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Stereoselective Isomerization Reactions of the (Ethylenediamine-*N,N′*-diacetato)(ethylenediamine)cobalt(III) and (Ethylenediamine-*N,N′*-diacetato)(glycinato)cobalt(III) Complexes in a Basic Aqueous Solution

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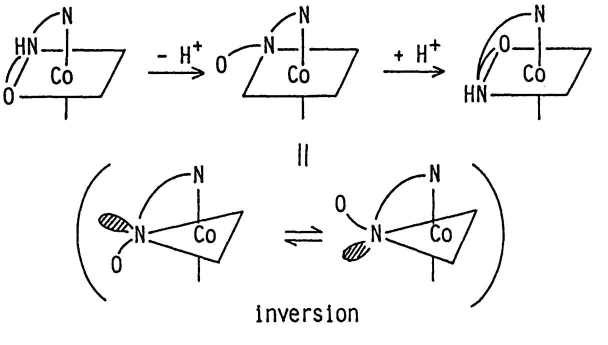
Isomerization reactions of the [Co(edda)(en)]$^+$ and [Co(edda)(gly)] systems were studied in a basic aqueous solution. $\Lambda(R)$-β-[Co(edda)(en)]$^+$ isomerized to the $\Delta(S,S)$-α-isomer with an optical purity (o.p.) of ca. 45%. In the reactions of three isomers of [Co(edda)(gly)], $\Lambda(R)$-β-*fac*(O) isomerized to $\Lambda(R)$-β-*mer*(O) (o.p.: ca. 100%) and $\Delta(S,S)$-α-*mer*(O) (o.p.: ca. 33%), $\Lambda(R)$-β-*mer*(O) to $\Lambda(R)$-β-*fac*(O) (o.p.: ca. 65%) and $\Delta(S,S)$-α-*mer*(O) (o.p.: ca. 40%), and $\Delta(S,S)$-α-*mer*(O) to $\Lambda(R)$-β-*fac*(O) (o.p.: ca. 50%) and $\Lambda(R)$-β-*mer*(O) (o.p.: ca. 60%). These results were explained on the basis of a Co–O bond-rupture mechanism.

Over the last few years we have been investigating the coordination site exchange reactions of cobalt(III) complexes containing the terdentate ligands such as edma, ida, and dien.[1] The *fac*-type isomers of [Co(edma)$_2$]$^+$ isomerized to other one with an inversion at one of the secondary nitrogen (sec-N) centers of the coordinated edma ligands.[2] In order to interpret the inversion-isomerization reaction, we proposed a bond-rupture mechanism, as shown in Scheme 1: the coordination site was exchanged between the sec-N and carboxylato oxygen (O) atoms; consequently, the asymmetry at the sec-N center was inverted. The stereoselective isomerization reactions of the [Co(ida)(edma)],[3] [Co(mida)(edma)],[4] and [Co(edma)(mdien)]$^{2+}$ [5] systems were also explained by the same mechanism as that described above. It is interesting to study whether such a isomerization mechanism for terdentate complexes can also be applied to the isomerization reactions of quadridentate complexes, such as [Co(edda)(en)]$^+$ and [Co(edda)(gly)] (where edda denotes ethylenediamine-*N,N′*-diacetate dianion).

As shown in Fig. 1, [Co(edda)(en)]$^+$ and [Co(edda)(gly)] provide two and three geometrical isomers, respectively. The sec-N atoms of the coordinated edda ligand are chiral centers. In the α-type isomers, the chiralities around two sec-N atoms are restricted by the absolute configuration around the Co(III) ion. Therefore, the possible configurations for the α-type isomer are $\Delta(R,R)$ and $\Lambda(S,S)$. (R and S denote the chiralities around the asymmetric nitrogen.) In β-type isomers, the two sec-N atoms of the coordinated edda ligand are in different situations; one is in the in-plane glycinate ring (with respect to the ethylenediamine ring of edda), and the other is in the out-of-plane glycinate ring. The sec-N atom of the out-of-plane glycinate ring is in the same situation as that in the case of the α-type isomer. Therefore, the chirality around the sec-N atom is restricted by the absolute configuration around the Co(III) ion. The sec-N atom of the in-plane glycinate ring, however, can adopt either of two possible chiralities (R or S). The possible configurations for [Co(edda)(en)]$^+$ and [Co(edda)(gly)] are listed in Table 1, where the chirality around the sec-N atom of the in-plane glycinate ring is not taken into consideration.



Scheme 1.

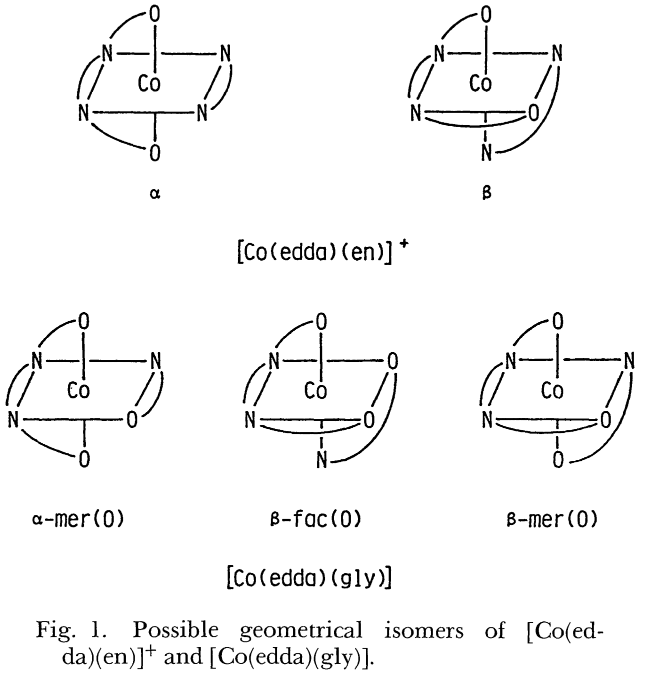


Fig. 1. Possible geometrical isomers of [Co(edda)(en)]$^+$ and [Co(edda)(gly)].

Table 1. Possible Configurations and CD Signs of $[\mathrm{Co(edda)(en)}]^+$ and [Co(edda)(gly)]

Geometrical isomer	Possible configuration and CD sign	
$[\mathrm{Co(edda)(en)}]^+$		
α	$(+)^{\rm CD}_{535}$-$\Lambda(S,S)$	$(-)^{\rm CD}_{535}$-$\Delta(R,R)$
β	$(+)^{\rm CD}_{483}$-$\Lambda(R)$	$(-)^{\rm CD}_{483}$-$\Delta(S)$
[Co(edda)(gly)]		
α-*mer*(*O*)	$(+)^{\rm CD}_{543}$-$\Lambda(S,S)$	$(-)^{\rm CD}_{543}$-$\Delta(R,R)$
β-*mer*(*O*)	$(+)^{\rm CD}_{509}$-$\Lambda(R)$	$(-)^{\rm CD}_{509}$-$\Delta(S)$
β-*fac*(*O*)	$(+)^{\rm CD}_{522}$-$\Lambda(R)$	$(-)^{\rm CD}_{522}$-$\Delta(S)$

All of the geometrical isomers of the $[\mathrm{Co(edda)(en)}]^+$ and [Co(edda)(gly)] complexes have been separated and optically resolved.[6–10] The absolute configurations of α- and β-$[\mathrm{Co(edda)(en)}]^+$ were assigned on the basis of CD data,[8,9] and checked by a comparison of CD data with those of α- and β-$[\mathrm{Co(edda)}(R\text{-pn})]^+$ of which the absolute configurations were determined.[11–13] The absolute configurations of three geometrical isomers of [Co(edda)(gly)] were assigned on the basis of the CD spectral patterns.[10] An additional check of the assignment was performed using the ^{1}H NMR data of these isomers containing optically active edda ($^-$OCO-C*HD-NH-$\mathrm{CH_2}$-$\mathrm{CH_2}$-NH-C*HD-COO$^-$; Chiralities around C* atoms are *R* configuration).[14] The isomerization reaction of racemic β-$[\mathrm{Co(edda)(en)}]^+$ has been studied in a carbonate buffered solution, and a Co-N(en) bond-rupture mechanism has been proposed.[15,16] We also presented preliminary results concerning the reactivities of the optically active $[\mathrm{Co(edda)(en)}]^+$ and [Co(edda)(gly)] complexes.[17] In this paper we describe a detailed study of the isomerization reactions of these optically active complexes.

Experimental

Complexes. $(-)^{\rm CD}_{535}$-$\Delta(R,R)$-α-$[\mathrm{Co(edda)(en)}]\mathrm{NO_3\cdot H_2O}$ and $(+)^{\rm CD}_{483}$-$\Lambda(R)$-β-$[\mathrm{Co(edda)(en)}]\mathrm{Cl\cdot 3H_2O}$. These complexes were prepared by the use of a different method from those described in the literature.[7,8]

To a solution (50 cm^3) containing 2.91 g (0.01 mol) of $\mathrm{Co(NO_3)_2\cdot 6H_2O}$ and 1.76 g (0.01 mol) of ethylenediamine-*N,N′*-diacetic acid ($\mathrm{H_2}$edda), 7.6 cm^3 of a 10% ethylenediamine aqueous solution was slowly added; the mixed solution was then adjusted to pH 6 with 1 M HCl (M=mol dm^{-3}). The pH being kept constant at 6, 4.78 g of $\mathrm{PbO_2}$ was stirred into the solution in small portions at 60 °C over a 1 h period. After the mixture was cooled to room temperature, insoluble materials were removed by filtration. The filtrate was chromatographed on an SP-Sephadex C-25 column (4.7 cm×90 cm, $\mathrm{K^+}$ form) using 0.2 M KCl as an eluent. Each eluate of purple and red bands was concentrated under reduced pressure; methanol was then added into the concentrated solution in order to eliminate KCl. Chloride salts of α- and β-$[\mathrm{Co(edda)(en)}]^+$ were obtained from desalted purple and red solutions, respectively. These isomers were recrystallized from water by adding methanol.

Optical resolutions of α- and β-[Co(edda)(en)]Cl were carried out according to methods described in the literature.[8,9] Found for $(-)^{\rm CD}_{535}$-α isomer: C, 25.96; H, 5.51; N, 18.79%. Calcd for $[\mathrm{Co(edda)(en)}]\mathrm{NO_3\cdot H_2O}=\mathrm{C_8H_{20}N_5O_8Co}$: C, 25.75; H, 5.40; N, 18.77%. Found for $(+)^{\rm CD}_{483}$-β isomer: C, 25.34; H, 6.47; N, 14.65%. Calcd for $[\mathrm{Co(edda)(en)}]\mathrm{Cl\cdot 3H_2O}=\mathrm{C_8H_{24}N_4O_7ClCo}$: C, 25.11; H, 6.32; N, 14.64%.

$(+)^{\rm CD}_{509}$-$\Lambda(R)$-β-*Mer*(*O*)-[Co(edda)(gly)], $(+)^{\rm CD}_{543}$-$\Lambda(S,S)$-α-*Mer*(*O*)-$[\mathrm{Co(edda)(gly)}]\cdot\mathrm{H_2O}$, and $(+)^{\rm CD}_{522}$-$\Lambda(R)$-β-*Fac*(*O*)-$[\mathrm{Co(edda)(gly)}]\cdot\mathrm{H_2O}$: Though the preparation and resolution of three geometrical isomers of [Co(edda)(gly)] have been reported in the literature,[9,10] β-*mer*(*O*) prepared by a method described in the literature[10] tends to include α-*mer*(*O*) as a contaminant. Therefore, the following method was used.

A solution containing 1.76 g (0.01 mol) of $\mathrm{H_2}$edda, 0.75 g (0.01 mol) of Hgly, and 2.38 g (0.01 mol) of $\mathrm{CoCl_2\cdot 6H_2O}$ in 50 cm^3 of water was adjusted to pH 5 with a 1 M NaOH solution. The pH being kept constant at 5, $\mathrm{PbO_2}$ (7 g) was stirred into the solution at 40 °C. After 1 h, insoluble materials were removed by filtration. The filtrate was poured onto an SP-Sephadex column (10 cm×25 cm, $\mathrm{K^+}$ form) and eluted with water. Cationic complexes were adsorbed on the top of the column and anionic complexes were eluted prior to neutral complexes. The band containing neutral complexes was transferred to another SP-Sephadex column (4.7 cm×90 cm, $\mathrm{K^+}$ form). By development with water, the band was separated into two parts: dark purple (a mixture of α-*mer*(*O*) and β-*mer*(*O*)) and pink (β-*fac*(*O*)). The dark purple band was transferred to a QAE-Sephadex column (4.7 cm×90 cm, $\mathrm{Cl^-}$ form) and separated into two parts, violet (α-*mer*(*O*)) and brown (β-*mer*(*O*)), by a recyclic development with water. The eluates of the three bands (pink, brown, and violet) were directly used for optical resolution.

The violet (α-*mer*(*O*)) solution was concentrated to ca. 50 cm^3 under reduced pressure and repeatedly developed on a QAE-Sephadex column (4.7 cm×90 cm, $\mathrm{Sb_2(tart)_2}^{2-}$ form), by which means $(+)^{\rm CD}_{543}$- (earlier eluate) and $(-)^{\rm CD}_{543}$-violet (later eluate) bands were separated. Each solution eluted from the two bands was concentrated under reduced pressure; ethanol was then added to the concentrated solution in order to obtain crystals. Recrystallization was carried out from water by adding ethanol.

The brown (β-*mer*(*O*)) and pink (β-*fac*(*O*)) solutions were also chromatographed on a QAE-Sephadex column ($\mathrm{Sb_2(tart)_2}^{2-}$ form) and optically resolved. The optically active isomers were crystallized in a similar manner as described above. In the chromatography of the brown solution, the adsorbed band was not completely separated into two bands upon recyclic development over several days; the head ($(+)^{\rm CD}_{509}$-brown) and tail ($(-)^{\rm CD}_{509}$-brown) parts of the broadened band were thus fractionally collected to obtain optically active isomers. In the chromatography of the pink solution, $(+)^{\rm CD}_{522}$-pink band was eluted earlier. The absorption and CD data of the three geometrical isomers are shown in Fig. 2 and Table 2. Found for $(+)^{\rm CD}_{509}$-β-*mer*(*O*): C, 31.15; H, 4.68; N, 13.39%. Calcd for $[\mathrm{Co(edda)(gly)}]=\mathrm{C_8H_{14}N_3O_6Co}$: C, 31.28; H, 4.59; N, 13.68%. Found for $(+)^{\rm CD}_{543}$-α-*mer*(*O*): C, 29.61; H, 5.05; N, 12.82%, and for $(+)^{\rm CD}_{522}$-β-*fac*(*O*): C, 29.29; H, 5.04; N, 12.65%. Calcd for $[\mathrm{Co(edda)(gly)}]\cdot\mathrm{H_2O}=\mathrm{C_8H_{16}N_3O_7Co}$: C, 29.55; H, 4.96, N, 12.92%.

Isomerization. $\Lambda(R)$-β-$[\mathrm{Co(edda)(en)}]\mathrm{Cl\cdot 3H_2O}$: All of the chemicals used were of a reagent grade, and deionized water was degassed before use. This isomer (0.300 g) was

Table 2. Absorption (AB) and CD Spectral Data of [Co(edda)(gly)]

Isomer	AB(ε)/nm	CD($\Delta\varepsilon$)/nm
$\Lambda(S,S)$-α-*mer*(O)	543(89)	543(+4.73)
	ca. 470 sh	464(−1.95)
	372(111)	384(+0.33)
		350(+0.26)
$\Lambda(R)$-β-*fac*(O)	519(239)	522(+1.52)
	374(173)	410(+0.056)
		368(−0.80)
$\Lambda(R)$-β-*mer*(O)	ca. 580 sh	597(−0.13)
	493(144)	509(+2.71)
	370(172)	363(−1.20)

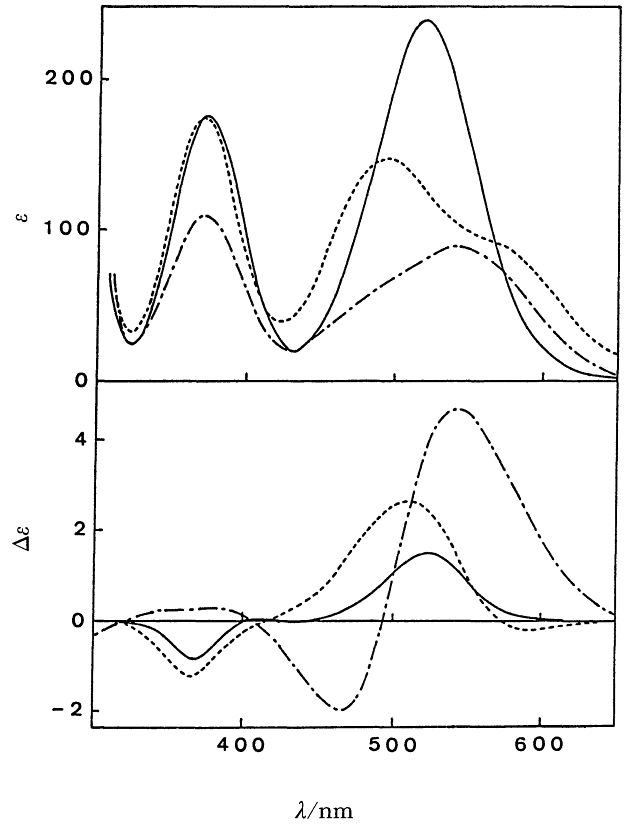


Fig. 2. Absorption and CD spectra of [Co(edda)(gly)]: $\Lambda(S,S)$-α-*mer*(O) (— - —), $\Lambda(R)$-β-*mer*(O) (------), and $\Lambda(R)$-β-*fac*(O) (——).

dissolved in 100 cm^3 of water in a reaction vessel kept in a thermostated bath at 40.0 °C. The reaction was started by stirring 100 cm^3 of a buffer solution [Na_2CO_3(2.2012 g)-$NaHCO_3$(0.6792 g)] previously kept at 40.0 °C into the reaction vessel. The reaction conditions were as follows: Complex concentration, 3.90×10^{-3} M; pH, 10.30±0.02; temperature, 40.0±0.1 °C. The temperature and pH of the reaction solution were checked with a thermistor thermometer (Takara D221) and a pH meter (Toa TSC-10A), respectively, throughout the kinetic run.

At prescribed time intervals, 20 cm^3 of the reaction solution was taken out and acidified to pH 5 with 1 M HCl in order to stop the reaction. The acidified solution was poured onto an SP-Sephadex C-25 column (2.7 cm×40 cm, K$^+$ form) and developed with 0.2 M KCl. The adsorbed band was separated into two bands: purple (α) and red (β). Each of the eluates was concentrated under reduced pressure to a constant volume (50.0 or 20.0 cm^3) and used for the measurements of the absorption and CD spectra. These spectra were recorded by a JASCO UVIDEC-670 spectrophotometer and a JASCO J-22 spectropolarimeter, respectively. The amounts and optical purities were calculated based on the following data:

$\Lambda(R)$-β: $\lambda_{\max}(\varepsilon)$, 493 nm (170); $\lambda_{\text{ext}}(\Delta\varepsilon)$, 483 nm (+2.24).

$\Lambda(S,S)$-α: $\lambda_{\max}(\varepsilon)$, 529 nm (87.3); $\lambda_{\text{ext}}(\Delta\varepsilon)$, 535 nm (+4.46).

Three Isomers of [Co(edda)(gly)]: The isomerization reaction of each isomer was carried out by a procedure similar to that used for β-[Co(edda)(en)]$^+$. The reaction conditions were as follows. For $\Lambda(R)$-β-*fac*(O): Complex concentration, 3.08×10^{-3} M; pH, 10.30±0.02; temperature, 40.0±0.1 °C. For $\Lambda(R)$-β-*mer*(O): Complex concentration, 3.26×10^{-3} M; pH, 10.28±0.02; temperature, 40.0±0.1 °C. For $\Lambda(S,S)$-α-*mer*(O): Complex concentration, 2.64×10^{-3} M; pH, 10.28±0.02; temperature, 40.0±0.1 °C.

The aliquot (40.0 cm^3) of the reaction solution, which was taken out at prescribed time intervals, was acidified to pH 5 in order to stop the reaction, and then concentrated to 20—10 cm^3 under reduced pressure at ca. 35 °C. The concentrated solution was chromatographed on a QAE-Sephadex column (3.0 cm×70 cm, Cl$^-$ form) using water as an eluent; two bands of el 1 (a mixture of α-*mer*(O) and β-*mer*(O)) and el 2 (β-*fac*(O)) were separated. The two eluates were collected separately and concentrated to appropriate constant volumes. The amount and optical purity of each isomer were determined from absorption and CD data. The amounts and optical purities of two isomers in el 1 were estimated from binary-curve analyses of the absorption and CD spectra. In these curve analyses, the spectral data at 20 points in the visible region were used; the analyses were carried out on an NEC PC-9801F computer using a least-squares method.

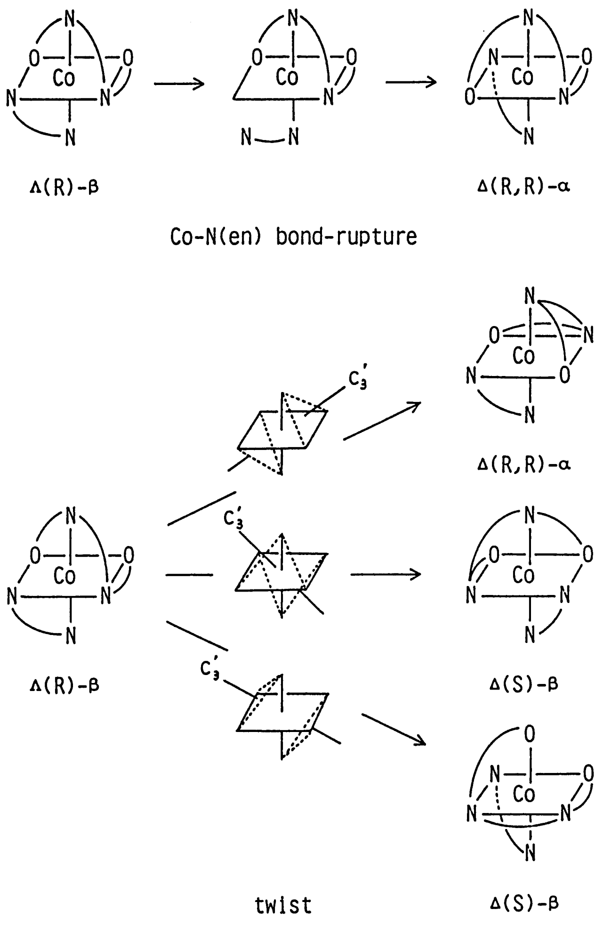
In weakly acidic and neutral solutions at room temperature, the absorption and CD spectral changes of all the isomers were very slow. Therefore, the progress of the isomerization reaction during such procedures as chromatographic separation and concentration under reduced pressure was ignored.

Results and Discussion

Base-Catalyzed Isomerization Reaction. $\Lambda(R)$-β-[Co(edda)(en)]$^+$: The isomerization reaction of $\Lambda(R)$-β was followed under the conditions of pH 10.30 and 40.0 °C. Table 3 shows the change in the proportions of the starting material and product together with the enantiomeric excess percentage of each isomer. Throughout the reaction, no other products were detected by the present experimental method. The proportion of the starting material ($\Lambda(R)$-β) decreased more rapidly compared with the decrease-rate of its optical purity. This fact means that the racemization of $\Lambda(R)$-β is very slow. (Under the conditions of pH 10.20 and 40.0 °C, the absorption and CD spectra of

Table 3. The Proportions and Optical Purities of the Starting Material and Product in the Isomerization Reaction of β-[Co(edda)(en)]$^+$ (40.0 °C, pH 10.30)

t	Isomer proportion (Optical purity/%)	
h	Λ(*R*)-β	Λ(*S*,*S*)-α
2	0.99(99)	0.01(36)
6	0.95(96)	0.05(45)
12	0.87(94)	0.13(46)
20	0.75(90)	0.25(45)
30	0.63(85)	0.37(45)
48	0.46(77)	0.54(42)



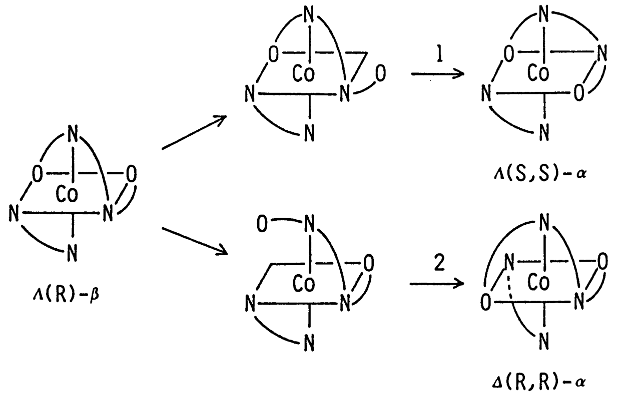
Scheme 2.

Λ(*S*,*S*)-α were almost constant over 50 h, indicating that the racemization and isomerization of Λ(*S*,*S*)-α may be ignored under the present reaction conditions.) The optical purity of Λ(*S*,*S*)-α formed from Λ(*R*)-β was nearly constant (ca. 45%) throughout the present reaction (48 h). Accordingly, it is thought that Λ(*R*)-β isomerizes to Λ(*S*,*S*)- and Δ(*R*,*R*)-α with a constant ratio (73 : 27).

For the isomerization of racemic β-[Co(edda)(en)]$^+$, a mechanism occuring through a Co–N(en) bond-ruptured intermediate has been proposed.[15,16] This mechanism can be used to interpret the Λ(*R*)-β→Δ(*R*,*R*)-α change (Scheme 2), but can not be used regarding the present Λ(*R*)-β→Λ(*S*,*S*)-α change (major path). One might consider a possible twist mechanism. Molecular models indicate that twisting around three of four axses perpendicular to the triangular faces of this octahedral complex (imaginary C_3) is possible. However, these three twistings lead Λ(*R*)-β to Δ(*R*,*R*)-α and Δ(*S*)-β (Scheme 2); the present major path of Λ(*R*)-β→Λ(*S*,*S*)-α can not also be explained on the basis of this mechanism.

For the isomerization of Λ(*R*)-β, we propose the Co–O bond-rupture mechanism shown in Scheme 3. When a bond-rupture occurs between the Co(III) ion and the O atom of the out-of-plane glycinate ring in the coordinated edda, the vacant position in the intermediate is occupied by the neighboring sec-N of the edda ligand while accompanying a concurrent shift of the "bond-ruptured O" atom to the position vacated by the sec-N atom (1 of Scheme 3). This path is similar to that proposed for the isomerization of Co-edma complexes,[2–5] and rationalizes the major reaction from Λ(*R*)-β to Λ(*S*,*S*)-α. When a bond-rupture occurs between the Co(III) ion and the O atom of the in-plane glycinate ring, the sec-N atom of the edda ligand can not occupy the vacant position in the intermediate. In this case, the vacant position in the intermediate may be occupied by the N atom of the en ligand while moving of the "bond-ruptured O" atom to the position originally occupied by the N(en) atom, as shown in 2 of Scheme 3. The experimental results for the isomerization reaction of Λ(*R*)-β may be explained by the simultaneous occurence of the two paths in Scheme 3, where path of 1 is the major one.

Λ(*R*)-β-*Fac*(*O*)-[Co(edda)(gly)]: The isomerization reaction of Λ(*R*)-β-*fac*(*O*) was carried out in a carbonate buffer (pH 10.30) at 40.0 °C. The changes in the proportions of the starting material and products are listed in Table 4, together with an enantiomeric excess percentage of each isomer. In this reaction, Λ(*R*)-β-



Scheme 3.

Table 4. The Proportions and Optical Purities of the Starting Materials and Products in the Isomerization Reaction of [Co(edda)(gly)] (40.0 °C)

(i) *Λ(R)-β-fac(O)* (pH 10.30)

t	Isomer proportion (Optical purity/%)		
h	*Λ(R)-β-fac(O)*	*Λ(R)-β-mer(O)*	*Λ(S,S)-α-mer(O)*
0.5	0.88(95)	0.09(99)	0.03(29)
2	0.63(90)	0.20(93)	0.17(34)
3	0.54(90)	0.21(86)	0.25(32)
4	0.46(88)	0.20(85)	0.34(32)
6	0.33(79)	0.17(75)	0.50(29)
9	0.23(63)	0.16(54)	0.61(26)

(ii) *Λ(R)-β-mer(O)* (pH 10.28)

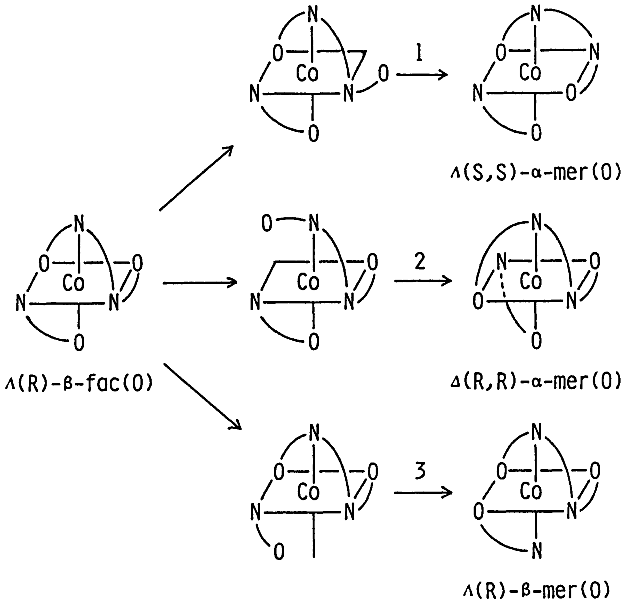
t	Isomer proportion (Optical purity/%)		
h	*Λ(R)-β-mer(O)*	*Λ(R)-β-fac(O)*	*Λ(S,S)-α-mer(O)*
0.167	0.93(98)	0.03(65)	0.04(39)
0.5	0.75(97)	0.08(64)	0.17(37)
1	0.55(94)	0.14(66)	0.31(36)
3	0.22(75)	0.20(67)	0.58(33)
6	0.20(36)	0.17(47)	0.63(33)

(iii) *Λ(S,S)-α-mer(O)* (pH 10.28)

t	Isomer proportion (Optical purity/%)		
h	*Λ(S,S)-α-mer(O)*	*Λ(R)-β-fac(O)*	*Λ(R)-β-mer(O)*
1	0.96(97)		0.04(61)
3	0.88(88)	0.05(50)	0.09(58)
6	0.84(72)	0.07(31)	0.10(51)
24	0.81(18)	0.09(18)	0.10(11)
36	0.81(7.0)	0.09(4.7)	0.10(6.1)

mer(O) and *Λ(S,S)-α-mer(O)* were simultaneously formed. Throughout the reaction, no other products were detected by the present experimental method. The *Λ(S,S)-α-mer(O)* increased in amount with the passage of time and was a major species after a prolonged reaction time. The amount of *Λ(R)-β-mer(O)* was maximal at about 3 h after the reaction start; thereafter, it decreased. During the initial stage of the reaction, *Λ(R)-β-mer(O)* formed from *Λ(R)-β-fac(O)* retained an optical purity of about 100%. The path of *Λ(R)-β-fac(O)→Λ(R)-β-mer(O)* is thus highly stereoselective. However, the *Λ(S,S)-α-mer(O)* formed in the same reaction showed a low optical purity (ca. 33%). It is thought that *Λ(R)-β-fac(O)* isomerizes to *Λ(S,S)*- and *Δ(R,R)-α-mer(O)* at a ratio of ca. 67 : 33. The gradual decrease in the optical purity of each isomer with the passage of time may be attributed to reverse isomerization from *Λ(S,S)-α-mer(O)* with a low optical purity to *β-mer(O)* and *β-fac(O)* (vide post).

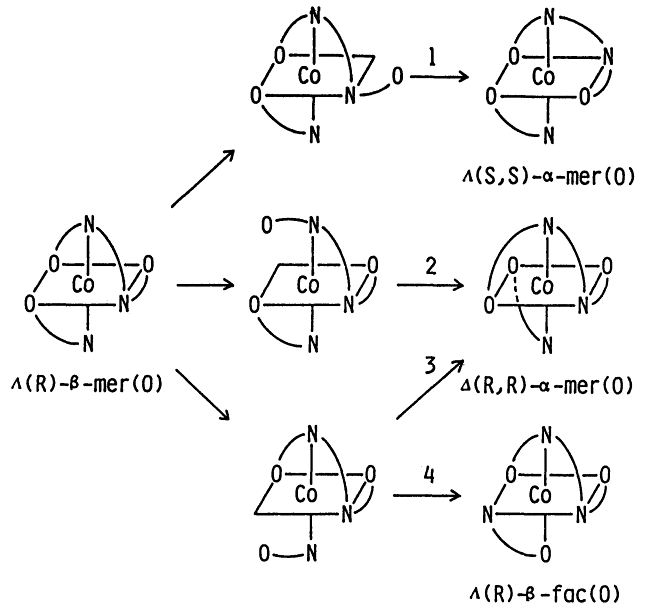
The isomerization reaction of *Λ(R)-β-fac(O)*, as well as that of *Λ(R)-β*-[Co(edda)(en)]$^+$, can not explain by a twist mechanism; the possible twisting around imaginary-C$_3$ axes leads *Λ(R)-β-fac(O)* to *Δ(R,R)-α-mer(O)*, *Δ(S)-β-fac(O)*, and *Δ(S)-β-mer(O)*. If the isomerization reaction of *Λ(R)-β-fac(O)* proceeds according to the Co–O bond-rupture mechanism, three paths may be expected, as shown in Scheme 4. The paths of 1 and 2 in Scheme 4 are the same as those proposed for the isomerization of *β*-[Co(edda)(en)]$^+$. Path 3 in Scheme 4 is proposed on the basis of the assumption that the reaction proceeds by a bond-rupture between the Co(III) ion and the O atom of the coordinated glycinate ligand. In this case, the donor atom, which can shift to the vacant position in the intermediate, is only the N atom of the glycinate ligand; the positions of the O and N atoms in the coordinated glycinate ligand exchange with each other. The experimental results described above, namely the simultaneous formation of *Λ(S,S)-α-mer(O)* with a low optical purity and *Λ(R)-β-mer(O)* are well explained by the simultaneous occurence of three paths in Scheme 4, where path 2 is the minor one.



Scheme 4.

***Λ(R)-β-Mer(O)*-[Co(edda)(gly)]:** The isomerization reaction of *Λ(R)-β-mer(O)* was also carried out in a carbonate buffer (pH 10.28) at 40.0 °C; the data are listed in Table 4. The isomerzation reaction of *Λ(R)-β-mer(O)* is faster than the reactions of other isomers. During the initial stage of the reaction, the *Λ(R)-β-fac(O)* formed from *Λ(R)-β-mer(O)* showed an optical purity of about 65%, indicating that the path was stereoselective. The *Λ(S,S)-α-mer(O)* formed in the same reaction, however, showed a low optical purity (below 40%).

The isomerization of *Λ(R)-β-mer(O)* can also be explained in a manner similar to that for the isomerization of *Λ(R)-β-fac(O)*, as shown in Scheme 5.[18] The *Λ(R)-β-mer(O)→Λ(S,S)-α-mer(O)* change with an accompanying inversion at the sec-N center of the coordinated edda ligand is interpreted by the path of 1. It may be attributed to the contribution of the paths of

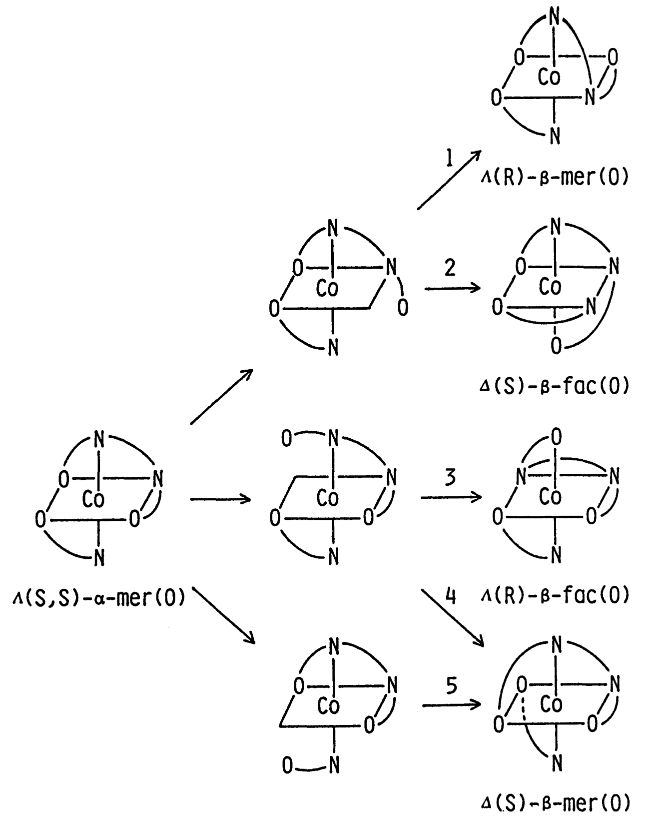


Scheme 5.

2 and 3 that the optical purity of $\Lambda(S,S)$-*α-mer*(*O*) formed from $\Lambda(R)$-*β-mer*(*O*) is low, even during the initial stage of the reaction. The $\Lambda(R)$-*β-mer*(*O*)→ $\Lambda(R)$-*β-fac*(*O*) change indicates a coordination site exchange between the O and N atoms of the coordinated glycinate ligand. This change can be explained by the path of 4 in Scheme 5. However, the fact that the optical purity of $\Lambda(R)$-*β-fac*(*O*) formed from $\Lambda(R)$-*β-mer*(*O*) is ca. 65%, even in the initial stage of the reaction, probably indicates the presence of another path which is not shown in Scheme 5.

$\Lambda(S,S)$-*α-Mer*(*O*)-[Co(edda)(gly)]: The isomerization data of $\Lambda(S,S)$-*α-mer*(*O*) are also listed in Table 4. In the initial stage of the reaction, $\Lambda(R)$-*β-mer*(*O*) and $\Lambda(R)$-*β-fac*(*O*), which were formed from $\Lambda(S,S)$-*α-mer*(*O*), showed optical purities of about 60 and 50%, respectively. These isomerization paths are, thus, stereoselective to a certain extent. However, the optical purities of these two products and the starting material decreased with the passage of time. The results may be attributed to the reversible reactions between $\Lambda(S,S)$-*α-mer*(*O*) and $\Lambda(R)$-*β-mer*(*O*) or $\Lambda(R)$-*β-fac*(*O*), where the stereoselectivity is not so high (Table 4). At times beyond 24 h, the proportions of the starting material and products are constant. This fact indicates that the reaction attains equilibrium, where *α-mer*(*O*) is more stable than *β-mer*(*O*) and *β-fac*(*O*). (At 36 h after the reaction start, by-products were observed in a slight amount on the chromatographic separation.)

In order to interpret these experimental results, the same idea as described in the preceding section was applied.[19] The expected paths are shown in Scheme 6. The isomerizations to $\Lambda(R)$-*β-mer*(*O*) and $\Lambda(R)$-*β-fac*(*O*), which accompany the inversion at the sec-N atom in the coordinated edda ligand, are explained by the paths of 1 and 3 in Scheme 6, respectively. In addition, the fact that the optical purities of the $\Lambda(R)$-*β-mer*(*O*) and $\Lambda(R)$-*β-fac*(*O*) formed from $\Lambda(S,S)$-*α-mer*(*O*) are 60 and 50% respectively indicates that the isomerizations via the paths 2, 4, and 5 also occur, even though they are minor paths.[20]



Scheme 6.

In order to interpret the isomerization reactions of $[Co(edda)(en)]^+$ and [Co(edda)(gly)], the Co-O bond-rupture mechanism was proposed. In addition, it was assumed that the Co-O(edda) bond-rupture occurred more easily in the out-of-plane glycinate ring than in the in-plane glycinate ring, even though the α-type isomers were more stable compared with the β-type isomers. In the $[Co(edta)]^-$ complex, the two glycinate rings in the plane of the diamine ring are considerably more strained than the out-of-plane glycinate rings.[21] Complexes of the type $[Co(edta)X]^{n-}$ or $[Co(Hedta)X]^{m-}$ where edta acts as a quinquedentate ligand, have also been reported.[22] In these complexes, X occupies the position lying in the plane of the diamine ring. Therefore, in the replacement reaction of $[Co(edta)]^-$ by ethylenediamine, Busch et al. proposed a mechanism in which the O atom of in-plane glycinate ring is first replaced by an N(en) atom.[23] However, it is difficult to estimate the reactivity of Co-edda complexes from the properties of Co-edta complexes.

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References

1) Abbreviations used: edma, ehtylenediamine-*N*-acetate anion; ida, iminodiacetate dianion; mida, *N*-methyliminodiacetate dianion; dien, 3-azapentane-1,5-diamine; mdien, 3-methyl-3-azapentane-1,5-diamine; edda, ethylenediamine-*N*,*N*′-diacetate dianion.

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19) Possible twistings lead $\Lambda(S,S)$-α-*mer*(*O*) to $\Delta(S)$-β-*mer*(*O*) and $\Delta(S)$-β-*fac*(*O*).

20) The path of 2 is the reverse one of 2 in Scheme 4. (However, the absolute configuration pictured in Scheme 4 is different from that of Scheme 6.) The paths of 4 and 5 are the reverse ones of 2 and 3 in Scheme 5, respectively.

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