



wwPDB X-ray Structure Validation Summary Report ⓘ

Mar 7, 2026 – 12:07 AM UTC

PDB ID : 3AEF / pdb_00003aef
Title : Crystal structure of porcine heart mitochondrial complex II with an empty quinone-binding pocket
Authors : Harada, S.; Sasaki, T.; Shindo, M.; Kido, Y.; Inaoka, D.K.; Omori, J.; Osanai, A.; Sakamoto, K.; Mao, J.; Matsuoka, S.; Inoue, M.; Honma, T.; Tanaka, A.; Kita, K.
Deposited on : 2010-02-04
Resolution : 2.80 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 ⓘ 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](#) ①) were used in the production of this report:

MolProbity : 4-5-2 with Phenix2.0
Mogul : 2022.3.0, CSD as543be (2022)
Xtrriage (Phenix) : 2.0
EDS : 3.0
Buster-report : wwPDB partial adaption of 1.1.7 (2018)
Percentile statistics : 20250101.v01 (using entries in the PDB archive January 1st 2025)
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) : 2.49

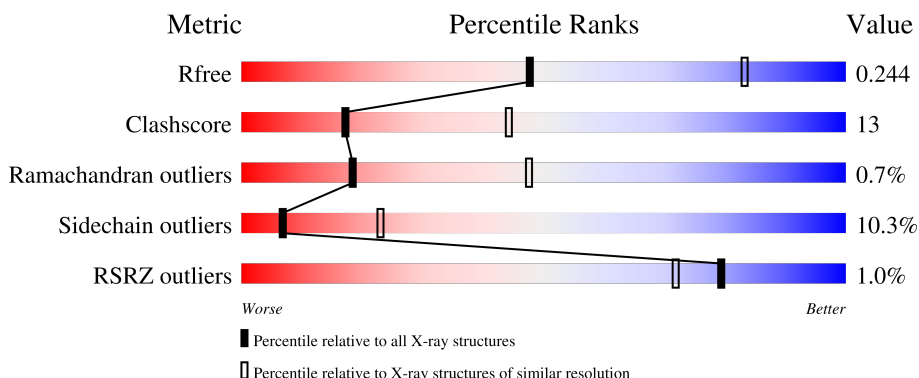
1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

X-RAY DIFFRACTION

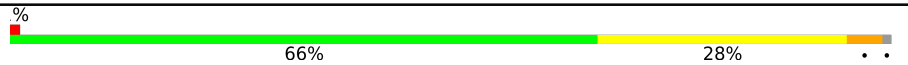
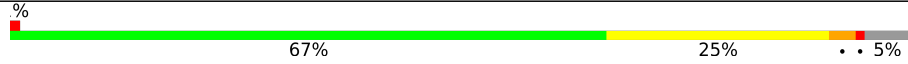


The reported resolution of this entry is 2.80 Å.

Percentile scores (ranging between 0-100) for global validation metrics of the entry are shown in the following graphic. The table shows the number of entries on which the scores are based.



Metric	Whole archive (#Entries)	Similar resolution (#Entries, resolution range(Å))
R_{free}	180053	3866 (2.80-2.80)
Clashscore	190562	4276 (2.80-2.80)
Ramachandran outliers	187476	4196 (2.80-2.80)
Sidechain outliers	187428	4198 (2.80-2.80)
RSRZ outliers	180081	3869 (2.80-2.80)

The table below summarises the geometric issues observed across the polymeric chains and their fit to the electron density. The red, orange, yellow and green segments of the lower bar indicate the fraction of residues that contain outliers for ≥ 3 , 2, 1 and 0 types of geometric quality criteria respectively. A grey segment represents the fraction of residues that are not modelled. The numeric value for each fraction is indicated below the corresponding segment, with a dot representing fractions $\leq 5\%$. The upper red bar (where present) indicates the fraction of residues that have poor fit to the electron density. The numeric value is given above the bar.

Mol	Chain	Length	Quality of chain
1	A	622	
2	B	252	
3	C	140	
4	D	103	

The following table lists non-polymeric compounds, carbohydrate monomers and non-standard

residues in protein, DNA, RNA chains that are outliers for geometric or electron-density-fit criteria:

Mol	Type	Chain	Res	Chirality	Geometry	Clashes	Electron density
10	EPH	D	1306	X	-	-	-

2 Entry composition

There are 11 unique types of molecules in this entry. The entry contains 8642 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 Succinate dehydrogenase [ubiquinone] flavoprotein subunit, mitochondrial.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	S			
1	A	613	4729	2954	848	895	32	0	0	0

- Molecule 2 is a protein called Succinate dehydrogenase [ubiquinone] iron-sulfur subunit, mitochondrial.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	S			
2	B	239	1922	1214	326	360	22	0	0	0

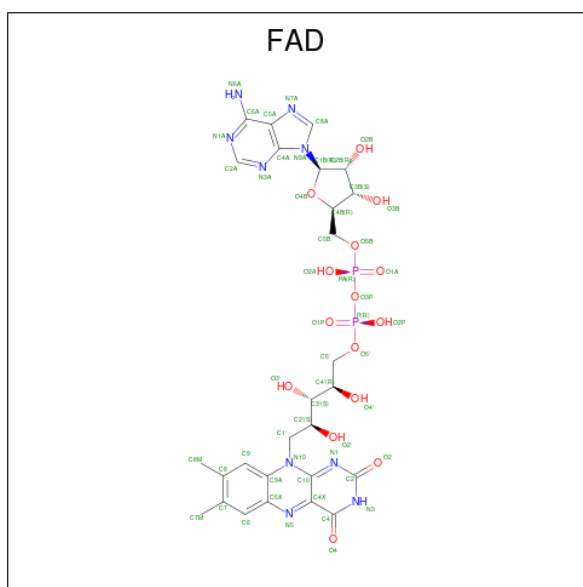
- Molecule 3 is a protein called Succinate dehydrogenase cytochrome b560 subunit, mitochondrial.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	S			
3	C	138	1064	695	179	183	7	0	0	0

- Molecule 4 is a protein called Succinate dehydrogenase [ubiquinone] cytochrome b small subunit, mitochondrial.

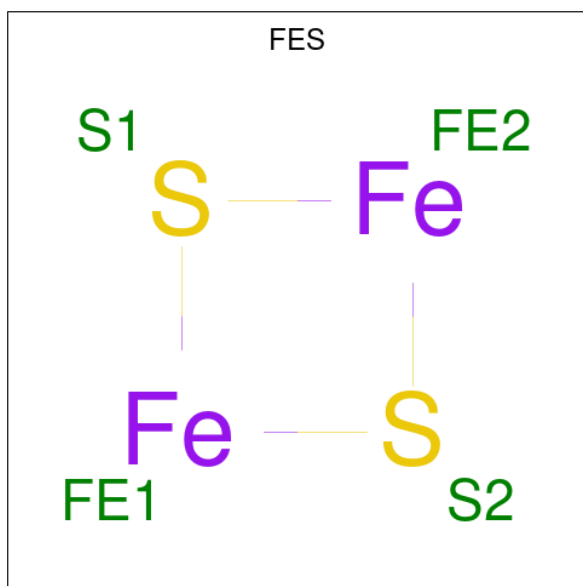
Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	S			
4	D	102	765	499	128	133	5	0	0	0

- Molecule 5 is FLAVIN-ADENINE DINUCLEOTIDE (CCD ID: FAD) (formula: $C_{27}H_{33}N_9O_{15}P_2$).



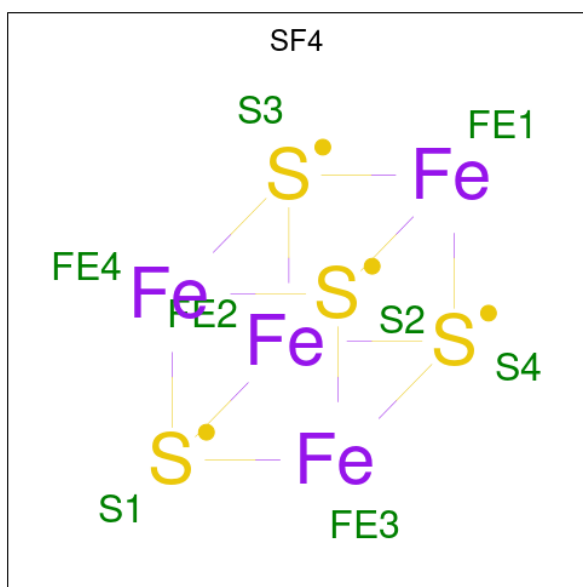
Mol	Chain	Residues	Atoms					ZeroOcc	AltConf
			Total	C	N	O	P		
5	A	1	53	27	9	15	2	0	0

- Molecule 6 is FE2/S2 (INORGANIC) CLUSTER (CCD ID: FES) (formula: Fe₂S₂).



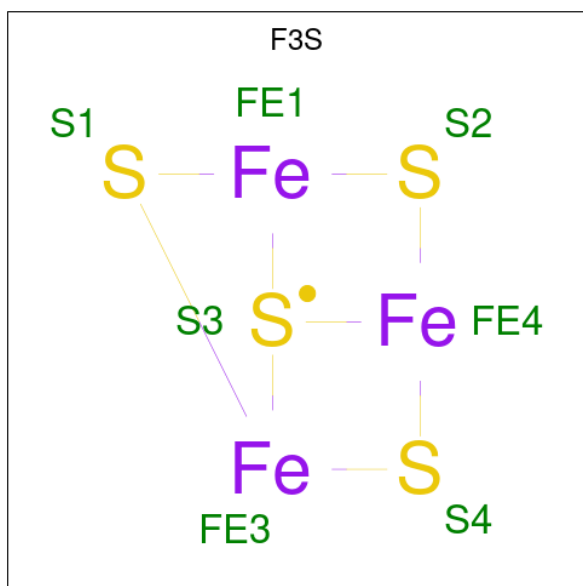
Mol	Chain	Residues	Atoms			ZeroOcc	AltConf
			Total	Fe	S		
6	B	1	4	2	2	0	0

- Molecule 7 is IRON/SULFUR CLUSTER (CCD ID: SF4) (formula: Fe₄S₄).



Mol	Chain	Residues	Atoms			ZeroOcc	AltConf
7	B	1	Total	Fe	S	0	0
			8	4	4		

- Molecule 8 is FE3-S4 CLUSTER (CCD ID: F3S) (formula: Fe_3S_4).

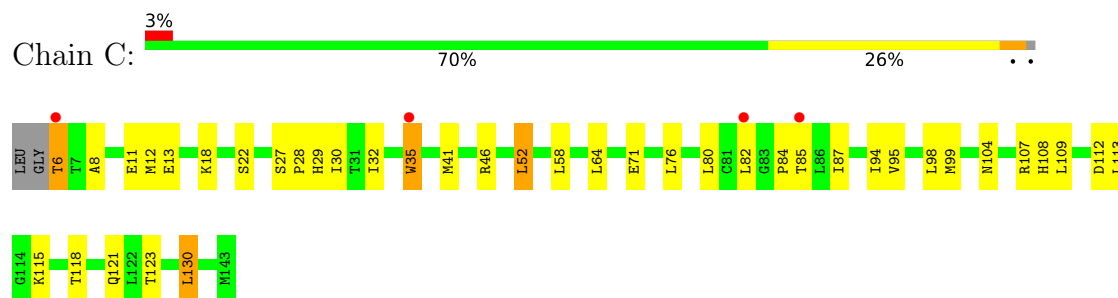


Mol	Chain	Residues	Atoms			ZeroOcc	AltConf
8	B	1	Total	Fe	S	0	0
			7	3	4		

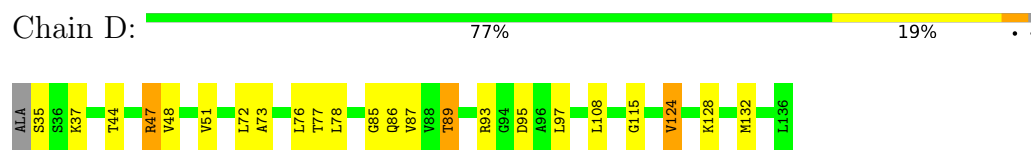
- Molecule 9 is PROTOPORPHYRIN IX CONTAINING FE (CCD ID: HEM) (formula: $\text{C}_{34}\text{H}_{32}\text{FeN}_4\text{O}_4$).

Mol	Chain	Residues	Atoms	ZeroOcc	AltConf
11	A	2	Total O 2 2	0	0
11	B	1	Total O 1 1	0	0

- Molecule 3: Succinate dehydrogenase cytochrome b560 subunit, mitochondrial



- Molecule 4: Succinate dehydrogenase [ubiquinone] cytochrome b small subunit, mitochondrial



4 Data and refinement statistics

Property	Value	Source
Space group	P 21 21 21	Depositor
Cell constants a, b, c, α , β , γ	71.22Å 84.21Å 293.32Å 90.00° 90.00° 90.00°	Depositor
Resolution (Å)	39.88 – 2.80 39.88 – 2.80	Depositor EDS
% Data completeness (in resolution range)	75.9 (39.88-2.80) 75.9 (39.88-2.80)	Depositor EDS
R_{merge}	0.08	Depositor
R_{sym}	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ ¹	3.19 (at 2.81Å)	Xtrriage
Refinement program	REFMAC	Depositor
R, R_{free}	0.202 , 0.251 0.200 , 0.244	Depositor DCC
R_{free} test set	1691 reflections (5.01%)	wwPDB-VP
Wilson B-factor (Å ²)	56.9	Xtrriage
Anisotropy	0.215	Xtrriage
Bulk solvent k_{sol} (e/Å ³), B_{sol} (Å ²)	0.30 , 36.1	EDS
L-test for twinning ²	$\langle L \rangle = 0.48$, $\langle L^2 \rangle = 0.31$	Xtrriage
Estimated twinning fraction	No twinning to report.	Xtrriage
F_o, F_c correlation	0.93	EDS
Total number of atoms	8642	wwPDB-VP
Average B, all atoms (Å ²)	54.0	wwPDB-VP

Xtrriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 4.34% of the height of the origin peak. No significant pseudotranslation is detected.*

¹Intensities estimated from amplitudes.

²Theoretical values of $\langle |L| \rangle$, $\langle L^2 \rangle$ for acentric reflections are 0.5, 0.333 respectively for untwinned datasets, and 0.375, 0.2 for perfectly twinned datasets.

5 Model quality [i](#)

5.1 Standard geometry [i](#)

Bond lengths and bond angles in the following residue types are not validated in this section: F3S, HEM, FAD, SF4, EPH, FES

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	0.57	0/4828	0.91	6/6531 (0.1%)
2	B	0.58	0/1964	0.86	2/2648 (0.1%)
3	C	0.55	0/1091	0.90	0/1483
4	D	0.57	0/784	0.93	0/1066
All	All	0.57	0/8667	0.90	8/11728 (0.1%)

There are no bond length outliers.

The worst 5 of 8 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
1	A	402	ALA	N-CA-C	-7.22	104.46	113.20
1	A	12	GLN	N-CA-C	-6.14	104.49	112.23
2	B	69	ILE	CB-CA-C	-6.06	104.93	110.63
2	B	66	ARG	N-CA-CB	-6.02	107.30	114.17
1	A	64	GLY	N-CA-C	5.88	118.09	110.45

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	4729	0	4618	132	0
2	B	1922	0	1900	57	0

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Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
3	C	1064	0	1104	23	0
4	D	765	0	773	15	0
5	A	53	0	31	12	0
6	B	4	0	0	1	0
7	B	8	0	0	1	0
8	B	7	0	0	0	0
9	C	43	0	30	3	0
10	D	44	0	53	0	0
11	A	2	0	0	1	0
11	B	1	0	0	0	0
All	All	8642	0	8509	215	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 13.

The worst 5 of 215 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:57:HIS:NE2	5:A:700:FAD:HM82	1.04	1.36
1:A:57:HIS:CE1	5:A:700:FAD:HM82	1.74	1.22
1:A:157:SER:O	1:A:161:THR:HG23	1.46	1.11
2:B:103:PRO:HD2	2:B:166:THR:HG23	1.33	1.08
2:B:67:GLU:HG2	2:B:69:ILE:HD11	1.56	0.86

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	611/622 (98%)	570 (93%)	36 (6%)	5 (1%)	16 44
2	B	237/252 (94%)	219 (92%)	17 (7%)	1 (0%)	30 60

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Mol	Chain	Analysed	Favoured	Allowed	Outliers	Percentiles	
3	C	136/140 (97%)	129 (95%)	6 (4%)	1 (1%)	18	47
4	D	100/103 (97%)	94 (94%)	5 (5%)	1 (1%)	12	38
All	All	1084/1117 (97%)	1012 (93%)	64 (6%)	8 (1%)	18	47

5 of 8 Ramachandran outliers are listed below:

Mol	Chain	Res	Type
2	B	110	ASP
1	A	260	GLY
1	A	283	ARG
4	D	95	ASP
1	A	438	LYS

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	499/506 (99%)	450 (90%)	49 (10%)	7	25
2	B	214/220 (97%)	196 (92%)	18 (8%)	10	32
3	C	117/118 (99%)	99 (85%)	18 (15%)	2	10
4	D	76/76 (100%)	68 (90%)	8 (10%)	6	22
All	All	906/920 (98%)	813 (90%)	93 (10%)	7	23

5 of 93 residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
2	B	97	SER
3	C	58	LEU
2	B	129	LEU
2	B	214	ARG
3	C	82	LEU

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. 5 of 31 such sidechains are listed below:

Mol	Chain	Res	Type
1	A	527	GLN
3	C	29	HIS
1	A	577	GLN
3	C	121	GLN
2	B	220	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
5	FAD	A	700	1	58,58,58	1.22	7 (12%)	85,89,89	1.62	18 (21%)
9	HEM	C	1305	4,3	50,50,50	1.79	9 (18%)	67,82,82	1.24	5 (7%)
6	FES	B	302	2	0,4,4	-	-	-	-	-
10	EPH	D	1306	-	43,43,48	1.54	6 (13%)	46,48,53	1.39	5 (10%)
7	SF4	B	303	2	0,12,12	-	-	-	-	-
8	F3S	B	304	2	0,9,9	-	-	-	-	-

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
5	FAD	A	700	1	-	2/34/50/50	0/6/6/6
9	HEM	C	1305	4,3	-	3/14/54/54	-
6	FES	B	302	2	-	-	0/1/1/1
10	EPH	D	1306	-	1/1/4/14	26/47/47/52	-
7	SF4	B	303	2	-	-	0/6/5/5
8	F3S	B	304	2	-	-	0/3/3/3

The worst 5 of 22 bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
9	C	1305	HEM	C3D-C2D	7.63	1.53	1.36
9	C	1305	HEM	FE-ND	4.76	2.09	1.94
10	D	1306	EPH	O1-C3	4.49	1.47	1.34
10	D	1306	EPH	O2-C4	4.15	1.45	1.33
10	D	1306	EPH	C25-C24	3.83	1.53	1.31

The worst 5 of 28 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
5	A	700	FAD	N3A-C2A-N1A	-6.19	119.22	128.58
10	D	1306	EPH	O1-C3-C5	4.89	122.07	111.48
9	C	1305	HEM	C4D-ND-C1D	4.41	110.43	105.21
5	A	700	FAD	C5A-C4A-N3A	-4.40	120.65	126.72
5	A	700	FAD	C2A-N3A-C4A	3.57	120.56	111.83

All (1) chirality outliers are listed below:

Mol	Chain	Res	Type	Atom
10	D	1306	EPH	C2

5 of 31 torsion outliers are listed below:

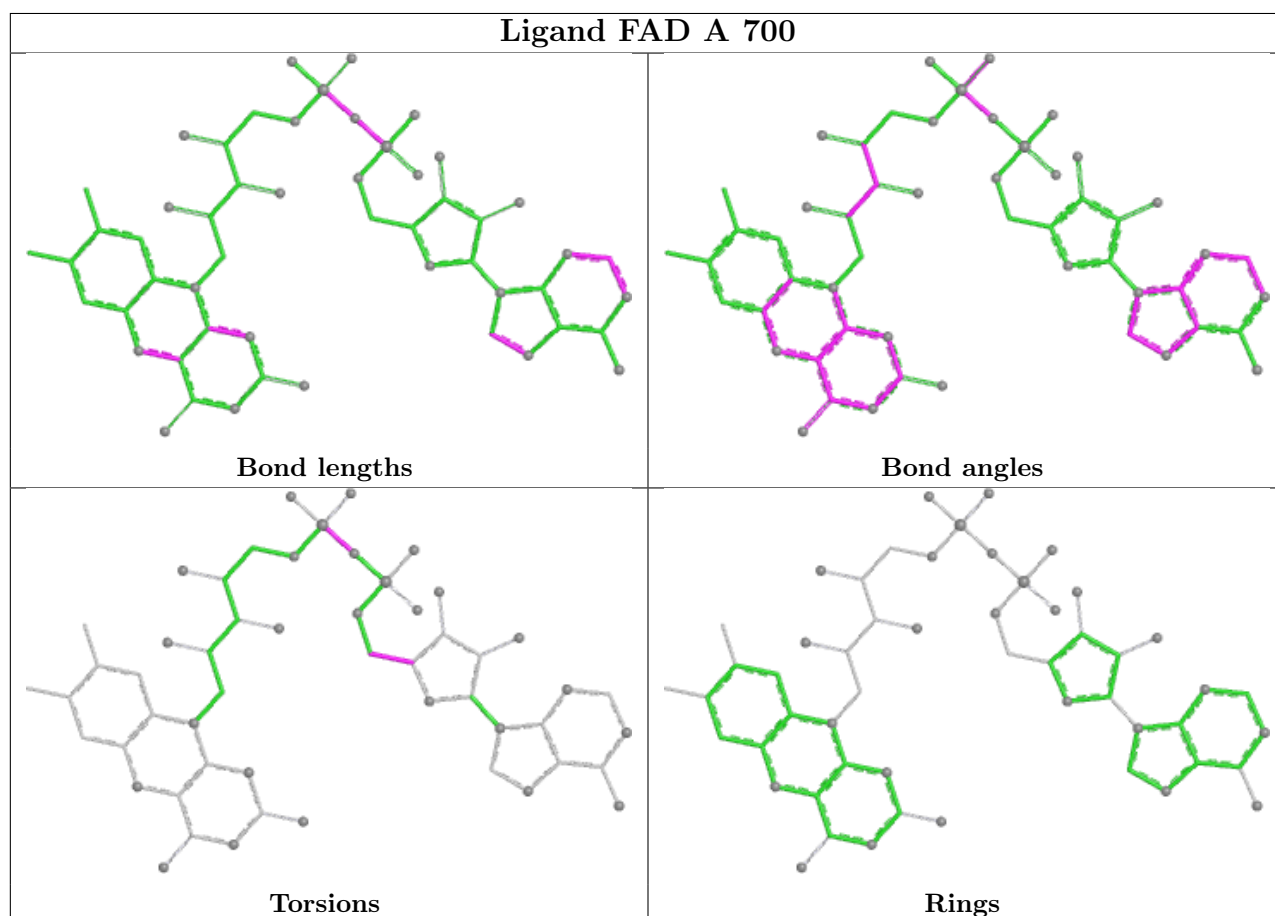
Mol	Chain	Res	Type	Atoms
5	A	700	FAD	PA-O3P-P-O5'
9	C	1305	HEM	C2B-C3B-CAB-CBB
9	C	1305	HEM	C4B-C3B-CAB-CBB
10	D	1306	EPH	O1-C2-C37-O5
10	D	1306	EPH	C37-O5-P1-O6

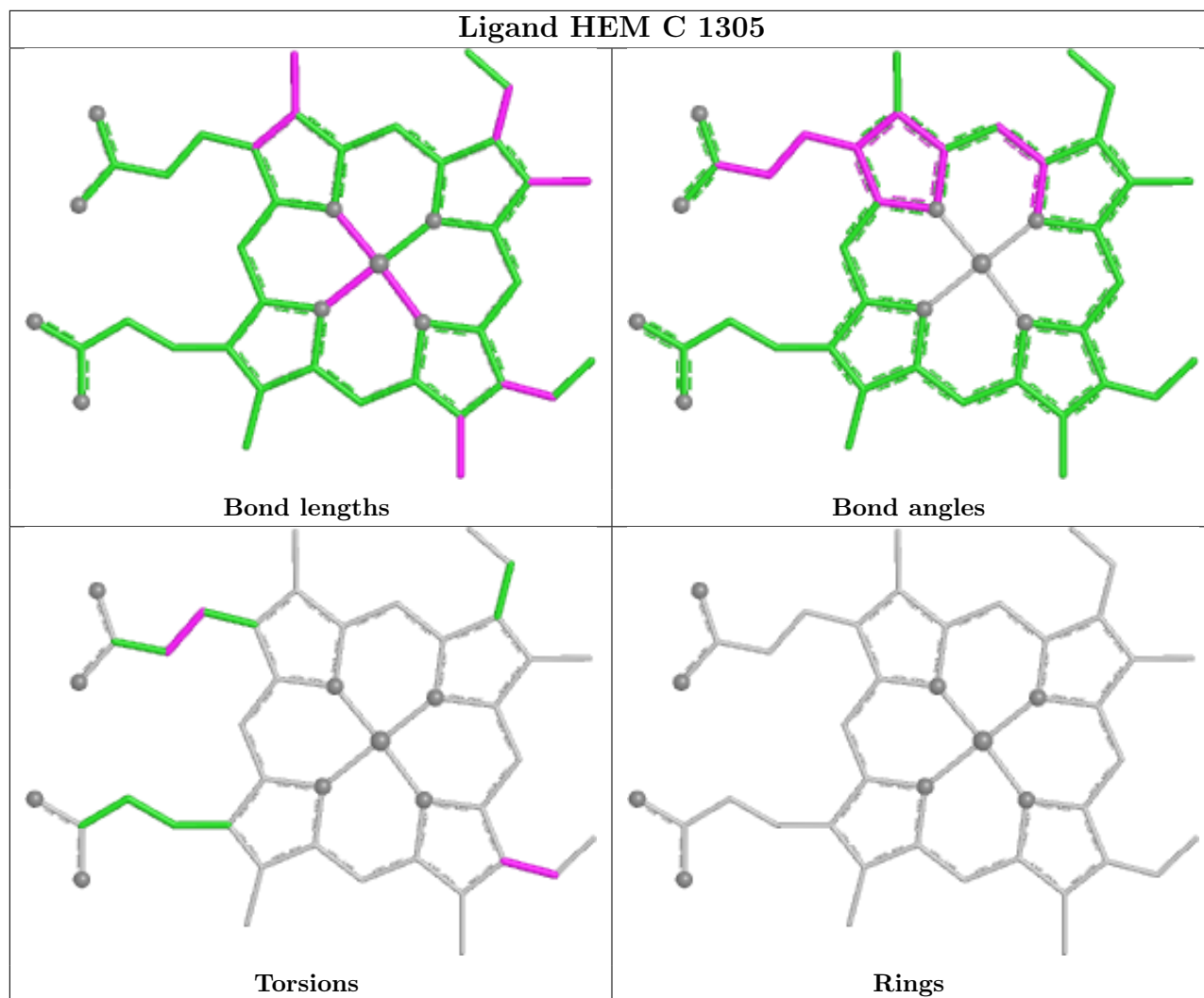
There are no ring outliers.

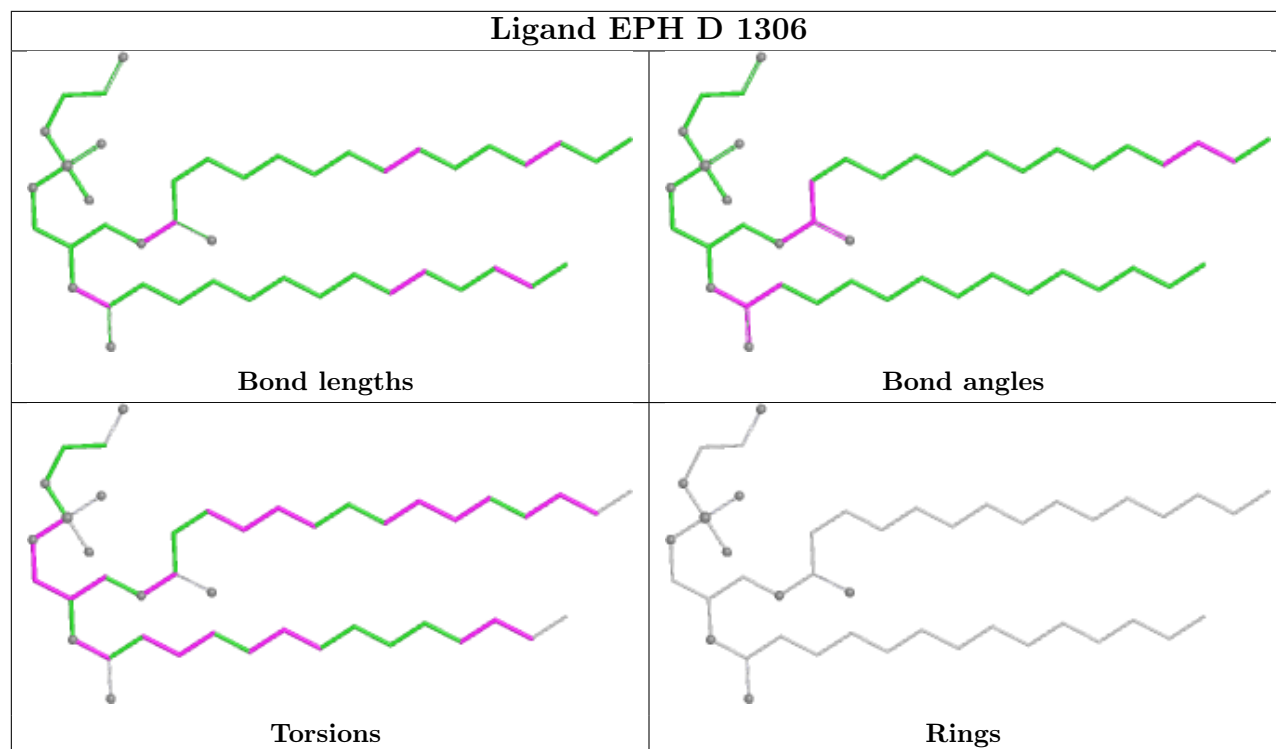
4 monomers are involved in 17 short contacts:

Mol	Chain	Res	Type	Clashes	Symm-Clashes
5	A	700	FAD	12	0
9	C	1305	HEM	3	0
6	B	302	FES	1	0
7	B	303	SF4	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, 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	613/622 (98%)	-0.22	5 (0%) 82 75	31, 51, 79, 94	0
2	B	239/252 (94%)	-0.38	2 (0%) 82 75	33, 46, 78, 90	0
3	C	138/140 (98%)	-0.19	4 (2%) 53 43	33, 57, 94, 103	0
4	D	102/103 (99%)	-0.26	0 100 100	38, 54, 76, 101	0
All	All	1092/1117 (97%)	-0.25	11 (1%) 79 72	31, 51, 81, 103	0

The worst 5 of 11 RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	A	449	GLU	2.9
3	C	35	TRP	2.8
1	A	10	SER	2.5
1	A	287	ARG	2.5
3	C	6	THR	2.4

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](#)

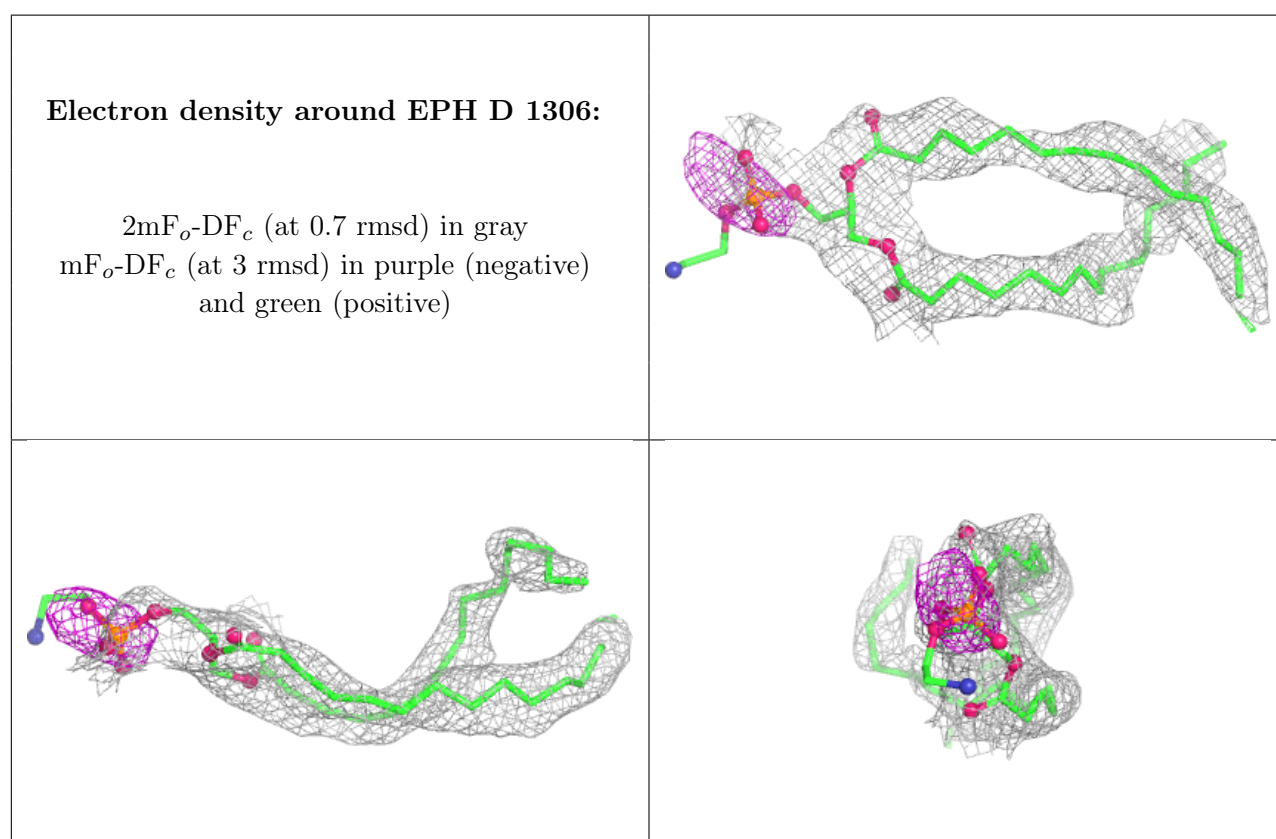
There are no oligosaccharides in this entry.

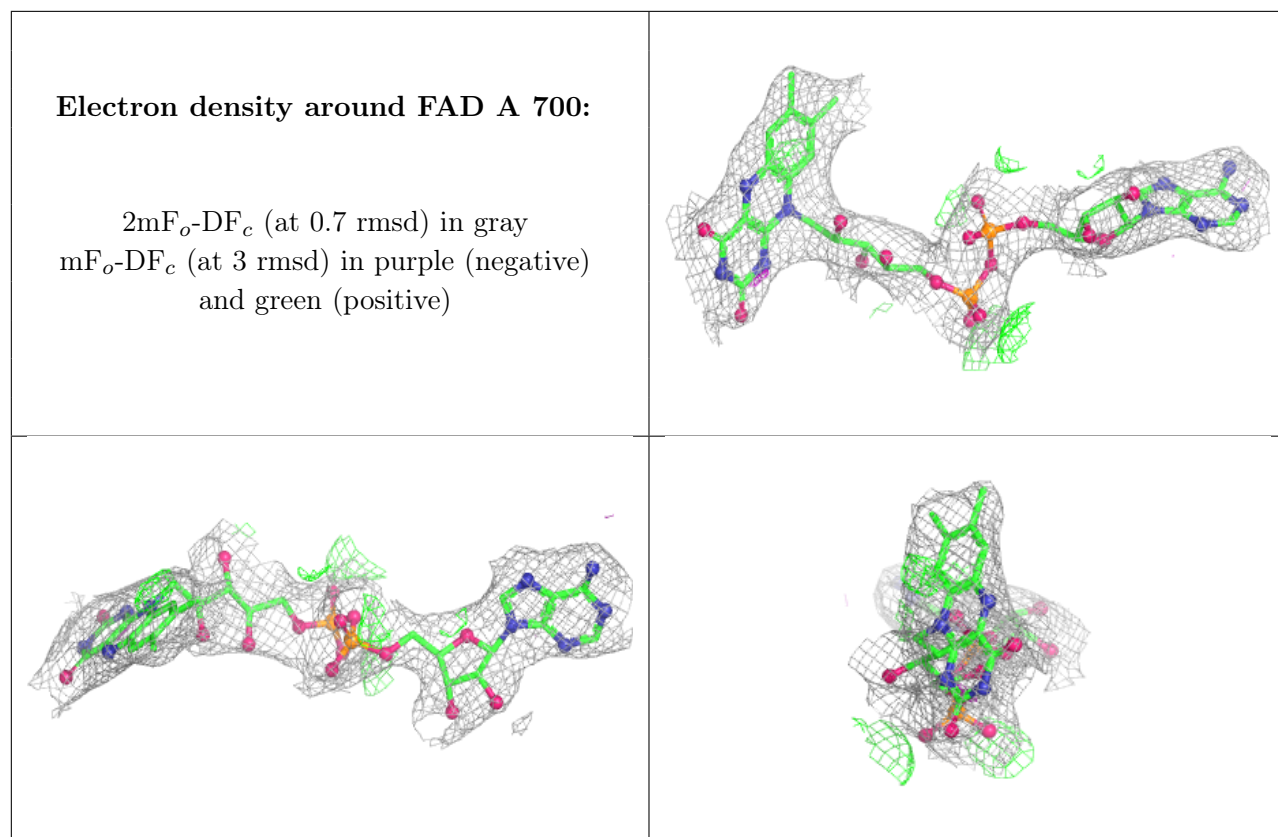
6.4 Ligands [i](#)

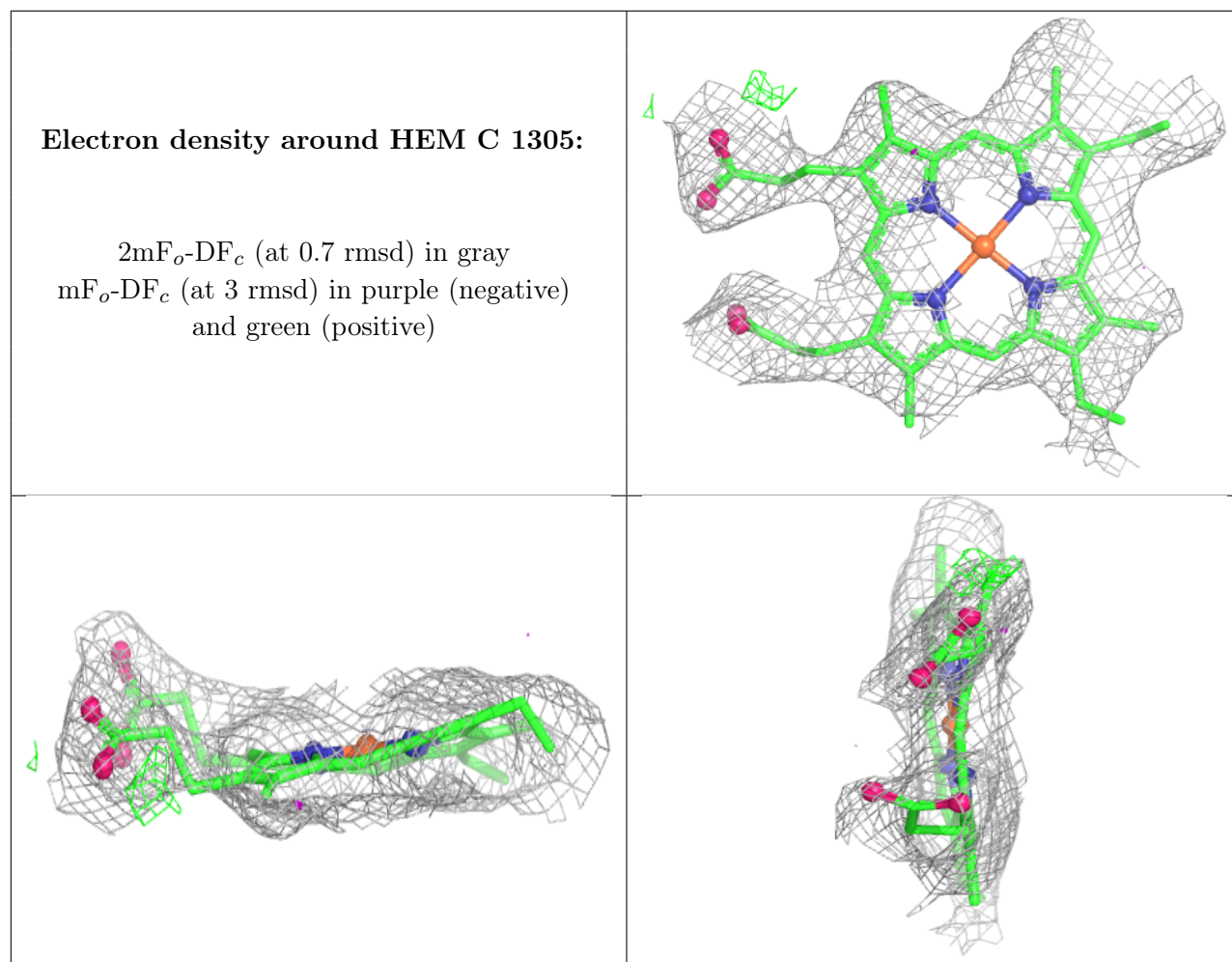
In the following table, the Atoms column lists the number of modelled atoms in the group and the number defined in the chemical component dictionary. The B-factors column lists the minimum, median, 95th percentile and maximum values of B factors of atoms in the group. The column labelled ‘Q< 0.9’ lists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

Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(\AA^2)	Q<0.9
10	EPH	D	1306	44/49	0.90	0.14	52,71,96,97	0
5	FAD	A	700	53/53	0.96	0.09	35,40,43,43	0
9	HEM	C	1305	43/43	0.98	0.08	40,43,51,54	0
8	F3S	B	304	7/7	0.99	0.04	35,35,37,40	0
6	FES	B	302	4/4	0.99	0.02	39,43,44,44	0
7	SF4	B	303	8/8	0.99	0.03	32,34,35,36	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.







6.5 Other polymers [i](#)

There are no such residues in this entry.