



# Full wwPDB X-ray Structure Validation Report ⓘ

Aug 28, 2025 – 04:25 PM EDT

PDB ID : 9OLN / pdb\_00009oln  
Title : Crystal structure of E. coli ApaH in complex with NAD+  
Authors : Nuthanakanti, A.; Serganov, A.  
Deposited on : 2025-05-12  
Resolution : 1.98 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](mailto: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>.

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The following versions of software and data (see [references ⓘ](#)) were used in the production of this report:

MolProbity : 4-5-2 with Phenix2.0rc1  
Mogul : 2022.3.0, CSD as543be (2022)  
Xtriage (Phenix) : 2.0rc1  
EDS : 3.0  
buster-report : 1.1.7 (2018)  
Percentile statistics : 20231227.v01 (using entries in the PDB archive December 27th 2023)  
CCP4 : 9.0.006 (Gargrove)  
Density-Fitness : 1.0.12  
Ideal geometry (proteins) : Engh & Huber (2001)  
Ideal geometry (DNA, RNA) : Parkinson et al. (1996)  
Validation Pipeline (wwPDB-VP) : 2.45.1

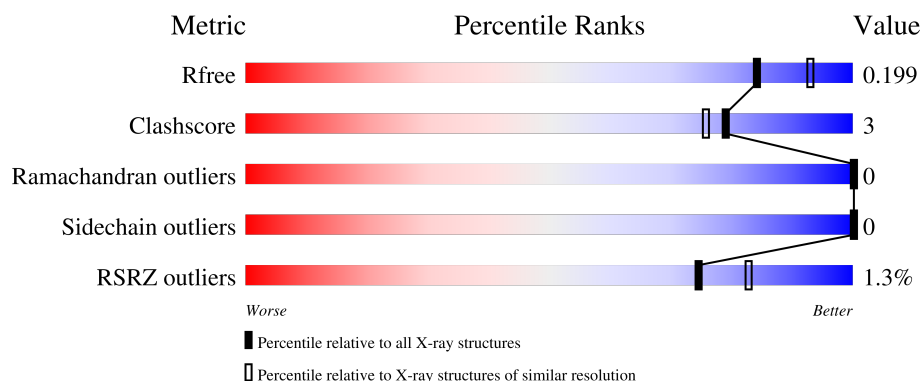
# 1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

*X-RAY DIFFRACTION*



The reported resolution of this entry is 1.98 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))
$R_{free}$	164625	1356 (1.98-1.98)
Clashscore	180529	1437 (1.98-1.98)
Ramachandran outliers	177936	1426 (1.98-1.98)
Sidechain outliers	177891	1426 (1.98-1.98)
RSRZ outliers	164620	1356 (1.98-1.98)

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  $\geq 3$ , 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	286	
1	B	286	

## 2 Entry composition

There are 7 unique types of molecules in this entry. The entry contains 4839 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.

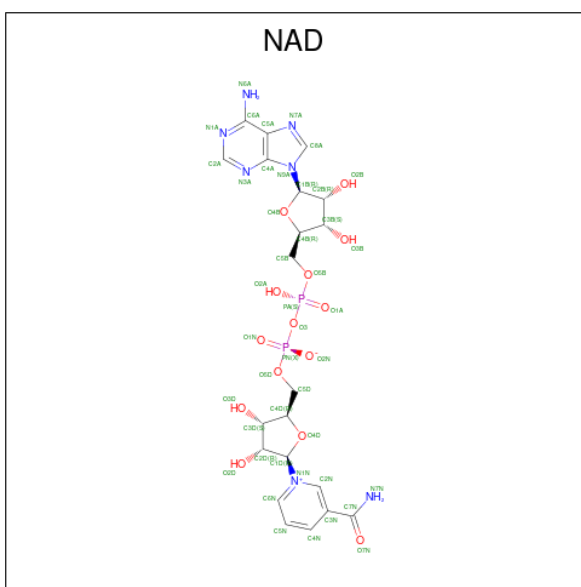
- Molecule 1 is a protein called Bis(5'-nucleosyl)-tetraphosphatase [symmetrical].

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
1	A	269	Total	C	N	O	S	0	4	0
			2123	1367	358	386	12			
1	B	269	Total	C	N	O	S	0	8	0
			2153	1390	364	386	13			

There are 12 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	281	HIS	-	expression tag	UNP P05637
A	282	HIS	-	expression tag	UNP P05637
A	283	HIS	-	expression tag	UNP P05637
A	284	HIS	-	expression tag	UNP P05637
A	285	HIS	-	expression tag	UNP P05637
A	286	HIS	-	expression tag	UNP P05637
B	281	HIS	-	expression tag	UNP P05637
B	282	HIS	-	expression tag	UNP P05637
B	283	HIS	-	expression tag	UNP P05637
B	284	HIS	-	expression tag	UNP P05637
B	285	HIS	-	expression tag	UNP P05637
B	286	HIS	-	expression tag	UNP P05637

- Molecule 2 is NICOTINAMIDE-ADENINE-DINUCLEOTIDE (CCD ID: NAD) (formula: C<sub>21</sub>H<sub>27</sub>N<sub>7</sub>O<sub>14</sub>P<sub>2</sub>) (labeled as "Ligand of Interest" by depositor).



Mol	Chain	Residues	Atoms					ZeroOcc	AltConf
2	A	1	Total	C	N	O	P	0	0
			28	11	5	10	2		
2	B	1	Total	C	N	O	P	0	0
			28	11	5	10	2		

- Molecule 3 is MANGANESE (II) ION (CCD ID: MN) (formula: Mn).

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
3	A	2	Total	Mn	0	1
			2	2		
3	B	2	Total	Mn	0	1
			2	2		

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

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

- Molecule 5 is SULFATE ION (CCD ID: SO4) (formula: O<sub>4</sub>S).



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

- Molecule 6 is 4-(2-HYDROXYETHYL)-1-PIPERAZINE ETHANESULFONIC ACID (CCD ID: EPE) (formula: C<sub>8</sub>H<sub>18</sub>N<sub>2</sub>O<sub>4</sub>S).



Mol	Chain	Residues	Atoms					ZeroOcc	AltConf
6	B	1	Total	C	N	O	S	0	0
			15	8	2	4	1		

- Molecule 7 is water.

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
7	A	219	Total	O	0	0
			219	219		
7	B	242	Total	O	0	0
			242	242		

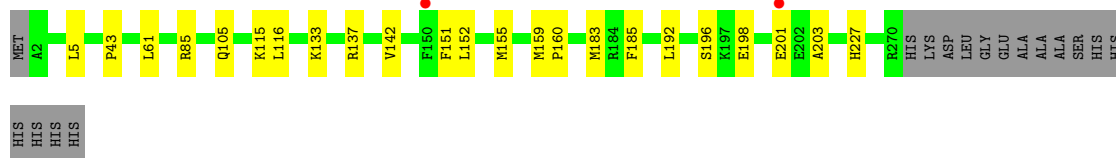
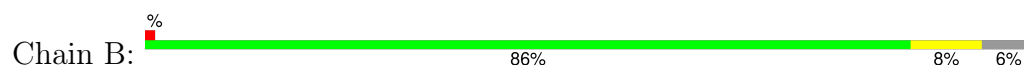
### 3 Residue-property plots

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: Bis(5'-nucleosyl)-tetraphosphatase [symmetrical]



- Molecule 1: Bis(5'-nucleosyl)-tetraphosphatase [symmetrical]



## 4 Data and refinement statistics

Property	Value	Source
Space group	C 1 2 1	Depositor
Cell constants a, b, c, $\alpha$ , $\beta$ , $\gamma$	167.28Å 54.97Å 120.18Å 90.00° 129.77° 90.00°	Depositor
Resolution (Å)	29.89 – 1.98 29.89 – 1.98	Depositor EDS
% Data completeness (in resolution range)	95.7 (29.89-1.98) 96.0 (29.89-1.98)	Depositor EDS
$R_{merge}$	0.18	Depositor
$R_{sym}$	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ <sup>1</sup>	1.40 (at 1.98Å)	Xtriage
Refinement program	PHENIX 1.20.1_4487	Depositor
R, $R_{free}$	0.172 , 0.199 0.172 , 0.199	Depositor DCC
$R_{free}$ test set	1937 reflections (3.30%)	wwPDB-VP
Wilson B-factor (Å <sup>2</sup> )	26.3	Xtriage
Anisotropy	0.130	Xtriage
Bulk solvent $k_{sol}$ (e/Å <sup>3</sup> ), $B_{sol}$ (Å <sup>2</sup> )	0.37 , 45.3	EDS
L-test for twinning <sup>2</sup>	$\langle  L  \rangle = 0.48$ , $\langle L^2 \rangle = 0.31$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
$F_o, F_c$ correlation	0.96	EDS
Total number of atoms	4839	wwPDB-VP
Average B, all atoms (Å <sup>2</sup> )	29.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 5.29% of the height of the origin peak. No significant pseudotranslation is detected.*

<sup>1</sup>Intensities estimated from amplitudes.

<sup>2</sup>Theoretical 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: EPE, SO4, NAD, MN, MG

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	0.36	0/2195	0.56	0/2989
1	B	0.36	0/2236	0.56	0/3042
All	All	0.36	0/4431	0.56	0/6031

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

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	2123	0	2065	8	0
1	B	2153	0	2107	13	0
2	A	28	0	12	0	0
2	B	28	0	12	0	0
3	A	2	0	0	0	0
3	B	2	0	0	0	0
4	A	1	0	0	0	0
4	B	1	0	0	0	0
5	A	15	0	0	1	0
5	B	10	0	0	0	0
6	B	15	0	17	0	0

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Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
7	A	219	0	0	2	1
7	B	242	0	0	1	0
All	All	4839	0	4213	22	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 (22) 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:133:LYS:O	1:B:137[A]:ARG:HG2	1.96	0.65
1:B:142:VAL:HB	1:B:151[B]:PHE:CD2	2.37	0.58
1:B:227:HIS:HA	7:B:424:HOH:O	2.03	0.58
1:B:159:MET:HE3	1:B:160:PRO:HA	1.86	0.56
1:A:170:LEU:O	1:A:174:ARG:HG3	2.09	0.52
1:A:148:TYR:CD1	1:A:149:PRO:HD3	2.46	0.51
1:A:227:HIS:HA	7:A:451:HOH:O	2.10	0.50
1:A:183:MET:HG3	1:A:192:LEU:HD22	1.92	0.50
5:A:305:SO4:O2	7:A:401:HOH:O	2.18	0.49
1:B:5:LEU:HD21	1:B:116:LEU:HD21	1.97	0.47
1:A:74:PHE:CD1	1:A:99:LEU:HD12	2.50	0.46
1:B:152:LEU:O	1:B:155[A]:MET:HG2	2.17	0.44
1:A:185:PHE:CZ	1:A:203:ALA:HB2	2.53	0.43
1:B:196:SER:HB3	1:B:198:GLU:OE2	2.18	0.43
1:B:201:GLU:CD	1:B:201:GLU:H	2.27	0.43
1:A:139:VAL:O	1:A:142:VAL:HG22	2.19	0.42
1:B:115:LYS:HD2	1:B:115:LYS:HA	1.74	0.42
1:B:185:PHE:CZ	1:B:203:ALA:HB2	2.55	0.42
1:A:115:LYS:HD2	1:A:115:LYS:HA	1.84	0.41
1:B:61:LEU:HD23	1:B:105:GLN:HG3	2.02	0.41
1:B:183:MET:HB2	1:B:192:LEU:HD22	2.03	0.41
1:B:43:PRO:HB3	1:B:85[B]:ARG:NH2	2.37	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)
7:A:463:HOH:O	7:A:615:HOH:O[4_545]	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	271/286 (95%)	266 (98%)	5 (2%)	0	100	100
1	B	274/286 (96%)	269 (98%)	5 (2%)	0	100	100
All	All	545/572 (95%)	535 (98%)	10 (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	221/239 (92%)	221 (100%)	0	100	100
1	B	226/239 (95%)	226 (100%)	0	100	100
All	All	447/478 (94%)	447 (100%)	0	100	100

There are no protein residues with a non-rotameric sidechain to report.

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	130	GLN
1	A	266	GLN
1	B	130	GLN
1	B	262	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 oligosaccharides in this entry.

## 5.6 Ligand geometry [i](#)

Of 14 ligands modelled in this entry, 6 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$
5	SO4	A	305	-	4,4,4	0.30	0	6,6,6	0.25	0
5	SO4	B	307	-	4,4,4	0.28	0	6,6,6	0.09	0
5	SO4	B	306	-	4,4,4	0.32	0	6,6,6	0.43	0
2	NAD	B	302	4,3	26,30,48	1.64	2 (7%)	29,46,73	0.98	2 (6%)
6	EPE	B	301	-	15,15,15	0.79	1 (6%)	19,20,20	1.44	4 (21%)
5	SO4	A	306	-	4,4,4	0.27	0	6,6,6	0.15	0
2	NAD	A	301	4,3	26,30,48	1.65	2 (7%)	29,46,73	0.86	2 (6%)
5	SO4	A	307	-	4,4,4	0.23	0	6,6,6	0.36	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	NAD	A	301	4,3	-	0/15/35/62	0/3/3/5

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Mol	Type	Chain	Res	Link	Chirals	Torsions	Rings
6	EPE	B	301	-	-	1/9/19/19	0/1/1/1
2	NAD	B	302	4,3	-	3/15/35/62	0/3/3/5

All (5) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
2	A	301	NAD	PN-O3	5.88	1.65	1.59
2	B	302	NAD	PN-O3	5.79	1.65	1.59
2	B	302	NAD	PA-O3	4.76	1.64	1.59
2	A	301	NAD	PA-O3	4.72	1.64	1.59
6	B	301	EPE	C10-S	2.66	1.81	1.77

All (8) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
6	B	301	EPE	C5-N4-C3	3.24	115.83	108.84
2	B	302	NAD	C4B-O4B-C1B	-2.62	107.52	109.92
6	B	301	EPE	O2S-S-C10	2.50	110.50	106.73
6	B	301	EPE	O1S-S-C10	2.25	110.13	106.73
2	A	301	NAD	C2B-C3B-C4B	2.16	106.78	102.61
2	B	302	NAD	O4B-C1B-N9A	2.16	111.61	108.75
2	A	301	NAD	O5B-C5B-C4B	-2.14	101.72	108.99
6	B	301	EPE	C7-N4-C3	2.11	116.86	111.24

There are no chirality outliers.

All (4) torsion outliers are listed below:

Mol	Chain	Res	Type	Atoms
2	B	302	NAD	C5D-O5D-PN-O2N
6	B	301	EPE	C8-C7-N4-C3
2	B	302	NAD	C5D-O5D-PN-O1N
2	B	302	NAD	PN-O3-PA-O5B

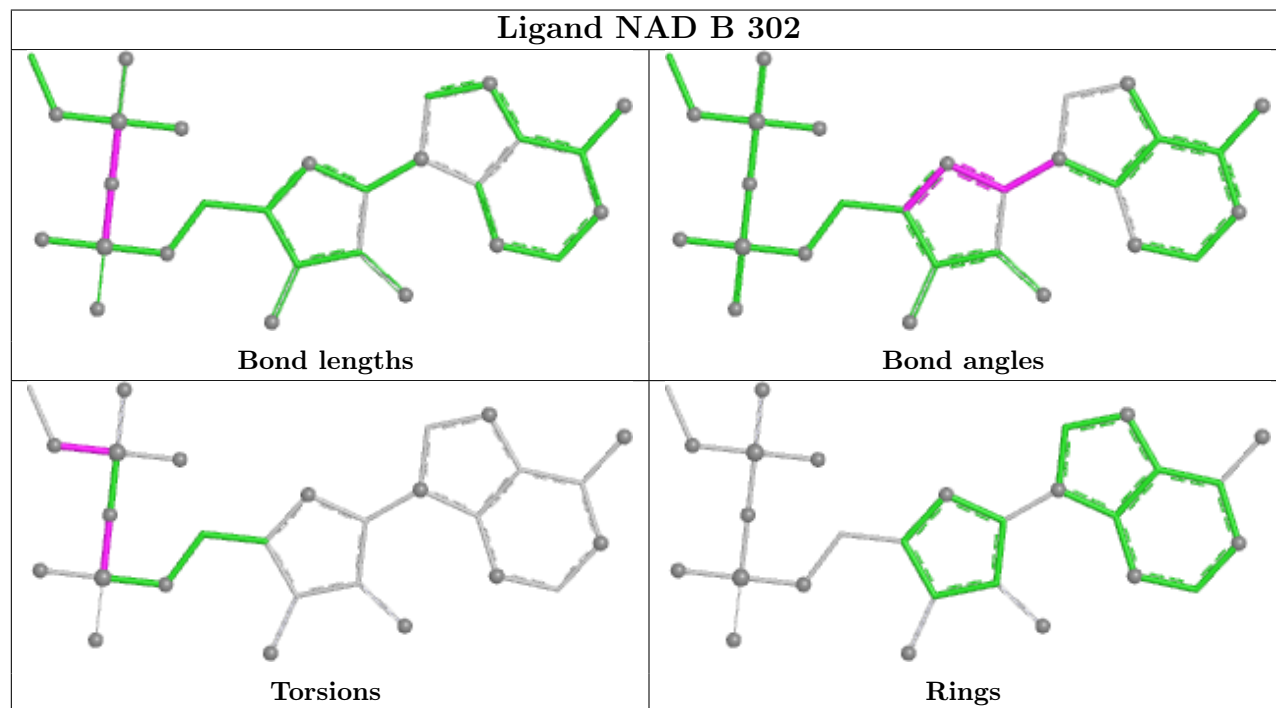
There are no ring outliers.

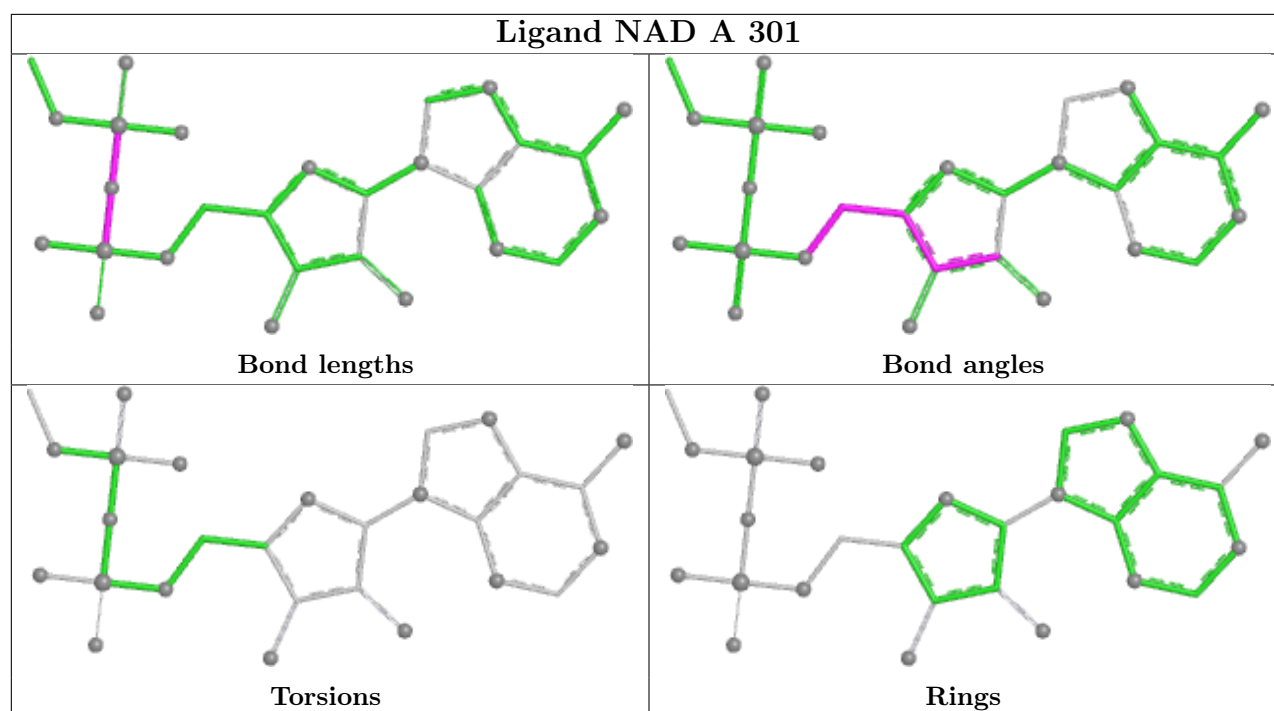
1 monomer is involved in 1 short contact:

Mol	Chain	Res	Type	Clashes	Symm-Clashes
5	A	305	SO4	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 than 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.





## 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, 95<sup>th</sup> 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 <sup>2</sup> )	Q<0.9
1	A	269/286 (94%)	-0.20	5 (1%) 66 75	15, 26, 45, 76	4 (1%)
1	B	269/286 (94%)	-0.33	2 (0%) 84 88	16, 25, 40, 70	7 (2%)
All	All	538/572 (94%)	-0.26	7 (1%) 74 83	15, 26, 43, 76	11 (2%)

All (7) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	A	270	ARG	2.9
1	B	150[A]	PHE	2.8
1	A	201	GLU	2.8
1	B	201	GLU	2.5
1	A	155	MET	2.1
1	A	137	ARG	2.1
1	A	219	GLU	2.0

### 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.

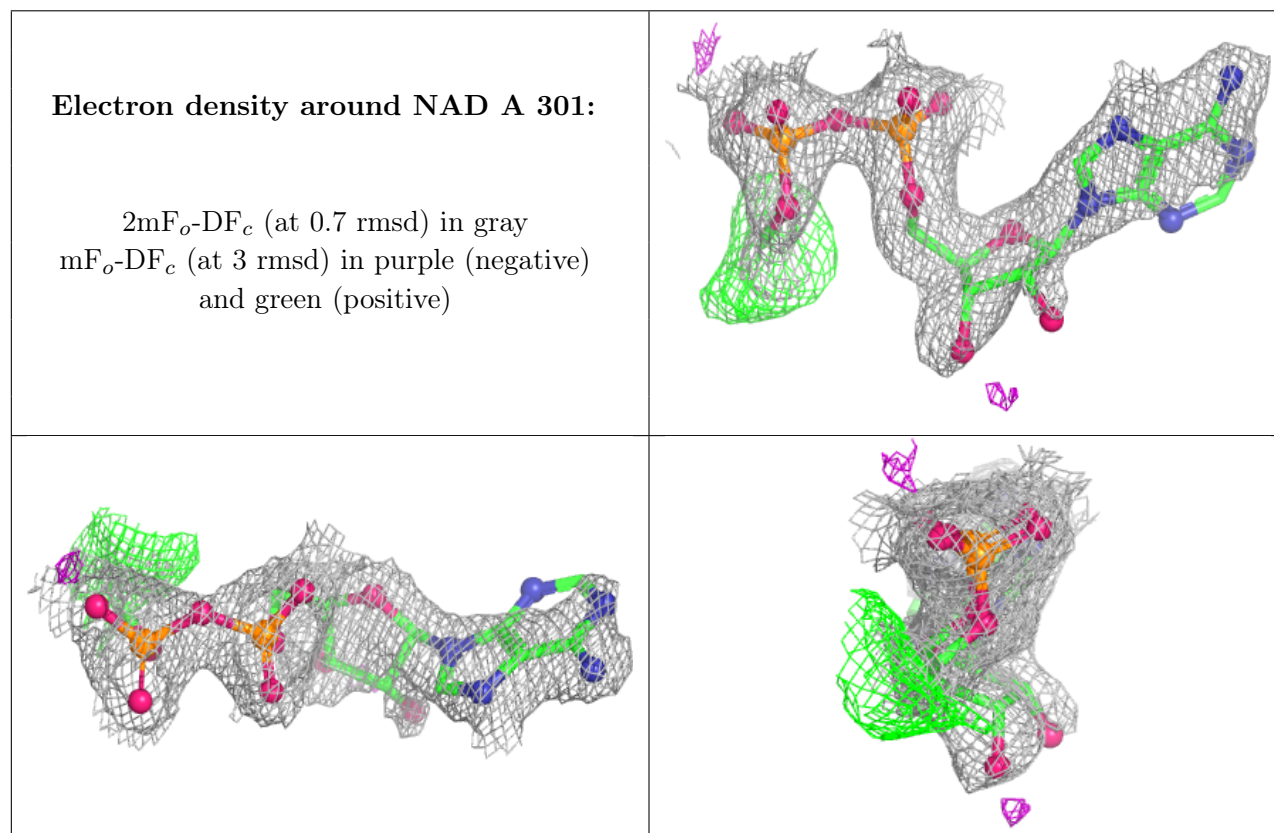
### 6.4 Ligands [i](#)

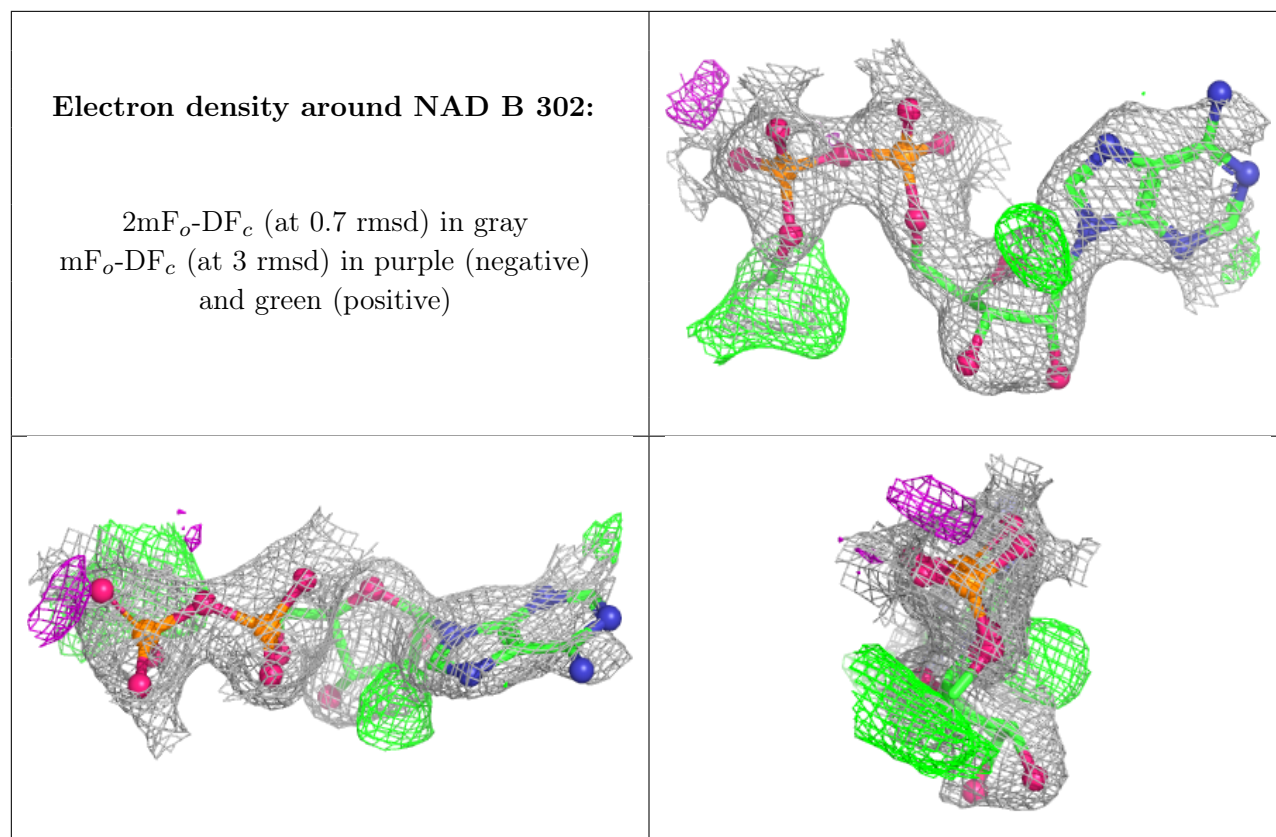
In the following table, the Atoms column lists the number of modelled atoms in the group and the number defined in the chemical component dictionary. The B-factors column lists the minimum, median, 95<sup>th</sup> percentile and maximum values of B factors of atoms in the group. The column labelled ‘Q < 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	305	5/5	0.63	0.29	31,36,40,45	5
5	SO4	B	306	5/5	0.76	0.18	28,28,45,50	5
5	SO4	A	306	5/5	0.84	0.14	46,46,54,59	5
5	SO4	B	307	5/5	0.84	0.14	40,42,50,53	5
5	SO4	A	307	5/5	0.87	0.13	40,45,49,53	5
2	NAD	A	301	28/44	0.91	0.14	36,49,54,54	27
2	NAD	B	302	28/44	0.92	0.13	33,45,51,55	27
6	EPE	B	301	15/15	0.95	0.08	35,39,45,48	2
3	MN	A	302[A]	1/1	0.99	0.02	27,27,27,27	1
3	MN	A	304	1/1	0.99	0.05	27,27,27,27	0
3	MN	B	303[A]	1/1	0.99	0.02	27,27,27,27	1
3	MN	B	305	1/1	0.99	0.04	26,26,26,26	0
4	MG	A	303[B]	1/1	0.99	0.02	27,27,27,27	1
4	MG	B	304[B]	1/1	0.99	0.02	27,27,27,27	1

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.





## 6.5 Other polymers ⓘ

There are no such residues in this entry.