wwPDB X-ray Structure Validation Summary Report (i)

Mar 9, 2026 – 04:24 PM UTC

PDB ID	:	2IX5 / pdb_00002ix5
Title	:	Short chain specific acyl-CoA oxidase from Arabidopsis thaliana, ACX4 in complex with acetoacetyl-CoA
Authors	:	Mackenzie, J.; Pedersen, L.; Arent, S.; Henriksen, A.
Deposited on	:	2006-07-07
Resolution	:	2.70 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:

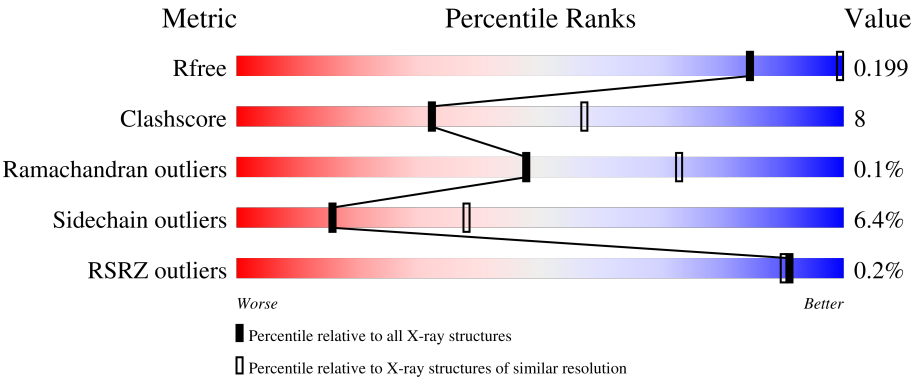
MolProbity	:	4-5-2 with Phenix2.0
Mogul	:	2022.3.0, CSD as543be (2022)
Xtriage (Phenix)	:	2.0
EDS	:	3.0
Buster-report	:	wwPDB partial adaption of 1.1.7 (2018)
Percentile statistics	:	20250101.v01 (using entries in the PDB archive January 1st 2025)
CCP4	:	9.0.010 (Gargrove)
Density-Fitness	:	1.0.12
Ideal 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 (i)

The following experimental techniques were used to determine the structure:
X-RAY DIFFRACTION

The reported resolution of this entry is 2.70 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	3538 (2.70-2.70)
Clashscore	190562	3843 (2.70-2.70)
Ramachandran outliers	187476	3778 (2.70-2.70)
Sidechain outliers	187428	3778 (2.70-2.70)
RSRZ outliers	180081	3538 (2.70-2.70)

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	436	75% 17% • 5%
1	B	436	78% 16% • 5%
1	C	436	78% 17% • 5%
1	D	436	76% 17% • 5%

2 Entry composition (i)

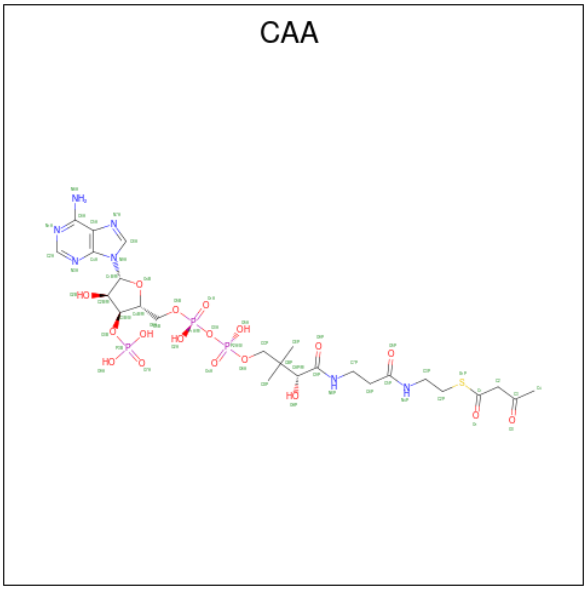
There are 4 unique types of molecules in this entry. The entry contains 13234 atoms, of which 0 are hydrogens and 0 are deuteriums.

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 ACYL-COENZYME A OXIDASE 4, PEROXISOMAL.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
1	A	416	Total	C	N	O	S	0	1	1
			3166	2022	531	590	23			
1	B	416	Total	C	N	O	S	0	1	1
			3179	2030	534	592	23			
1	C	416	Total	C	N	O	S	0	0	1
			3162	2021	534	584	23			
1	D	416	Total	C	N	O	S	0	0	1
			3159	2017	530	590	22			

- Molecule 2 is ACETOACETYL-COENZYME A (CCD ID: CAA) (formula: $C_{25}H_{40}N_7O_{18}P_3S$).



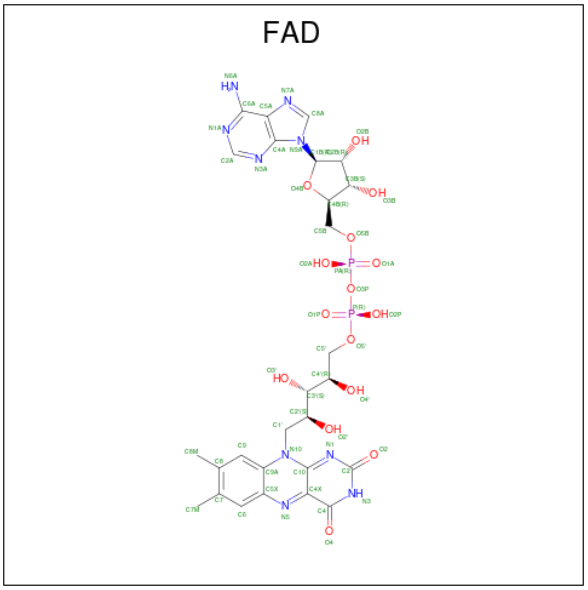
Mol	Chain	Residues	Atoms						ZeroOcc	AltConf
2	A	1	Total	C	N	O	P	S	0	0
			48	21	7	16	3	1		
2	B	1	Total	C	N	O	P	S	0	0
			48	21	7	16	3	1		

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Mol	Chain	Residues	Atoms						ZeroOcc	AltConf
2	C	1	Total	C	N	O	P	S	0	0
			48	21	7	16	3	1		
2	D	1	Total	C	N	O	P	S	0	0
			48	21	7	16	3	1		

- Molecule 3 is FLAVIN-ADENINE DINUCLEOTIDE (CCD ID: FAD) (formula: $C_{27}H_{33}N_9O_{15}P_2$).



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

- Molecule 4 is water.

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
4	A	24	Total	O	0	0
			24	24		
4	B	48	Total	O	0	0
			48	48		
4	C	48	Total	O	0	0
			48	48		

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Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
4	D	44	Total	O	0	0
			44	44		

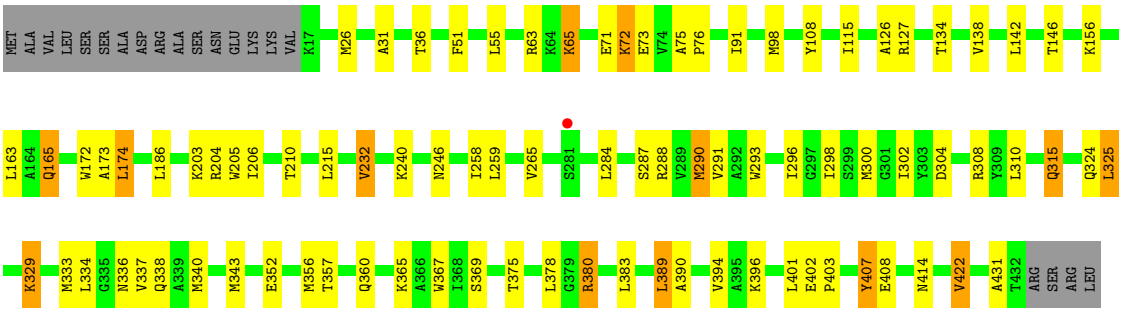
3 Residue-property plots (i)

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: ACYL-COENZYME A OXIDASE 4, PEROXISOMAL

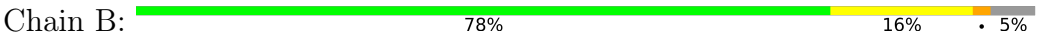
Chain A:

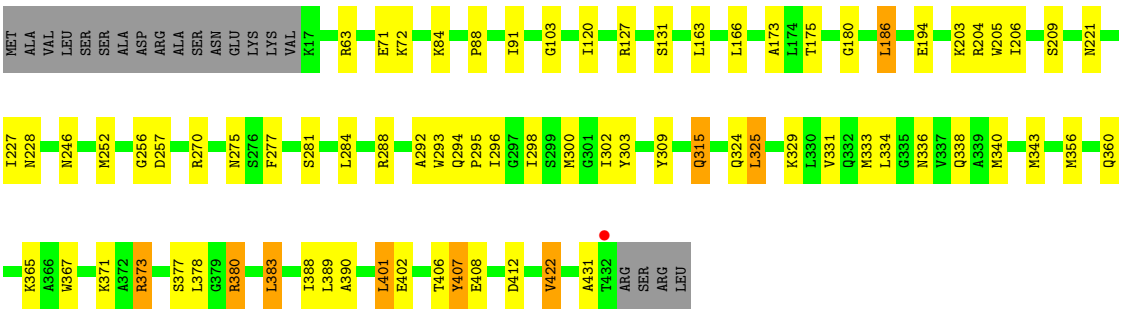




• Molecule 1: ACYL-COENZYME A OXIDASE 4, PEROXISOMAL

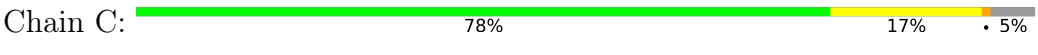
Chain B:

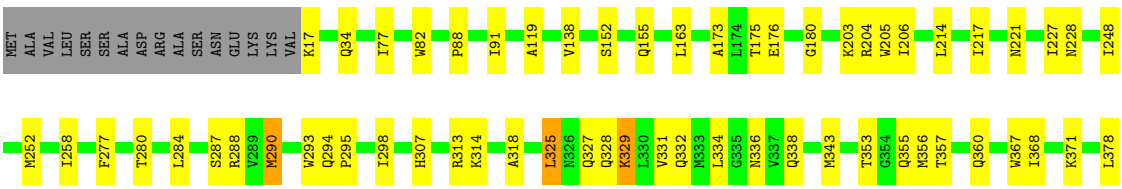


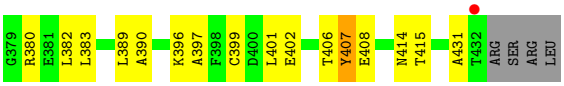


• Molecule 1: ACYL-COENZYME A OXIDASE 4, PEROXISOMAL

Chain C:



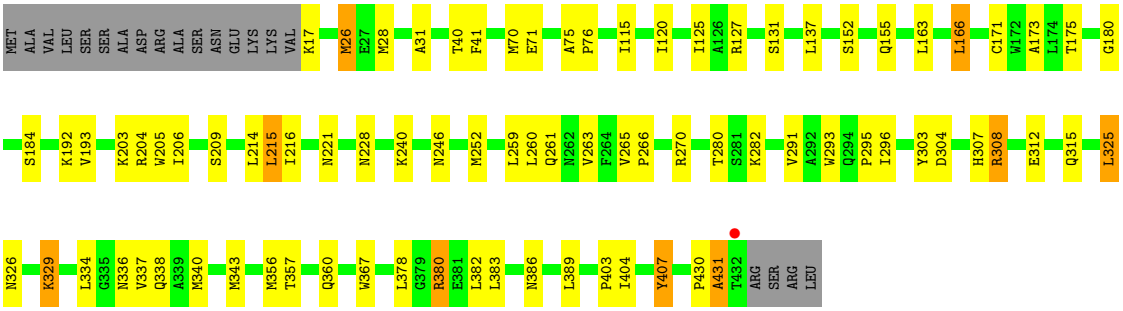




• Molecule 1: ACYL-COENZYME A OXIDASE 4, PEROXISOMAL

Chain D:





4 Data and refinement statistics (i)

Property	Value	Source
Space group	P 32 2 1	Depositor
Cell constants a, b, c, α, β, γ	144.75Å 144.75Å 149.21Å 90.00° 90.00° 120.00°	Depositor
Resolution (Å)	20.00 – 2.70 20.00 – 2.70	Depositor EDS
% Data completeness (in resolution range)	99.7 (20.00-2.70) 99.4 (20.00-2.70)	Depositor EDS
R_{merge}	0.13	Depositor
R_{sym}	(Not available)	Depositor
$< I/\sigma(I) >$ [1]	1.73 (at 2.71Å)	Xtriage
Refinement program	REFMAC 5.2.0019	Depositor
R, R_{free}	0.186 , 0.232 (Not available) , 0.199	Depositor DCC
R_{free} test set	2525 reflections (5.08%)	wwPDB-VP
Wilson B-factor (Å^2)	45.0	Xtriage
Anisotropy	0.234	Xtriage
Bulk solvent k_{sol}(e/Å^3), B_{sol}(Å^2)	0.33 , 40.5	EDS
L-test for twinning[2]	$< \|L\| > = 0.48$, $< L^2 > = 0.31$	Xtriage
Estimated twinning fraction	0.025 for -h,-k,l	Xtriage
F_o,F_c correlation	0.93	EDS
Total number of atoms	13234	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 2.54% 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

5.1 Standard geometry

Bond lengths and bond angles in the following residue types are not validated in this section: FAD, CAA

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	0.52	1/3238 (0.0%)	0.84	0/4393
1	B	0.52	1/3251 (0.0%)	0.83	0/4407
1	C	0.53	1/3231 (0.0%)	0.84	0/4381
1	D	0.52	1/3228 (0.0%)	0.85	2/4381 (0.0%)
All	All	0.52	4/12948 (0.0%)	0.84	2/17562 (0.0%)

All (4) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
1	A	431	ALA	C-N	-7.08	1.23	1.33
1	D	431	ALA	C-N	-7.06	1.23	1.33
1	C	431	ALA	C-N	-7.05	1.23	1.33
1	B	431	ALA	C-N	-7.03	1.23	1.33

All (2) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
1	D	41	PHE	CA-C-N	5.05	123.35	119.66
1	D	41	PHE	C-N-CA	5.05	123.35	119.66

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	3166	0	3169	65	0
1	B	3179	0	3196	56	0
1	C	3162	0	3180	58	0
1	D	3159	0	3149	57	0
2	A	48	0	31	0	0
2	B	48	0	31	0	0
2	C	48	0	31	2	0
2	D	48	0	31	1	0
3	A	53	0	31	1	0
3	B	53	0	31	5	0
3	C	53	0	31	2	0
3	D	53	0	31	4	0
4	A	24	0	0	0	0
4	B	48	0	0	0	0
4	C	48	0	0	1	0
4	D	44	0	0	1	0
All	All	13234	0	12942	207	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 8.

The worst 5 of 207 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:26:MET:HE3	1:A:31:ALA:HA	1.56	0.87
1:B:194[B]:GLU:H	1:B:194[B]:GLU:CD	1.90	0.80
1:D:357:THR:H	1:D:360:GLN:HE21	1.31	0.78
1:A:343:MET:HE1	1:D:338:GLN:HB2	1.65	0.77
1:C:204:ARG:HH21	1:D:386:ASN:HD21	1.32	0.77

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	415/436 (95%)	406 (98%)	9 (2%)	0	100	100
1	B	415/436 (95%)	401 (97%)	13 (3%)	1 (0%)	43	68
1	C	414/436 (95%)	405 (98%)	9 (2%)	0	100	100
1	D	414/436 (95%)	402 (97%)	11 (3%)	1 (0%)	43	68
All	All	1658/1744 (95%)	1614 (97%)	42 (2%)	2 (0%)	48	73

All (2) Ramachandran outliers are listed below:

Mol	Chain	Res	Type
1	B	103	GLY
1	D	431	ALA

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	336/357 (94%)	310 (92%)	26 (8%)	12	30
1	B	339/357 (95%)	320 (94%)	19 (6%)	19	44
1	C	335/357 (94%)	318 (95%)	17 (5%)	21	48
1	D	333/357 (93%)	309 (93%)	24 (7%)	13	32
All	All	1343/1428 (94%)	1257 (94%)	86 (6%)	16	38

5 of 86 residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	C	383	LEU
1	D	193	VAL
1	C	401	LEU
1	D	120	ILE
1	D	261	GLN

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. 5 of 48 such sidechains are listed below:

Mol	Chain	Res	Type
1	C	294	GLN
1	D	90	HIS
1	C	307	HIS
1	C	360	GLN
1	D	155	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)

8 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	FAD	C	1433	-	58,58,58	1.05	5 (8%)	85,89,89	1.56	15 (17%)
3	FAD	A	1433	-	58,58,58	1.06	6 (10%)	85,89,89	1.67	18 (21%)
2	CAA	B	1432	-	47,50,56	1.23	5 (10%)	69,75,83	1.56	12 (17%)
3	FAD	B	1433	-	58,58,58	1.11	6 (10%)	85,89,89	1.68	19 (22%)
2	CAA	C	1432	-	47,50,56	1.18	5 (10%)	69,75,83	1.57	11 (15%)
2	CAA	D	1432	-	47,50,56	1.38	6 (12%)	69,75,83	1.62	10 (14%)
3	FAD	D	1433	-	58,58,58	1.11	7 (12%)	85,89,89	1.61	22 (25%)
2	CAA	A	1432	-	47,50,56	1.37	6 (12%)	69,75,83	1.62	11 (15%)

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	FAD	C	1433	-	-	4/34/50/50	0/6/6/6
3	FAD	A	1433	-	-	9/34/50/50	0/6/6/6
2	CAA	B	1432	-	-	12/48/64/71	0/3/3/3
3	FAD	B	1433	-	-	13/34/50/50	0/6/6/6
2	CAA	C	1432	-	-	11/48/64/71	0/3/3/3
2	CAA	D	1432	-	-	10/48/64/71	0/3/3/3
3	FAD	D	1433	-	-	7/34/50/50	0/6/6/6
2	CAA	A	1432	-	-	12/48/64/71	0/3/3/3

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

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
2	D	1432	CAA	P2A-O3A	4.22	1.64	1.59
2	A	1432	CAA	P1A-O3A	3.92	1.63	1.59
2	B	1432	CAA	P3B-O7A	3.84	1.62	1.50
2	A	1432	CAA	P3B-O7A	3.75	1.62	1.50
3	B	1433	FAD	C9A-N10	-3.73	1.34	1.41

The worst 5 of 118 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
2	A	1432	CAA	C5A-C4A-N3A	-5.49	119.16	126.72
3	A	1433	FAD	C5A-C4A-N3A	-5.41	119.27	126.72
3	B	1433	FAD	C5A-C4A-N3A	-5.32	119.39	126.72
3	C	1433	FAD	C5A-C4A-N3A	-5.28	119.45	126.72
2	C	1432	CAA	C5A-C4A-N3A	-5.23	119.52	126.72

There are no chirality outliers.

5 of 78 torsion outliers are listed below:

Mol	Chain	Res	Type	Atoms
2	A	1432	CAA	C5B-O5B-P1A-O1A
2	A	1432	CAA	CEP-CBP-CCP-O6A
2	A	1432	CAA	CAP-CBP-CCP-O6A
2	B	1432	CAA	CCP-O6A-P2A-O3A
2	B	1432	CAA	CCP-O6A-P2A-O4A

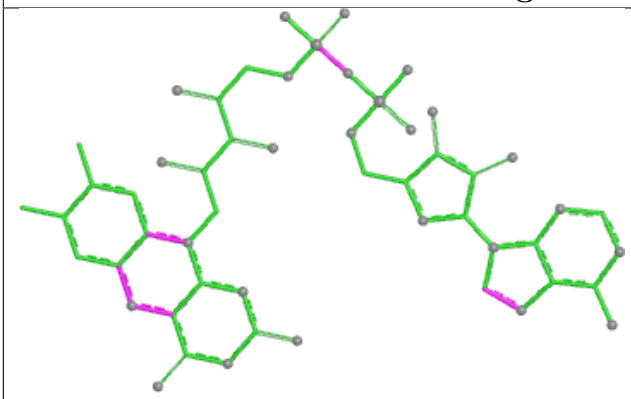
There are no ring outliers.

6 monomers are involved in 15 short contacts:

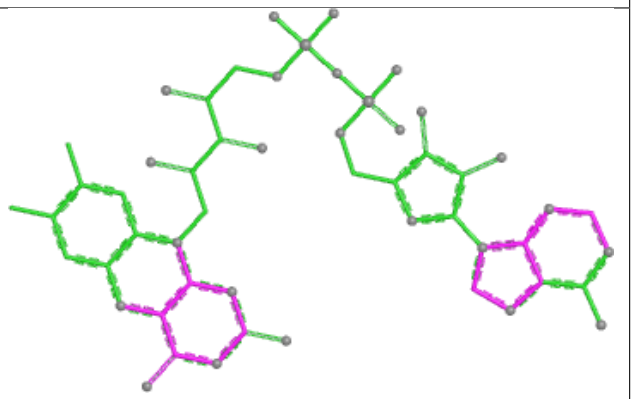
Mol	Chain	Res	Type	Clashes	Symm-Clashes
3	C	1433	FAD	2	0
3	A	1433	FAD	1	0
3	B	1433	FAD	5	0
2	C	1432	CAA	2	0
2	D	1432	CAA	1	0
3	D	1433	FAD	4	0

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.

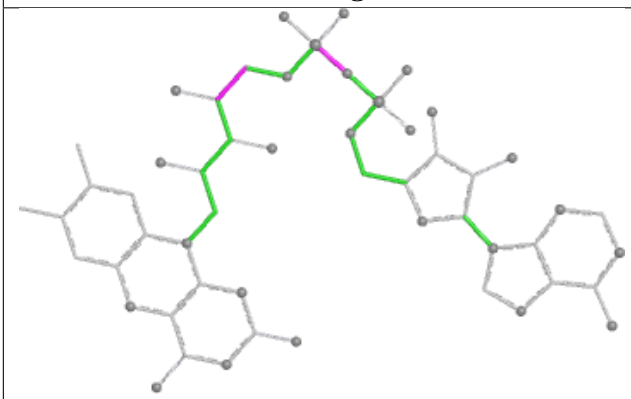
Ligand FAD C 1433



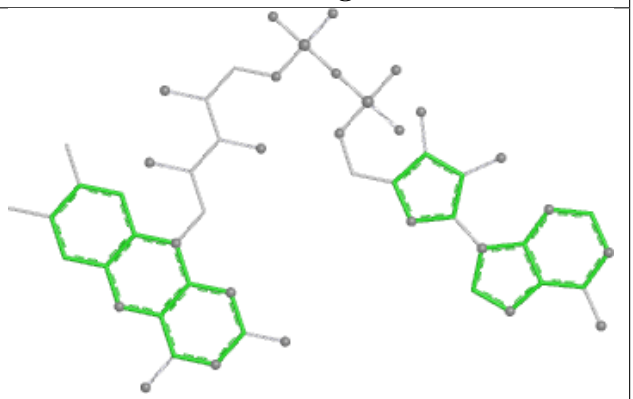
Bond lengths



Bond angles

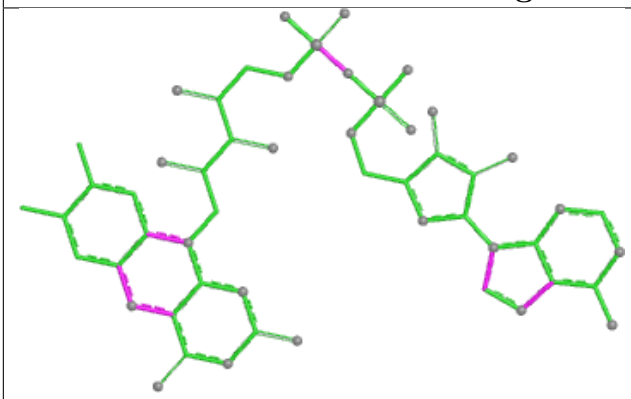


Torsions

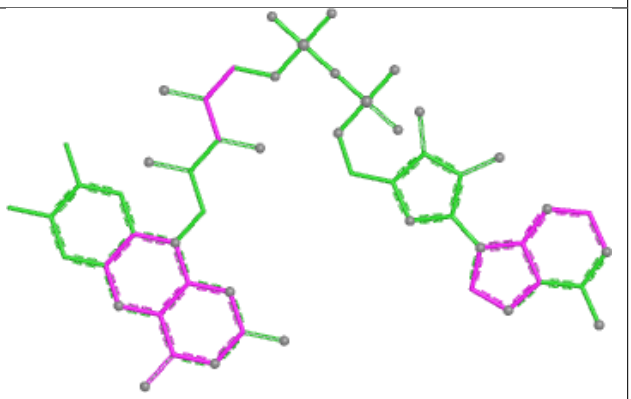


Rings

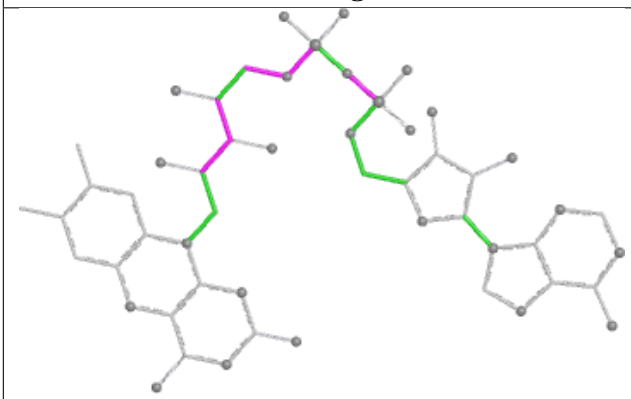
Ligand FAD A 1433



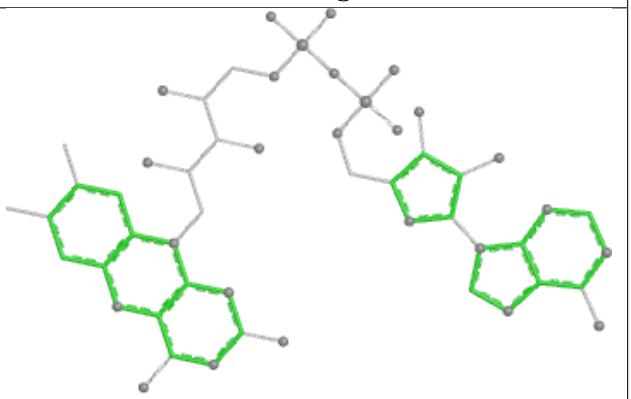
Bond lengths



Bond angles

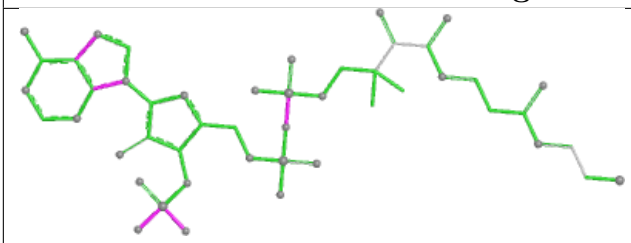


Torsions

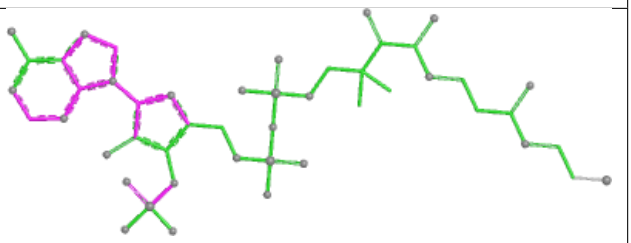


Rings

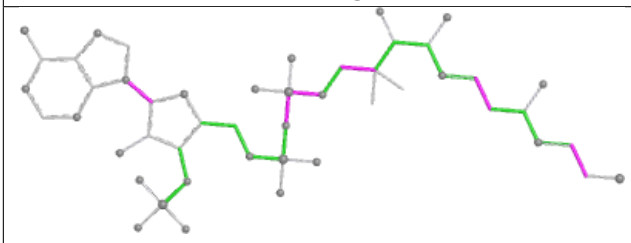
Ligand CAA B 1432



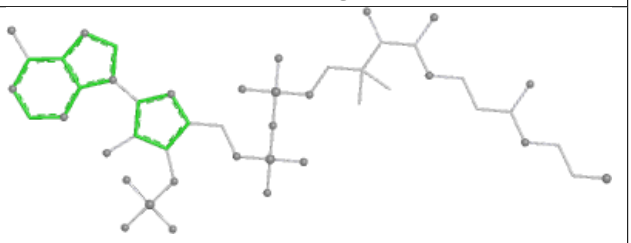
Bond lengths



Bond angles

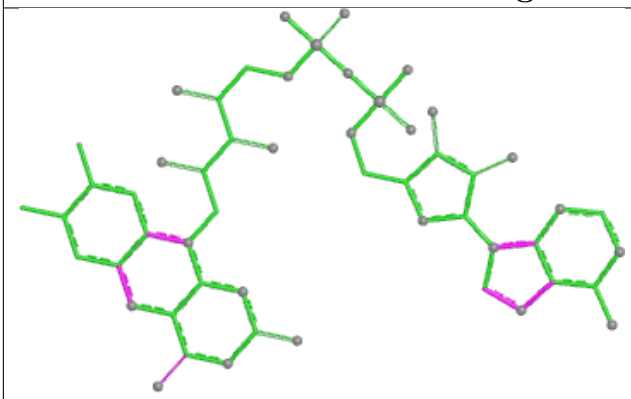


Torsions

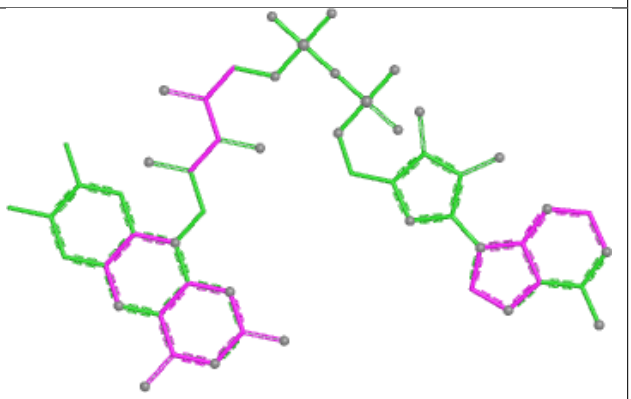


Rings

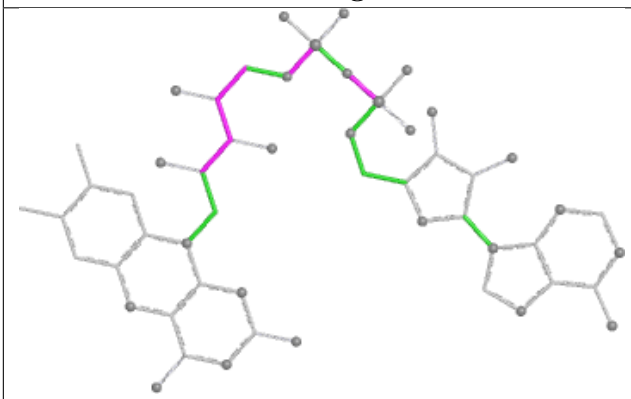
Ligand FAD B 1433



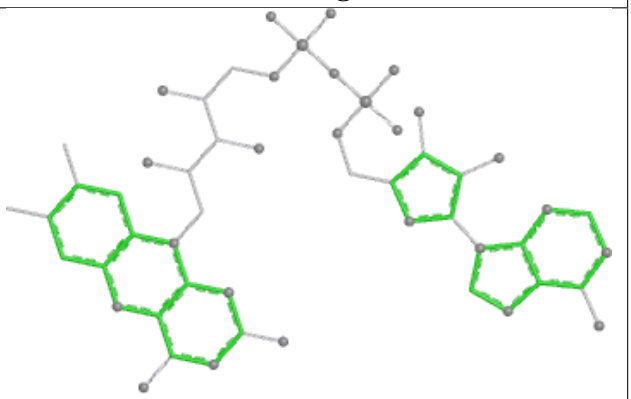
Bond lengths



Bond angles

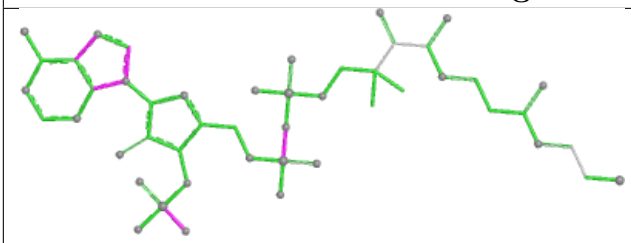


Torsions

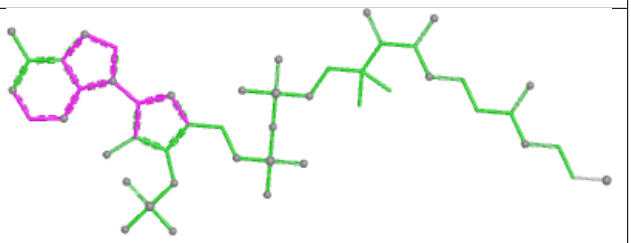


Rings

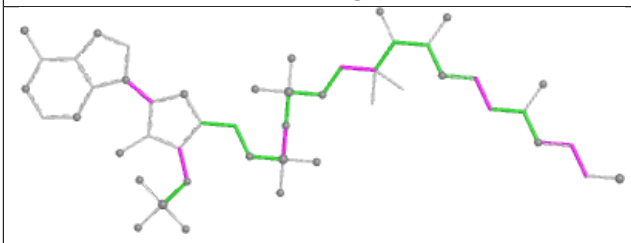
Ligand CAA C 1432



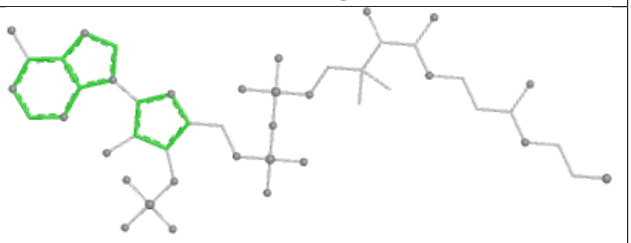
Bond lengths



Bond angles

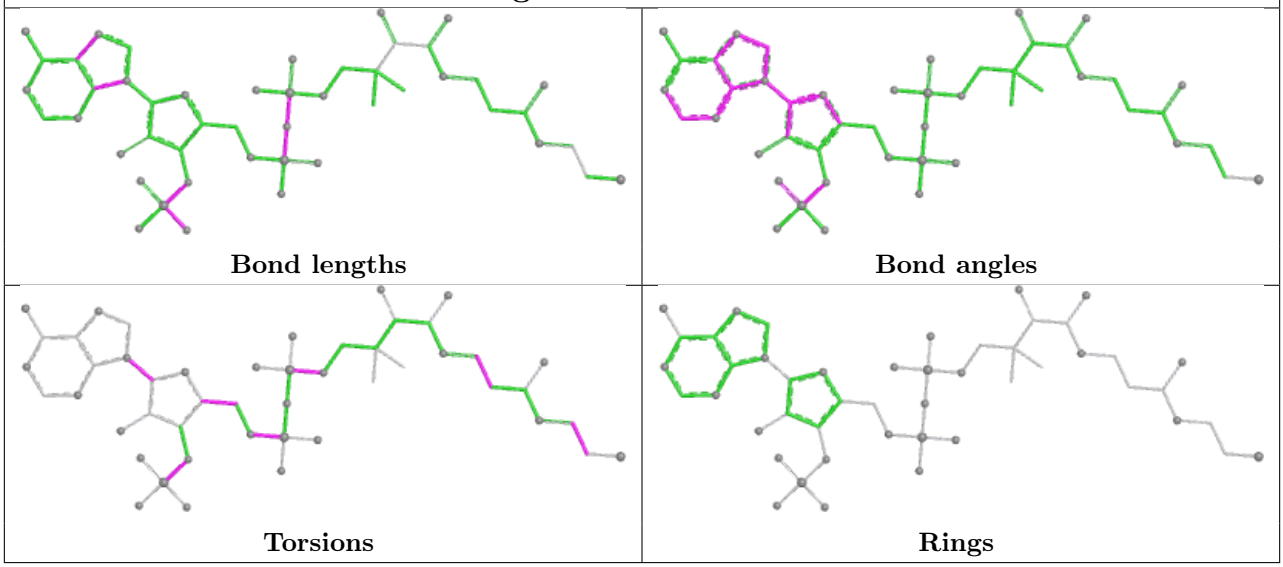


Torsions

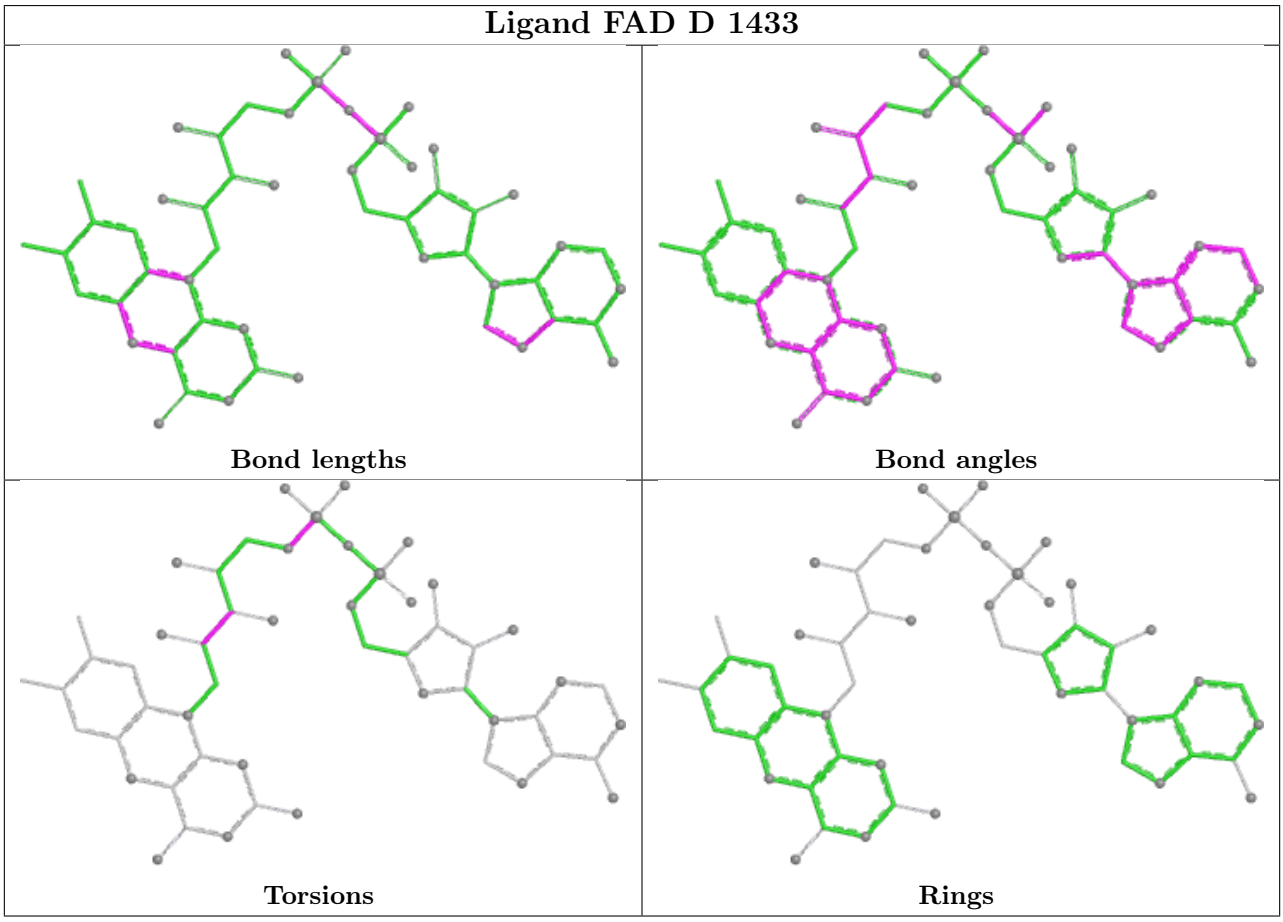


Rings

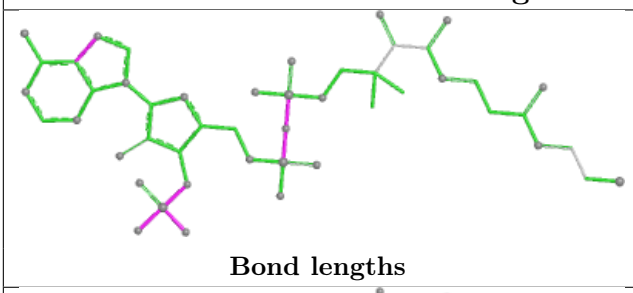
Ligand CAA D 1432



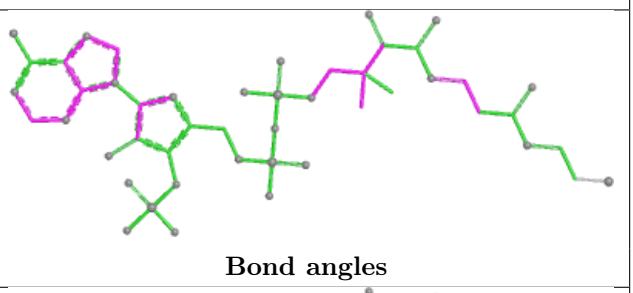
Ligand FAD D 1433



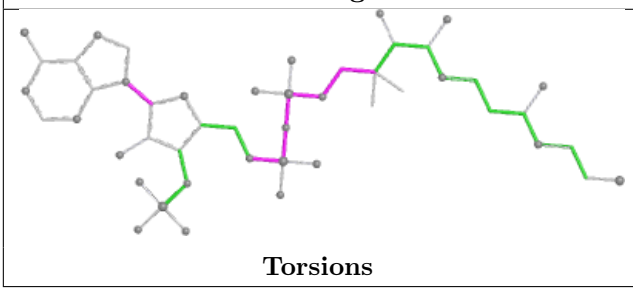
Ligand CAA A 1432



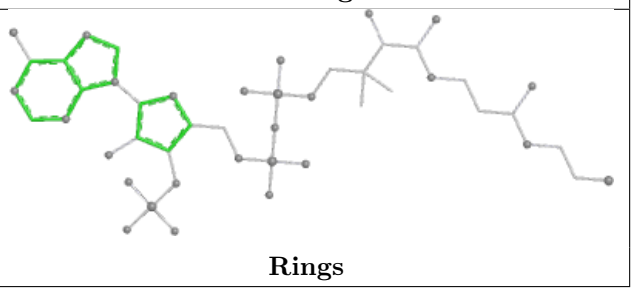
Bond lengths



Bond angles



Torsions



Rings

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

6.1 Protein, DNA and RNA chains

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^{th} 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	416/436 (95%)	-0.15	1 (0%)	91	90	19, 36, 47, 52	1 (0%)
1	B	416/436 (95%)	-0.42	1 (0%)	91	90	22, 35, 47, 52	1 (0%)
1	C	416/436 (95%)	-0.37	1 (0%)	91	90	28, 35, 44, 54	0
1	D	416/436 (95%)	-0.27	1 (0%)	91	90	29, 35, 45, 48	0
All	All	1664/1744 (95%)	-0.30	4 (0%)	91	90	19, 35, 46, 54	2 (0%)

All (4) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	D	432	THR	7.8
1	C	432	THR	2.7
1	B	432	THR	2.4
1	A	281	SER	2.0

6.2 Non-standard residues in protein, DNA, RNA chains

There are no non-standard protein/DNA/RNA residues in this entry.

6.3 Carbohydrates

There are no oligosaccharides in this entry.

6.4 Ligands

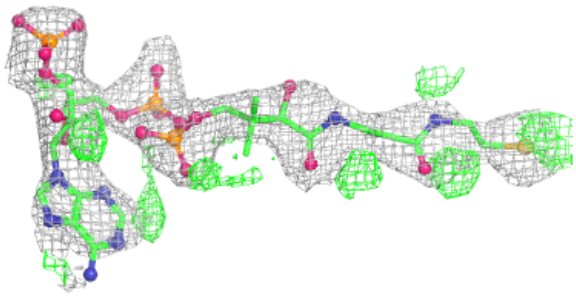
In the following table, the Atoms column lists the number of modelled atoms in the group and the number defined in the chemical component dictionary. The B-factors column lists the minimum, median, 95^{th} percentile and maximum values of B factors of atoms in the group. The column labelled 'Q< 0.9'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

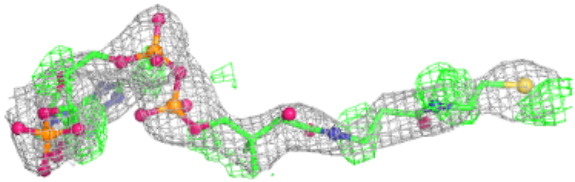
Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(Å^2)	Q<0.9
2	CAA	A	1432	48/54	0.85	0.14	33,41,45,46	48
2	CAA	C	1432	48/54	0.91	0.11	42,52,56,56	48
3	FAD	A	1433	53/53	0.92	0.09	43,45,53,53	0
2	CAA	B	1432	48/54	0.94	0.09	29,36,50,50	0
2	CAA	D	1432	48/54	0.95	0.08	32,41,45,46	0
3	FAD	C	1433	53/53	0.95	0.07	29,31,32,33	0
3	FAD	D	1433	53/53	0.95	0.08	23,27,32,32	0
3	FAD	B	1433	53/53	0.96	0.07	20,24,27,27	0

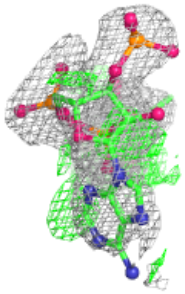
The following is a graphical depiction of the model fit to experimental electron density of all instances of the Ligand of Interest. In addition, ligands with molecular weight > 250 and outliers as shown on the geometry validation Tables will also be included. Each fit is shown from different orientation to approximate a three-dimensional view.

Electron density around CAA A 1432:

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

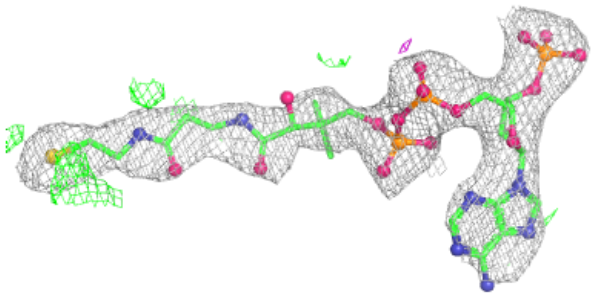


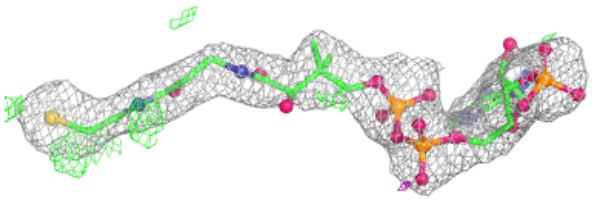


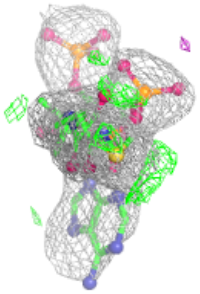


Electron density around CAA C 1432:

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

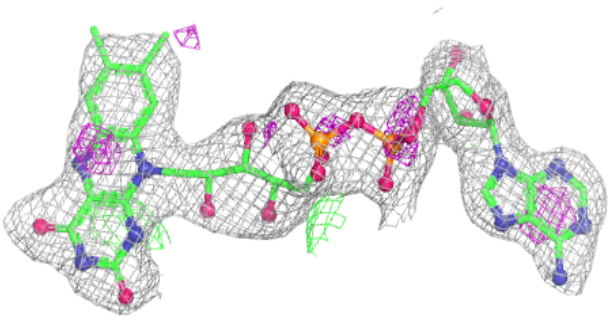


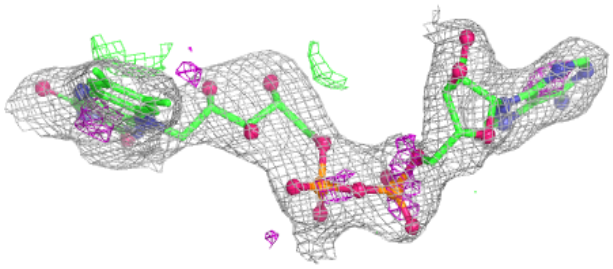


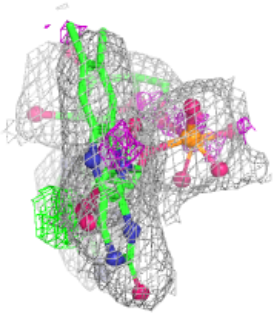


Electron density around FAD A 1433:

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

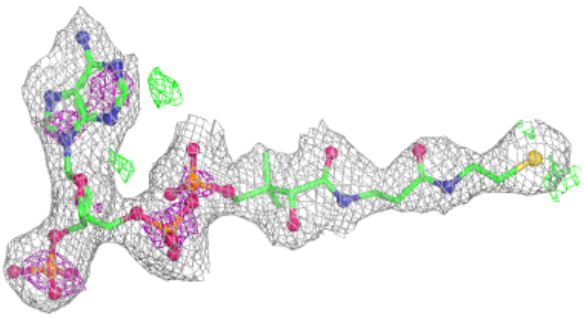


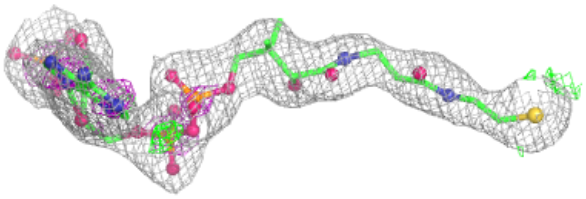


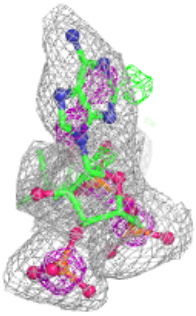


Electron density around CAA B 1432:

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

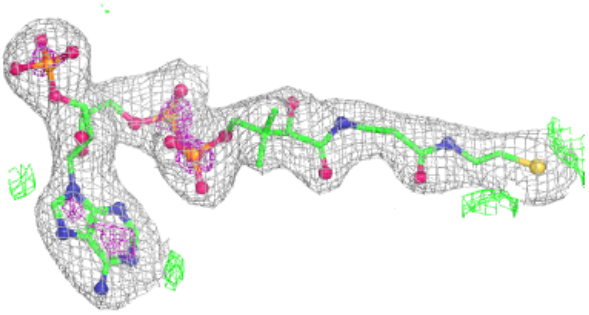


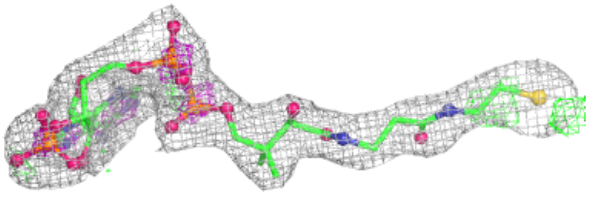


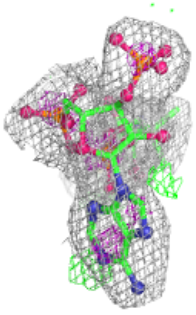


Electron density around CAA D 1432:

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

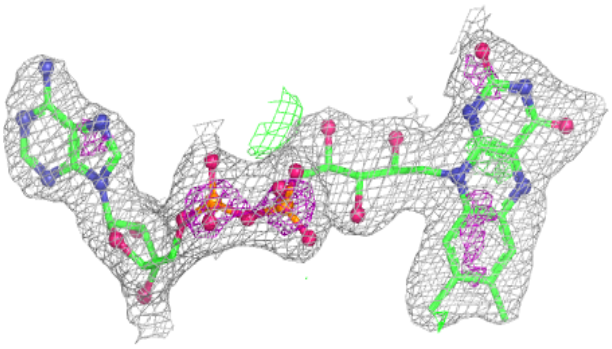


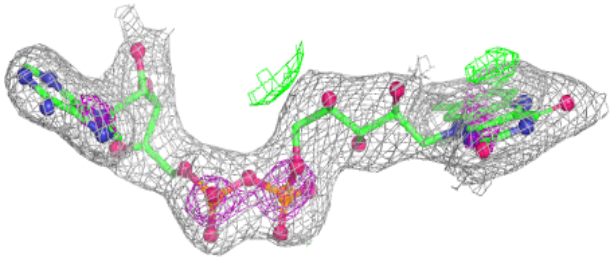


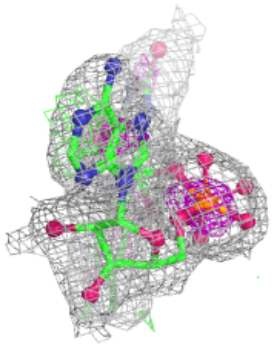


Electron density around FAD C 1433:

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

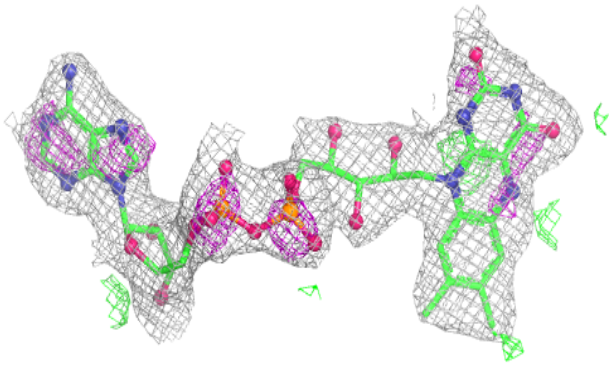


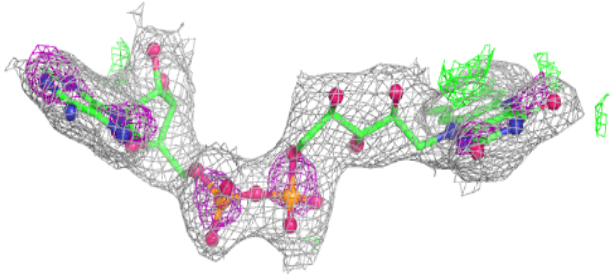


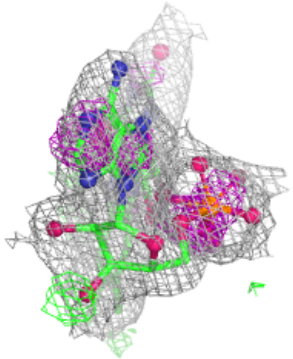


Electron density around FAD D 1433:

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

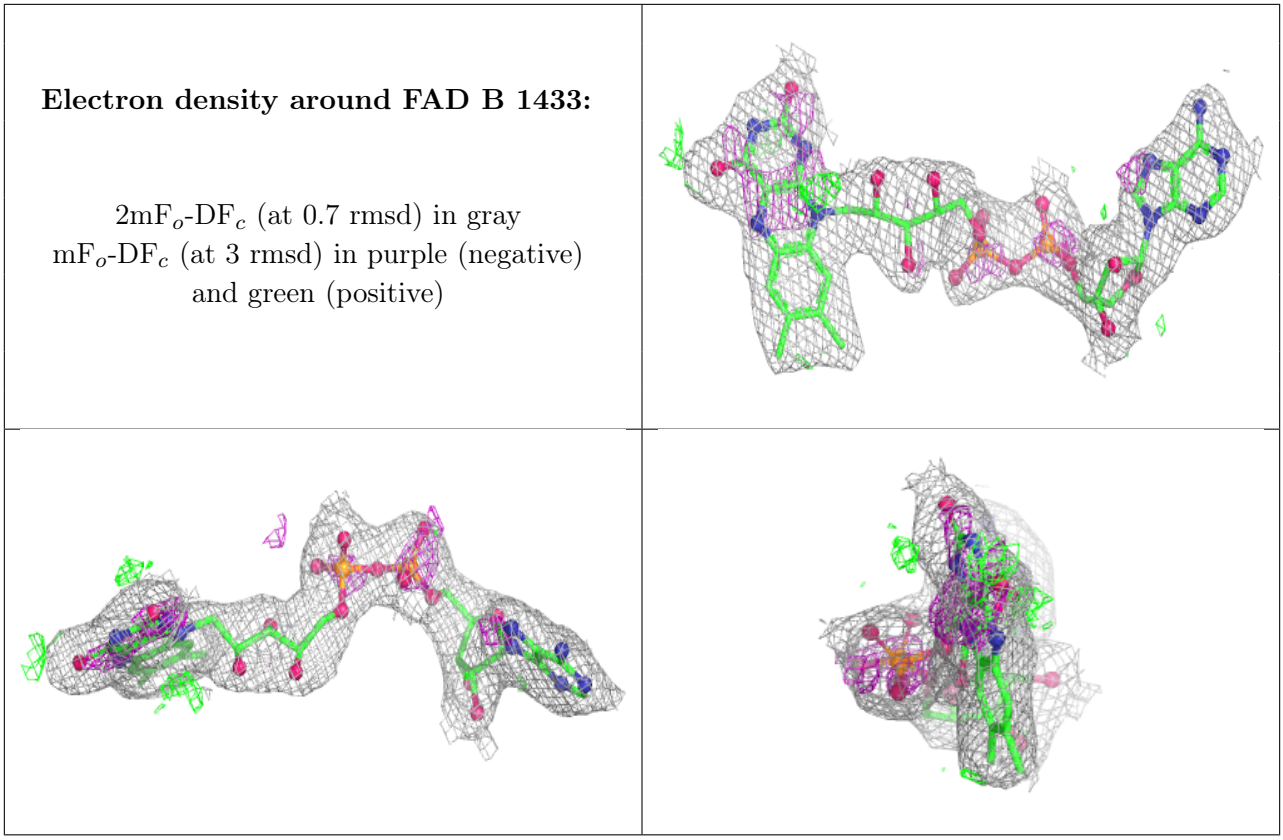






Electron density around FAD B 1433:

$2mF_o$-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.