



# wwPDB X-ray Structure Validation Summary Report ⓘ

Apr 9, 2026 – 10:09 PM UTC

PDB ID : 28KD / pdb\_000028kd  
Title : ACE2 extracellular domain in complex with the macrocyclic peptide GR3.1.2  
Authors : Brear, P.; Hyvonen, M.  
Deposited on : 2026-02-04  
Resolution : 2.02 Å(reported)

This is a wwPDB X-ray Structure Validation Summary Report for a publicly released PDB entry.

We welcome your comments at [validation@mail.wwpdb.org](mailto:validation@mail.wwpdb.org)

A user guide is available at

<https://www.wwpdb.org/validation/2017/XrayValidationReportHelp>

with specific help available everywhere you see the ⓘ symbol.

The types of validation reports are described at

<http://www.wwpdb.org/validation/2017/FAQs#types>.

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The following versions of software and data (see [references ⓘ](#)) were used in the production of this report:

MolProbity	:	4-5-2 with Phenix2.0
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

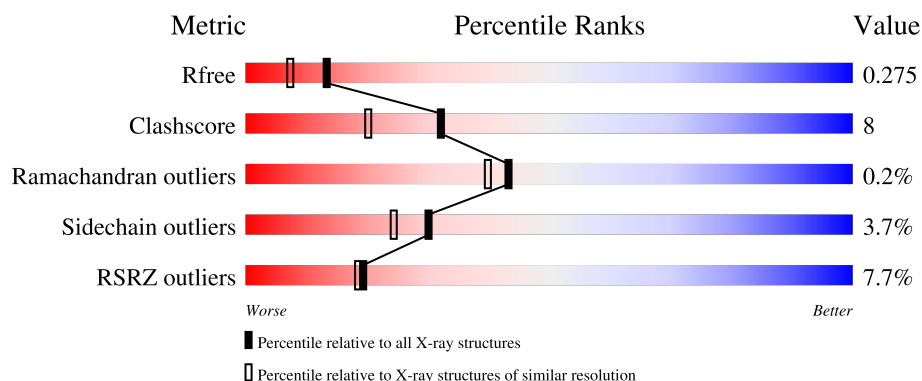
# 1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

*X-RAY DIFFRACTION*

The reported resolution of this entry is 2.02 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	13299 (2.04-2.00)
Clashscore	190562	1022 (2.02-2.02)
Ramachandran outliers	187476	1014 (2.02-2.02)
Sidechain outliers	187428	1014 (2.02-2.02)
RSRZ outliers	180081	13314 (2.04-2.00)

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

Mol	Chain	Length	Quality of chain
1	A	609	<div> <div>10%</div> <div>75%</div> <div>21%</div> <div>..</div> </div>
1	B	609	<div> <div>4%</div> <div>80%</div> <div>16%</div> <div>..</div> </div>
2	C	18	<div> <div>22%</div> <div>72%</div> <div>17%</div> <div>11%</div> </div>
2	D	18	<div> <div>33%</div> <div>61%</div> <div>39%</div> </div>

## 2 Entry composition

There are 4 unique types of molecules in this entry. The entry contains 10621 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 Processed angiotensin-converting enzyme 2.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
1	B	596	Total	C	N	O	S	0	1	0
			4872	3117	808	918	29			
1	A	596	Total	C	N	O	S	0	1	0
			4872	3117	808	918	29			

There are 24 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
B	18	GLY	-	expression tag	UNP Q9BYF1
B	616	SER	-	expression tag	UNP Q9BYF1
B	617	SER	-	expression tag	UNP Q9BYF1
B	618	PRO	-	expression tag	UNP Q9BYF1
B	619	HIS	-	expression tag	UNP Q9BYF1
B	620	HIS	-	expression tag	UNP Q9BYF1
B	621	HIS	-	expression tag	UNP Q9BYF1
B	622	HIS	-	expression tag	UNP Q9BYF1
B	623	HIS	-	expression tag	UNP Q9BYF1
B	624	HIS	-	expression tag	UNP Q9BYF1
B	625	HIS	-	expression tag	UNP Q9BYF1
B	626	HIS	-	expression tag	UNP Q9BYF1
A	18	GLY	-	expression tag	UNP Q9BYF1
A	616	SER	-	expression tag	UNP Q9BYF1
A	617	SER	-	expression tag	UNP Q9BYF1
A	618	PRO	-	expression tag	UNP Q9BYF1
A	619	HIS	-	expression tag	UNP Q9BYF1
A	620	HIS	-	expression tag	UNP Q9BYF1
A	621	HIS	-	expression tag	UNP Q9BYF1
A	622	HIS	-	expression tag	UNP Q9BYF1
A	623	HIS	-	expression tag	UNP Q9BYF1
A	624	HIS	-	expression tag	UNP Q9BYF1
A	625	HIS	-	expression tag	UNP Q9BYF1
A	626	HIS	-	expression tag	UNP Q9BYF1

- Molecule 2 is a protein called ALA-CYS-PHE-LEU-ARG-CYS-HIS-ARG-ASP-VAL-LYS-CYS-TRP-LEU-TRP-CYS-SER-GLY.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
2	C	18	Total 151	C 96	N 29	O 22	S 4	0	0	0
2	D	18	Total 151	C 96	N 29	O 22	S 4	0	0	0

- Molecule 3 is ZINC ION (CCD ID: ZN) (formula: Zn).

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
3	B	1	Total 1	Zn 1	0	0
3	A	1	Total 1	Zn 1	0	0

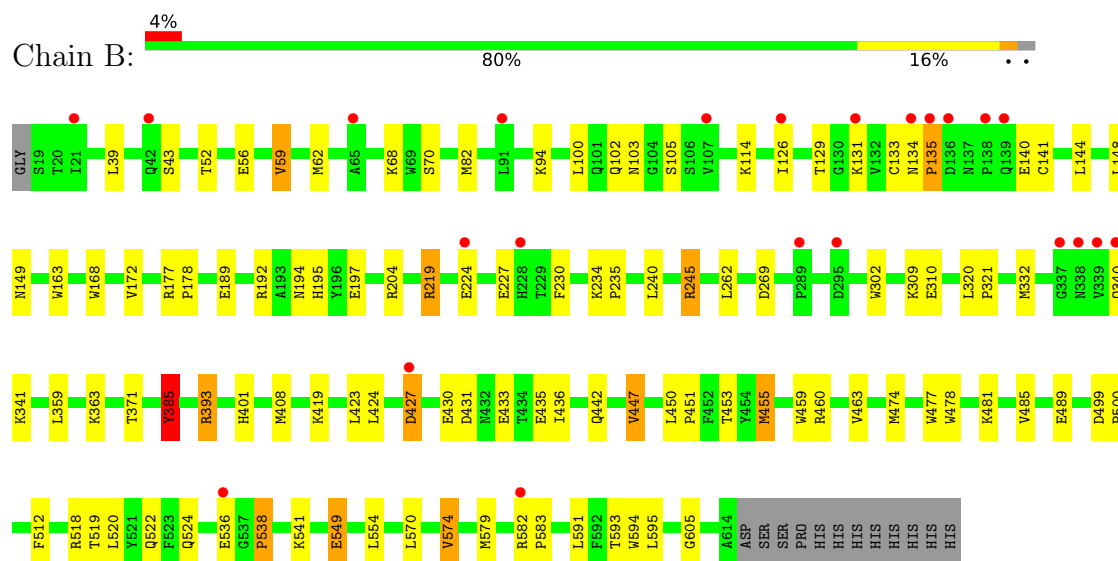
- Molecule 4 is water.

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
4	B	343	Total 344	O 344	0	1
4	C	6	Total 6	O 6	0	0
4	A	218	Total 218	O 218	0	0
4	D	5	Total 5	O 5	0	0

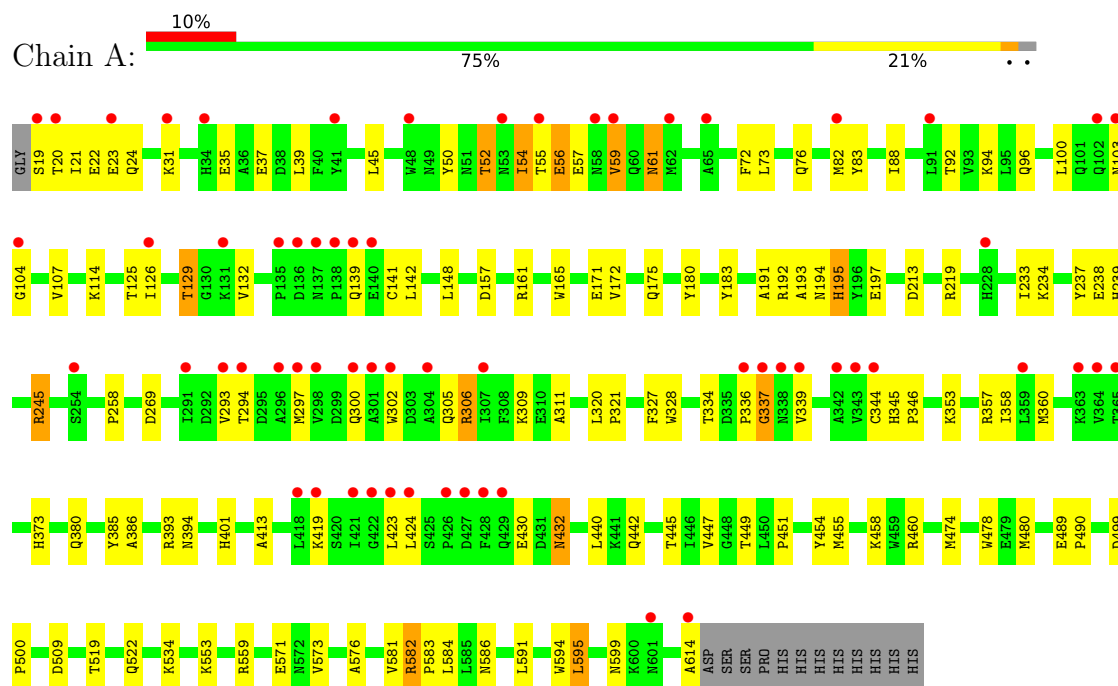
### 3 Residue-property plots [i](#)

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.

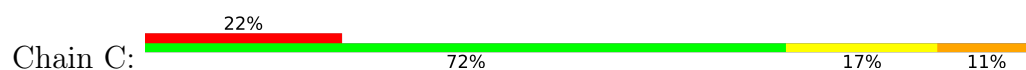
- Molecule 1: Processed angiotensin-converting enzyme 2



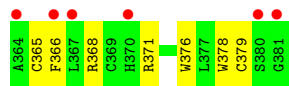
- Molecule 1: Processed angiotensin-converting enzyme 2



- Molecule 2: ALA-CYS-PHE-LEU-ARG-CYS-HIS-ARG-ASP-VAL-LYS-CYS-TRP-LEU-TRP-CYS-SER-GLY



- Molecule 2: ALA-CYS-PHE-LEU-ARG-CYS-HIS-ARG-ASP-VAL-LYS-CYS-TRP-LEU-TRP-CYS-SER-GLY



## 4 Data and refinement statistics

Property	Value	Source
Space group	P 1 21 1	Depositor
Cell constants a, b, c, $\alpha$ , $\beta$ , $\gamma$	74.26Å 77.82Å 115.18Å 90.00° 100.82° 90.00°	Depositor
Resolution (Å)	64.11 – 2.02 64.11 – 2.02	Depositor EDS
% Data completeness (in resolution range)	99.9 (64.11-2.02) 99.9 (64.11-2.02)	Depositor EDS
$R_{merge}$	0.23	Depositor
$R_{sym}$	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ <sup>1</sup>	1.05 (at 2.02Å)	Xtriage
Refinement program	REFMAC 5.8.0430	Depositor
R, $R_{free}$	0.218 , 0.273 0.228 , 0.275	Depositor DCC
$R_{free}$ test set	2065 reflections (2.43%)	wwPDB-VP
Wilson B-factor (Å <sup>2</sup> )	34.1	Xtriage
Anisotropy	0.180	Xtriage
Bulk solvent $k_{sol}$ (e/Å <sup>3</sup> ), $B_{sol}$ (Å <sup>2</sup> )	0.34 , 40.6	EDS
L-test for twinning <sup>2</sup>	$\langle  L  \rangle = 0.50$ , $\langle L^2 \rangle = 0.34$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
$F_o, F_c$ correlation	0.95	EDS
Total number of atoms	10621	wwPDB-VP
Average B, all atoms (Å <sup>2</sup> )	41.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 4.02% of the height of the origin peak. No significant pseudotranslation is detected.*

<sup>1</sup>Intensities estimated from amplitudes.

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

## 5 Model quality

### 5.1 Standard geometry

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

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	0.70	0/5010	1.19	8/6807 (0.1%)
1	B	0.71	0/5010	1.23	21/6807 (0.3%)
2	C	0.76	0/156	1.40	3/208 (1.4%)
2	D	0.84	0/156	1.18	0/208
All	All	0.71	0/10332	1.21	32/14030 (0.2%)

Chiral center outliers are detected by calculating the chiral volume of a chiral center and verifying if the center is modelled as a planar moiety or with the opposite hand. A planarity outlier is detected by checking planarity of atoms in a peptide group, atoms in a mainchain group or atoms of a sidechain that are expected to be planar.

Mol	Chain	#Chirality outliers	#Planarity outliers
1	A	0	7
1	B	0	4
2	C	0	2
2	D	0	1
All	All	0	14

There are no bond length outliers.

The worst 5 of 32 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
1	B	269	ASP	CA-CB-CG	7.75	120.36	112.60
1	A	195	HIS	CB-CA-C	7.67	117.42	109.83
1	B	189	GLU	CB-CA-C	-7.44	98.44	110.79
1	B	310	GLU	N-CA-CB	-7.25	99.43	110.16
1	B	245	ARG	NE-CZ-NH1	-7.13	114.37	121.50

There are no chirality outliers.

5 of 14 planarity outliers are listed below:



Mol	Chain	Res	Type	Group
1	B	204	ARG	Sidechain
1	B	219	ARG	Sidechain
1	B	393	ARG	Sidechain
1	B	460	ARG	Sidechain
2	C	368	ARG	Sidechain

## 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	4872	0	4645	89	0
1	B	4872	0	4645	68	0
2	C	151	0	138	3	0
2	D	151	0	138	3	0
3	A	1	0	0	0	0
3	B	1	0	0	0	0
4	A	218	0	0	17	0
4	B	344	0	0	15	0
4	C	6	0	0	0	0
4	D	5	0	0	1	0
All	All	10621	0	9566	156	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 156 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:19:SER:OG	1:A:22:GLU:HB2	1.69	0.92
1:A:300:GLN:OE1	1:A:423:LEU:HD23	1.74	0.88
1:A:300:GLN:OE1	1:A:423:LEU:CD2	2.33	0.77
1:B:455:MET:HE1	1:B:481:LYS:HD3	1.65	0.76
1:B:43:SER:HB3	2:C:366:PHE:CE1	2.27	0.70

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	595/609 (98%)	571 (96%)	22 (4%)	2 (0%)	36	31
1	B	595/609 (98%)	581 (98%)	14 (2%)	0	100	100
2	C	16/18 (89%)	15 (94%)	1 (6%)	0	100	100
2	D	16/18 (89%)	14 (88%)	2 (12%)	0	100	100
All	All	1222/1254 (97%)	1181 (97%)	39 (3%)	2 (0%)	43	40

All (2) Ramachandran outliers are listed below:

Mol	Chain	Res	Type
1	A	337	GLY
1	A	54	ILE

### 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	527/538 (98%)	506 (96%)	21 (4%)	28	22
1	B	527/538 (98%)	511 (97%)	16 (3%)	36	32
2	C	16/16 (100%)	15 (94%)	1 (6%)	16	9
2	D	16/16 (100%)	14 (88%)	2 (12%)	4	1
All	All	1086/1108 (98%)	1046 (96%)	40 (4%)	30	24

5 of 40 residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	305	GLN
1	A	449	THR
1	A	334	THR
1	A	430	GLU
1	A	573	VAL

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. 5 of 27 such sidechains are listed below:

Mol	Chain	Res	Type
1	A	194	ASN
1	A	432	ASN
1	A	586	ASN
1	A	417	HIS
1	A	442	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](#)

Of 2 ligands modelled in this entry, 2 are monoatomic - leaving 0 for Mogul analysis.

There are no bond length outliers.

There are no bond angle outliers.

There are no chirality outliers.

There are no torsion outliers.

There are no ring outliers.

No monomer is involved in short contacts.

## 5.7 Other polymers [i](#)

There are no such residues in this entry.

## 5.8 Polymer linkage issues [i](#)

There are no chain breaks in this entry.

## 6 Fit of model and data [i](#)

### 6.1 Protein, DNA and RNA chains [i](#)

In the following table, the column labelled ‘#RSRZ> 2’ contains the number (and percentage) of RSRZ outliers, followed by percent RSRZ outliers for the chain as percentile scores relative to all X-ray entries and entries of similar resolution. The OWAB column contains the minimum, median, 95<sup>th</sup> percentile and maximum values of the occupancy-weighted average B-factor per residue. The column labelled ‘Q< 0.9’ lists the number of (and percentage) of residues with an average occupancy less than 0.9.

Mol	Chain	Analysed	<RSRZ>	#RSRZ>2		OWAB(Å <sup>2</sup> )	Q<0.9
1	A	596/609 (97%)	0.54	62 (10%)	11 11	15, 40, 84, 140	1 (0%)
1	B	596/609 (97%)	0.17	23 (3%)	43 43	14, 33, 61, 138	1 (0%)
2	C	18/18 (100%)	1.51	4 (22%)	2 2	33, 44, 80, 81	0
2	D	18/18 (100%)	1.54	6 (33%)	1 1	40, 54, 83, 95	0
All	All	1228/1254 (97%)	0.39	95 (7%)	19 18	14, 36, 77, 140	2 (0%)

The worst 5 of 95 RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
2	C	381	GLY	6.5
1	A	302	TRP	5.8
1	A	339	VAL	5.5
1	B	339	VAL	5.4
1	A	19	SER	5.3

### 6.2 Non-standard residues in protein, DNA, RNA chains [i](#)

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

### 6.3 Carbohydrates [i](#)

There are no oligosaccharides in this entry.

### 6.4 Ligands [i](#)

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

Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors( $\text{\AA}^2$ )	Q<0.9
3	ZN	B	701	1/1	0.92	0.11	91,91,91,91	0
3	ZN	A	701	1/1	0.95	0.08	99,99,99,99	0

## 6.5 Other polymers [i](#)

There are no such residues in this entry.