Chiroptical Properties of an Isolated Pyridine Chromophore: the Circular Dichroism Spectra in the Near Ultraviolet Region of (−)-(*R*)-2-(1,2,2-Trimethylpropyl)pyridine

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The circular dichroism spectra of (−)-(*R*)-2-(1,2,2-trimethylpropyl)pyridine, under various conditions of solvent and temperature, are reported. The results are consistent with the presence of three electronic transitions (two $n \longrightarrow \pi^*$ and one $\pi \longrightarrow \pi^*$ excitations)in the spectral range examined (300—230 nm).

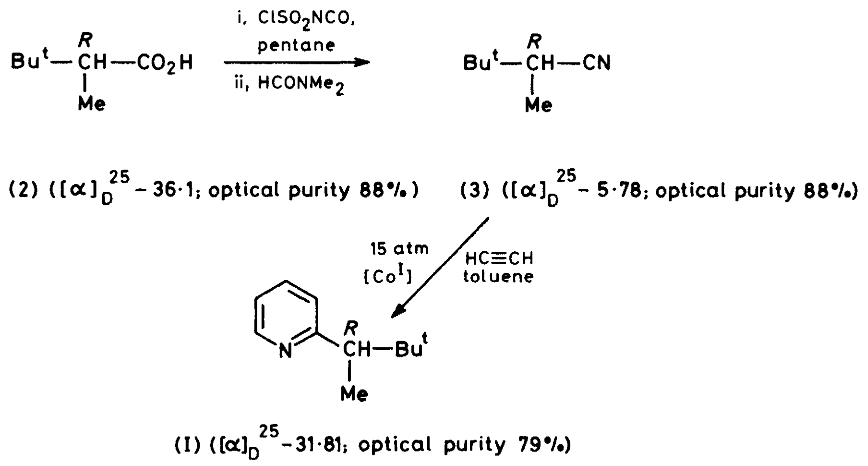
Several papers [1-8] have appeared concerning the near-u.v. (300—230 nm) circular dichroism (c.d.) spectra of chiral pyridine derivatives. Whilst there is general agreement on the assignment of the absorptions observed to the $^1A_1 \longrightarrow {}^1B_1$ ($n \longrightarrow \pi^*$) and $^1A_1 \longrightarrow {}^1B_2$ ($\pi \longrightarrow \pi^*$, ^1L_b) transitions (in order of increasing energy) the presence of a second $n \longrightarrow \pi^*$ ($^1A_1 \longrightarrow {}^1A_2$) transition on the higher energy side of the ^1L_b absorption is still questionable. The c.d. data which support the existence of this last absorption have been obtained from pyridylethylamines or pyridylethanols, *i.e.* molecules where other functional groups are present. Such groups could in some way ' interact ' with the pyridine chromophore or with the solvents, affecting to some extent the spectral properties of the chromophore itself.

We believed that the investigation of the near-u.v. c.d. spectra of simple monosubstituted alkylpyridines could be of interest in clarifying the nature of the absorptions of the pyridine chromophore. The introduction of a 1,2,2-trimethylpropyl group in simple aromatic chromophores has been used previously to obtain simple, monosubstituted, optically active benzene [9] and α- and β-naphthalene [10] derivatives, in order to study the chiroptical properties of an ' isolated ' chromophore. For this reason we chose to study the 2-, 3-, and 4-(1,2,2-trimethylpropyl)pyridines, and describe here the preparation and c.d. properties of the 2-isomer.

Results and Discussion

Preparation of(−)-(R)-2-(1,2,2-*Trimethylpropyl*)*pyridine* (1).—Compound (1) was prepared by the reaction sequence shown in the Scheme. (−)-(*R*)-2,3,3-Trimethylbutanoic acid (2),[11] ($[\alpha]_D^{25}$ −36.1; 88% optical purity) was converted into (−)-(*R*)-2,3,3-trimethylbutanenitrile (3), by treatment with chlorosulphonyl isocyanate in boiling pentane and subsequent reaction with *NN*-dimethylformamide.[12,13] The nitrile (3) reacts with acetylene in the presence of (cyclopentadienyl)(cyclo-octadiene)cobalt(I) to afford the pyridine (1) in 77% yield. Since the mechanism proposed [12,13] for the reaction giving the nitrile does not involve the asymmetric carbon atom, it is reasonable to assume for (3), the same optical purity as the starting acid. However, it has been shown [14] that in the case of the cyclization of (+)-(*S*)-2-methylbutanenitrile to (+)-(*S*)-2-s-butylpyridine, about 9% racemization takes place; in view of this one must assign a minimum optical purity of 79% to (1).

U.v. and C.d. Spectra.—U.v. and c.d. spectra of (1) were measured in the 300—230 nm region, under various conditions of solvent and temperature. The u.v. spectrum of (1) in heptane solution (Figure 1) shows a structured band ($\varepsilon_{max.}$ 2 800 at $\lambda_{max.}$ 257 nm) with a broad, low-intensity tail on the higher energy side. Changing the solvent from a non-protic to a protic one (methanol) (Figure 1) results in an increase in intensity and the appearance of fine structure. In addition, the shoulder at longer wavelength is reduced, and the tail at shorter wavelength increased. In the same spectral region, the c.d. spectrum of (1) in heptane solution shows two bands of opposite sign at 270 ($\Delta\varepsilon_{max.}$ −2.6) and 243 nm ($\Delta\varepsilon_{max.}$ +0.2). On going to a protic solvent, like methanol, the intensity of the 270 nm band is strongly reduced ($R = -5.3 \times 10^{-40}$ in heptane; $R = -2.3 \times 10^{-40}$ in methanol), and a well-defined fine structure appears with $\lambda_{max.}$ 263 nm ($\Delta\varepsilon_{max.}$ −1.5). The band at 243 nm in heptane shifts to the blue, and the intensity increases on increasing the protic character of the solvent. In acidic medium (HCl–MeOH) the u.v. band suffers a loss of fine structure and an intensity enhancement (ε 7 900 at $\lambda_{max.}$ 265 nm) as is well known.[15] The intensity of the c.d. spectrum is strongly reduced ($\Delta\varepsilon_{max.}$ 0.6 at $\lambda_{max.}$ 265 nm) and no c.d. absorptions are observable in the range 220—250 nm. The effect of lowering the temperature on the u.v. and c.d. spectra as measured in hydrocarbon solution, is shown in Figure 2. On changing the temperature from 20 to −180 °C, the u.v. spectrum shows better resolution of the vibrational fine structure and a slight increase in intensity. More remarkable is the effect of lowering the temperature on the c.d. spectrum. In addition to the resolution of the fine structure, the intensity of both bands is increased [for the 270 nm band: R (20 °C) = -5.3×10^{-40} and $R(-180\ °\mathrm{C}) = -8.1 \times 10^{-40}$; for the 244 nm band: R (20 °C) = 0.18×10^{-40} and R (−180 °C) = 0.43×10^{-40}] and the higher energy one appears to be red-shifted. It is generally accepted [15] that the near-u.v. spectrum of pyridine is dominated by two electronic transitions between 300 and 220 nm: an $n \longrightarrow \pi^*$ ($^1A_1 \longrightarrow {}^1B_1$) excitation at lower energy and a $\pi \longrightarrow \pi^*$ ($^1A_1 \longrightarrow {}^1B_2$, ^1L_b) excitation at higher energy. The existence of a second $n \longrightarrow \pi^*$ transition ($^1A_1 \longrightarrow {}^1A_2$) was proposed by Kasha.[16] Rush and Sponer,[17] discussing the absorption spectrum of 3-picoline, assumed the existence of another transition near the ^1L_b band, and they identified it with this second $n \longrightarrow \pi^*$ excitation. CNDO/S-CI calculations [18] by Jaffé *et al.* on the pyridine molecule predicted a transition of this kind at shorter wavelengths (221 nm) than the ^1L_b (253 nm) and the $^1A_1 \longrightarrow {}^1B_1$ transitions (295 nm); an analogous sequence was obtained in the picoline series. These results gave support to the findings of Smith *et al.*[5] on the c.d. spectra of some pyridylethylamines: they in fact assigned a c.d. maximum at 240 nm, observed in these spectra, to the $^1A_1 \longrightarrow {}^1A_2$ transition of the pyridine chromophore. Moreover, the data of Gottarelli and Samori' on the spectra of three isomeric pyridylethanols were interpreted [6] by assuming the existence of the second $n \longrightarrow \pi^*$ ($^1A_1 \longrightarrow {}^1A_2$)



Scheme

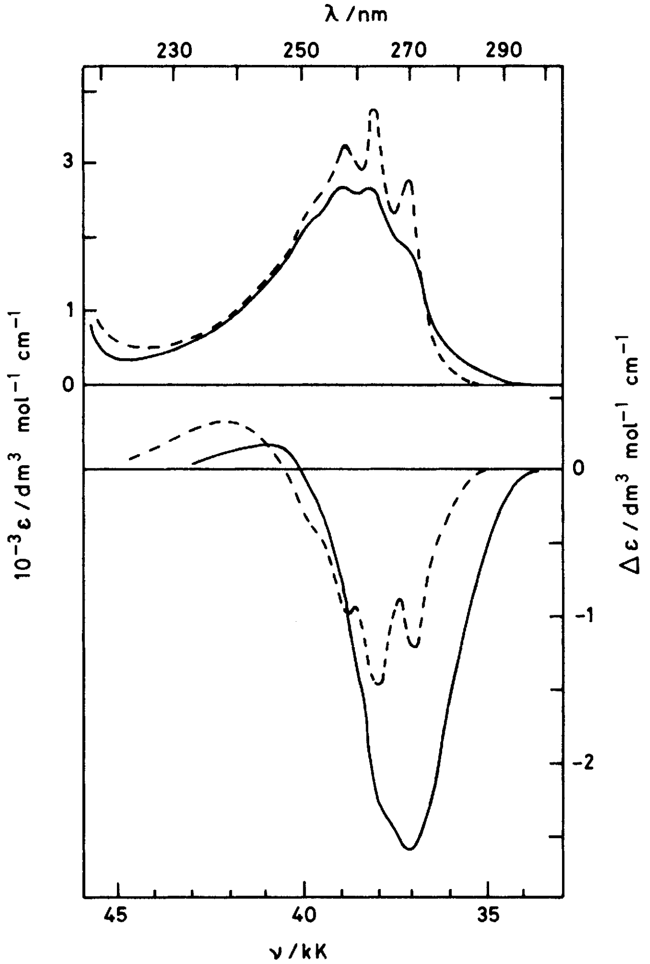


Figure 1. Electronic absorption (upper curves) and circular dichroism (lower curves) spectra of (1) in heptane (——) and in methanol (- - - -) solution

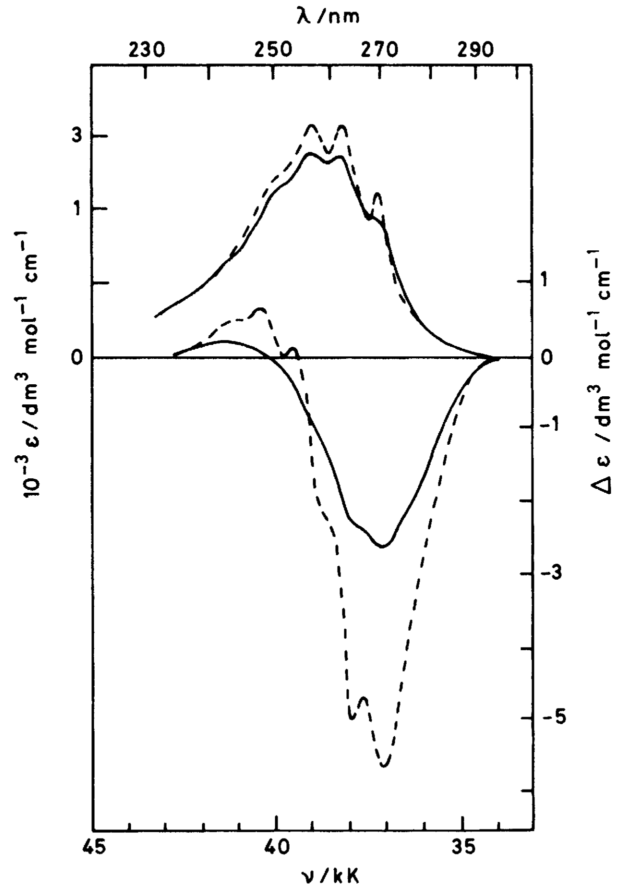


Figure 2. Electronic absorption and circular dichroism spectra of (1) in hydrocarbon solution at 20 °C (——) and at −180 °C (- - - -)

transition. Recent independent-systems calculations on some pyridine derivatives[7] and *ab intio* MO–CI computations[8] on 5,6,7,8-tetrahydroquinoline in a fixed, chiral conformation implied that the higher energy $n \longrightarrow \pi^*$ transition is, in practice, both electrically and magnetically forbidden and hence its contribution to the c.d. spectrum should be very weak. In contrast, the low energy $n \longrightarrow \pi^*$ transition is calculated to be magnetically allowed, and it should therefore contribute appreciably to the c.d. spectrum.

A reasonable interpretation of the spectral data reported in the present paper is as follows. The absorption spectrum is dominated by the $\pi \longrightarrow \pi^*$ ($^1A_1 \longrightarrow {}^1B_2$, ^1L_b) transition of the pyridine chromophore; the strong negative c.d. feature centred at 270 nm can then be considered as largely due to this transition. There is in fact a good correspondence between the vibrational structure of the u.v. and c.d. spectra in heptane and, particularly in methanol solution. Contributions to the c.d., on the long wavelength side of this band, coming from the low energy $n \longrightarrow \pi^*$ transition cannot be excluded: on passing from heptane to methanol the long-wavelength tail of the absorption spectrum is reduced and so, in a much more evident way, is the intensity of the c.d. spectrum. In addition, support for the presence of an $n \longrightarrow \pi^*$ transition on the low energy side of ^1L_b has been recently obtained by linear dichroism measurements [19] carried out on a molecule which is electronically very similar to (1), *i.e.* 2-methylpyridine. However the existence of this c.d. band for (1) requires that it contributes to the spectrum with a negative c.d., as does the ^1L_b transition. An assignment of this band to $^1A_1 \longrightarrow {}^1B_1$ excitation is in disagreement with the simple two-transition treatment proposed for the optical activity of the low-energy $^1A_1 \longrightarrow {}^1B_1$, $^1A_1 \longrightarrow {}^1B_2$ transitions of the pyridine chromophore.[4] This model gives opposite sign for the c.d. associated with these two transitions, and the independent-systems calculations by Yeh and Richardson [7] for some chiral pyridine derivatives support the same conclusions. However, Smith *et al.* have modified the foregoing two-transition treatment, taking into account the interaction of the low energy $n \longrightarrow \pi^*$ transition even with the high energy, electrically allowed excitations of the pyridine chromophore (the E_{1u} benzene-like states), providing an expression for the rotational strength of the $^1A_1 \longrightarrow {}^1B_1$ transition which is not simply that of the $^1A_1 \longrightarrow {}^1B_2(^1L_b)$ transition changed in sign. Contributions from the high-energy excitations are also present, and they could even affect the sign of the rotational strength, so an assignment of this absorption to the $^1A_1 \longrightarrow {}^1B_1$ transition cannot be disallowed on these grounds.

With regard to the 243 nm positive band, its $n \longrightarrow \pi^*$ character is indicated by the blue shift in going from hydrocarbon to methanol solution, and by its disappearance in acidic medium.

The increase in intensity of this band in methanol with respect to heptane solution can be explained by considering that the two electronic ^1L_b and 243 nm $n \longrightarrow \pi^*$ transitions are very close in energy, and the observed c.d. spectrum is due to two bands of opposite sign with extensive overlap between them. The blue shift of the 243 nm band reduces the overlap with the lower energy one, and the former is thus apparently increased in intensity. The existence of a dichroic band in this region is supported also by the low-temperature c.d. spectrum of (1) in hydrocarbon solution (Figure 2). The observed increase in rotational strength of both bands can be related to the higher conformational homogeneity of (1) at low temperature with respect to room temperature. However we stress that the change in rotational strength is more pronounced for the 243 nm band than for the 270 nm one: this fact, in addition to the observed red shift of the former band, can be explained in terms of a reduced width of the bands at low temperature and a resulting smaller overlap between them.

Conclusions

The u.v. and c.d. data in the range 300—230 nm of a mono-substituted alkylpyridine (an 'isolated' pyridine chromophore) can be interpreted in terms of three optically active transitions: a $\pi \longrightarrow \pi^*$ excitation at about 260 nm which is flanked by two $n \longrightarrow \pi^*$ transitions, one on the low- and the other on the high-energy side. If the energy order obtained for these transitions by means of *ab initio* [8] or semiempirical [18] MO computations is accepted, the two $n \longrightarrow \pi^*$ transitions can be assigned to the $^1A_1 \longrightarrow {}^1B_1$ and $^1A_1 \longrightarrow {}^1A_2$ excitations of the pyridine chromophore, respectively.

However, the present data afford additional experimental evidence of the existence of a second $n \longrightarrow \pi^*$ transition, which provides a non-negligible contribution to the c.d. spectrum. Taking into account the literature data,[1,8] it appears that this contribution is strongly dependent on the structure (nature and position of the substituents) of the pyridine derivatives examined. A study of the isomeric 3- and 4-(1,2,2-trimethylpropyl)pyridines could afford comparative data of importance in clarifying the c.d. spectrum of the pyridine chromophore in the near-u.v. region.

Experimental

Spectroscopic Measurements.—Electronic absorption spectra in the range 300—230 nm were obtained with a Cary 14 spectrophotometer and c.d. spectra, in the same range, with a JASCO J-500C spectropolarimeter. Hydrocarbon and methanol solutions (c 0.3—0.4 g l^{-1}) and standard cylindrical quartz cells (0.05—0.2 cm) were used.

(−)-(*R*)-2-(1,2,2-Trimethylpropyl)pyridine (1) in solvent heptane at 20 °C showed u.v. $\lambda_{max.}$ (ε) 268sh (1 950), 261 (2 750), 257 (2 800), and 252sh nm (2 300); c.d., $\lambda_{max.}$ (Δε) 270 (−2.6), 265sh (−2.4), 259sh (−1.2), and 243 nm (+0.2); and in solvent methanol at 20 °C showed u.v. $\lambda_{max.}$ (ε) 269 (2 250), 262 (3 200), 257 (3 330), and 253sh nm (2 600); c.d. $\lambda_{max.}$ (Δε) 270 (−1.2), 263 (−1.5), 257 (−1.0), and 237 nm (+0.3). A few drops of hydrochloric acid were added to the methanol solution in order to obtain the u.v. and c.d. spectra in acidic medium between 230 and 300 nm. In solvent 3-methylpentane at −180 °C compound (1) showed u.v. $\lambda_{max.}$ (ε) 269 (2 900), 262 (3 200), 257 (3 200), and 252sh nm (2 600); c.d. $\lambda_{max.}$ (Δε) 270 (−5.6), 264 (−5.0), 258 (−2.2), 253 (+0.1), 248 (+0.7), and 242 nm (+0.5).

Preparations.—G.l.c. analyses were performed on a Perkin-Elmer 3920B gas-chromatograph. Optical rotations were measured with a Perkin-Elmer 241 instrument, (−)(*R*)-2,3,3-trimethylbutanoic acid (2) and (−)-(*R*)-2,3,3-trimethylbutanenitrile (3) were obtained following procedures described previously.[11-14]

(−)-(R)-2-(1,2,2-*Trimethylpropyl)pyridine.*—To the nitrile (3) (4 g, 0.04 mol), $[\alpha]_D^{25}$ −5.78 (c 3.3, pentane) in dry toluene (6 cm^3) was added, under nitrogen (cyclopentadienyl)(cyclooctadiene) cobalt (500 mg, 0.022 mol). The red-brown solution obtained was introduced into a stainless steel autoclave (150 ml), which, after charging with C_2H_2 (15 atm) was rocked in an oil-bath at 140 °C. After 20 h, 25 atm of gas had been absorbed. The solution was diluted with ether and treated with 5% HCl; the aqueous layer was continuously extracted with ether, treated with 20% NaOH, and again continuously extracted with ether. The ethereal fractions were kept overnight on Na_2SO_4; evaporation and distillation under reduced pressure then gave the product (1) (5 g, 0.0306 mol, 77%), b.p. 85—86 °C at 12 mmHg (Found: C, 80.7; H, 10.3; N, 8.4. $C_{11}H_{17}N$ requires C, 80.9; H, 10.5; N, 8.6%), $[\alpha]_D^{25}$ −31.81° (c 2.078, ethanol); δ (60 MHz; CCl_4) 0.91 (9 H, s, CMe_3), 1.30 (3 H, d, CH_3CH), 2.70 (1 H, m, q, $CHCH_3$), 6.90 (1 H, m, pyridine H-3), 7.02 (1 H, m, pyridine H-5), 7.42 (1 H, m, pyridine H-4), and 8.45 (1 H, m, pyridine H-6).

Note added in proof: A detailed study of the u.v. and c.d. spectra of 2- and 3- and 4-s-butylpridine in acidic and hydrocarbon media has recently been carried out by P. Pino and his co-workers (*Helv. Chim. Acta.*, 1982, **65**, 2102).

References

1 A. Tomita, E. Ochiai, H. Hirei, and S. Makishima, *J. Org. Chem.*, 1966, **31**, 4307.

2 J. C. Craig and S. K. Roy, *Tetrahedron*, 1965, **21**, 401.

3 G. Gottarelli and B. Samori', *Tetrahedron Lett.*, 1970, 2055.

4 G. Gottarelli and B. Samori', *J. Chem. Soc., Perkin Trans. 2*, 1972, 1998.

5 H. E. Smith, L. J. Schaad, R. B. Banks, C. J. Wiant, and C. F. Jordan, *J. Am. Chem. Soc.*, 1973, **95**, 811.

6 G. Gottarelli and B. Samori', *J. Chem. Soc., Perkin Trans. 2*, 1974, 1562.

7 C.-Y. Yeh and F. S. Richardson, *J. Chem. Soc., Faraday Trans. 2*, 1976, 331.

8 S. Gladiali, G. Gottarelli, B. Samori', and P. Palmieri, *J. Chem. Soc., Perkin Trans. 2*, 1980, 598.

9 P. Salvadori, L. Lardicci, R. Menicagli, and C. Bertucci, *J. Am. Chem. Soc.*, 1972, **94**, 8598.

10 P. Salvadori, O. Piccolo, C. Bertucci, R. Menicagli, L. Lardicci, *J. Am. Chem. Soc.*, 1980, **102**, 6859.

11 M. Farina and E. Mostardini Peronaci, *Chim. Ind. (Milan)*, 1966, **48**, 602.

12 G. Lohaus, *Chem. Ber.*, 1967, **100**, 2719.

13 C. Botteghi, G. Chelucci, and M. Marchetti, *Synth. Commun.*, 1982, **12**, 25.

14 D. Tatone, T.-C. Dich, R. Nacco, and C. Botteghi, *J. Org. Chem.*, 1975, **40**, 2987.

15 (*a*) H. H. Jaffé and M. Orchin, 'Theory and Application of Ultraviolet Spectroscopy,' Wiley, New York, 1962, p. 361; (*b*) J. N. Murrell, 'The Theory of the Electronic Spectra of Organic Molecules,' Methuen, London, 1963, p. 176.

16 M. Kasha, *Disc. Faraday Soc.*, 1950, **9**, 14.

17 J. H. Rush and H. Sponer, *J. Chem. Phys.*, 1952, **20**, 1847.

18 R. L. Ellis, G. Kuehulenz, and H. H. Jaffé, *Theor. Chim. Acta*, 1972, **26**, 131.

19 G. Gottarelli, B. Samori', and R. D. Peacock, *J. Chem. Soc., Perkin Trans. 2*, 1976, 1208.

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