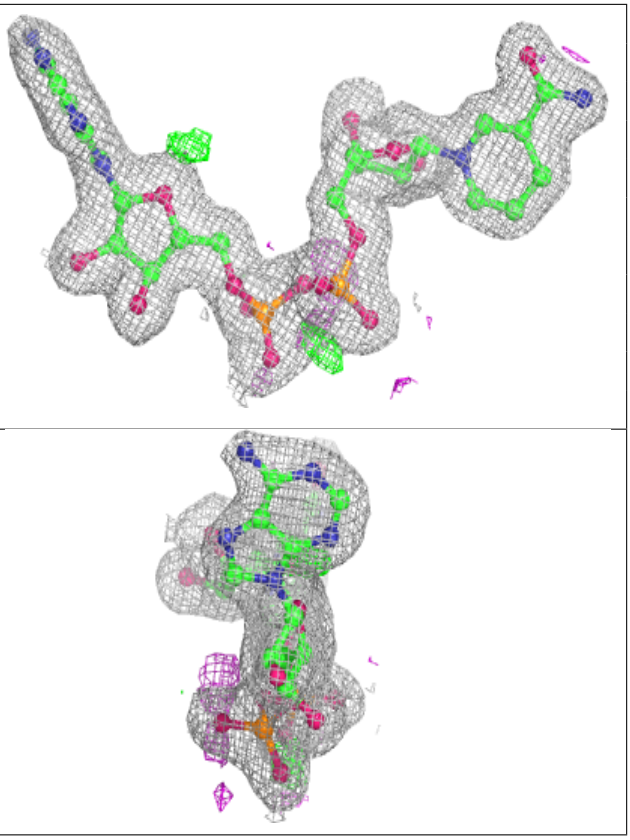
Electron density around NAI B 402:

2mF$_o$-DF$_c$ (at 0.7 rmsd) in gray
mF$_o$-DF$_c$ (at 3 rmsd) in purple (negative)
and green (positive)



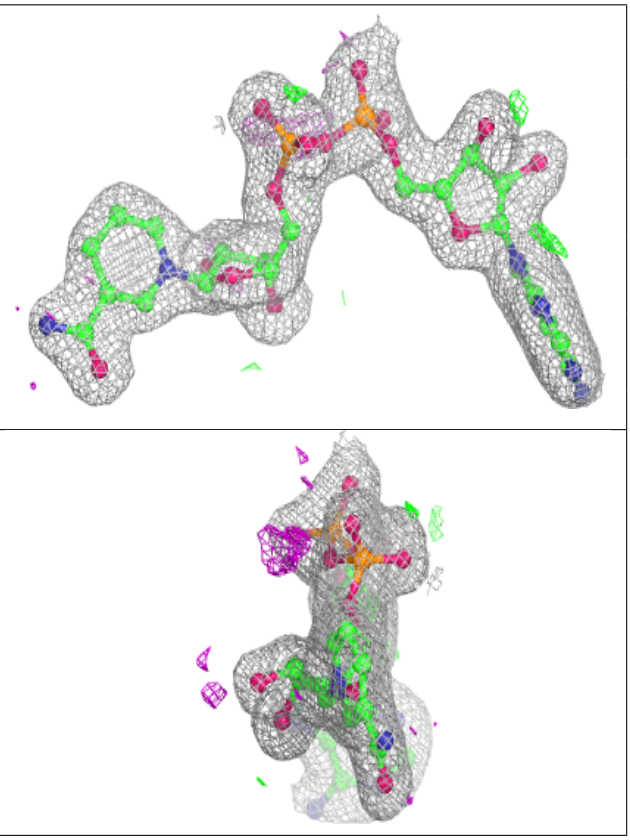
Electron density around NAI D 403:

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



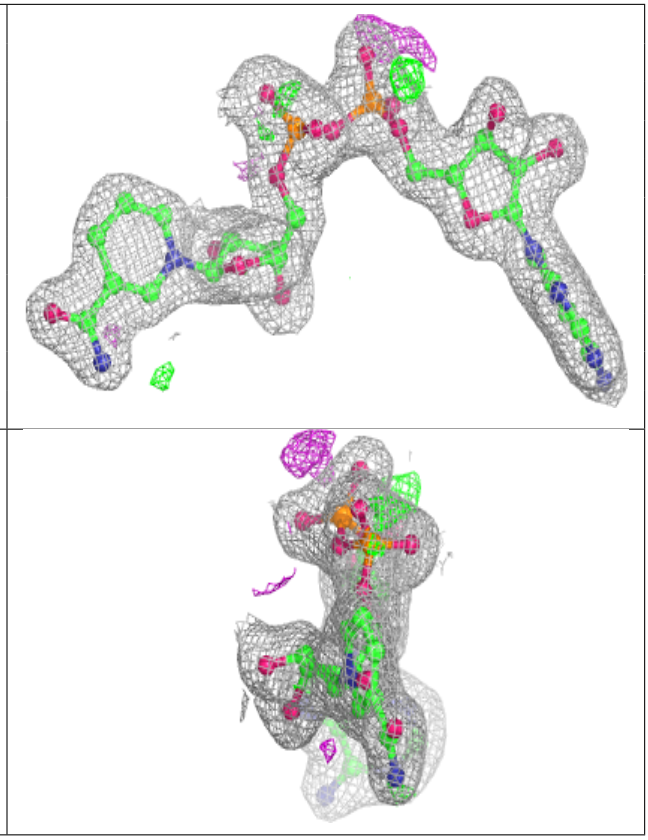
Electron density around NAI C 402:

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



Electron density around NAI A 403:

$2mF_o$-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.