

## Structure of 4-Cyclohexyl-3,4-dihydro-2-hydroxy-2-methyl-2H,5H-pyrano-[3,2-c][1]benzopyran-5-one

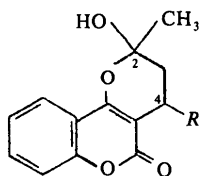
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**Abstract.**  $C_{19}H_{22}O_4$ , monoclinic,  $P2_1/c$ ,  $a = 12.515$  (2),  $b = 17.472$  (3),  $c = 7.489$  (1) Å,  $\beta = 100.40$  (1)°. The structure was solved by direct methods. The cyclohexyl group is pseudo-equatorial and *trans* to the axial hydroxyl; the dihydropyran ring is a half-chair distorted towards the *d,e*-diplanar conformation. Hydrogen bonding between the coumarin carbonyl and the hydroxyl groups at an O...O distance of 2.834 (4) Å is found. In  $CDCl_3$  solution, this compound exists predominantly in the open-chain keto form.

**Introduction.** Michael-type addition of 4-alkyl- or 4-arylbut-3-en-2-ones to 4-hydroxycoumarin produces 3-substituted 4-hydroxycoumarins that may exist as cyclic hemiketals (Ikawa, Stahmann & Link, 1944). Such isomers are diastereomeric, and the configuration of the molecule in the crystal will depend on the steric interactions between the substituents on the dihydropyran (hemiketal) ring. Substituents at the 2 and 4 positions have the largest interactions. The 2-hydroxyl or alkoxy group normally prefers the axial conformation, related to the anomeric effect. The 4-pseudo-axial substituent will therefore have a short diaxial contact while a 4-pseudo-equatorial substituent is close to the coumarin carbonyl oxygen. Previously, (1) was found to induce distortions in the dihydropyran ring relative to (2) in both 4 placements (Valente, Santarsiero & Schomaker, 1979). The present contribution extends this series to  $R =$  cyclohexyl, (3), a substituent envisioned to be larger than methyl, and describes the conformation of the distorted dihydropyran ring obtained in the crystal, and the structure in solution revealed by nuclear magnetic resonance.



- (1)  $R = CH_3$   
 (2)  $R = C_6H_5$   
 (3)  $R = C_6H_{11}$

Colorless rods of (3) crystallize from ethyl acetate or acetone solutions. After a preliminary photographic

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study of several crystals which established the space group as  $P2_1/c$  ( $h0l$  absent for  $l$  odd,  $0k0$  absent for  $k$  odd), an individual  $0.156 \times 0.063 \times 0.469$  mm was mounted along the long crystal axis. Cell constants were measured from 12 reflections ( $2\theta > 30^\circ$ ) and 2385 reflections were observed on a Picker FACS-I automated diffractometer with quartz-mo-chromatized  $Mo K\alpha$  radiation ( $\lambda = 0.70926$  Å). Of these, 1621 exceeded  $1.5\sigma(I)$  and were used in the final refinement stages. The structure was discovered with *MULTAN* (Main, 1978), and refined by full-matrix least-squares calculations until the model, represented by anisotropic and isotropic  $U$ 's associated with the non-hydrogen and hydrogen-atom positions respectively, converged at  $R = 0.055$ ; goodness-of-fit = 1.8. No absorption or extinction corrections were applied to the data. The atom positions appear in Table 1.\*

In  $CDCl_3$ , the  $^1H$  and  $^{13}C$  magnetic resonance spectra of (3) (HA-100 spectrometer) and its methyl ketal, (3a), formed by treatment of (3) with methanol and acid, were recorded and show that for (3) a mixture of one cyclic diastereomeric hemiketal and the open form is present. By integration, the open form represents 75% of the mixture. The spectra of (3a) indicate that it is the *trans* diastereomer.

**Discussion.** An ellipsoid plot (Johnson, 1965) of the structure is given in Fig. 1 together with the numbering scheme which is based on the coumarin heterocycle. The cyclohexyl group is pseudo-equatorial on the dihydropyran ring and *trans* to the axial hydroxyl group. The dihydropyran ring has a half-chair conformation distorted towards the *d,e*-diplanar form (Valente, Santarsiero & Schomaker, 1979). Relevant torsion angles are shown in Fig. 2. Both methylenes C(16) and C(20), bound to C(15), are plainly disposed

\* Lists of structure factors, thermal parameters and bond lengths and angles, and the tabulated spectra have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 34561 (17 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Table 1. Atom positions ( $\times 10^4$ , for H  $\times 10^3$ ) with e.s.d.'s in parentheses

	x	y	z		x	y	z
O(1)	-4736 (2)	2536 (2)	4987 (4)	H(31)	-340 (4)	110 (3)	46 (6)
O(2)	-3026 (2)	2818 (2)	5029 (4)	H(51)	-637 (4)	42 (3)	269 (6)
O(3)	-3520 (3)	612 (2)	368 (4)	H(61)	-812 (4)	92 (3)	290 (6)
O(4)	-4409 (2)	416 (2)	2793 (4)	H(71)	-822 (4)	214 (3)	420 (6)
C(2)	-3719 (3)	2323 (2)	4725 (5)	H(81)	-665 (5)	286 (3)	521 (8)
C(3)	-3547 (3)	1550 (2)	4140 (5)	H(111)	-221 (3)	162 (2)	299 (5)
C(4)	-4438 (3)	1106 (2)	3574 (5)	H(121)	-180 (4)	31 (3)	290 (5)
C(5)	-6460 (4)	923 (3)	3153 (6)	H(122)	-246 (3)	16 (2)	448 (6)
C(6)	-7458 (4)	1223 (3)	3314 (6)	H(141)	-420 (3)	-70 (2)	79 (5)
C(7)	-7534 (4)	1935 (3)	4072 (7)	H(142)	-357 (4)	-90 (3)	276 (6)
C(8)	-6624 (4)	2372 (3)	4671 (6)	H(143)	-290 (4)	-77 (2)	107 (6)
C(9)	-5624 (3)	2074 (2)	4469 (5)	H(151)	-154 (3)	201 (3)	584 (5)
C(10)	-5517 (3)	1356 (2)	3743 (5)	H(161)	-171 (4)	45 (3)	718 (7)
C(11)	-2411 (3)	1295 (2)	3964 (5)	H(162)	-247 (4)	118 (3)	755 (5)
C(12)	-2448 (4)	451 (3)	3382 (6)	H(171)	-97 (5)	185 (3)	926 (7)
C(13)	-3446 (3)	237 (2)	2028 (6)	H(172)	-107 (4)	104 (3)	1011 (7)
C(14)	-3542 (4)	-611 (3)	1637 (7)	H(181)	32 (4)	51 (3)	858 (7)
C(15)	-1537 (3)	1444 (3)	5671 (6)	H(182)	81 (5)	129 (3)	973 (8)
C(16)	-1749 (4)	1044 (3)	7378 (6)	H(191)	40 (4)	208 (3)	705 (7)
C(17)	-895 (5)	1270 (4)	9021 (7)	H(192)	118 (5)	134 (3)	681 (5)
C(18)	251 (5)	1104 (4)	8697 (8)	H(201)	-34 (4)	66 (3)	506 (6)
C(19)	456 (4)	1476 (4)	6972 (8)	H(202)	-26 (3)	147 (3)	417 (6)
C(20)	-401 (4)	1251 (3)	5337 (7)				

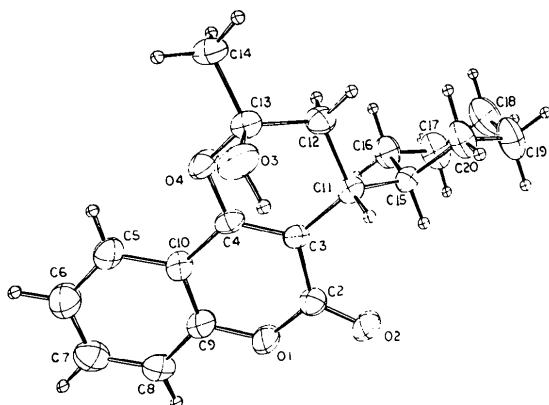


Fig. 1. An ellipsoid plot of (3) with the numbering scheme.

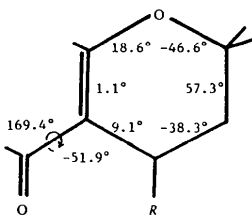


Fig. 2. Selected torsion angles for (3); e.s.d.'s are about 0.5°.

away from the carbonyl oxygen. The cyclohexyl group is accommodated as though it were an isopropyl group, and thus only small conformational differences between the dihydropyran rings of (3) and the *trans* (1) methyl ketal are seen.

Carbonyl and hydroxyl groups are intermolecularly hydrogen bonded along the *c* glide at an O...O distance of 2.834 (4) Å. The H on O(3) is antiperiplanar to the methyl C(14) and therefore disposed over the dihydropyran ring. This is in contrast to the more common conformation in which the substituent on O(3) is antiperiplanar to C(12) (Valente, Trager & Jensen, 1975; Valente, Lingafelter, Porter & Trager, 1977) and therefore directed away from the ring (McConnell, Schwartz & Stevens, 1979). The most obvious effect of this arrangement is the widening of O(3)—C(13)—C(12) to 113.4 (4)° and the closing of O(3)—C(13)—C(14) to 107.4 (4)° over the representative values of 109 and 112° respectively for the H antiperiplanar to C(12) (Valente, Santarsiero & Schomaker, 1979).

The solution spectra of (3) show that the open-chain keto form predominates, representing a continuation of the trend correlating decreased stability of the hemiketals with increasing bulk of the 4 substituent on the ring. The hemiketal diastereomer that constitutes the minor portion of (3) in solution is most likely the *trans* isomer, as in the crystal. This is suggested by the formation of the *trans* methyl ketal, (3a), as the product of methylation.

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4-*tert*-Butyl-1-aza-2-cyclohexanone

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**Abstract.** C<sub>9</sub>H<sub>17</sub>NO, monoclinic, *P*2<sub>1</sub>/*c*, *a* = 14.674 (4), *b* = 6.158 (1), *c* = 10.363 (2) Å, β = 105.62 (2)° (all at 138 K), *Z* = 4, *M<sub>r</sub>* = 155.24, *D<sub>x</sub>* (room temperature) = 1.101, *D<sub>m</sub>* = 1.097 Mg m<sup>-3</sup>. The final *R* value is 0.048 for all 1752 data. The molecule is observed in a half-chair conformation and contains a *cis*-amide bond which exhibits significant non-planar character [*χ<sub>N</sub>* = 8.5 (15)°].

**Introduction.** 4-*tert*-Butyl-1-aza-2-cyclohexanone was prepared by Tichý, Malón, Frič & Bláha (1977) as part of a general investigation of the conformation of six-membered lactams in which the conformation was stabilized by the introduction of a *tert*-butyl group. In addition, they were able to synthesize the optically active (4*S*) isomer. The present communication deals, however, with the structure determination of the racemic mixture.

The title compound was recrystallized from diethyl ether. A cubic crystal with dimensions of 0.5 mm was selected for data collection and unit-cell determination at 138 ± 2 K using a Nonius CAD-4 automatic diffractometer. The unit-cell dimensions were determined from 42 reflections distributed throughout all octants of reciprocal space using Cu Kα<sub>1</sub> (λ = 1.5405 Å) radiation. The intensities of 1752 reflections [*I* > 2σ(*I*)] with 2θ ≤ 150° were measured using θ–2θ scans and Cu Kα radiation. The scan angle and aperture width were (1.5 + 0.15 tan θ)° and (4.0 + 0.86 tan θ) mm respectively. The maximum scan time per reflection was 60 s. Crystal orientation was checked every 100 reflections and an intensity monitor was measured every 20 reflections. The intensity of the monitor reflection decreased by 4% during data collection. Lorentz and polarization factors were applied but no absorption correction was made.

The structure was solved by direct methods (Karle & Karle, 1966) using the *MULTAN* program (Germain, Main & Woolfson, 1971). The H positions were located from a difference Fourier map based on the partially refined positions of the O, N and C atoms. The structure was refined with block-diagonal least-squares techniques (Ahmed, 1966) with anisotropic thermal parameters for O, N and C atoms and isotropic thermal parameters for H atoms. Refinement was discontinued when all parameter shifts were less than one-half of the corresponding standard deviation. A final *R* value (*R* = ∑ ||*kF<sub>o</sub>*| – |*F<sub>c</sub>*|| / ∑ |*kF<sub>o</sub>*|) of 0.048 was obtained for all data using the final parameters (Tables 1 and 2).<sup>\*</sup> Scattering factors for C, N and O atoms were taken

<sup>\*</sup> Lists of structure factors, anisotropic thermal parameters and bond distances involving H atoms have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 34599 (11 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Table 1. Positional parameters (× 10<sup>5</sup>) for C, N and O atoms

	<i>x</i>	<i>y</i>	<i>z</i>
N(1)	43577 (7)	109572 (18)	33948 (12)
C(2)	38299 (8)	91817 (20)	30373 (13)
O(2)	40337 (7)	77588 (16)	23114 (11)
C(3)	29621 (9)	89292 (19)	35469 (14)
C(4)	25719 (9)	110936 (18)	39025 (12)
C(5)	34014 (10)	122133 (20)	48951 (14)
C(6)	41643 (9)	127574 (21)	42026 (14)
C(7)	16541 (9)	108761 (19)	43578 (12)
C(8)	8768 (9)	98419 (25)	32281 (15)
C(9)	13064 (11)	131495 (23)	46231 (15)
C(10)	18050 (11)	95081 (22)	56253 (14)

Standard deviations for last digit are in parentheses.