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CRYSTALLINE-STATE RACEMIZATION BY X-RAY EXPOSURE IN COBALOXIME COMPLEXES

Yuji OHASHI, Yoshio SASADA, and Yoshiaki OHGO*
Laboratory of Chemistry for Natural Products, Tokyo Institute of Technology, Nagatsuta, Midori-ku, Yokohama 227
*Niigata College of Pharmacy, 5829 Kamishinei-cho, Niigata 950-21

A new example of the direct observation on the racemization of the α-cyanoethyl group by X-ray exposure is obtained with the crystal of S-α-cyanoethyl(S-α-methylbenzylamine)cobaloxime, the diastereoisomer of the previously reported compound [Ohashi and Sasada, Nature, 267, 142 (1977)]. The structure and the thermal behavior of the present crystal are similar to those of the crystal of its diastereoisomer. This fact confirms the previous proposal on the mechanism of the racemization.

Recently we have found that the crystal of R-α-cyanoethyl(S-α-methylbenzylamine)cobaloxime changes its unit cell dimensions by X-ray exposure without degradation of a single crystal form, and proved from the electron density calculation that the change reflects the racemization of the cyanoethyl group.$^{1)}$ When the crystal was cooled below 173 K, the gradual change of its unit cell dimensions by X-ray exposure was no longer detectable. From the structure analyses at 173 K and room temperature, the mechanism of the racemization was proposed.$^{2)}$

Since it seemed necessary to study comprehensively this quite new finding, we have tried to examine the behavior of S-α-cyanoethyl(S-α-methylbenzylamine)-cobaloxime(Fig.1), which exhibits a different crystalline field. This complex, hereafter abbreviated to S-S, is the diastereoisomer of the previously reported cobaloxime complex (R-S). The crystal of the S-S complex also changes its unit cell dimensions by X-ray exposure without degradation of a single crystal form. The values of *b* and β increase remarkably, whereas the value of *c* decreases appreciably. After about 30 days, the changes are within the experimental errors. The space group, $P2_1$, remains unaltered. The values of the cell dimensions at the initial and final stages are listed in Table 1, in which the corresponding values for the R-S crystal are also shown. Although the rate of the changes of *a*, *b*, *c* and β is different for both crystals, the changes of the volume resemble each other.

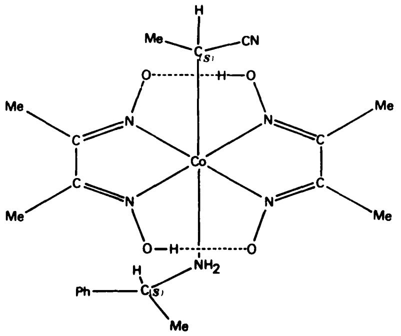

Fig.1 S-α-cyanoethyl(S-α-methylbenzylamine)cobaloxime.

When the crystal was cooled below 173 K, the

Table 1 The change of the unit cell dimensions

	S-S complex				R-S complex		
	initial	final	Δ		initial	final	Δ
a	8.768(2)Å	8.818(2)Å	+0.050Å	*a*	8.665(2)Å	8.637(2)Å	-0.028Å
b	13.356(2)	13.707(2)	+0.351	*b*	13.485(3)	13.833(3)	+0.348
c	9.538(3)	9.417(3)	-0.121	*c*	9.584(3)	9.539(3)	-0.045
β	96.73(3)°	98.77(3)°	+2.04°	β	96.95(3)°	99.07(3)°	+2.12°
V	1109.3(4)Å^3	1124.9(5)Å^3	+15.6Å^3	*V*	1111.6(5)Å^3	1125.5(4)Å^3	+13.9Å^3

gradual change of its unit cell dimensions by X-rays was no longer detectable. This fact is also found in the R-S crystal. In Fig.2, the relative values of *a*, *b*, *c* and β to those at 133 K are plotted against temperature. In view of experimental error, there are no discontinuities with temperature. The linear coefficients of thermal expansion were derived to be 1.12×10^{-4}, 0.86×10^{-4} and 0.66×10^{-5} K^{-1} for *a*, *b* and *c*, respectively. The thermal expansion of the present crystal is not so anisotropic as that of the R-S crystal, in which the corresponding coefficients are -1.00×10^{-4}, -0.10×10^{-4} and 2.95×10^{-4} K^{-1}, respectively.

In order to interpret this observation on the basis of the crystal structure, the three-dimensional intensity data at the initial, intermediate and final stages were collected at 293 K. The crystal structure at the initial stage is shown in Fig.3, in which the atoms neighboring the α-cyanoethyl group and the short interatomic distances are depicted. The electron density at the intermediate stage indicates that the occupancy of the methyl of the cyanoethyl group decreases significantly and a new peak appears. At the final stage the height of the new peak is

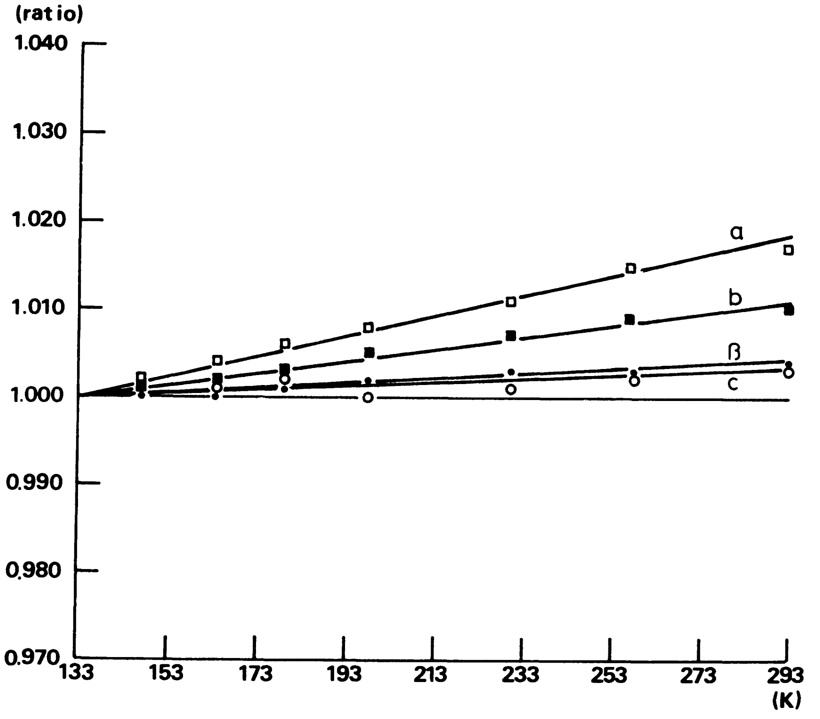

Fig.2 The change of the unit cell dimensions with temperature. Each value is normalized by the corresponding one at 133 K; 8.623(4), 13.222(4), 9.514(6) Å and 96.32(7)° for *a*, *b*, *c* and β, respectively. The crystal was cooled by nitrogen gas flow method.

nearly the same as that of the methyl group. Figure 4 shows the molecular structure at the final stage. The position of the new peak, C(20), corresponds to that of the methyl group if the absolute configuration of the cyanoethyl group is converted from S to R with the cyano group fixed.

The epimerized structure shown in Fig.4, however, is not the same as that obtained from the R-S complex. Two racemates of the cyanoethyl groups differ from one another in rotation angle around the axial Co-C bond, that is, the torsion angle of N(1)-Co-C(17)-C(19) of one racemate is different by about 180° from that of another racemate. This is caused by the fact that at the initial stage the torsion angle of N(1)-Co-C(17)-C(19) in the present complex differs by about 180° from that of the R-S complex.

The cyano group, as shown in Fig.3, makes close contacts with the neighboring

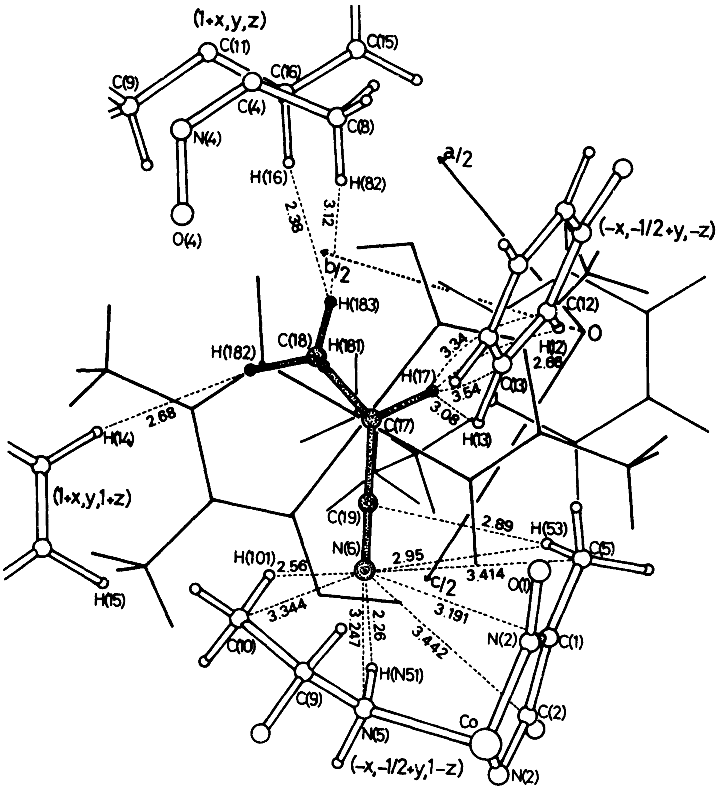

Fig.3 The atoms in the vicinity of the α-cyanoethyl group and the short interatomic distances at 293 K. The shaded atoms are those of the α-cyanoethyl group in the original unit. The coordinates in parentheses indicate the equivalent positions.

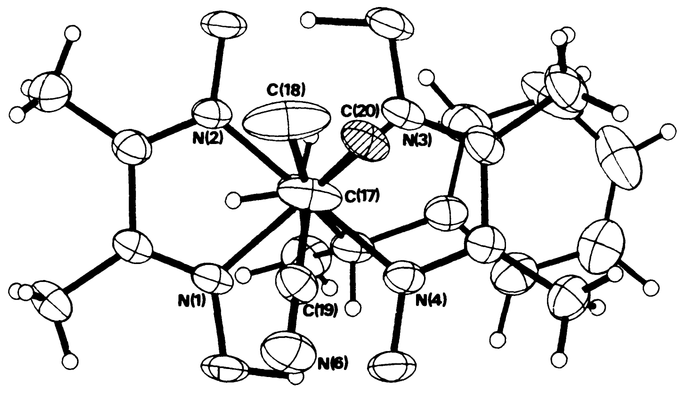

Fig.4 The epimerized structure at 293 K viewed along the normal to the average plane of the cobaloxime. The thermal ellipsoids are drawn at 30% probability. The hydrogen atoms of the α-cyanoethyl group cannot be found in the difference map. The difference in thermal ellipsoids of C(18) and C(20) may indicate that the occupancy factors of these atoms are not exactly equal.

molecule at -x, -1/2+y, 1-z. In particular, the N(6) atom forms a weak hydrogen bond with N(5). On the other hand, the methyl of the cyanoethyl group makes fairly loose contacts with the neighboring molecules, except the contact between H(183) and H(16) of the adjoining molecule along the a axis. Moreover, the H(17) atom makes very loose contacts with the neighboring molecule related by 2_1 symmetry, leaving a space around it.

These structural features are similar to those of the R-S crystal. The local structure around the cyanoethyl group in the present crystal is constructed by visualizing the image of the corresponding structure of the R-S crystal in the mirror, in which the S-cyanoethyl group is the image of its enantiomeric group of the R-S crystal, except the minor difference around the asymmetric carbon atom, C(9). These facts strongly suggest that the planar cyanoethyl radical produced by the Co-C bond cleavage rotates around the C-C≡N bond to face the opposite side of the plane to the cobalt atom and recombines with the cobalt atom to give the racemic cyanoethyl group. The methyl group transferred to the racemic position, C(20), fills up the space around H(17). The space is, however, so small for the methyl group that the molecule related by 2_1 symmetry must be pushed out along the b axis and the value of *b* should increase as the racemic cyanoethyl groups grow.

The crystal structure at 173 K was analyzed, in order to clarify the inhibition of the gradual change of the unit cell dimensions by X-ray exposure. As shown in Table 1, the crystal contracts along the a and b axes when it is cooled. At 173 K, the interatomic distances of H(17)...C(12), H(17)...C(13), H(17)...H(12) and H(17)...H(13) are reduced to 3.15, 3.26, 2.50 and 2.78Å, respectively. The other short interatomic distances are not so much reduced as those including H(17). This fact indicates that the space around H(17) is filled up when the crystal is cooled, and that the cyanoethyl radical cannot rotate around the C-C≡N bond because of the large steric repulsion between the methyl group of the cyanoethyl radical and the phenyl group at -x, -1/2+y, -z. Therefore, the space around H(17) results in the racemization in the crystalline state and the abnormally anisotropic thermal expansion.

In the previous papers,[1,2] we proposed the mechanism of the racemization in the crystalline state, by analyzing the crystal structure and the thermal behavior of the R-S crystal. The hypothesis holds good for the S-S crystal, although it has the different crystalline field from the R-S crystal. It is worth noting that both crystals have common features as follows; (1) the molecule in the crystal contains a bond which is sensitive to X-ray or the electromagnetic waves of longer wavelengths than X-ray, and (2) the very loose contacts neighboring the bond are found in the crystal structure. For the crystal of R-α-methoxycarbonylethyl(R-α-methylbenzylamine)cobaloxime,[3] such racemization was not observed because the second condition is not fulfilled. However, it seems quite plausible to say that there may be many crystals satisfying these two conditions and the different kinds of crystalline-state reaction would be found.

References

1) Y. Ohashi and Y. Sasada, Nature, 267, 142 (1977).
2) Y. Ohashi, Y. Sasada, and Y. Ohgo, Chem. Lett., 1978, 457.
3) Y. Ohashi and Y. Sasada, Bull. Chem. Soc. Jpn., 50, 2863 (1977).

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