



wwPDB X-ray Structure Validation Summary Report ⓘ

Feb 28, 2026 – 10:40 PM UTC

PDB ID : 2E4O / pdb_00002e4o
Title : X-ray Crystal Structure of Aristolochene Synthase from *Aspergillus terreus* and the Evolution of Templates for the Cyclization of Farnesyl Diphosphate
Authors : Shishova, E.Y.; Di Costanzo, L.; Cane, D.E.; Christianson, D.W.
Deposited on : 2006-12-15
Resolution : 2.20 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 ⓘ](#)) 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
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

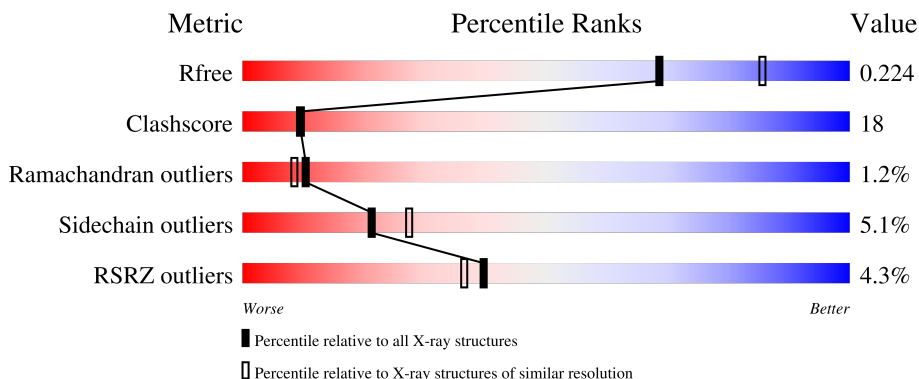
1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

X-RAY DIFFRACTION

The reported resolution of this entry is 2.20 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	6164 (2.20-2.20)
Clashscore	190562	6851 (2.20-2.20)
Ramachandran outliers	187476	6768 (2.20-2.20)
Sidechain outliers	187428	6769 (2.20-2.20)
RSRZ outliers	180081	6166 (2.20-2.20)

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	320	 2% 65% 27% • 8%
1	B	320	 2% 67% 23% • 8%
1	C	320	 8% 55% 33% • 8%
1	D	320	 5% 57% 31% • 8%

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	BME	C	502	-	-	X	-

2 Entry composition [i](#)

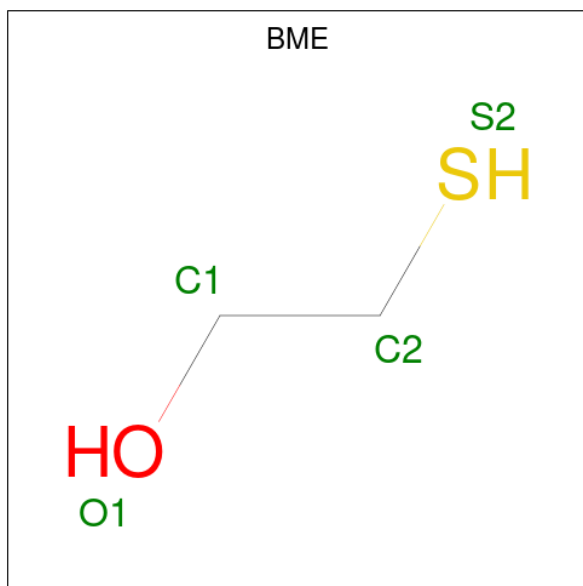
There are 5 unique types of molecules in this entry. The entry contains 9795 atoms, of which 0 are hydrogens and 0 are deuteriums.

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 Aristolochene synthase.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	S			
1	A	295	Total 2392	C 1529	N 403	O 445	S 15	0	0	0
1	B	295	Total 2393	C 1531	N 403	O 444	S 15	0	0	0
1	C	296	Total 2400	C 1535	N 404	O 446	S 15	0	0	0
1	D	294	Total 2385	C 1525	N 402	O 443	S 15	0	0	0

- Molecule 2 is BETA-MERCAPTOETHANOL (CCD ID: BME) (formula: C₂H₆OS).



Mol	Chain	Residues	Atoms				ZeroOcc	AltConf
			Total	C	O	S		
2	A	1	Total 4	C 2	O 1	S 1	0	0
2	A	1	Total 4	C 2	O 1	S 1	0	0

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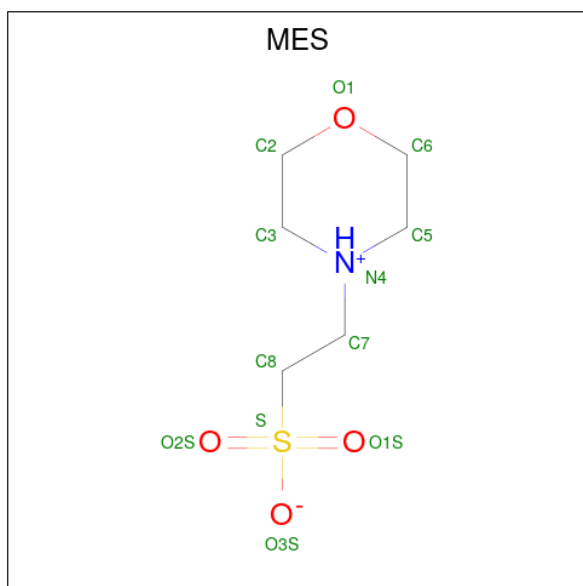
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Mol	Chain	Residues	Atoms				ZeroOcc	AltConf
2	C	1	Total	C	O	S	0	0
			4	2	1	1		
2	C	1	Total	C	O	S	0	0
			4	2	1	1		
2	D	1	Total	C	O	S	0	0
			4	2	1	1		

- Molecule 3 is CHLORIDE ION (CCD ID: CL) (formula: Cl).

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
3	B	1	Total	Cl	0	0
			1	1		
3	C	1	Total	Cl	0	0
			1	1		

- Molecule 4 is 2-(N-MORPHOLINO)-ETHANESULFONIC ACID (CCD ID: MES) (formula: C₆H₁₃NO₄S).



Mol	Chain	Residues	Atoms					ZeroOcc	AltConf
4	D	1	Total	C	N	O	S	0	0
			12	6	1	4	1		

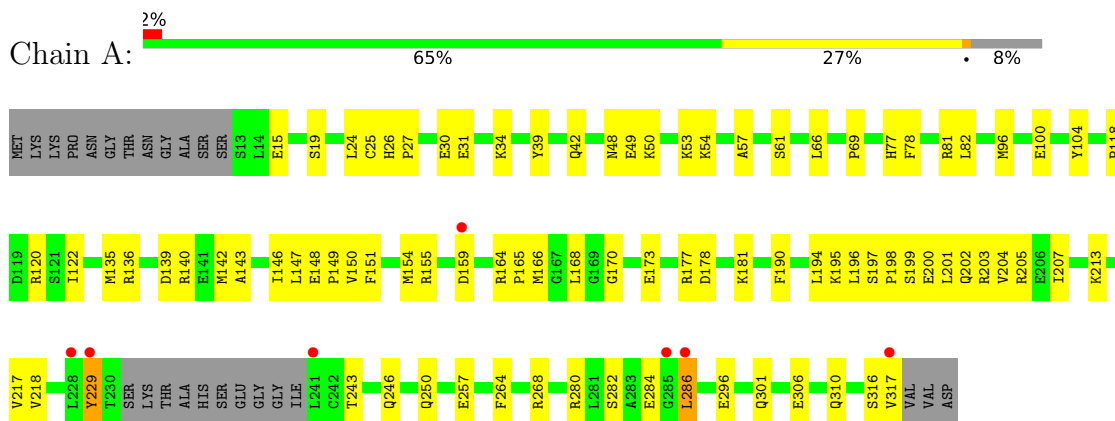
- Molecule 5 is water.

Mol	Chain	Residues	Atoms	ZeroOcc	AltConf
5	A	75	Total O 75 75	0	0
5	B	44	Total O 44 44	0	0
5	C	35	Total O 35 35	0	0
5	D	37	Total O 37 37	0	0

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.

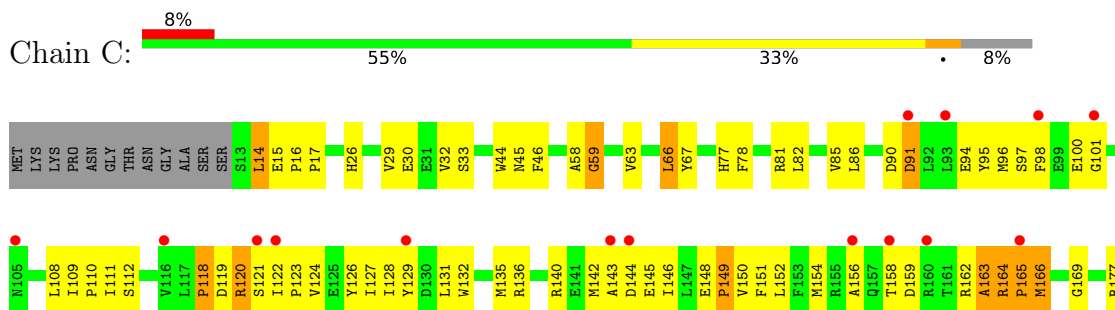
- Molecule 1: Aristolochene synthase

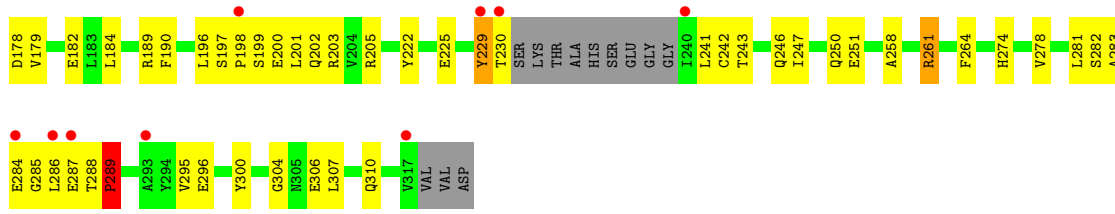


- Molecule 1: Aristolochene synthase

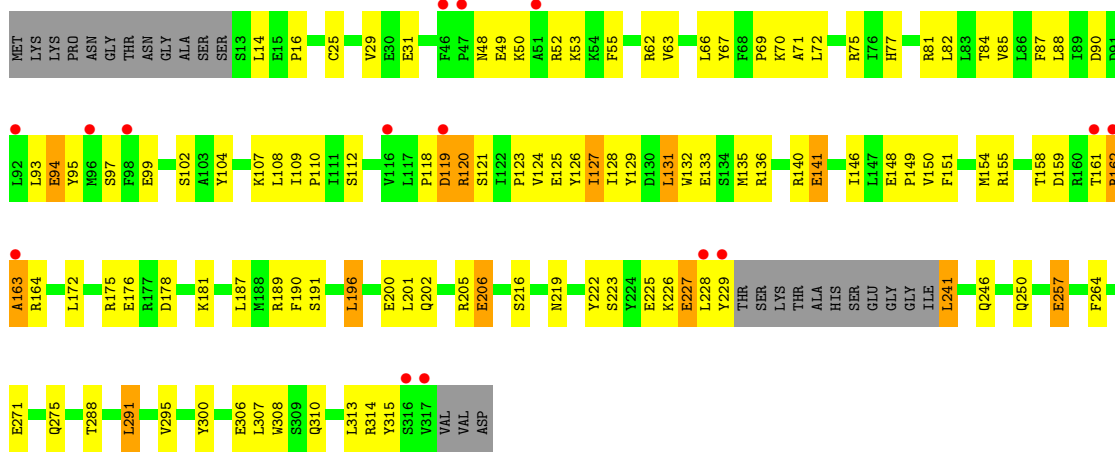


- Molecule 1: Aristolochene synthase





● Molecule 1: Aristolochene synthase



4 Data and refinement statistics

Property	Value	Source
Space group	P 1 21 1	Depositor
Cell constants a, b, c, α , β , γ	61.19Å 147.24Å 83.74Å 90.00° 97.91° 90.00°	Depositor
Resolution (Å)	50.00 – 2.20 50.00 – 2.20	Depositor EDS
% Data completeness (in resolution range)	(Not available) (50.00-2.20) 97.1 (50.00-2.20)	Depositor EDS
R_{merge}	0.08	Depositor
R_{sym}	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ ¹	1.41 (at 2.17Å)	Xtrriage
Refinement program	CNS	Depositor
R, R_{free}	0.222 , 0.272 0.226 , 0.224	Depositor DCC
R_{free} test set	3686 reflections (4.83%)	wwPDB-VP
Wilson B-factor (Å ²)	36.2	Xtrriage
Anisotropy	0.150	Xtrriage
Bulk solvent k_{sol} (e/Å ³), B_{sol} (Å ²)	0.36 , 43.7	EDS
L-test for twinning ²	$\langle L \rangle = 0.49$, $\langle L^2 \rangle = 0.32$	Xtrriage
Estimated twinning fraction	No twinning to report.	Xtrriage
F_o, F_c correlation	0.94	EDS
Total number of atoms	9795	wwPDB-VP
Average B, all atoms (Å ²)	46.0	wwPDB-VP

Xtrriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 3.43% 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

5.1 Standard geometry

Bond lengths and bond angles in the following residue types are not validated in this section: CL, MES, BME

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	0/2445	0.93	10/3309 (0.3%)
1	B	0.52	1/2446 (0.0%)	0.89	2/3310 (0.1%)
1	C	0.48	0/2453	0.97	6/3320 (0.2%)
1	D	0.46	0/2438	0.88	4/3299 (0.1%)
All	All	0.49	1/9782 (0.0%)	0.92	22/13238 (0.2%)

All (1) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
1	B	118	PRO	CA-C	-6.64	1.44	1.52

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

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
1	C	165	PRO	CA-N-CD	-9.95	98.07	112.00
1	C	289	PRO	CA-N-CD	-9.93	98.10	112.00
1	A	42	GLN	OE1-CD-NE2	-9.87	112.73	122.60
1	A	310	GLN	OE1-CD-NE2	-9.51	113.09	122.60
1	C	26	HIS	CA-C-N	6.70	126.96	119.32

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	2392	0	2364	66	0
1	B	2393	0	2369	61	0
1	C	2400	0	2375	122	0
1	D	2385	0	2358	103	0
2	A	8	0	11	3	0
2	C	8	0	11	4	0
2	D	4	0	6	3	0
3	B	1	0	0	0	0
3	C	1	0	0	0	0
4	D	12	0	13	0	0
5	A	75	0	0	3	0
5	B	44	0	0	2	0
5	C	35	0	0	2	0
5	D	37	0	0	1	0
All	All	9795	0	9507	341	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 18.

The worst 5 of 341 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:C:242:CYS:SG	2:C:502:BME:S2	2.46	1.13
1:C:150:VAL:HG12	1:C:154:MET:HE2	1.26	1.11
1:D:150:VAL:HG12	1:D:154:MET:HE2	1.30	1.08
1:A:96:MET:HE2	1:A:100:GLU:HG2	1.36	1.03
1:A:96:MET:CE	1:A:100:GLU:HG2	1.93	0.99

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	291/320 (91%)	281 (97%)	10 (3%)	0	100	100
1	B	291/320 (91%)	286 (98%)	3 (1%)	2 (1%)	18	19
1	C	292/320 (91%)	273 (94%)	13 (4%)	6 (2%)	5	3
1	D	290/320 (91%)	274 (94%)	10 (3%)	6 (2%)	5	3
All	All	1164/1280 (91%)	1114 (96%)	36 (3%)	14 (1%)	10	8

5 of 14 Ramachandran outliers are listed below:

Mol	Chain	Res	Type
1	B	120	ARG
1	C	120	ARG
1	C	163	ALA
1	D	162	ARG
1	D	163	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	260/279 (93%)	251 (96%)	9 (4%)	32	43
1	B	260/279 (93%)	246 (95%)	14 (5%)	20	25
1	C	261/279 (94%)	246 (94%)	15 (6%)	18	23
1	D	259/279 (93%)	244 (94%)	15 (6%)	18	22
All	All	1040/1116 (93%)	987 (95%)	53 (5%)	21	27

5 of 53 residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	C	159	ASP
1	C	264	PHE
1	D	291	LEU
1	C	165	PRO
1	C	229	TYR

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	D	77	HIS
1	D	219	ASN
1	A	250	GLN
1	A	301	GLN
1	B	219	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](#)

Of 8 ligands modelled in this entry, 2 are monoatomic - leaving 6 for Mogul analysis.

In the following table, the Counts columns list the number of bonds (or angles) for which Mogul statistics could be retrieved, the number of bonds (or angles) that are observed in the model and the number of bonds (or angles) that are defined in the Chemical Component Dictionary. The Link column lists molecule types, if any, to which the group is linked. The Z score for a bond length (or angle) is the number of standard deviations the observed value is removed from the expected value. A bond length (or angle) with $|Z| > 2$ is considered an outlier worth inspection. RMSZ is the root-mean-square of all Z scores of the bond lengths (or angles).

Mol	Type	Chain	Res	Link	Bond lengths			Bond angles		
					Counts	RMSZ	$\# Z > 2$	Counts	RMSZ	$\# Z > 2$
4	MES	D	4246	-	12,12,12	1.38	1 (8%)	15,16,16	0.99	1 (6%)
2	BME	A	503	-	3,3,3	0.38	0	2,2,2	0.63	0
2	BME	D	500	-	3,3,3	0.52	0	2,2,2	0.42	0
2	BME	C	504	-	3,3,3	0.31	0	2,2,2	0.63	0
2	BME	C	502	-	3,3,3	0.40	0	2,2,2	0.50	0
2	BME	A	501	-	3,3,3	0.55	0	2,2,2	0.40	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
4	MES	D	4246	-	-	0/6/14/14	0/1/1/1
2	BME	A	503	-	-	0/1/1/1	-
2	BME	D	500	-	-	0/1/1/1	-
2	BME	C	504	-	-	0/1/1/1	-
2	BME	C	502	-	-	0/1/1/1	-
2	BME	A	501	-	-	0/1/1/1	-

All (1) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
4	D	4246	MES	C8-S	3.49	1.82	1.77

All (1) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
4	D	4246	MES	O1S-S-C8	2.03	109.79	106.73

There are no chirality outliers.

There are no torsion outliers.

There are no ring outliers.

4 monomers are involved in 10 short contacts:

Mol	Chain	Res	Type	Clashes	Symm-Clashes
2	A	503	BME	2	0
2	D	500	BME	3	0
2	C	502	BME	4	0
2	A	501	BME	1	0

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	295/320 (92%)	0.08	7 (2%) 59 56	22, 39, 64, 88	0
1	B	295/320 (92%)	0.14	5 (1%) 69 66	24, 40, 65, 78	0
1	C	296/320 (92%)	0.64	24 (8%) 18 15	22, 49, 76, 89	0
1	D	294/320 (91%)	0.43	15 (5%) 33 30	23, 44, 82, 96	0
All	All	1180/1280 (92%)	0.32	51 (4%) 40 36	22, 43, 74, 96	0

The worst 5 of 51 RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	B	317	VAL	4.1
1	D	229	TYR	4.1
1	C	98	PHE	4.0
1	B	229	TYR	3.7
1	C	240	ILE	3.6

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(\AA^2)	Q<0.9
2	BME	A	503	4/4	0.78	0.18	69,70,70,73	0
2	BME	A	501	4/4	0.85	0.14	65,65,68,72	0
2	BME	D	500	4/4	0.88	0.14	47,49,51,63	0
2	BME	C	504	4/4	0.89	0.16	59,60,63,71	0
2	BME	C	502	4/4	0.89	0.12	58,66,69,80	0
4	MES	D	4246	12/12	0.92	0.11	57,64,68,69	0
3	CL	C	507	1/1	0.94	0.17	56,56,56,56	0
3	CL	B	506	1/1	0.94	0.11	60,60,60,60	0

6.5 Other polymers [i](#)

There are no such residues in this entry.