



# wwPDB X-ray Structure Validation Summary Report ⓘ

Feb 19, 2026 – 12:33 pm GMT

PDB ID : 9S4V / pdb\_00009s4v  
Title : AcuB from Bacillus subtilis with AMP and ADP  
Authors : Janetzky, M.; Palm, G.J.; Lammers, M.  
Deposited on : 2025-07-28  
Resolution : 2.64 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](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 Phenix2.0  
Mogul : 1.8.4, CSD as541be (2020)  
Xtriage (Phenix) : 2.0  
EDS : 3.0  
buster-report : 1.1.7 (2018)  
Percentile statistics : 20231227.v01 (using entries in the PDB archive December 27th 2023)  
CCP4 : 9.0.010 (Gargrove)  
Density-Fitness : 1.0.12  
Ideal geometry (proteins) : Engh & Huber (2001)  
Ideal geometry (DNA, RNA) : Parkinson et al. (1996)  
Validation Pipeline (wwPDB-VP) : 2.48

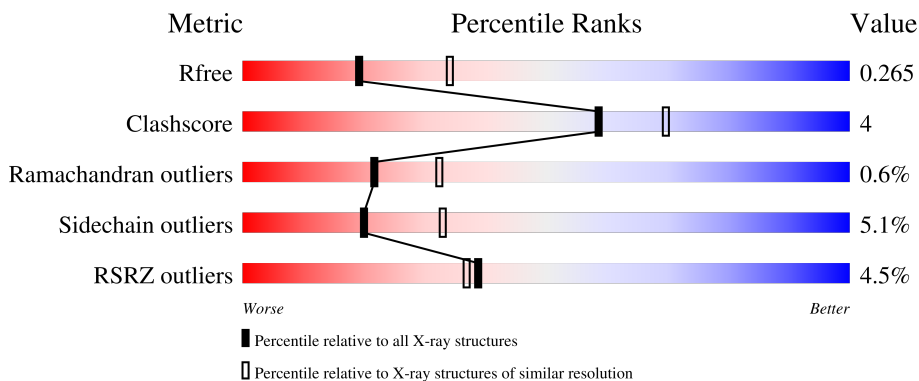
# 1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

*X-RAY DIFFRACTION*

The reported resolution of this entry is 2.64 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	1851 (2.66-2.62)
Clashscore	180529	1953 (2.66-2.62)
Ramachandran outliers	177936	1929 (2.66-2.62)
Sidechain outliers	177891	1929 (2.66-2.62)
RSRZ outliers	164620	1850 (2.66-2.62)

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	224	 4% 79% 18% ..
1	B	224	 % 86% 11% ..
1	C	224	 8% 77% 12% • 10%

## 2 Entry composition i

There are 4 unique types of molecules in this entry. The entry contains 10661 atoms, of which 5394 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 Acetoin utilization protein AcuB.

Mol	Chain	Residues	Atoms						ZeroOcc	AltConf	Trace
			Total	C	H	N	O	S			
1	A	219	3572	1118	1820	308	316	10	59	0	0
1	B	220	3580	1119	1825	307	319	10	59	1	0
1	C	202	3273	1024	1677	274	288	10	50	0	0

There are 30 discrepancies between the modelled and reference sequences:

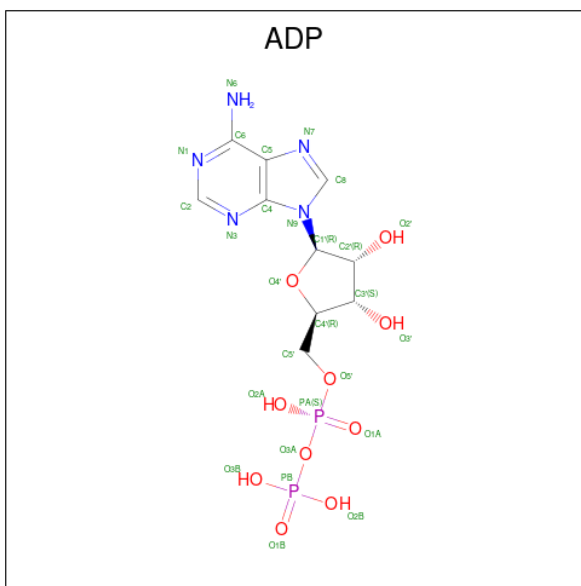
Chain	Residue	Modelled	Actual	Comment	Reference
A	0	GLY	-	expression tag	UNP P39066
A	215	GLY	-	expression tag	UNP P39066
A	216	SER	-	expression tag	UNP P39066
A	217	SER	-	expression tag	UNP P39066
A	218	HIS	-	expression tag	UNP P39066
A	219	HIS	-	expression tag	UNP P39066
A	220	HIS	-	expression tag	UNP P39066
A	221	HIS	-	expression tag	UNP P39066
A	222	HIS	-	expression tag	UNP P39066
A	223	HIS	-	expression tag	UNP P39066
B	0	GLY	-	expression tag	UNP P39066
B	215	GLY	-	expression tag	UNP P39066
B	216	SER	-	expression tag	UNP P39066
B	217	SER	-	expression tag	UNP P39066
B	218	HIS	-	expression tag	UNP P39066
B	219	HIS	-	expression tag	UNP P39066
B	220	HIS	-	expression tag	UNP P39066
B	221	HIS	-	expression tag	UNP P39066
B	222	HIS	-	expression tag	UNP P39066
B	223	HIS	-	expression tag	UNP P39066
C	0	GLY	-	expression tag	UNP P39066
C	215	GLY	-	expression tag	UNP P39066
C	216	SER	-	expression tag	UNP P39066

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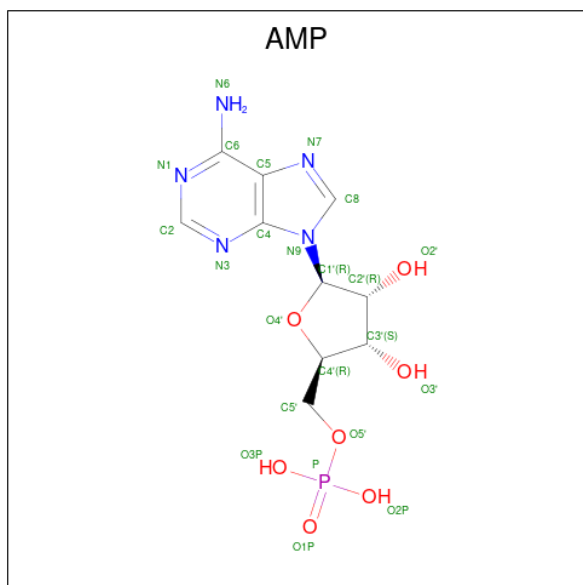
Chain	Residue	Modelled	Actual	Comment	Reference
C	217	SER	-	expression tag	UNP P39066
C	218	HIS	-	expression tag	UNP P39066
C	219	HIS	-	expression tag	UNP P39066
C	220	HIS	-	expression tag	UNP P39066
C	221	HIS	-	expression tag	UNP P39066
C	222	HIS	-	expression tag	UNP P39066
C	223	HIS	-	expression tag	UNP P39066

- Molecule 2 is ADENOSINE-5'-DIPHOSPHATE (CCD ID: ADP) (formula:  $C_{10}H_{15}N_5O_{10}P_2$ ) (labeled as "Ligand of Interest" by depositor).



Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	
			Total	C	H	N	O			P
2	A	1	Total	C	H	N	O	P	2	0
			39	10	12	5	10	2		
2	B	1	Total	C	H	N	O	P	2	0
			39	10	12	5	10	2		
2	C	1	Total	C	H	N	O	P	2	0
			39	10	12	5	10	2		

- Molecule 3 is ADENOSINE MONOPHOSPHATE (CCD ID: AMP) (formula:  $C_{10}H_{14}N_5O_7P$ ) (labeled as "Ligand of Interest" by depositor).



Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	
			Total	C	H	N	O			P
3	A	1	Total	C	H	N	O	P	2	0
			35	10	12	5	7	1		
3	B	1	Total	C	H	N	O	P	2	0
			35	10	12	5	7	1		
3	C	1	Total	C	H	N	O	P	2	0
			35	10	12	5	7	1		

- Molecule 4 is water.

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
4	A	7	Total	O	0	0
			7	7		
4	B	5	Total	O	0	0
			5	5		
4	C	2	Total	O	0	0
			2	2		



## 4 Data and refinement statistics

Property	Value
Space group	P 21 2 21
Cell constants a, b, c, $\alpha$ , $\beta$ , $\gamma$	67.31Å 79.78Å 153.79Å 90.00° 90.00° 90.00°
Resolution (Å)	48.79 – 2.64 48.79 – 2.64
% Data completeness (in resolution range)	97.4 (48.79-2.64) 97.4 (48.79-2.64)
$R_{merge}$	(Not available)
$R_{sym}$	0.14
$\langle I/\sigma(I) \rangle$ <sup>1</sup>	1.29 (at 2.65Å)
Refinement program	REFMAC 5.8.0430 (refmacat 0.4.105), REFMAC 5.8.0430 (refmacat 0.4.105)
R, $R_{free}$	0.207 , 0.266 0.204 , 0.265
$R_{free}$ test set	1214 reflections (4.83%)
Wilson B-factor (Å <sup>2</sup> )	75.1
Anisotropy	0.520
Bulk solvent $k_{sol}$ (e/Å <sup>3</sup> ), $B_{sol}$ (Å <sup>2</sup> )	0.37 , 68.5
L-test for twinning <sup>2</sup>	$\langle  L  \rangle = 0.50$ , $\langle L^2 \rangle = 0.34$
Estimated twinning fraction	No twinning to report.
$F_o, F_c$ correlation	0.95
Total number of atoms	10661
Average B, all atoms (Å <sup>2</sup> )	101.0

Xtrriage'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.*

<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: AMP, ADP

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	0.53	0/1786	1.07	4/2416 (0.2%)
1	B	0.51	0/1792	1.03	1/2425 (0.0%)
1	C	0.52	0/1625	1.03	2/2201 (0.1%)
All	All	0.52	0/5203	1.04	7/7042 (0.1%)

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
1	B	0	1
All	All	0	2

There are no bond length outliers.

The worst 5 of 7 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
1	C	127	PHE	CB-CA-C	6.93	123.45	110.63
1	A	127	PHE	CA-CB-CG	6.68	120.48	113.80
1	A	10	ASP	CA-CB-CG	6.22	118.82	112.60
1	A	62	GLU	N-CA-CB	-5.89	103.02	110.45
1	A	171	TYR	N-CA-CB	5.68	117.96	110.29

There are no chirality outliers.

All (2) planarity outliers are listed below:

Mol	Chain	Res	Type	Group
1	A	42	ARG	Sidechain
1	B	66	ARG	Sidechain

## 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	1752	1820	1805	19	0
1	B	1755	1825	1812	18	0
1	C	1596	1677	1666	13	0
2	A	27	12	12	1	0
2	B	27	12	12	1	0
2	C	27	12	12	1	0
3	A	23	12	12	1	0
3	B	23	12	12	1	0
3	C	23	12	12	1	0
4	A	7	0	0	1	0
4	B	5	0	0	0	0
4	C	2	0	0	0	0
All	All	5267	5394	5355	46	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 4.

The worst 5 of 46 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:210:GLN:O	1:A:214:LEU:HG	1.82	0.79
1:A:214:LEU:HD22	1:B:5:GLN:HG2	1.67	0.76
1:B:121:THR:HB	2:B:301:ADP:O1B	1.87	0.73
1:C:139:GLN:C	1:C:140:ILE:HD12	2.20	0.66
1:B:139:GLN:C	1:B:140:ILE:HD12	2.20	0.66

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	215/224 (96%)	208 (97%)	5 (2%)	2 (1%)	14	22
1	B	219/224 (98%)	211 (96%)	7 (3%)	1 (0%)	25	37
1	C	198/224 (88%)	192 (97%)	5 (2%)	1 (0%)	25	37
All	All	632/672 (94%)	611 (97%)	17 (3%)	4 (1%)	22	32

All (4) Ramachandran outliers are listed below:

Mol	Chain	Res	Type
1	A	133	ALA
1	A	66	ARG
1	C	187	THR
1	B	66	ARG

### 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	203/207 (98%)	193 (95%)	10 (5%)	21	34
1	B	204/207 (99%)	194 (95%)	10 (5%)	21	34
1	C	186/207 (90%)	176 (95%)	10 (5%)	18	31
All	All	593/621 (96%)	563 (95%)	30 (5%)	20	33

5 of 30 residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	B	72	ARG
1	C	81	ASP
1	B	159	GLN
1	C	174	ASP
1	C	60	ILE

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. 5 of 17 such sidechains are listed below:

Mol	Chain	Res	Type
1	C	101	HIS
1	C	135	GLN
1	B	112	GLN
1	B	135	GLN
1	B	145	ASN

### 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](#)

6 ligands 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
3	AMP	C	302	-	22,25,25	0.63	0	25,38,38	0.71	1 (4%)
2	ADP	B	301	-	24,29,29	0.65	0	29,45,45	0.84	1 (3%)
3	AMP	B	302	-	22,25,25	0.67	0	25,38,38	0.78	1 (4%)
3	AMP	A	302	-	22,25,25	0.61	0	25,38,38	0.78	1 (4%)
2	ADP	C	301	-	24,29,29	0.65	0	29,45,45	0.88	2 (6%)
2	ADP	A	301	-	24,29,29	0.71	0	29,45,45	0.92	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
3	AMP	C	302	-	-	5/6/26/26	0/3/3/3
2	ADP	B	301	-	-	3/12/32/32	0/3/3/3
3	AMP	B	302	-	-	4/6/26/26	0/3/3/3
3	AMP	A	302	-	-	0/6/26/26	0/3/3/3
2	ADP	C	301	-	-	2/12/32/32	0/3/3/3
2	ADP	A	301	-	-	0/12/32/32	0/3/3/3

There are no bond length outliers.

The worst 5 of 6 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
3	A	302	AMP	C5-C6-N6	2.63	124.35	120.35
2	C	301	ADP	PA-O3A-PB	-2.46	124.38	132.83
2	B	301	ADP	C5-C6-N6	2.44	124.06	120.35
3	C	302	AMP	C5-C6-N6	2.41	124.02	120.35
2	C	301	ADP	C5-C6-N6	2.22	123.72	120.35

There are no chirality outliers.

5 of 14 torsion outliers are listed below:

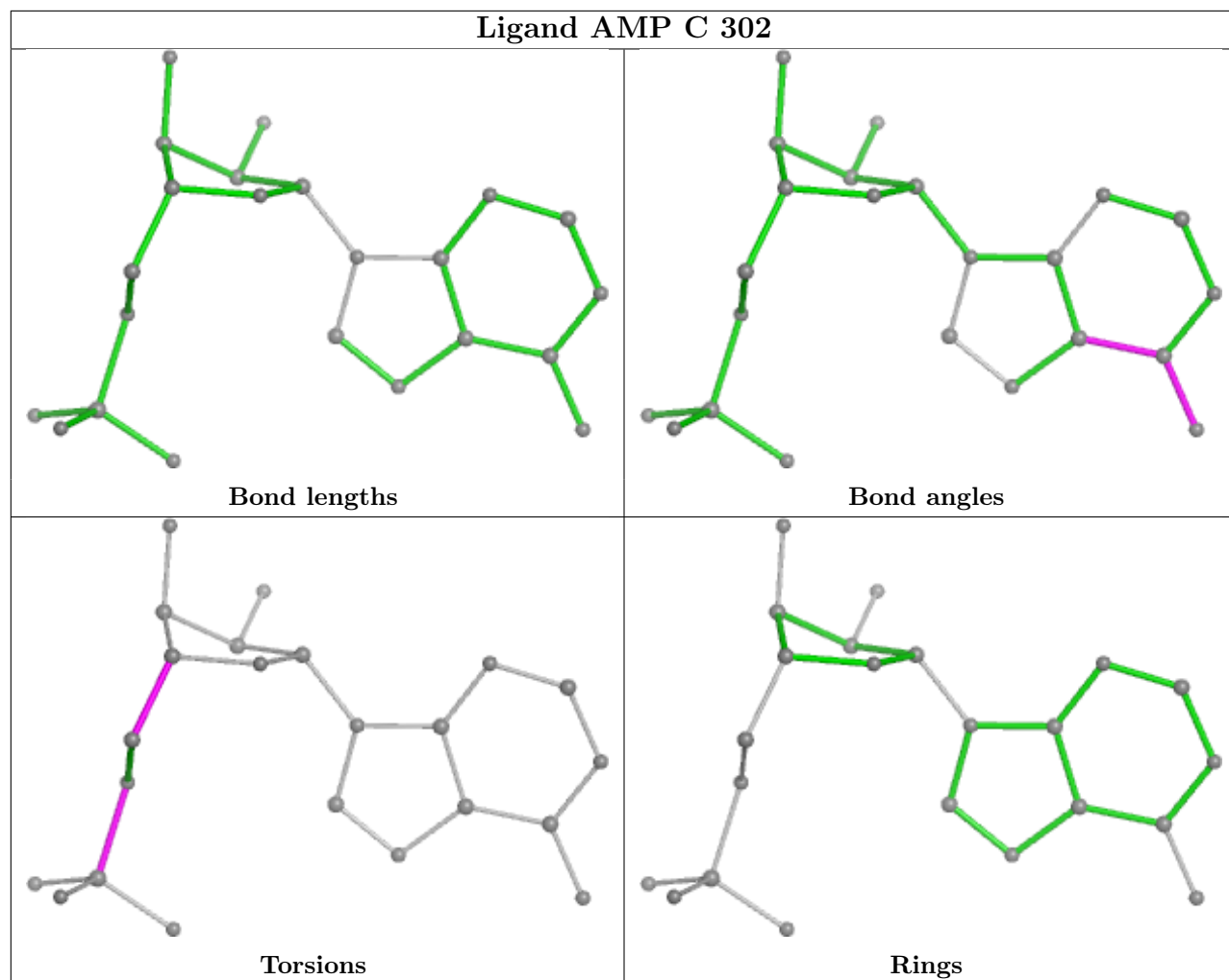
Mol	Chain	Res	Type	Atoms
2	B	301	ADP	C5'-O5'-PA-O1A
2	B	301	ADP	C5'-O5'-PA-O2A
2	B	301	ADP	C5'-O5'-PA-O3A
3	B	302	AMP	C5'-O5'-P-O2P
3	B	302	AMP	C5'-O5'-P-O3P

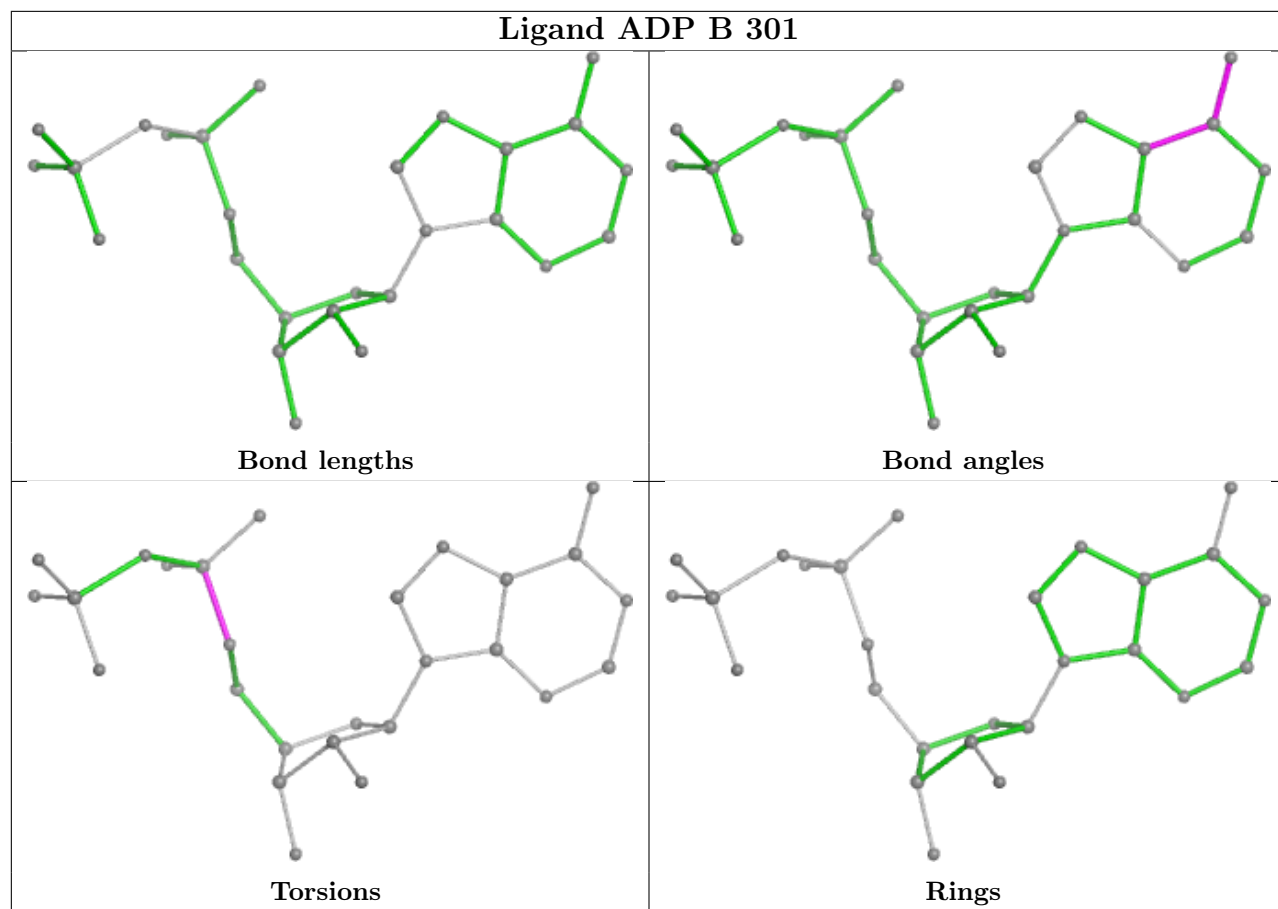
There are no ring outliers.

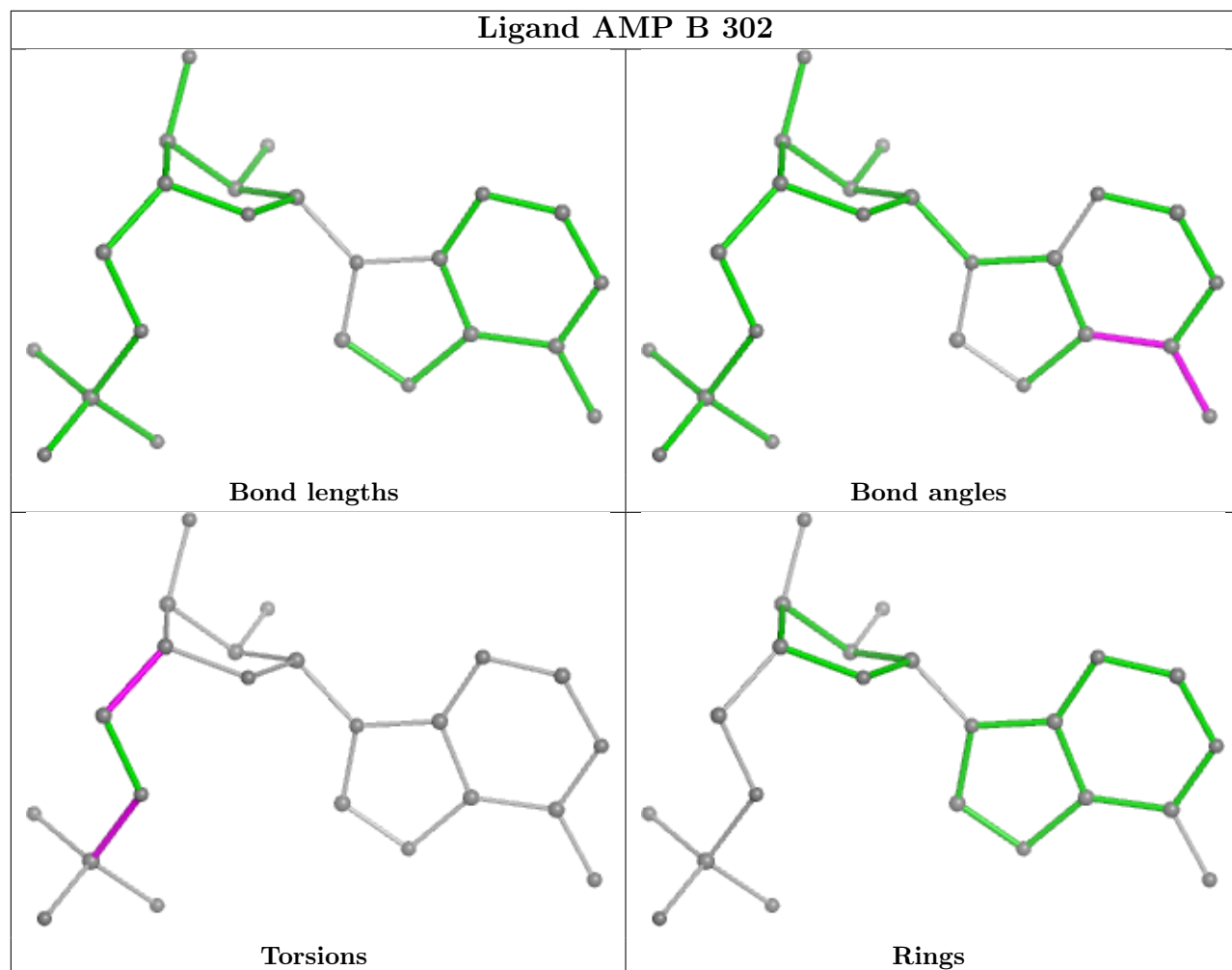
6 monomers are involved in 6 short contacts:

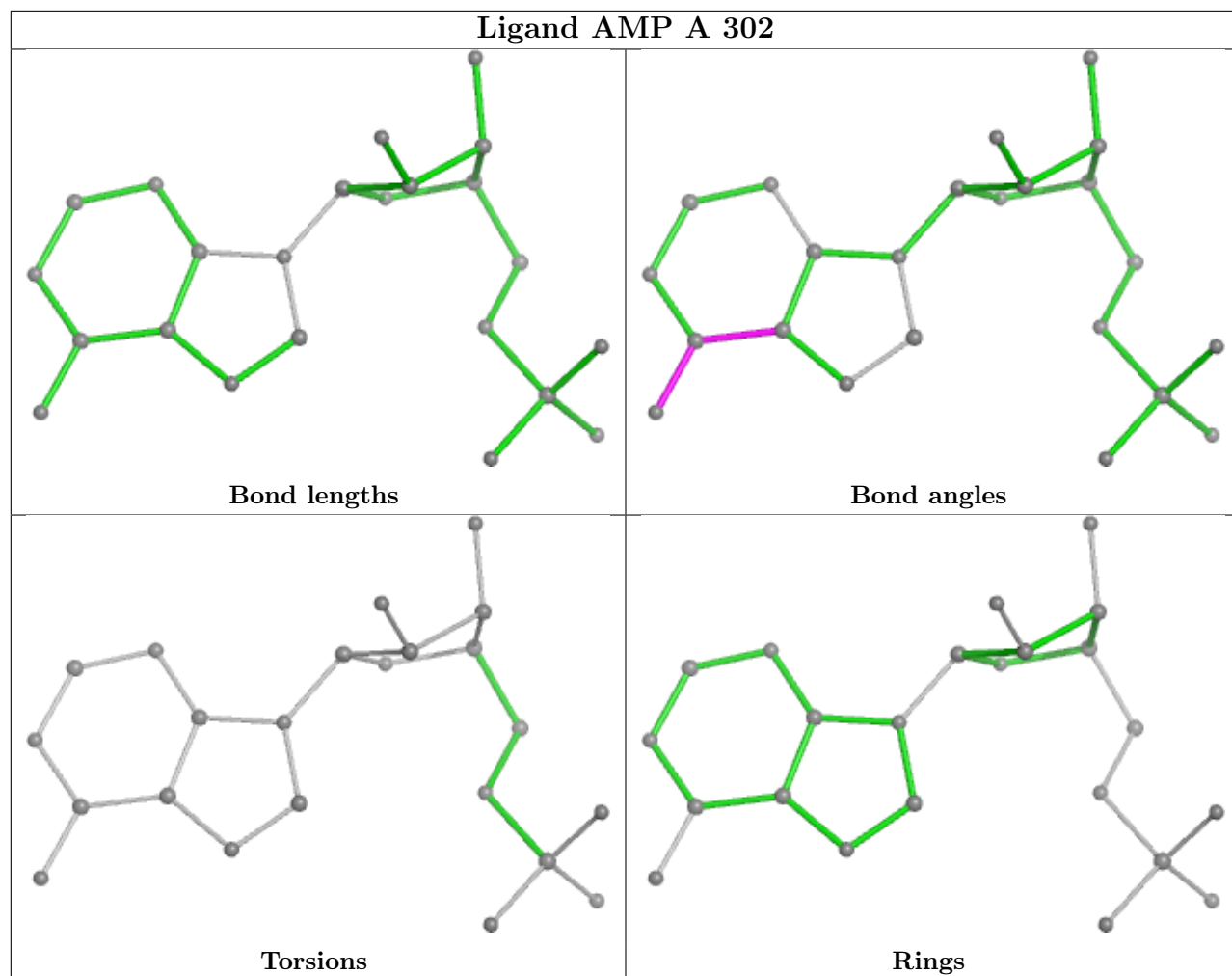
Mol	Chain	Res	Type	Clashes	Symm-Clashes
3	C	302	AMP	1	0
2	B	301	ADP	1	0
3	B	302	AMP	1	0
3	A	302	AMP	1	0
2	C	301	ADP	1	0
2	A	301	ADP	1	0

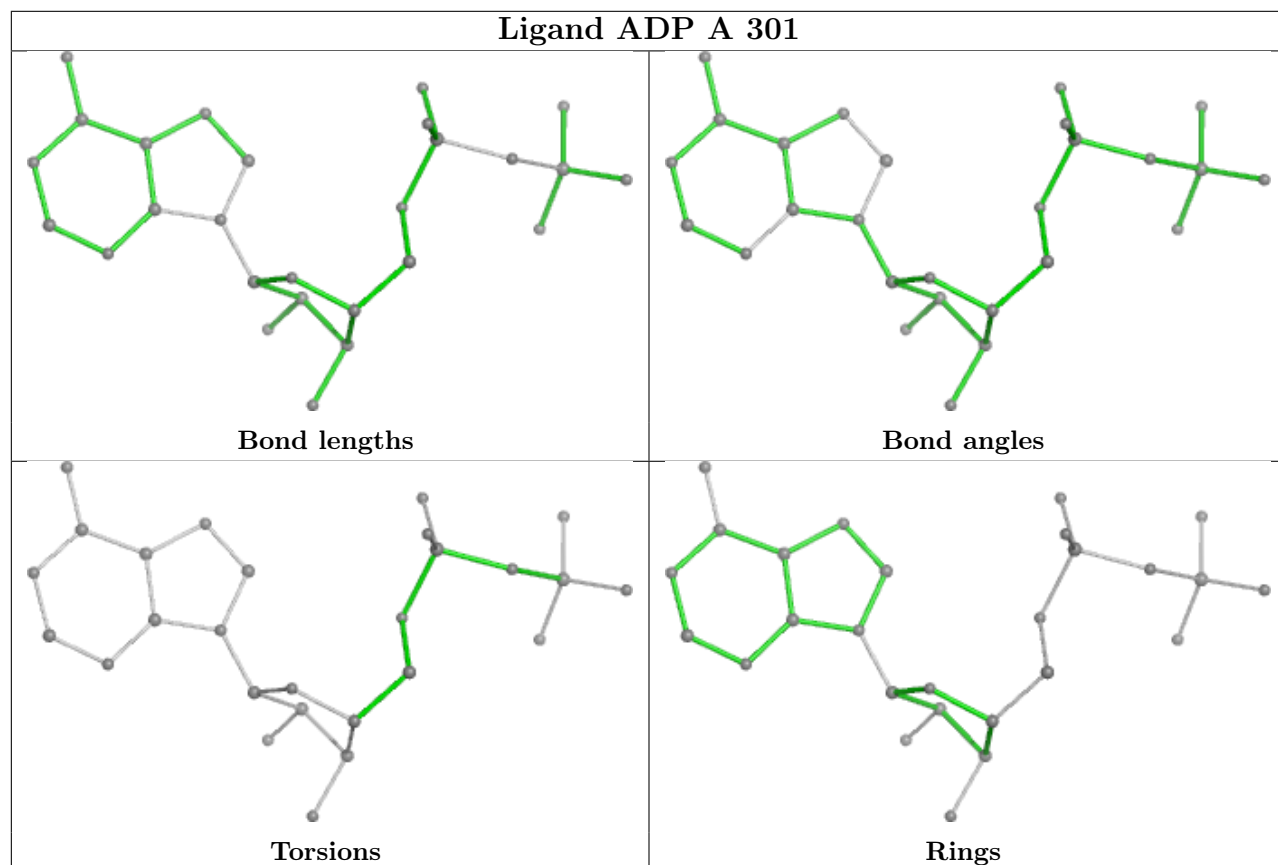
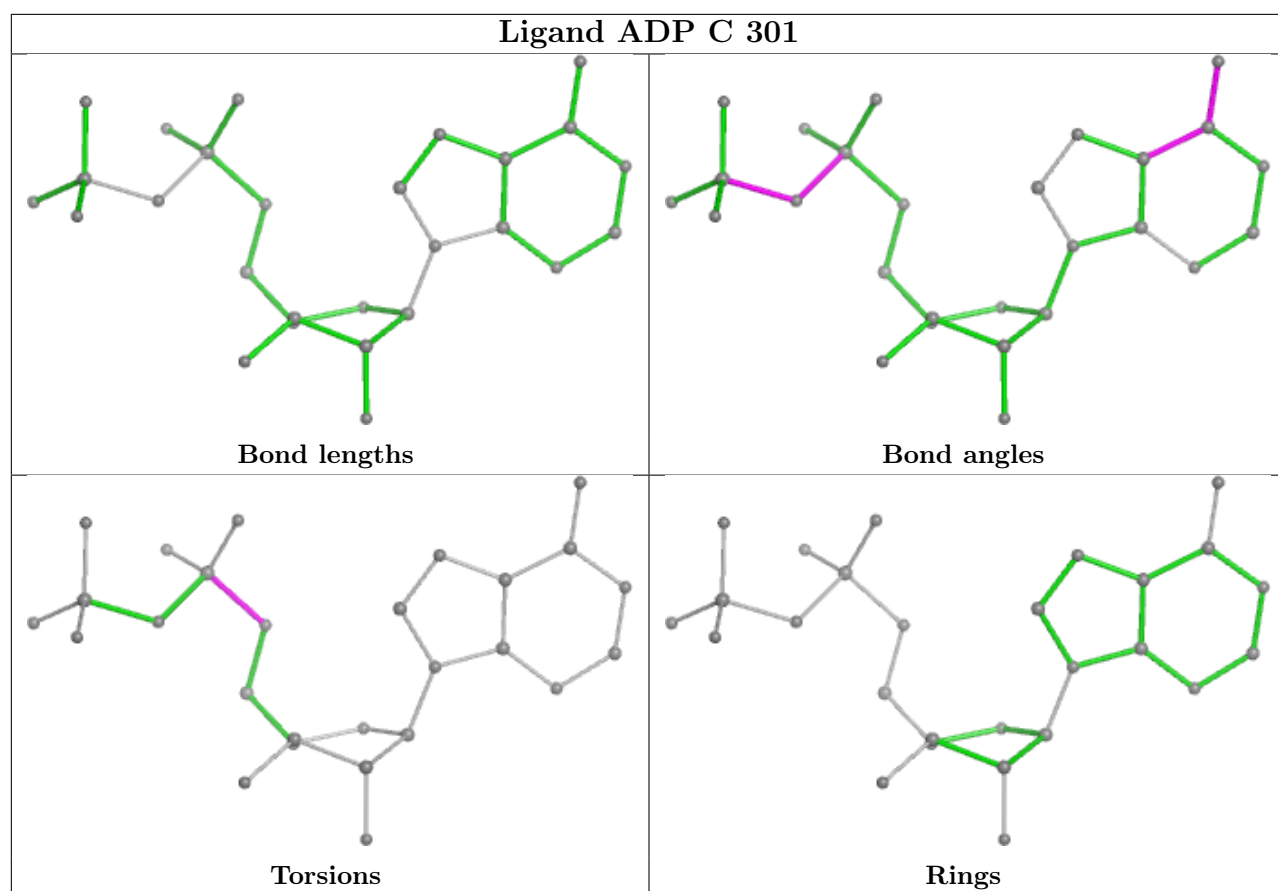
The following is a two-dimensional graphical depiction of Mogul quality analysis of bond lengths, bond angles, torsion angles, and ring geometry for all instances of the Ligand of Interest. In addition, ligands with molecular weight > 250 and outliers as shown on the validation Tables will also be included. 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	219/224 (97%)	-0.03	9 (4%) 42 40	51, 80, 161, 210	0
1	B	220/224 (98%)	-0.24	2 (0%) 81 79	45, 79, 142, 199	1 (0%)
1	C	202/224 (90%)	0.40	18 (8%) 17 16	67, 123, 170, 195	0
All	All	641/672 (95%)	0.03	29 (4%) 39 37	45, 91, 166, 210	1 (0%)

The worst 5 of 29 RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	C	81	ASP	6.9
1	C	60	ILE	4.0
1	C	118	LEU	3.7
1	C	163	VAL	2.9
1	A	69	PHE	2.8

### 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](#)

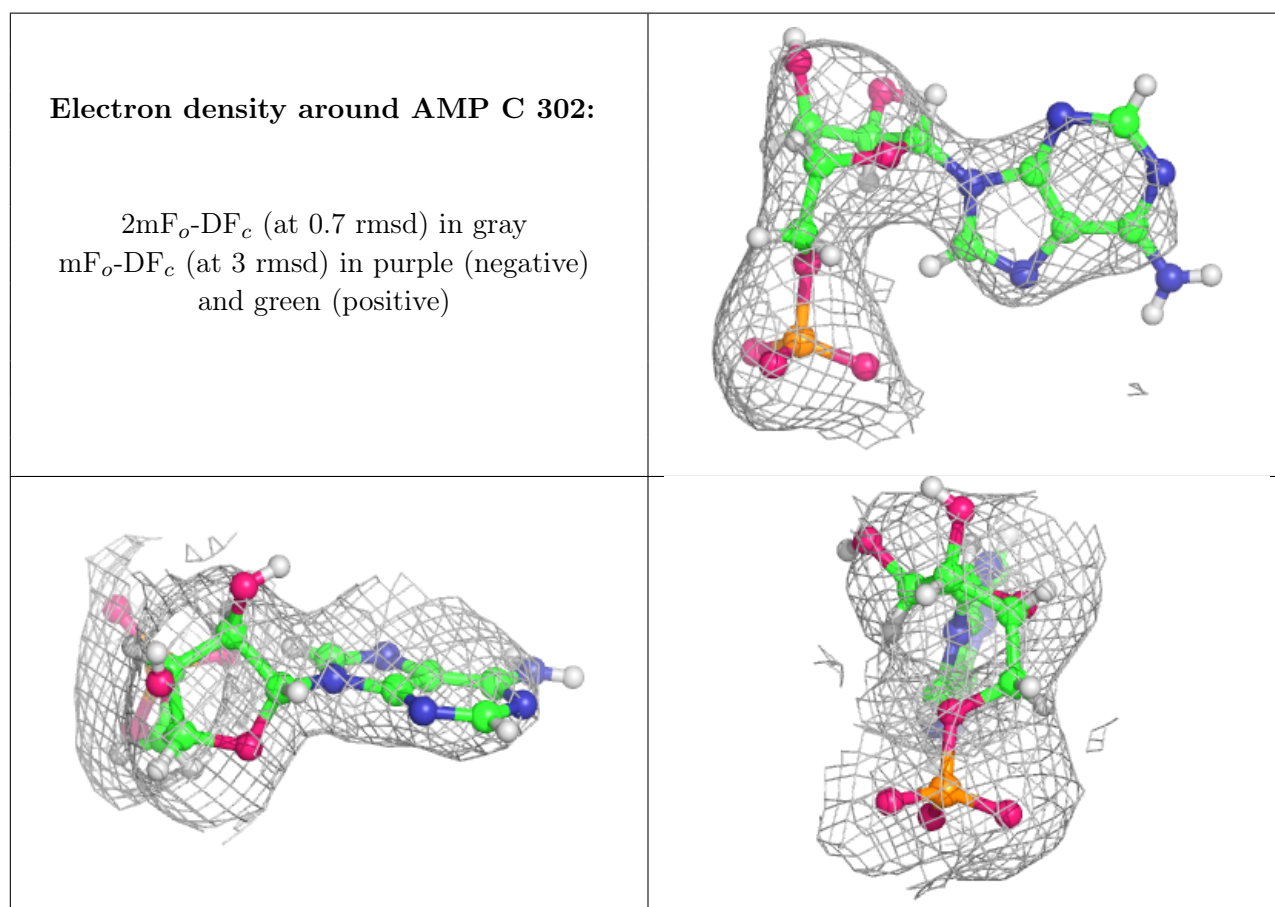
There are no oligosaccharides in this entry.

### 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.

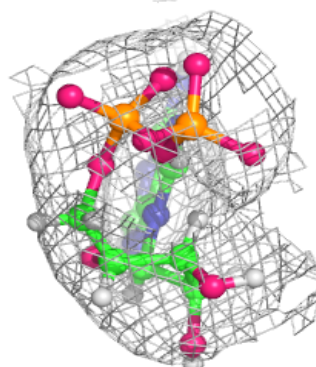
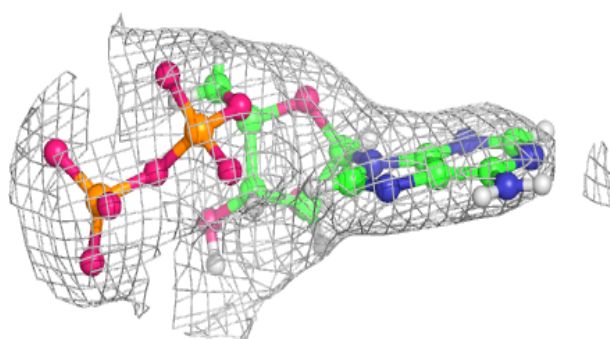
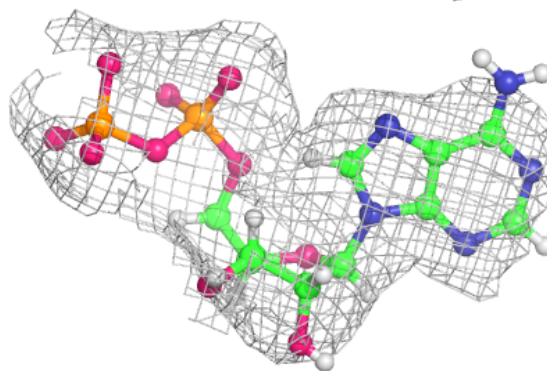
Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors( $\text{\AA}^2$ )	Q<0.9
3	AMP	C	302	23/23	0.91	0.08	69,116,122,123	2
2	ADP	C	301	27/27	0.94	0.07	90,109,116,119	2
2	ADP	A	301	27/27	0.97	0.05	50,61,69,71	2
3	AMP	A	302	23/23	0.97	0.06	62,74,82,85	2
3	AMP	B	302	23/23	0.97	0.05	70,79,89,100	2
2	ADP	B	301	27/27	0.97	0.05	67,80,91,94	2

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.

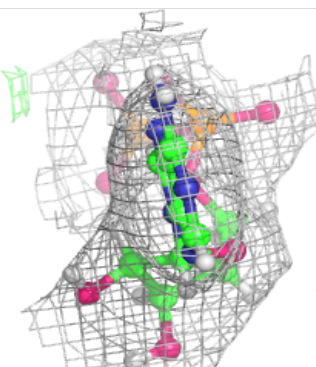
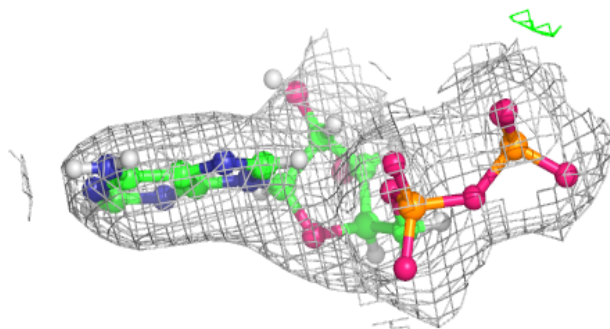
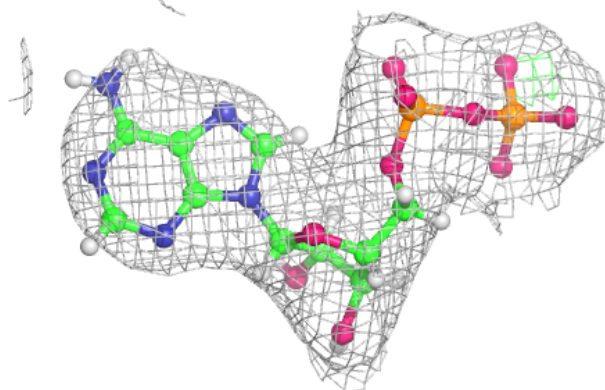


**Electron density around ADP C 301:**

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

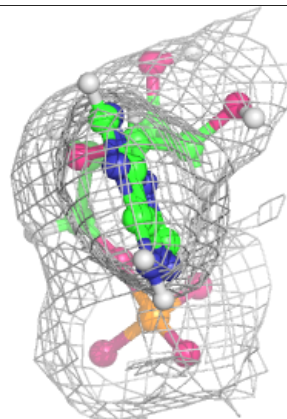
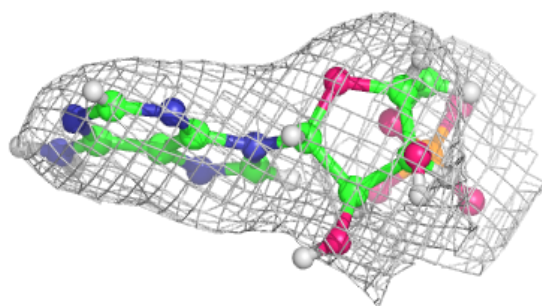
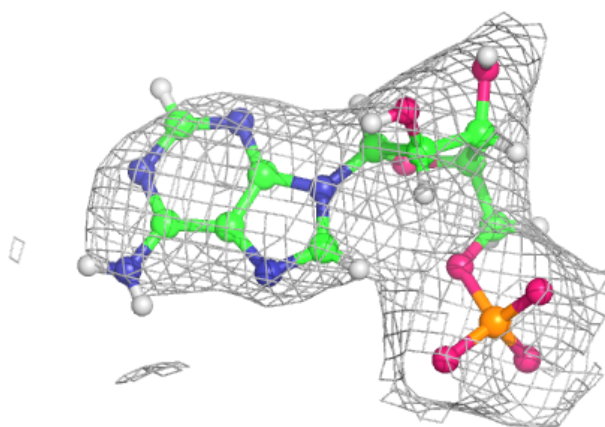
**Electron density around ADP A 301:**

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

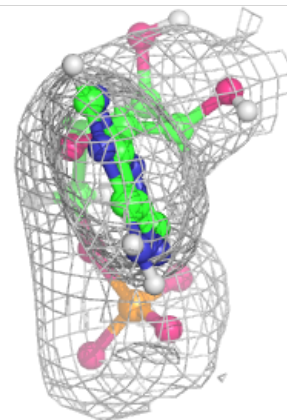
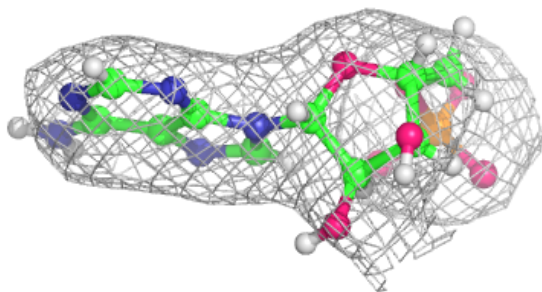
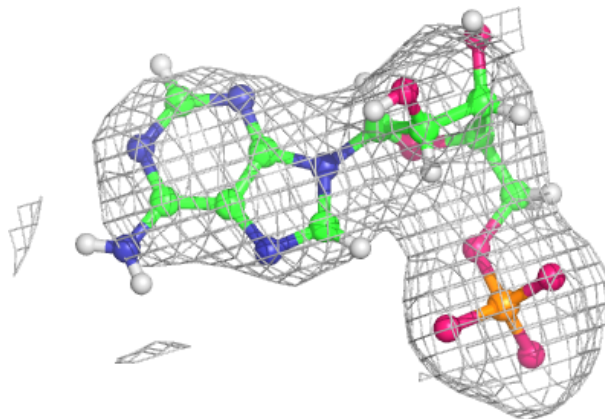


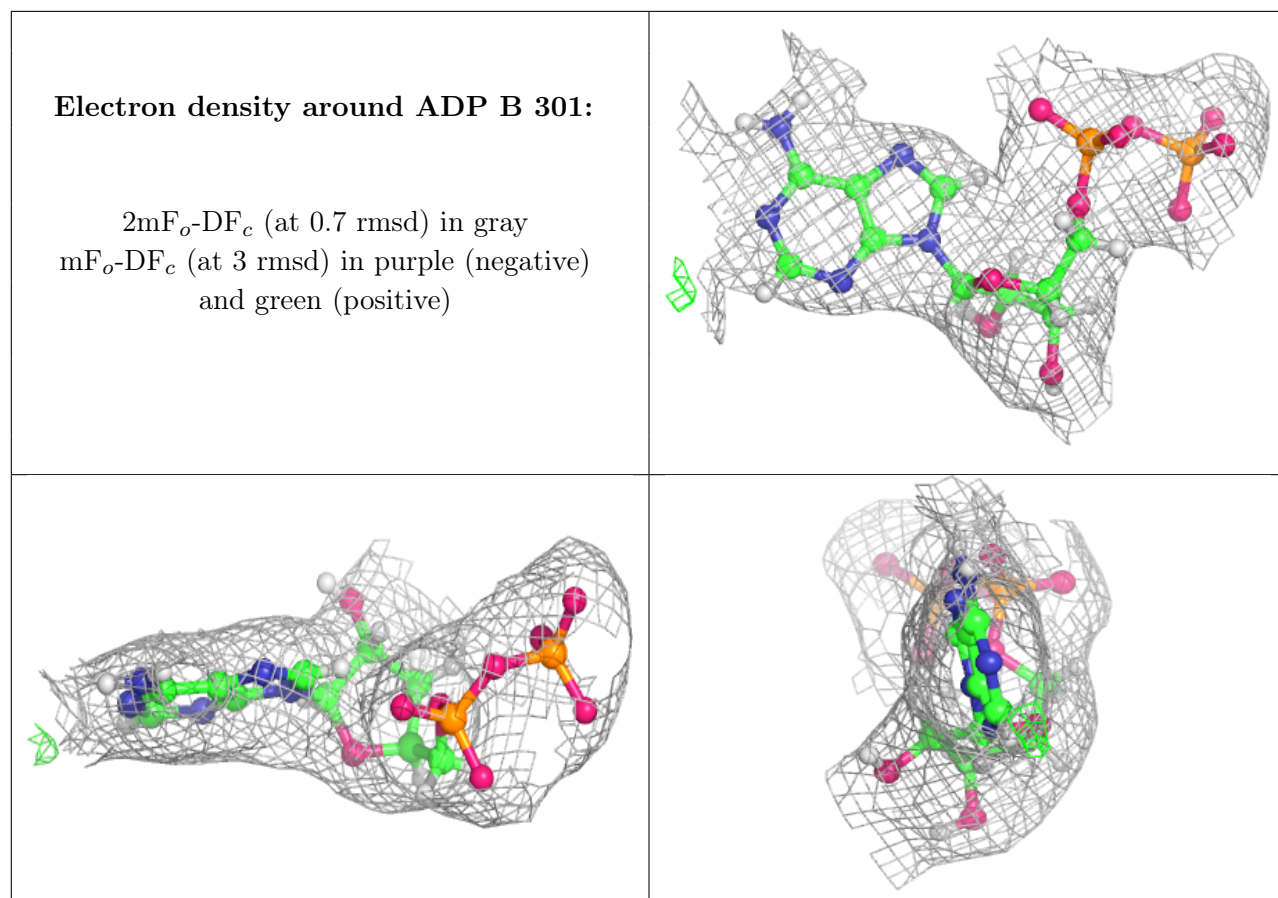
**Electron density around AMP A 302:**

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

**Electron density around AMP B 302:**

$2mF_o-DF_c$  (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.