wwPDB X-ray Structure Validation Summary Report (i)

Aug 5, 2026 – 12:09 PM EDT

PDB ID	:	4MU8 / pdb_00004mu8
Title	:	Crystal structure of an oxidized form of yeast iso-1-cytochrome c at pH 8.8
Authors	:	McClelland, L.J.; Mou, T.-C.; Jeakins-Cooley, M.E.; Sprang, S.R.; Bowler, B.E.
Deposited on	:	2013-09-20
Resolution	:	1.45 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:

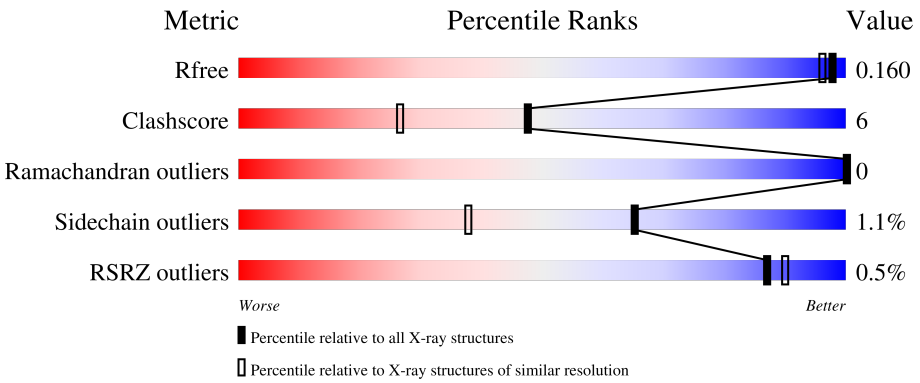
MolProbity	:	4-5-2 with Phenix2.0
Mogul	:	2022.3.0, CSD as543be (2022)
Xtriage (Phenix)	:	2.0
EDS	:	3.0
Buster-report	:	wwPDB partial adaption of 1.1.7 (2018)
Percentile statistics	:	20250101.v01 (using entries in the PDB archive January 1st 2025)
CCP4	:	9.0.015 (Gargrove)
Density-Fitness	:	1.0.12
Ideal geometry (proteins)	:	Engh & Huber (2001)
Ideal geometry (DNA, RNA)	:	Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP)	:	2.50

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 1.45 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	1756 (1.46-1.46)
Clashscore	190562	1795 (1.46-1.46)
Ramachandran outliers	187476	1776 (1.46-1.46)
Sidechain outliers	187428	1776 (1.46-1.46)
RSRZ outliers	180081	1756 (1.46-1.46)

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	108	92% 7% •
1	B	108	% 94% 6% •

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
2	HEC	A	201	X	-	-	-
2	HEC	B	202	X	-	-	-

2 Entry composition (i)

There are 6 unique types of molecules in this entry. The entry contains 3967 atoms, of which 1715 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.

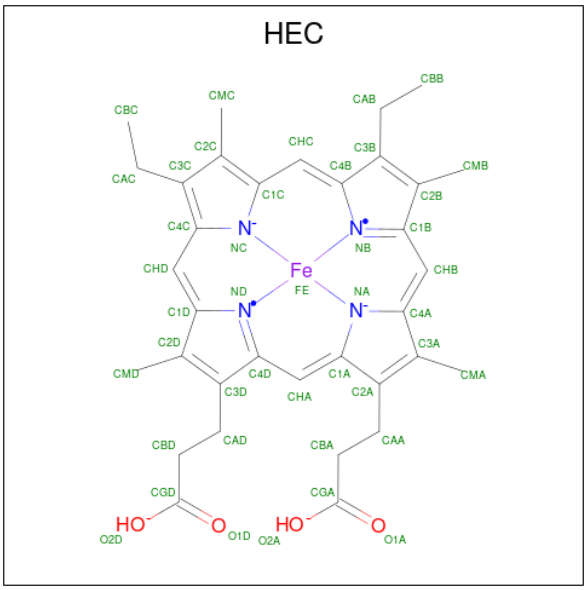
- Molecule 1 is a protein called Cytochrome c iso-1.

Mol	Chain	Residues	Atoms						ZeroOcc	AltConf	Trace
			Total	C	H	N	O	S			
1	A	107	1753	554	879	155	160	5	0	6	0
1	B	107	1690	543	836	150	156	5	0	4	0

There are 4 discrepancies between the modelled and reference sequences:

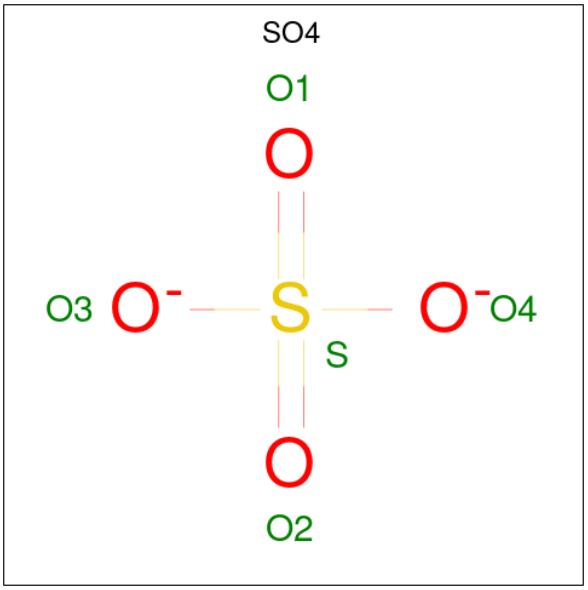
Chain	Residue	Modelled	Actual	Comment	Reference
A	72	ALA	LYS	engineered mutation	UNP P00044
A	102	SER	CYS	engineered mutation	UNP P00044
B	72	ALA	LYS	engineered mutation	UNP P00044
B	102	SER	CYS	engineered mutation	UNP P00044

- Molecule 2 is HEME C (CCD ID: HEC) (formula: $C_{34}H_{36}FeN_4O_4$).



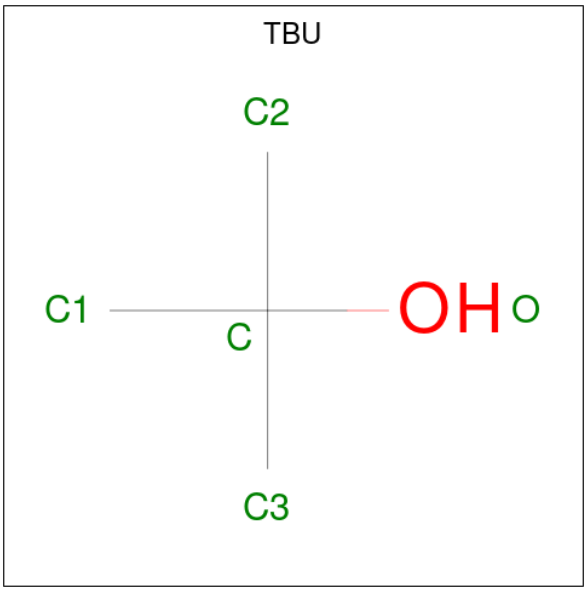
Mol	Chain	Residues	Atoms					ZeroOcc	AltConf
			Total	C	Fe	N	O		
2	A	1	43	34	1	4	4	0	0
			Total	C	Fe	N	O		
2	B	1	43	34	1	4	4	0	0

- Molecule 3 is SULFATE ION (CCD ID: SO4) (formula: O_4S).



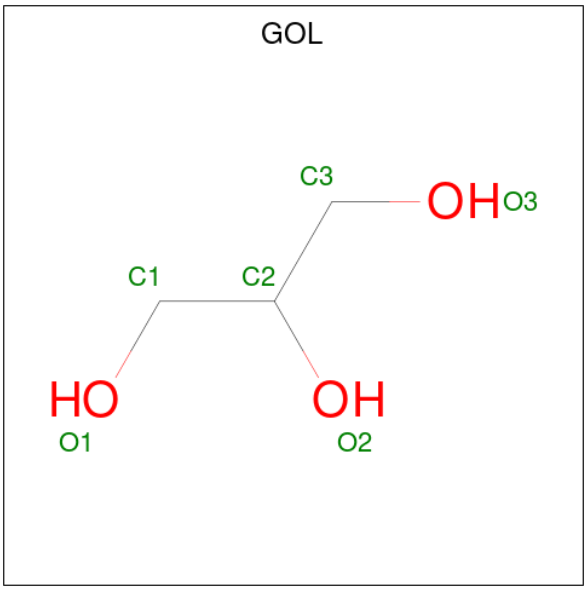
Mol	Chain	Residues	Atoms			ZeroOcc	AltConf
			Total	O	S		
3	A	1	5	4	1	0	0
			Total	O	S		
3	A	1	5	4	1	0	0
			Total	O	S		
3	A	1	5	4	1	0	0
			Total	O	S		
3	A	1	5	4	1	0	0
			Total	O	S		
3	B	1	5	4	1	0	0
			Total	O	S		
3	B	1	5	4	1	0	0
			Total	O	S		
3	B	1	5	4	1	0	0
			Total	O	S		
3	B	1	5	4	1	0	0

- Molecule 4 is TERTIARY-BUTYL ALCOHOL (CCD ID: TBU) (formula: $C_4H_{10}O$).



Mol	Chain	Residues	Atoms			ZeroOcc	AltConf
			Total	C	O		
4	A	1	5	4	1	0	0
			Total	C	O		
4	B	1	5	4	1	0	0
			Total	C	O		
4	B	1	10	8	2	0	1

- Molecule 5 is GLYCEROL (CCD ID: GOL) (formula: $C_3H_8O_3$).



Mol	Chain	Residues	Atoms			ZeroOcc	AltConf
			Total	C	O		
5	B	1	6	3	3	0	0

- Molecule 6 is water.

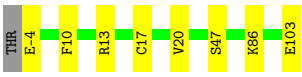
Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
			Total	O		
6	A	193	195	195	0	2
			Total	O		
6	B	175	177	177	0	2

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.

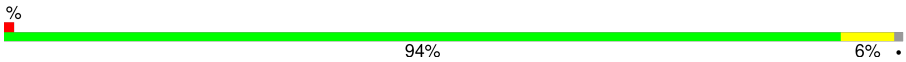
- Molecule 1: Cytochrome c iso-1

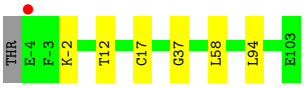
Chain A:



- Molecule 1: Cytochrome c iso-1

Chain B:





4 Data and refinement statistics (i)

Property	Value	Source
Space group	P 63 2 2	Depositor
Cell constants a, b, c, α, β, γ	93.62Å 93.62Å 155.01Å 90.00° 90.00° 120.00°	Depositor
Resolution (Å)	8.00 – 1.45 8.00 – 1.45	Depositor EDS
% Data completeness (in resolution range)	99.9 (8.00-1.45) 93.7 (8.00-1.45)	Depositor EDS
R_{merge}	(Not available)	Depositor
R_{sym}	0.09	Depositor
$< I/\sigma(I) >$ [1]	2.05 (at 1.45Å)	Xtriage
Refinement program	PHENIX (phenix.refine: 1.8.2_1309)	Depositor
R, R_{free}	0.145 , 0.154 0.149 , 0.160	Depositor DCC
R_{free} test set	2000 reflections (1.45%)	wwPDB-VP
Wilson B-factor (Å^2)	14.3	Xtriage
Anisotropy	0.126	Xtriage
Bulk solvent k_{sol}(e/Å^3), B_{sol}(Å^2)	0.58 , 63.4	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	0.97	EDS
Total number of atoms	3967	wwPDB-VP
Average B, all atoms (Å^2)	21.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 9.18% 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: SO4, HEC, TBU, GOL

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	0/904	0.66	0/1210
1	B	0.54	0/884	0.72	0/1184
All	All	0.54	0/1788	0.69	0/2394

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 (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	874	879	886	10	1
1	B	854	836	869	11	0
2	A	43	0	30	5	0
2	B	43	0	30	4	0
3	A	20	0	0	0	0
3	B	20	0	0	0	0
4	A	5	0	10	0	0
4	B	15	0	30	0	0
5	B	6	0	8	0	0
6	A	195	0	0	2	0
6	B	177	0	0	3	0
All	All	2252	1715	1863	21	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 6.

The worst 5 of 21 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:17:CYS:SG	2:B:202:HEC:CAC	2.02	1.46
1:A:17:CYS:SG	2:A:201:HEC:CAC	2.03	1.44
1:B:12:THR:HG21	6:B:436:HOH:O	1.59	1.02
1:B:58:LEU:HD12	6:B:401:HOH:O	1.71	0.89
1:A:17:CYS:SG	2:A:201:HEC:CBC	2.74	0.75

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)
1:A:47:SER:HG	1:A:86:LYS:HZ1[2_565]	1.22	0.38

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	111/108 (103%)	107 (96%)	4 (4%)	0	100	100
1	B	109/108 (101%)	107 (98%)	2 (2%)	0	100	100
All	All	220/216 (102%)	214 (97%)	6 (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	93/88 (106%)	92 (99%)	1 (1%)	65	38
1	B	91/88 (103%)	90 (99%)	1 (1%)	65	38
All	All	184/176 (104%)	182 (99%)	2 (1%)	65	38

All (2) residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	103	GLU
1	B	-2	LYS

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (2) such sidechains are listed below:

Mol	Chain	Res	Type
1	B	39	HIS
1	B	42	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)

15 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	$\#\|Z\| > 2$
4	TBU	B	208[A]	-	4,4,4	0.64	0	6,6,6	0.50	0
3	SO4	A	205	-	4,4,4	0.27	0	6,6,6	0.07	0
3	SO4	A	202	-	4,4,4	0.33	0	6,6,6	0.28	0
3	SO4	B	204	-	4,4,4	0.38	0	6,6,6	0.22	0
3	SO4	B	205	-	4,4,4	0.26	0	6,6,6	0.09	0
3	SO4	A	204	-	4,4,4	0.30	0	6,6,6	0.16	0
4	TBU	A	206	-	4,4,4	0.51	0	6,6,6	0.38	0
2	HEC	A	201	6,1	50,50,50	2.39	18 (36%)	68,82,82	2.24	21 (30%)
4	TBU	B	207	-	4,4,4	0.86	0	6,6,6	0.37	0
5	GOL	B	206	-	5,5,5	0.24	0	5,5,5	0.36	0
2	HEC	B	202	6,1	50,50,50	2.36	19 (38%)	68,82,82	2.54	25 (36%)
3	SO4	B	201	-	4,4,4	0.33	0	6,6,6	0.55	0
3	SO4	B	203	-	4,4,4	0.26	0	6,6,6	0.09	0
3	SO4	A	203	-	4,4,4	0.24	0	6,6,6	0.17	0
4	TBU	B	208[B]	-	4,4,4	0.77	0	6,6,6	0.28	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	HEC	A	201	6,1	1/1/3/7	4/14/54/54	-
2	HEC	B	202	6,1	1/1/3/7	5/14/54/54	-
5	GOL	B	206	-	-	0/4/4/4	-

The worst 5 of 37 bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
2	A	201	HEC	FE-NB	7.96	2.19	1.94
2	B	202	HEC	FE-NB	7.73	2.18	1.94
2	B	202	HEC	FE-NC	4.97	2.11	1.95
2	A	201	HEC	FE-NC	4.90	2.11	1.95
2	B	202	HEC	FE-ND	4.71	2.09	1.94

The worst 5 of 46 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
2	B	202	HEC	C4B-NB-C1B	8.45	115.22	105.21
2	A	201	HEC	C4B-NB-C1B	7.60	114.21	105.21
2	A	201	HEC	C3B-C4B-NB	-5.74	103.87	110.17
2	B	202	HEC	C3B-C4B-NB	-5.72	103.90	110.17
2	B	202	HEC	C3C-C4C-NC	-5.24	104.33	110.15

All (2) chirality outliers are listed below:

Mol	Chain	Res	Type	Atom
2	A	201	HEC	NA
2	B	202	HEC	NA

5 of 9 torsion outliers are listed below:

Mol	Chain	Res	Type	Atoms
2	B	202	HEC	C2B-C3B-CAB-CBB
2	A	201	HEC	C2B-C3B-CAB-CBB
2	B	202	HEC	C4C-C3C-CAC-CBC
2	A	201	HEC	C4C-C3C-CAC-CBC
2	A	201	HEC	C2C-C3C-CAC-CBC

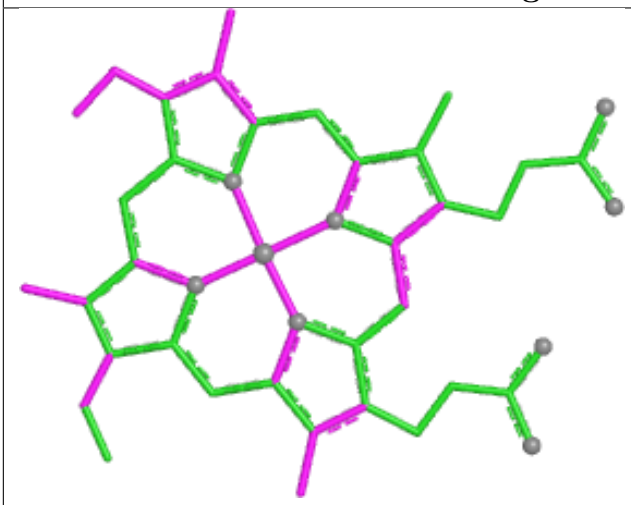
There are no ring outliers.

2 monomers are involved in 9 short contacts:

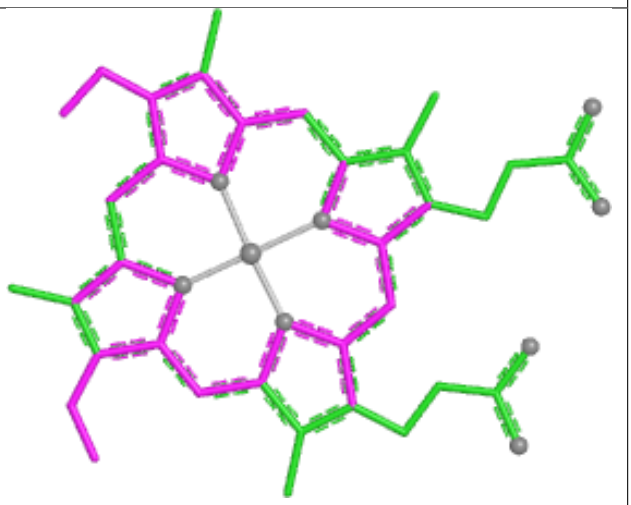
Mol	Chain	Res	Type	Clashes	Symm-Clashes
2	A	201	HEC	5	0
2	B	202	HEC	4	0

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.

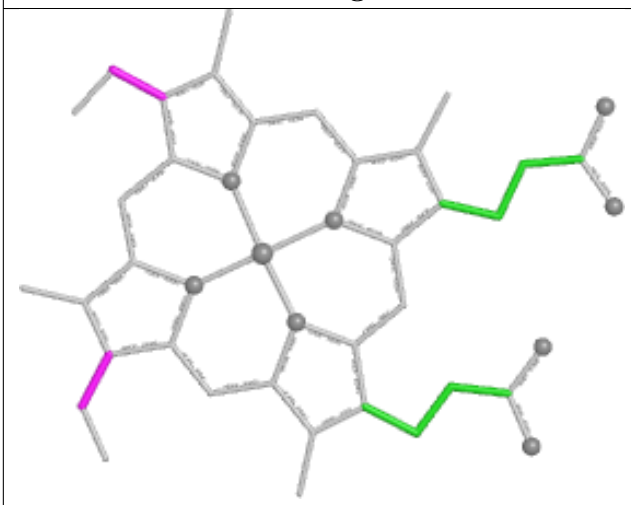
Ligand HEC A 201



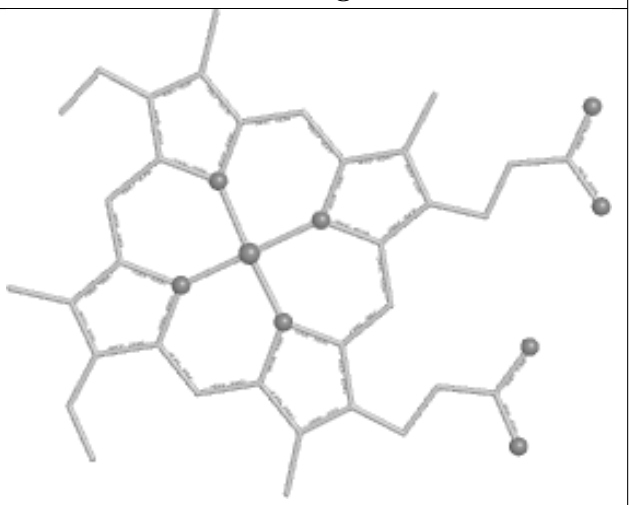
Bond lengths



Bond angles

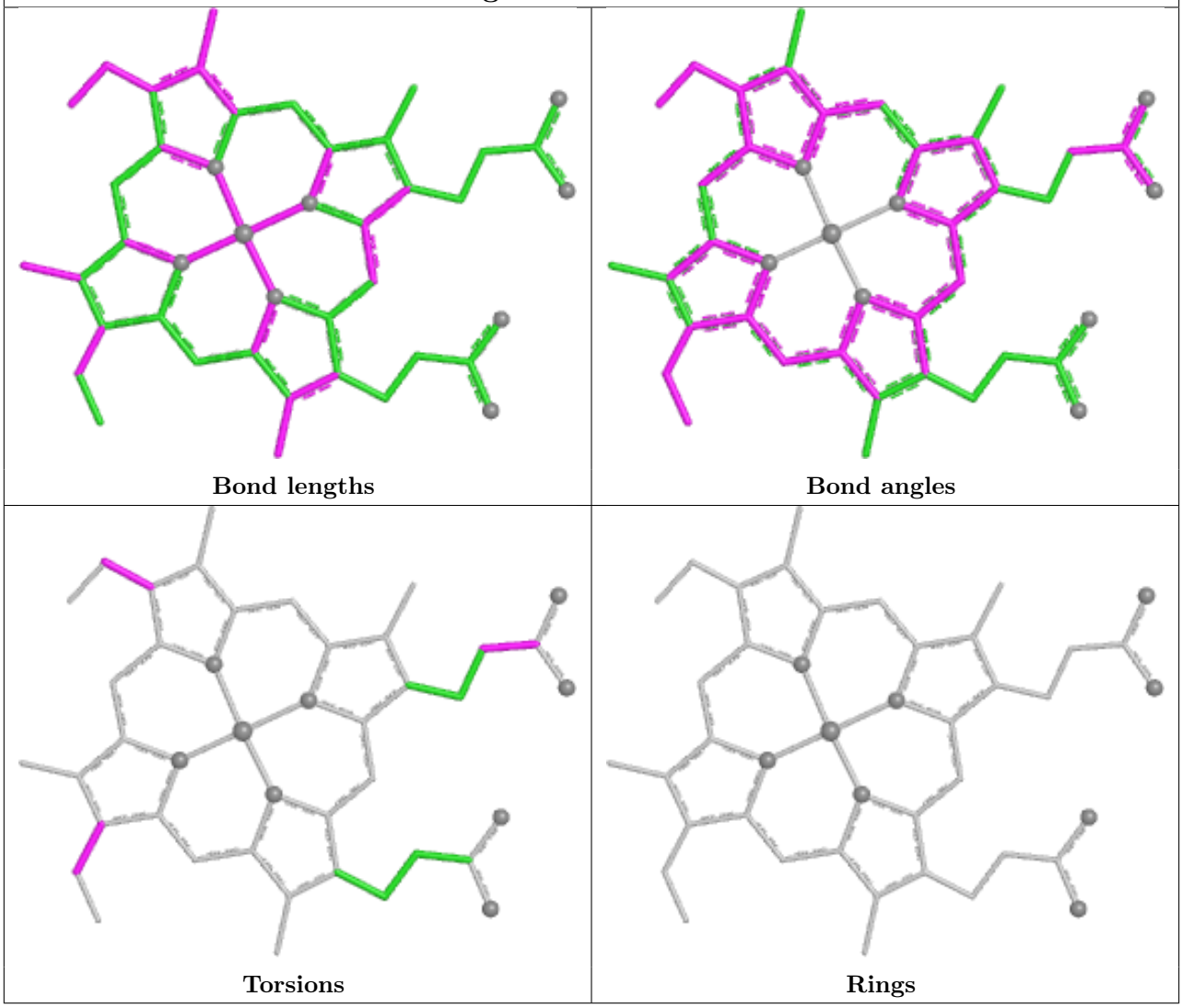


Torsions



Rings

Ligand HEC B 202



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	107/108 (99%)	-0.96	0	100	100	7, 15, 38, 58	6 (5%)
1	B	107/108 (99%)	-0.82	1 (0%)	81	84	7, 17, 42, 59	5 (4%)
All	All	214/216 (99%)	-0.89	1 (0%)	87	90	7, 16, 42, 59	11 (5%)

All (1) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	B	-4	GLU	2.6

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(Å^2)	Q<0.9
4	TBU	B	208[A]	5/5	0.92	0.08	13,13,15,19	5
4	TBU	B	208[B]	5/5	0.92	0.08	11,12,14,17	5
3	SO4	A	202	5/5	0.93	0.10	21,22,28,28	5
3	SO4	B	204	5/5	0.93	0.11	17,20,25,26	5

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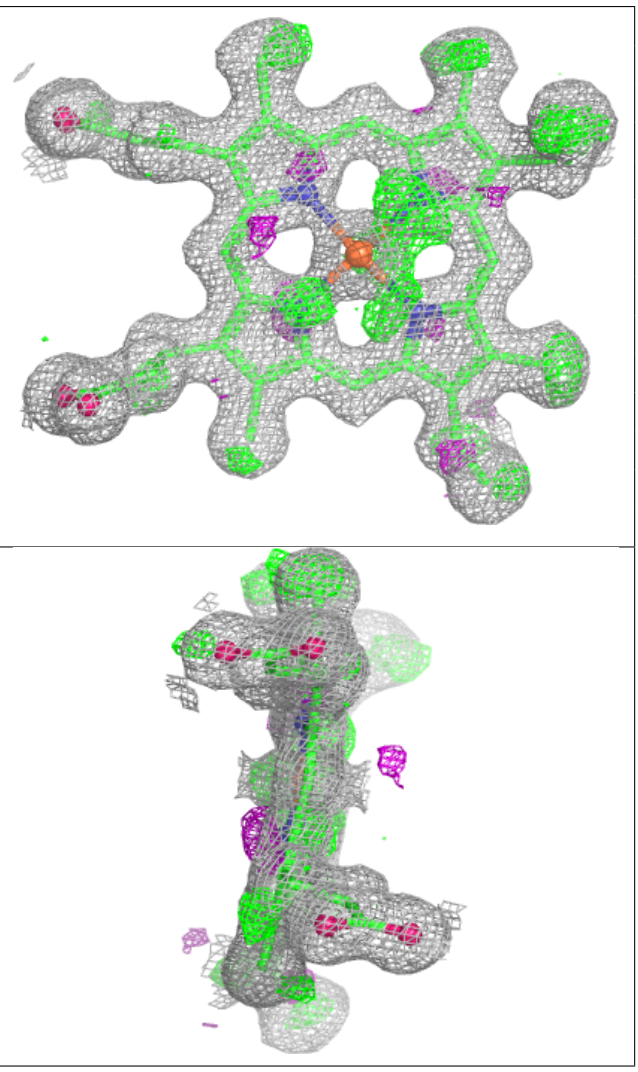
Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(Å^2)	Q<0.9
3	SO4	A	204	5/5	0.94	0.10	22,30,45,46	5
3	SO4	B	205	5/5	0.95	0.06	30,43,49,51	5
3	SO4	A	205	5/5	0.96	0.07	27,40,42,48	5
5	GOL	B	206	6/6	0.97	0.04	17,18,18,19	0
4	TBU	A	206	5/5	0.98	0.04	14,15,16,16	5
3	SO4	B	201	5/5	0.98	0.05	21,22,26,27	5
2	HEC	B	202	43/43	0.99	0.04	8,10,11,13	0
2	HEC	A	201	43/43	0.99	0.04	8,9,11,13	0
4	TBU	B	207	5/5	0.99	0.03	13,14,14,15	5
3	SO4	B	203	5/5	1.00	0.02	9,12,12,12	5
3	SO4	A	203	5/5	1.00	0.06	9,12,13,13	5

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.

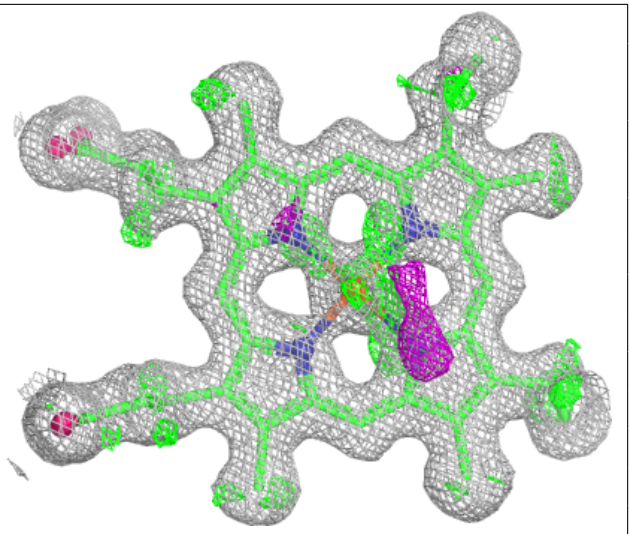
Electron density around HEC B 202:

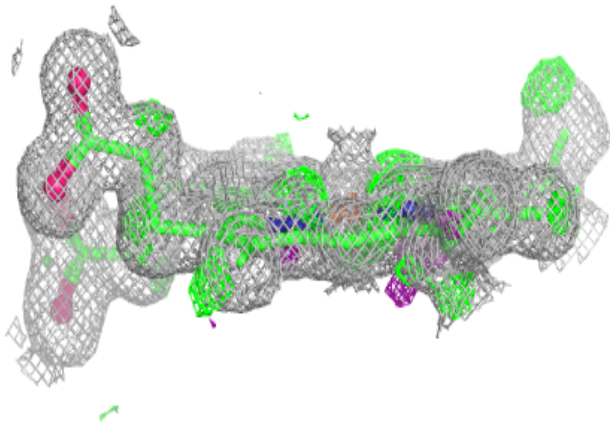
2mF$_o$-DF$_c$ (at 0.7 rmsd) in gray
mF$_o$-DF$_c$ (at 3 rmsd) in purple (negative) and green (positive)

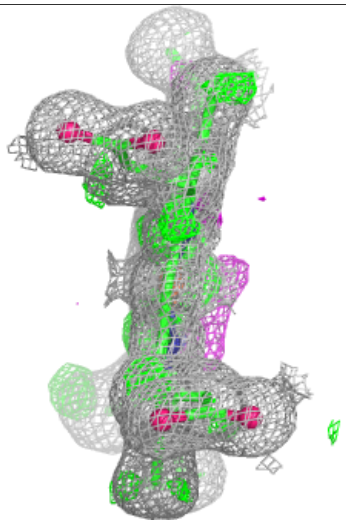


Electron density around HEC A 201:

$2mF_o$-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.