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# (1*S*,2*S*,3*S*)-*N*-(2-(4-Chlorophenyl)-1-{*N*-[2-methyl-1-(*N*-methylcarbamoyl)-propyl]carbamoyl}-3-phenylcyclopropyl)benzamide

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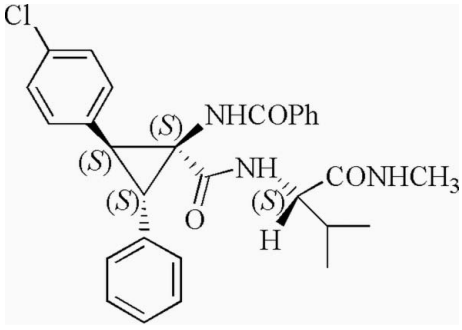
Key indicators: single-crystal X-ray study; $T$ = 223 K; mean $\sigma$(C–C) = 0.003 Å; $R$ factor = 0.039; $wR$ factor = 0.087; data-to-parameter ratio = 14.2.

The title compound, $C_{29}H_{30}ClN_3O_3$, is a conformationally restricted model compound for dipeptides. The diastereomers were separated by column chromaography and the absolute configuration of the phenylalanine cyclopropyl unit of the investigated enatiomer was found to be 2*S*,3*S* by anomalous dispersion. The crystal structure involves intermolecular N—H···O and C—H···O hydrogen bonds.

## Related literature

For related literature, see: Casanovas *et al.* (2003); Huang *et al.* (2007); Jiménez *et al.* (2005); Royo *et al.* (2005); Su *et al.* (2003).




## Experimental

### Crystal data

$C_{29}H_{30}ClN_3O_3$
$M_r$ = 504.01
Monoclinic, $P2_1$
$a$ = 10.8821 (19) Å
$b$ = 9.5688 (16) Å
$c$ = 12.952 (2) Å
$\beta$ = 95.754 (4)°
$V$ = 1341.9 (4) Å$^3$
$Z$ = 2
Mo $K\alpha$ radiation
$\mu$ = 0.18 mm$^{-1}$
$T$ = 223 (2) K
0.50 × 0.36 × 0.30 mm

### Data collection

Rigaku Mercury diffractometer
Absorption correction: multi-scan (Jacobson, 1998)
$T_{min}$ = 0.720, $T_{max}$ = 0.948
13162 measured reflections
4678 independent reflections
4334 reflections with $I > 2\sigma(I)$
$R_{int}$ = 0.028

### Refinement

$R[F^2 > 2\sigma(F^2)]$ = 0.039
$wR(F^2)$ = 0.087
$S$ = 1.09
4678 reflections
329 parameters
1 restraint
H-atom parameters constrained
$\Delta\rho_{max}$ = 0.13 e Å$^{-3}$
$\Delta\rho_{min}$ = −0.19 e Å$^{-3}$
Absolute structure: Flack (1983), with 2067 Friedel pairs
Flack parameter: 0.03 (7)

**Table 1**
Hydrogen-bond geometry (Å, °).

| $D$—H···$A$ | $D$—H | H···$A$ | $D$···$A$ | $D$—H···$A$ |
|---|---|---|---|---|
| N1—H1···O3$^{i}$ | 0.87 | 2.00 | 2.854 (2) | 166 |
| N2—H2···O2$^{i}$ | 0.87 | 2.17 | 2.912 (2) | 144 |
| N3—H3···O2$^{i}$ | 0.87 | 2.25 | 3.114 (2) | 173 |
| C14—H14*B*···O1$^{i}$ | 0.97 | 2.42 | 3.283 (3) | 148 |

Symmetry code: (i) $-x+1, y-\frac{1}{2}, -z+1$.

Data collection: *CrystalClear* (Rigaku/MSC, 2000); cell refinement: *CrystalClear*; data reduction: *CrystalStructure* (Rigaku, 1999); program(s) used to solve structure: *SHELXS97* (Sheldrick, 1997); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *SHELXTL* (Sheldrick, 2000); software used to prepare material for publication: *SHELXTL*.

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Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: ZL2036).

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# supplementary materials

*Acta Cryst.* (2007). E**63**, o3743 [ **doi:10.1107/S1600536807038391** ]

# (1*S*,2*S*,3*S*)-*N*-(2-(4-Chlorophenyl)-1-{*N*-[2-methyl-1-(*N*-methylcarbamoyl)propyl]carbamoyl}-3-phenylcyclopropyl)benzamide

**W.-Y. Huang, G.-F. Su, C.-X. Pan, Z.-L. Chen and Y. Zhang**

## Comment

The synthesis of conformationally restricted model peptides has become one of the research foci in bioorganic and medicinal chemistry in recent years. One common strategy in the design of conformationally restricted model peptides is to incorporate conformationally restricted amino acids into peptide chains to reduce the degrees of freedom of the peptide, which will greatly enhance their selectivity to the receptor, a prerequisite for their successful use as biologically active compounds (Jiménez *et al.*, 2005; Royo *et al.*, 2005; Casanovas *et al.*, 2003).

The title compound (I) (PhCO-c$_3$diAr-Val-NHCH$_3$) is a conformationally restricted model dipeptide. The absolute configuration of the c$_3$diAr residue was established as (2*S*,3S) (Fig.1). The two substituents of the phenyl and *p*-chloro-phenyl on the three-membered ring are in a *trans* arrangement. The rigidity of the three-membered ring fixes the side chain in a well defined orientation and this disposition is different for each stereoisomer. There is a compromise between the inflexible molecule and its desire to form strong N—H···O hydrogen bonds that leads to a very short H···H contact of 2.134 (1) Angstrom (H29···H12). The crystal packing is stabilized by several N—H···O hydrogen bonds and there are also a several relatively short intermolecular C—H···O hydrogen bonds (Table 1). All these interactions link the molecules into one-dimensional chains and are attributable to stabilize the structure (Fig. 2).

## Experimental

0.83 g (2.12 mmol) of 1-benzoylamino-2-(4-chloro-phenyl)-3-phenyl- cyclopropanecarboxylic acid (1), obtained by treatment of 1-benzoylamino-2-(4-chloro-phenyl)-3-phenyl-cyclopropanecarboxylic acid methyl ester with a solution of 2 *M* potassium hydroxide in anhydrous methanol (Su *et al.*, 2003, Huang *et al.*, 2007), was coupled with 2-amino-3-methyl-butyric acid methyl ester hydrochloride (0.36 g, 2.12 mmol) at 254 K by the classic mixed anhydride method using isobutyl chloroformate as the coupling agent. Then the resulting mixture of diastereoisomers (2 and 3 in Figure 3) (0.65 g, white solid) was aminolyzed in a 9.8 *M* methanolic solution of MeNH$_2$ (15 ml). A careful column chromatography on silica gel (eluent: CHCl$_3$/AcOEt 5:3, *v*/*v*) affords the corresponding enantiomerically pure dipeptides PhCO-(2*S*,3S)-c$_3$diAr-Val-NHCH$_3$ (4) and PhCO-(2*R*,3*R*)-c$_3$diAr-Val-NHCH$_3$ (5) in 36% and 26% yield respectively (Fig. 3). Recrystallization from CH$_2$Cl$_2$/CH$_3$OH (5:1 *v*/*v*) afforded colourless crystals (m.p. 516–517 K) of PhCO-(2*S*,3S)-c$_3$diAr-Val-NHCH$_3$ (4).

## Refinement

The H atoms bound to C atoms were positioned geometrically and included in the refinement in the riding-model approximation, with C—H = 0.94–0.99 Å and with $U_{iso}$(H) = 1.5$U_{eq}$(C) for methyl and 1.2$U_{eq}$(C) for all other H atoms.

## Figures

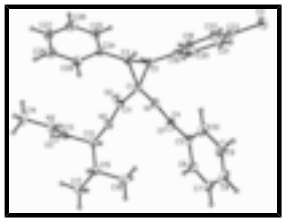


Fig. 1. The molecular structure of (I). Displacement ellipsoids are drawn at the 30% probability level and H atoms are shown as spheres of arbitrary radii.

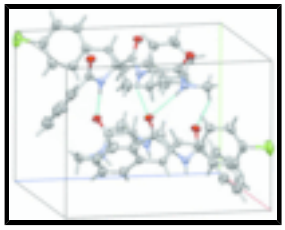


Fig. 2. View of the interactions by H-bonding between adjacent molecules in the unit cell. Displacement ellipsoids drawn at the 30% probability level and H-bonds are indicated as green lines.

Fig. 3. Synthesis of the title compound.

## (1*S*,2*S*,3*S*)-*N*-(2-(4-Chlorophenyl)-1-{*N*-[2-methyl-1-(N– methylcarbamoyl)propyl]carbamoyl}-3-phenylcyclopropyl)benzamide

*Crystal data*

| | |
|---|---|
| $C_{29}H_{30}ClN_3O_3$ | $F_{000}$ = 532 |
| $M_r$ = 504.01 | $D_x$ = 1.247 Mg m$^{-3}$ |
| Monoclinic, $P2_1$ | Mo $K\alpha$ radiation<br>λ = 0.71070 Å |
| Hall symbol: P 2yb | Cell parameters from 5213 reflections |
| $a$ = 10.8821 (19) Å | θ = 3.2–25.3º |
| $b$ = 9.5688 (16) Å | μ = 0.18 mm$^{-1}$ |
| $c$ = 12.952 (2) Å | $T$ = 223 (2) K |
| β = 95.754 (4)º | Block, colourless |
| $V$ = 1341.9 (4) Å$^3$ | 0.50 × 0.36 × 0.30 mm |
| $Z$ = 2 | |

*Data collection*

| | |
|---|---|
| Rigaku Mercury diffractometer | 4678 independent reflections |
| Radiation source: fine-focus sealed tube | 4334 reflections with $I > 2\sigma(I)$ |
| Monochromator: graphite | $R_{int}$ = 0.028 |
| $T$ = 223(2) K | $\theta_{max}$ = 25.3º |
| ω scans | $\theta_{min}$ = 3.2º |
| Absorption correction: multi-scan (Jacobson, 1998) | $h$ = −12→13 |

$T_{min}$ = 0.720, $T_{max}$ = 0.948
13162 measured reflections
$k$ = −11→11
$l$ = −15→15

*Refinement*

Refinement on $F^2$
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)]$ = 0.039
$wR(F^2)$ = 0.087
$S$ = 1.09
4678 reflections
329 parameters
1 restraint
Primary atom site location: structure-invariant direct methods
Secondary atom site location: difference Fourier map
Hydrogen site location: inferred from neighbouring sites
H-atom parameters constrained
$w = 1/[\sigma^2(F_o^2) + (0.0394P)^2 + 0.1618P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.001$
$\Delta\rho_{max}$ = 0.13 e Å$^{-3}$
$\Delta\rho_{min}$ = −0.19 e Å$^{-3}$
Extinction correction: none
Absolute structure: Flack (1983), with 2067 Friedel pairs
Flack parameter: 0.03 (7)

*Special details*

**Geometry**. All e.s.d.'s (except the e.s.d. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell e.s.d.'s are taken into account individually in the estimation of e.s.d.'s in distances, angles and torsion angles; correlations between e.s.d.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell e.s.d.'s is used for estimating e.s.d.'s involving l.s. planes.

**Refinement**. Refinement of $F^2$ against ALL reflections. The weighted *R*-factor *wR* and goodness of fit S are based on $F^2$, conventional *R*-factors *R* are based on F, with F set to zero for negative $F^2$. The threshold expression of $F^2 > 2$sigma($F^2$) is used only for calculating *R*-factors(gt) *etc*. and is not relevant to the choice of reflections for refinement. *R*-factors based on $F^2$ are statistically about twice as large as those based on F, and R– factors based on ALL data will be even larger.

*Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å$^2$)*

| | *x* | *y* | *z* | $U_{iso}$*/$U_{eq}$ |
|---|---|---|---|---|
| Cl1 | −0.04548 (6) | 0.93271 (10) | 0.97899 (5) | 0.0693 (2) |
| O1 | 0.51546 (14) | 0.93017 (16) | 0.76039 (11) | 0.0401 (4) |
| O2 | 0.44949 (13) | 1.03295 (14) | 0.51521 (12) | 0.0343 (3) |
| O3 | 0.69537 (14) | 0.97648 (15) | 0.32163 (12) | 0.0387 (4) |
| N1 | 0.40924 (14) | 0.75020 (17) | 0.68410 (12) | 0.0281 (4) |
| H1 | 0.3900 | 0.6620 | 0.6849 | 0.034* |
| N2 | 0.55739 (14) | 0.83074 (16) | 0.53124 (13) | 0.0276 (4) |
| H2 | 0.5547 | 0.7427 | 0.5478 | 0.033* |
| N3 | 0.61830 (17) | 0.75935 (18) | 0.32730 (13) | 0.0367 (4) |
| H3 | 0.5969 | 0.6912 | 0.3662 | 0.044* |
| C1 | 0.36200 (17) | 0.83804 (19) | 0.59967 (15) | 0.0271 (4) |
| C2 | 0.23957 (17) | 0.9144 (2) | 0.60451 (15) | 0.0308 (4) |
| H2B | 0.2357 | 1.0055 | 0.5681 | 0.037* |

| | | | | |
|---|---|---|---|---|
| C3 | 0.24678 (18) | 0.7912 (2) | 0.53285 (15) | 0.0297 (4) |
| H3B | 0.2090 | 0.7044 | 0.5568 | 0.036* |
| C4 | 0.48463 (19) | 0.8075 (2) | 0.76281 (16) | 0.0319 (5) |
| C5 | 0.5331 (2) | 0.7109 (2) | 0.84811 (15) | 0.0344 (5) |
| C6 | 0.6533 (2) | 0.7319 (3) | 0.89339 (17) | 0.0434 (6) |
| H6 | 0.7002 | 0.8065 | 0.8710 | 0.052* |
| C7 | 0.7041 (3) | 0.6441 (3) | 0.97087 (19) | 0.0553 (7) |
| H7 | 0.7860 | 0.6574 | 0.9996 | 0.066* |
| C8 | 0.6352 (3) | 0.5375 (3) | 1.00590 (19) | 0.0567 (7) |
| H8 | 0.6701 | 0.4773 | 1.0582 | 0.068* |
| C9 | 0.5153 (3) | 0.5188 (3) | 0.9647 (2) | 0.0634 (8) |
| H9 | 0.4671 | 0.4477 | 0.9905 | 0.076* |
| C10 | 0.4646 (3) | 0.6050 (3) | 0.88447 (18) | 0.0510 (7) |
| H10 | 0.3831 | 0.5903 | 0.8553 | 0.061* |
| C11 | 0.46021 (17) | 0.9113 (2) | 0.54537 (14) | 0.0265 (4) |
| C12 | 0.66756 (17) | 0.8836 (2) | 0.48946 (15) | 0.0290 (4) |
| H12 | 0.6767 | 0.9831 | 0.5097 | 0.035* |
| C13 | 0.65934 (18) | 0.8770 (2) | 0.37172 (16) | 0.0308 (5) |
| C14 | 0.6078 (3) | 0.7401 (3) | 0.21541 (17) | 0.0482 (6) |
| H14A | 0.5414 | 0.7981 | 0.1835 | 0.072* |
| H14B | 0.5901 | 0.6428 | 0.1990 | 0.072* |
| H14C | 0.6848 | 0.7667 | 0.1890 | 0.072* |
| C15 | 0.78250 (18) | 0.8054 (2) | 0.53901 (17) | 0.0370 (5) |
| H15 | 0.7725 | 0.7052 | 0.5213 | 0.044* |
| C16 | 0.7953 (2) | 0.8184 (3) | 0.65662 (19) | 0.0559 (7) |
| H16A | 0.8710 | 0.7732 | 0.6851 | 0.084* |
| H16B | 0.7253 | 0.7740 | 0.6840 | 0.084* |
| H16C | 0.7978 | 0.9165 | 0.6758 | 0.084* |
| C17 | 0.8986 (2) | 0.8572 (4) | 0.4957 (2) | 0.0622 (8) |
| H17A | 0.8876 | 0.8524 | 0.4205 | 0.093* |
| H17B | 0.9680 | 0.7992 | 0.5216 | 0.093* |
| H17C | 0.9144 | 0.9532 | 0.5171 | 0.093* |
| C18 | 0.16989 (17) | 0.9123 (2) | 0.69795 (15) | 0.0325 (5) |
| C19 | 0.1195 (2) | 1.0362 (2) | 0.72906 (18) | 0.0394 (5) |
| H19 | 0.1309 | 1.1181 | 0.6910 | 0.047* |
| C20 | 0.0527 (2) | 1.0435 (3) | 0.81444 (19) | 0.0465 (6) |
| H20 | 0.0181 | 1.1286 | 0.8335 | 0.056* |
| C21 | 0.03798 (19) | 0.9244 (3) | 0.87064 (16) | 0.0435 (5) |
| C22 | 0.0854 (2) | 0.7992 (3) | 0.84255 (18) | 0.0434 (6) |
| H22 | 0.0742 | 0.7183 | 0.8817 | 0.052* |
| C23 | 0.1505 (2) | 0.7927 (2) | 0.75545 (17) | 0.0381 (5) |
| H23 | 0.1817 | 0.7064 | 0.7352 | 0.046* |
| C24 | 0.23451 (18) | 0.8098 (2) | 0.41708 (16) | 0.0308 (4) |
| C25 | 0.1599 (2) | 0.9128 (3) | 0.36832 (17) | 0.0420 (5) |
| H25 | 0.1180 | 0.9754 | 0.4084 | 0.050* |
| C26 | 0.1466 (2) | 0.9245 (3) | 0.26140 (19) | 0.0556 (7) |
| H26 | 0.0961 | 0.9951 | 0.2295 | 0.067* |
| C27 | 0.2066 (2) | 0.8335 (3) | 0.20145 (19) | 0.0543 (7) |
| H27 | 0.1963 | 0.8411 | 0.1287 | 0.065* |

| | | | | |
|---|---|---|---|---|
| C28 | 0.2814 (2) | 0.7317 (3) | 0.24767 (17) | 0.0473 (6) |
| H28 | 0.3229 | 0.6696 | 0.2068 | 0.057* |
| C29 | 0.2959 (2) | 0.7204 (2) | 0.35476 (16) | 0.0378 (5) |
| H29 | 0.3483 | 0.6510 | 0.3860 | 0.045* |

*Atomic displacement parameters (Å$^2$)*

| | $U^{11}$ | $U^{22}$ | $U^{33}$ | $U^{12}$ | $U^{13}$ | $U^{23}$ |
|---|---|---|---|---|---|---|
| Cl1 | 0.0616 (4) | 0.1030 (6) | 0.0466 (4) | −0.0071 (4) | 0.0225 (3) | −0.0152 (4) |
| O1 | 0.0530 (9) | 0.0268 (8) | 0.0392 (8) | −0.0032 (7) | −0.0017 (7) | −0.0039 (7) |
| O2 | 0.0374 (8) | 0.0221 (8) | 0.0439 (9) | 0.0009 (6) | 0.0059 (7) | 0.0054 (6) |
| O3 | 0.0479 (9) | 0.0266 (8) | 0.0430 (9) | −0.0031 (7) | 0.0117 (7) | 0.0034 (6) |
| N1 | 0.0325 (9) | 0.0230 (9) | 0.0283 (9) | −0.0006 (7) | 0.0012 (7) | 0.0025 (7) |
| N2 | 0.0297 (8) | 0.0196 (8) | 0.0342 (9) | 0.0003 (7) | 0.0072 (7) | 0.0005 (7) |
| N3 | 0.0503 (11) | 0.0292 (10) | 0.0313 (9) | −0.0060 (8) | 0.0071 (8) | −0.0007 (8) |
| C1 | 0.0307 (10) | 0.0229 (10) | 0.0277 (10) | 0.0016 (8) | 0.0024 (8) | 0.0013 (8) |
| C2 | 0.0285 (10) | 0.0289 (11) | 0.0349 (11) | 0.0023 (9) | 0.0031 (8) | 0.0039 (9) |
| C3 | 0.0278 (10) | 0.0295 (11) | 0.0314 (11) | −0.0040 (8) | 0.0020 (8) | 0.0028 (9) |
| C4 | 0.0355 (11) | 0.0307 (12) | 0.0298 (11) | 0.0021 (9) | 0.0052 (9) | −0.0040 (9) |
| C5 | 0.0473 (13) | 0.0316 (11) | 0.0241 (10) | 0.0022 (10) | 0.0027 (9) | −0.0018 (9) |
| C6 | 0.0494 (14) | 0.0499 (14) | 0.0302 (12) | 0.0028 (11) | 0.0000 (10) | −0.0003 (11) |
| C7 | 0.0597 (16) | 0.073 (2) | 0.0304 (13) | 0.0187 (15) | −0.0062 (12) | 0.0018 (12) |
| C8 | 0.085 (2) | 0.0533 (16) | 0.0292 (12) | 0.0142 (15) | −0.0068 (13) | 0.0020 (12) |
| C9 | 0.099 (2) | 0.0501 (16) | 0.0384 (14) | −0.0173 (15) | −0.0051 (15) | 0.0113 (12) |
| C10 | 0.0643 (17) | 0.0509 (15) | 0.0352 (13) | −0.0126 (13) | −0.0084 (12) | 0.0073 (12) |
| C11 | 0.0285 (10) | 0.0242 (11) | 0.0260 (10) | −0.0022 (8) | −0.0010 (8) | −0.0018 (8) |
| C12 | 0.0283 (10) | 0.0241 (10) | 0.0352 (11) | −0.0021 (8) | 0.0059 (9) | −0.0019 (8) |
| C13 | 0.0280 (10) | 0.0271 (11) | 0.0377 (11) | 0.0024 (8) | 0.0061 (9) | −0.0017 (9) |
| C14 | 0.0708 (16) | 0.0410 (14) | 0.0331 (12) | −0.0061 (13) | 0.0069 (11) | −0.0040 (10) |
| C15 | 0.0301 (10) | 0.0408 (13) | 0.0397 (12) | 0.0033 (9) | 0.0007 (9) | −0.0066 (10) |
| C16 | 0.0470 (14) | 0.076 (2) | 0.0427 (14) | 0.0094 (14) | −0.0037 (11) | 0.0017 (13) |
| C17 | 0.0314 (12) | 0.093 (2) | 0.0618 (17) | −0.0015 (13) | 0.0043 (12) | 0.0001 (16) |
| C18 | 0.0247 (9) | 0.0368 (12) | 0.0353 (11) | −0.0014 (9) | 0.0000 (8) | 0.0008 (10) |
| C19 | 0.0376 (12) | 0.0381 (12) | 0.0424 (13) | 0.0015 (10) | 0.0041 (10) | −0.0028 (10) |
| C20 | 0.0414 (13) | 0.0520 (15) | 0.0464 (14) | 0.0052 (12) | 0.0053 (11) | −0.0135 (12) |
| C21 | 0.0331 (11) | 0.0657 (16) | 0.0318 (11) | −0.0050 (12) | 0.0044 (9) | −0.0103 (12) |
| C22 | 0.0380 (12) | 0.0546 (15) | 0.0380 (13) | −0.0050 (11) | 0.0064 (10) | 0.0074 (11) |
| C23 | 0.0353 (11) | 0.0380 (13) | 0.0413 (12) | 0.0009 (10) | 0.0057 (10) | 0.0020 (10) |
| C24 | 0.0275 (10) | 0.0315 (11) | 0.0329 (11) | −0.0064 (9) | 0.0013 (8) | 0.0056 (9) |
| C25 | 0.0404 (12) | 0.0446 (14) | 0.0397 (12) | 0.0048 (11) | −0.0023 (10) | 0.0077 (11) |
| C26 | 0.0577 (15) | 0.0586 (16) | 0.0473 (14) | 0.0079 (14) | −0.0106 (12) | 0.0181 (14) |
| C27 | 0.0585 (15) | 0.0732 (19) | 0.0300 (12) | −0.0068 (15) | −0.0016 (11) | 0.0097 (12) |
| C28 | 0.0528 (14) | 0.0550 (15) | 0.0344 (13) | −0.0027 (13) | 0.0059 (11) | 0.0005 (11) |
| C29 | 0.0398 (12) | 0.0373 (12) | 0.0357 (12) | −0.0004 (10) | 0.0008 (10) | 0.0030 (10) |

*Geometric parameters (Å, °)*

| | | | |
|---|---|---|---|
| Cl1—C21 | 1.748 (2) | C12—H12 | 0.9900 |
| O1—C4 | 1.222 (3) | C14—H14A | 0.9700 |

| | | | |
|---|---|---|---|
| O2—C11 | 1.230 (2) | C14—H14B | 0.9700 |
| O3—C13 | 1.238 (2) | C14—H14C | 0.9700 |
| N1—C4 | 1.358 (3) | C15—C17 | 1.516 (3) |
| N1—C1 | 1.433 (2) | C15—C16 | 1.521 (3) |
| N1—H1 | 0.8700 | C15—H15 | 0.9900 |
| N2—C11 | 1.336 (2) | C16—H16A | 0.9700 |
| N2—C12 | 1.455 (2) | C16—H16B | 0.9700 |
| N2—H2 | 0.8700 | C16—H16C | 0.9700 |
| N3—C13 | 1.321 (3) | C17—H17A | 0.9700 |
| N3—C14 | 1.454 (3) | C17—H17B | 0.9700 |
| N3—H3 | 0.8700 | C17—H17C | 0.9700 |
| C1—C11 | 1.510 (3) | C18—C19 | 1.384 (3) |
| C1—C3 | 1.518 (3) | C18—C23 | 1.393 (3) |
| C1—C2 | 1.526 (3) | C19—C20 | 1.385 (3) |
| C2—C18 | 1.491 (3) | C19—H19 | 0.9400 |
| C2—C3 | 1.507 (3) | C20—C21 | 1.370 (4) |
| C2—H2B | 0.9900 | C20—H20 | 0.9400 |
| C3—C24 | 1.503 (3) | C21—C22 | 1.369 (4) |
| C3—H3B | 0.9900 | C22—C23 | 1.392 (3) |
| C4—C5 | 1.496 (3) | C22—H22 | 0.9400 |
| C5—C10 | 1.369 (3) | C23—H23 | 0.9400 |
| C5—C6 | 1.393 (3) | C24—C25 | 1.389 (3) |
| C6—C7 | 1.381 (3) | C24—C29 | 1.392 (3) |
| C6—H6 | 0.9400 | C25—C26 | 1.382 (3) |
| C7—C8 | 1.369 (4) | C25—H25 | 0.9400 |
| C7—H7 | 0.9400 | C26—C27 | 1.375 (4) |
| C8—C9 | 1.371 (4) | C26—H26 | 0.9400 |
| C8—H8 | 0.9400 | C27—C28 | 1.368 (4) |
| C9—C10 | 1.396 (3) | C27—H27 | 0.9400 |
| C9—H9 | 0.9400 | C28—C29 | 1.384 (3) |
| C10—H10 | 0.9400 | C28—H28 | 0.9400 |
| C12—C13 | 1.520 (3) | C29—H29 | 0.9400 |
| C12—C15 | 1.541 (3) | | |
| C4—N1—C1 | 118.66 (16) | N3—C14—H14A | 109.5 |
| C4—N1—H1 | 120.7 | N3—C14—H14B | 109.5 |
| C1—N1—H1 | 120.7 | H14A—C14—H14B | 109.5 |
| C11—N2—C12 | 122.92 (16) | N3—C14—H14C | 109.5 |
| C11—N2—H2 | 118.5 | H14A—C14—H14C | 109.5 |
| C12—N2—H2 | 118.5 | H14B—C14—H14C | 109.5 |
| C13—N3—C14 | 122.09 (19) | C17—C15—C16 | 110.4 (2) |
| C13—N3—H3 | 119.0 | C17—C15—C12 | 111.0 (2) |
| C14—N3—H3 | 119.0 | C16—C15—C12 | 111.50 (18) |
| N1—C1—C11 | 114.29 (16) | C17—C15—H15 | 107.9 |
| N1—C1—C3 | 118.32 (16) | C16—C15—H15 | 107.9 |
| C11—C1—C3 | 117.03 (16) | C12—C15—H15 | 107.9 |
| N1—C1—C2 | 119.81 (16) | C15—C16—H16A | 109.5 |
| C11—C1—C2 | 117.30 (16) | C15—C16—H16B | 109.5 |
| C3—C1—C2 | 59.35 (13) | H16A—C16—H16B | 109.5 |
| C18—C2—C3 | 123.47 (18) | C15—C16—H16C | 109.5 |

| | | | |
|---|---|---|---|
| C18—C2—C1 | 122.95 (17) | H16A—C16—H16C | 109.5 |
| C3—C2—C1 | 60.06 (13) | H16B—C16—H16C | 109.5 |
| C18—C2—H2B | 113.4 | C15—C17—H17A | 109.5 |
| C3—C2—H2B | 113.4 | C15—C17—H17B | 109.5 |
| C1—C2—H2B | 113.4 | H17A—C17—H17B | 109.5 |
| C24—C3—C2 | 121.14 (18) | C15—C17—H17C | 109.5 |
| C24—C3—C1 | 121.31 (17) | H17A—C17—H17C | 109.5 |
| C2—C3—C1 | 60.59 (13) | H17B—C17—H17C | 109.5 |
| C24—C3—H3B | 114.5 | C19—C18—C23 | 117.56 (19) |
| C2—C3—H3B | 114.5 | C19—C18—C2 | 118.3 (2) |
| C1—C3—H3B | 114.5 | C23—C18—C2 | 124.2 (2) |
| O1—C4—N1 | 120.99 (19) | C18—C19—C20 | 122.1 (2) |
| O1—C4—C5 | 122.35 (19) | C18—C19—H19 | 119.0 |
| N1—C4—C5 | 116.56 (18) | C20—C19—H19 | 119.0 |
| C10—C5—C6 | 118.9 (2) | C21—C20—C19 | 118.7 (2) |
| C10—C5—C4 | 123.2 (2) | C21—C20—H20 | 120.6 |
| C6—C5—C4 | 117.9 (2) | C19—C20—H20 | 120.6 |
| C7—C6—C5 | 120.5 (2) | C22—C21—C20 | 121.3 (2) |
| C7—C6—H6 | 119.7 | C22—C21—Cl1 | 119.6 (2) |
| C5—C6—H6 | 119.7 | C20—C21—Cl1 | 119.1 (2) |
| C8—C7—C6 | 120.1 (3) | C21—C22—C23 | 119.4 (2) |
| C8—C7—H7 | 119.9 | C21—C22—H22 | 120.3 |
| C6—C7—H7 | 119.9 | C23—C22—H22 | 120.3 |
| C7—C8—C9 | 120.0 (2) | C22—C23—C18 | 120.9 (2) |
| C7—C8—H8 | 120.0 | C22—C23—H23 | 119.6 |
| C9—C8—H8 | 120.0 | C18—C23—H23 | 119.6 |
| C8—C9—C10 | 120.1 (3) | C25—C24—C29 | 117.74 (19) |
| C8—C9—H9 | 119.9 | C25—C24—C3 | 121.83 (19) |
| C10—C9—H9 | 119.9 | C29—C24—C3 | 120.41 (18) |
| C5—C10—C9 | 120.4 (2) | C26—C25—C24 | 120.7 (2) |
| C5—C10—H10 | 119.8 | C26—C25—H25 | 119.6 |
| C9—C10—H10 | 119.8 | C24—C25—H25 | 119.6 |
| O2—C11—N2 | 123.64 (18) | C27—C26—C25 | 120.4 (2) |
| O2—C11—C1 | 122.59 (18) | C27—C26—H26 | 119.8 |
| N2—C11—C1 | 113.75 (16) | C25—C26—H26 | 119.8 |
| N2—C12—C13 | 113.02 (16) | C28—C27—C26 | 120.0 (2) |
| N2—C12—C15 | 109.95 (16) | C28—C27—H27 | 120.0 |
| C13—C12—C15 | 111.18 (16) | C26—C27—H27 | 120.0 |
| N2—C12—H12 | 107.5 | C27—C28—C29 | 119.8 (2) |
| C13—C12—H12 | 107.5 | C27—C28—H28 | 120.1 |
| C15—C12—H12 | 107.5 | C29—C28—H28 | 120.1 |
| O3—C13—N3 | 122.54 (19) | C28—C29—C24 | 121.3 (2) |
| O3—C13—C12 | 120.27 (18) | C28—C29—H29 | 119.3 |
| N3—C13—C12 | 117.11 (18) | C24—C29—H29 | 119.3 |
| C4—N1—C1—C11 | 56.8 (2) | C11—N2—C12—C13 | −88.6 (2) |
| C4—N1—C1—C3 | −159.11 (18) | C11—N2—C12—C15 | 146.52 (18) |
| C4—N1—C1—C2 | −90.1 (2) | C14—N3—C13—O3 | −2.5 (3) |
| N1—C1—C2—C18 | 5.4 (3) | C14—N3—C13—C12 | −179.27 (19) |
| C11—C1—C2—C18 | −140.58 (19) | N2—C12—C13—O3 | 137.01 (18) |

| | | | |
|---|---|---|---|
| C3—C1—C2—C18 | 112.6 (2) | C15—C12—C13—O3 | −98.8 (2) |
| N1—C1—C2—C3 | −107.22 (19) | N2—C12—C13—N3 | −46.2 (2) |
| C11—C1—C2—C3 | 106.77 (19) | C15—C12—C13—N3 | 78.0 (2) |
| C18—C2—C3—C24 | 137.30 (19) | N2—C12—C15—C17 | 179.2 (2) |
| C1—C2—C3—C24 | −110.9 (2) | C13—C12—C15—C17 | 53.3 (2) |
| C18—C2—C3—C1 | −111.8 (2) | N2—C12—C15—C16 | −57.2 (2) |
| N1—C1—C3—C24 | −139.70 (19) | C13—C12—C15—C16 | 176.83 (19) |
| C11—C1—C3—C24 | 3.4 (3) | C3—C2—C18—C19 | −149.82 (19) |
| C2—C1—C3—C24 | 110.6 (2) | C1—C2—C18—C19 | 136.7 (2) |
| N1—C1—C3—C2 | 109.70 (19) | C3—C2—C18—C23 | 29.1 (3) |
| C11—C1—C3—C2 | −107.23 (19) | C1—C2—C18—C23 | −44.3 (3) |
| C1—N1—C4—O1 | −2.6 (3) | C23—C18—C19—C20 | 0.5 (3) |
| C1—N1—C4—C5 | −178.99 (17) | C2—C18—C19—C20 | 179.5 (2) |
| O1—C4—C5—C10 | 146.1 (2) | C18—C19—C20—C21 | 1.1 (3) |
| N1—C4—C5—C10 | −37.5 (3) | C19—C20—C21—C22 | −1.5 (3) |
| O1—C4—C5—C6 | −32.8 (3) | C19—C20—C21—Cl1 | 179.66 (17) |
| N1—C4—C5—C6 | 143.5 (2) | C20—C21—C22—C23 | 0.3 (3) |
| C10—C5—C6—C7 | 2.5 (3) | Cl1—C21—C22—C23 | 179.18 (17) |
| C4—C5—C6—C7 | −178.5 (2) | C21—C22—C23—C18 | 1.3 (3) |
| C5—C6—C7—C8 | −1.8 (4) | C19—C18—C23—C22 | −1.7 (3) |
| C6—C7—C8—C9 | −0.6 (4) | C2—C18—C23—C22 | 179.35 (19) |
| C7—C8—C9—C10 | 2.3 (4) | C2—C3—C24—C25 | −32.7 (3) |
| C6—C5—C10—C9 | −0.8 (4) | C1—C3—C24—C25 | −105.0 (2) |
| C4—C5—C10—C9 | −179.7 (2) | C2—C3—C24—C29 | 149.11 (19) |
| C8—C9—C10—C5 | −1.6 (4) | C1—C3—C24—C29 | 76.8 (3) |
| C12—N2—C11—O2 | 7.5 (3) | C29—C24—C25—C26 | 0.7 (3) |
| C12—N2—C11—C1 | −174.07 (16) | C3—C24—C25—C26 | −177.6 (2) |
| N1—C1—C11—O2 | −140.36 (18) | C24—C25—C26—C27 | 0.4 (4) |
| C3—C1—C11—O2 | 75.1 (2) | C25—C26—C27—C28 | −0.9 (4) |
| C2—C1—C11—O2 | 7.5 (3) | C26—C27—C28—C29 | 0.3 (4) |
| N1—C1—C11—N2 | 41.2 (2) | C27—C28—C29—C24 | 0.8 (3) |
| C3—C1—C11—N2 | −103.4 (2) | C25—C24—C29—C28 | −1.3 (3) |
| C2—C1—C11—N2 | −170.97 (16) | C3—C24—C29—C28 | 177.0 (2) |

*Hydrogen-bond geometry (Å, °)*

| *D*—H···*A* | *D*—H | H···*A* | *D*···*A* | *D*—H···*A* |
|---|---|---|---|---|
| N1—H1···O3$^{i}$ | 0.87 | 2.00 | 2.854 (2) | 166 |
| N2—H2···O2$^{i}$ | 0.87 | 2.17 | 2.912 (2) | 144 |
| N3—H3···O2$^{i}$ | 0.87 | 2.25 | 3.114 (2) | 173 |
| C14—H14B···O1$^{i}$ | 0.97 | 2.42 | 3.283 (3) | 148 |

Symmetry codes: (i) −*x*+1, *y*−1/2, −*z*+1.

**Fig. 1**

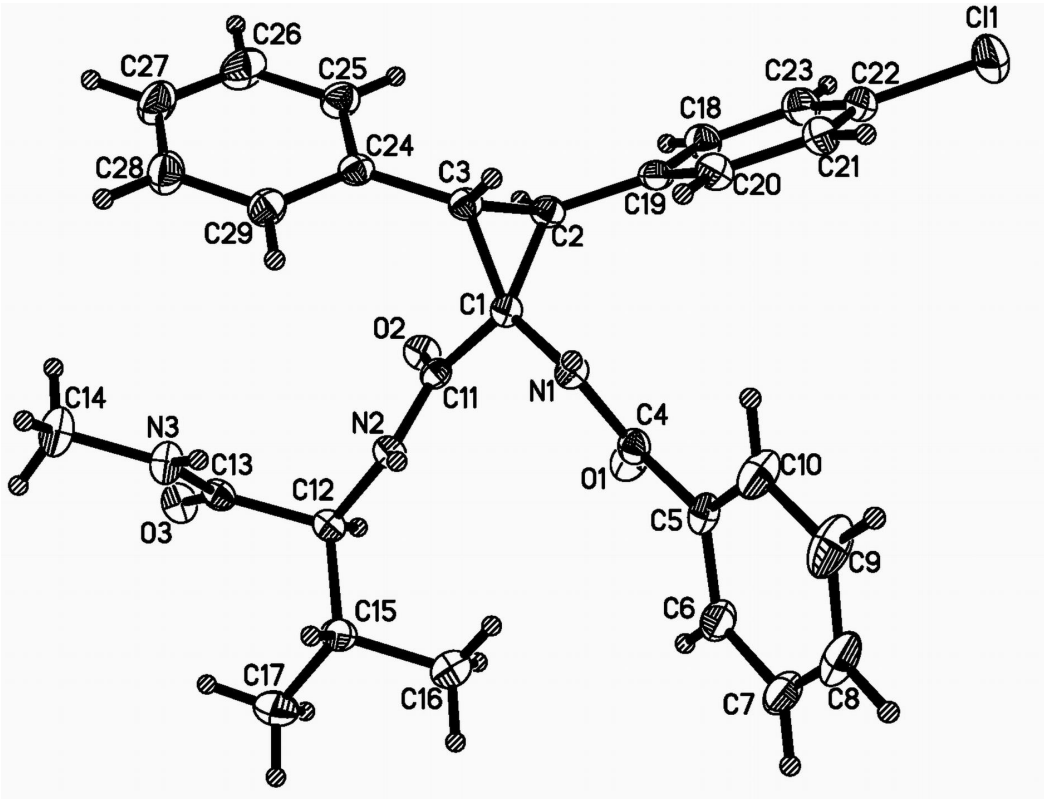

Cl1
C26
C27
C25
C23
C22
C18
C24
C28
C3
C21
C20
C19
C29
C2
C1
O2
C14
C11
N1
N3
N2
C4
C13
C10
O1
C12
C5
O3
C9
C15
C6
C17
C16
C7
C8

**Fig. 2**

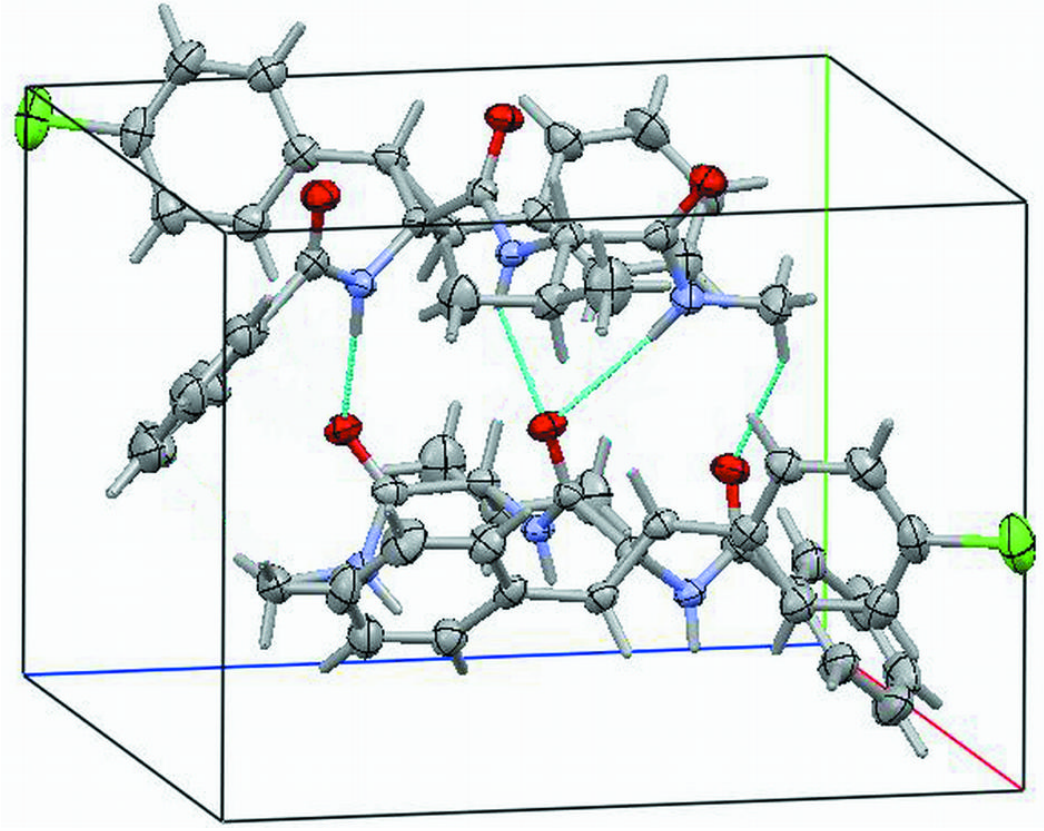
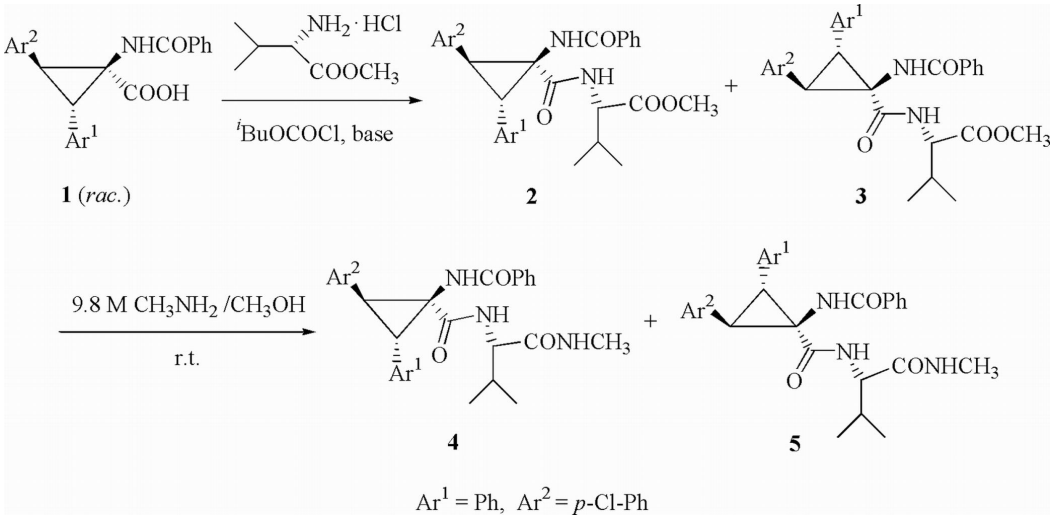


**Fig. 3**


Ar2
NHCOPh
COOH
Ar1
NH2 · HCl
COOCH3
iBuOCOCl, base
1 (rac.)
2
3
9.8 M CH3NH2 /CH3OH
r.t.
CONHCH3
4
5
Ar1 = Ph, Ar2 = p-Cl-Ph