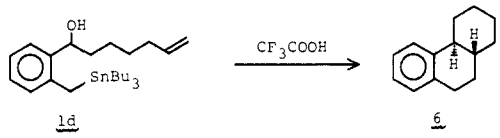

Efforts to further expand the scope and utility of this methodology to polycyclic systems are under active investigation in our laboratory.

Supplementary Material Available: ^{1}H NMR data for the stannanes **1** and cycloadducts **3** (1 page). Ordering information is given on any current masthead page.

(12) The trans stereochemistry of **3–iii** was confirmed by comparison of the corresponding hydrolysis compound's mp (229–230 °C) with that reported: Haworth, R. D.; Slinger, F. H. *J. Chem. Soc.* **1940**, 1321.
(13) **3–v**: ^{1}H NMR ($CDCl_3$) δ 1.7 (d, 3 H, J = 7 Hz), 2.8–3.8 (m, 5 H), 7.1–7.4 (m, 4 H).
(14) **3–vi**: ^{1}H NMR ($CDCl_3$) δ 0.7–2.0 (m, 13 H), 3.6–4.0 (m, 3 H), 3.8 (s, 3 H), 3.83 (s, 3 H), 7.2 (s, 4 H).

Fingerprints of the C–N Bond Formation between Ethylenediamine and an Aldose on Cobalt(III) Complexes. Isotopic Multiplets in the ^{13}C NMR Spectra of Cobalt(III) Complexes with Partially Deuteriated Coordinated Amino Groups

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Interligand reactions on transition-metal complexes accompanied by the formation of new C–N bond(s)[3,4] have been of great interest in macrocyclic chemistry and coordination chemistry. In these investigations, it is desirable to identify the C–N bond formation unambiguously and easily. We wish to present here a simple method for identification of the C–N bond formation in diamagnetic complexes.

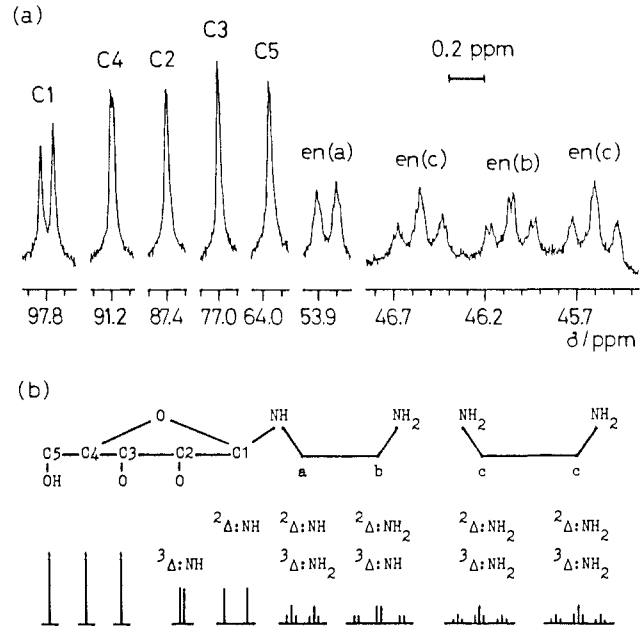

Figure 1. (a) Isotopic multiplets in the low power broad band proton decoupled 100 MHz ^{13}C NMR spectrum of $[Co(D\text{-Rib-en})(en)]^+$ (**1**) in a neutral ca. 1:1 H_2O–D_2O mixture. (b) Possible two- and three-bond isotope effects and expected isotopic multiplet patterns of **1**.

We have already reported the synthesis and characterization of Co(III) complexes containing an *N*-glycoside derived from ethylenediamine (en) and an aldose.[4] In the report, the formation of a new C–N bond has been presumed according to the chemical shifts of the ^{13}C signals from the en units in their routine ^{13}C NMR spectra. One of the signals assigned to the en carbons, which presumably corresponds to the carbon atom adjacent to the glycosidic nitrogen, appears at 7–8 ppm downfield from the other three.

Deuterium isotope effects on ^{13}C NMR chemical shifts are very helpful in spectral assignments and molecular structure determination.[5-14] Partial deuteriation of exchangeable protons in amines,[5-7] amides,[8] alcohols,[9,10] carbohydrates,[11,12] and nucleosides,[7] etc. leads to isotopic multiplets in ^{13}C NMR spectra observed under slow exchange conditions. In the spectra of the cobalt(III)–amine complexes, indeed, isotopic multiplets corresponding to isotopomers of coordinated amino groups could be observed even in neutral H_2O–D_2O mixtures.[6] We applied this technique to the cobalt-

(1) The University of Tokyo.
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(3) (a) Curtis, N. F. *Coord. Chem. Rev.* **1968**, *3*, 3–47. Busch, D. H.; Farmery, K.; Goedken, V. L.; Katovic, V.; Melnyk, A. C.; Sperati, C. R.; Tokei, N. *Adv. Chem. Ser.* **1971**, *no. 100*, 44–78. Christensen, J. J.; Eatough, D. J.; Izatt, R. M. *Chem. Rev.* **1974**, *74*, 351–384. (b) Gainsford, A. R.; Pizer, A. R.; Sargeson, A. M.; Whimp, P. O. *J. Am. Chem. Soc.* **1981**, *103*, 792–805. Lawson, P. J.; McCarthy, M. G.; Sargeson, A. M. *Ibid.* **1982**, *104*, 6710–6716. Dixon, N. E.; Sargeson, A. M. *Ibid.* **1982**, *104*, 6716–6725. (c) Sargeson, A. M. *Chem. Br.* **1979**, *15*, 23–27. Harrowfield, J. M.; Herlt, A. J.; Sargeson, A. M. *Inorg. Synth.* **1980**, *20*, 85–86. Gahan, L. R.; Hambley, T. W.; Sargeson, A. M.; Snow, M. R. *Inorg. Chem.* **1982**, *21*, 2699–2706. Creaser, I. I.; Geue, R. J.; Harrowfield, J. M.; Herlt, A. J.; Sargeson, A. M.; Snow, M. R.; Springborg, J. *J. Am. Chem. Soc.* **1982**, *104*, 6016–6025. Boucher, H. A.; Lawrance, G. A.; Lay, P. A.; Sargeson, A. M.; Bond, A. M.; Sangster, D. F.; Sullivan, J. C. *J. Am. Chem. Soc.* **1983**, *105*, 4652–4661. Harrowfield, J. M.; Herlt, A. J.; Lay, P. A.; Sargeson, A. M. *J. Am. Chem. Soc.* **1983**, *105*, 5503–5505. Geue, R. J.; Hambley, T. W.; Harrowfield, J. M.; Sargeson, A. M.; Snow, M. R. *J. Am. Chem. Soc.* **1984**, *106*, 5478–5488. Geue, R. J.; McCarthy, M. G.; Sargeson, A. M. *J. Am. Chem. Soc.* **1984**, *106*, 8282–8291. Comba, P.; Creaser, I. I.; Gahan, L. R.; Harrowfield, J. M.; Lawrance, G. A.; Martin, L. L.; Mau, A. W. H.; Sargeson, A. M.; Sasse, W. H. F.; Snow, M. R. *Inorg. Chem.* **1986**, *25*, 384–389. (d) Yashiro, M.; Shimada, A.; Usui, T.; Yano, S.; Kobayashi, K.; Sakurai, T.; Yoshikawa, S. *J. Am. Chem. Soc.* **1985**, *107*, 4351–4353. (e) Takizawa, S.; Sugita, H.; Yano, S.; Yoshikawa, S. *J. Am. Chem. Soc.* **1980**, *102*, 7969–7971. Tsubomura, T.; Yano, S.; Toriumi, K.; Ito, K.; Yoshikawa, S. *Polyhedron* **1983**, *2*, 123–124. Shioi, H.; Yano, S.; Toriumi, K.; Ito, T.; Yoshikawa, S. *J. Chem. Soc., Chem. Commun.* **1983**, 201–202. Tsubomura, T.; Yano, S.; Toriumi, K.; Ito, T.; Ito, H.; Yoshikawa, S. *Bull. Chem. Soc. Jpn.* **1984**, *57*, 1833–1838. Yano, S.; Sakai, Y.; Toriumi, K.; Ito, T.; Ito, H.; Yoshikawa, S. *Inorg. Chem.* **1985**, *24*, 498–504. Tsubomura, T.; Yano, S.; Toriumi, K.; Yoshikawa, S. *Inorg. Chem.* **1985**, *24*, 3218–3223. Tanase, T.; Kurihara, K.; Yano, S.; Kobayashi, K.; Sakurai, T.; Yoshikawa, S. *J. Chem. Soc., Chem. Commun.* **1985**, 1562–1563.

(4) Ishida, K.; Yano, S.; Yoshikawa, S. *Inorg. Chem.* **1986**, *25*, 3552–3554.
(5) Reuben, J. *J. Am. Chem. Soc.* **1985**, *107*, 1433–1435.
(6) Yashiro, M.; Yano, S.; Yoshikawa, S. *J. Am. Chem. Soc.* **1986**, *108*, 1096–1097.
(7) Reuben, J. *J. Am. Chem. Soc.* **1986**, *108*, 1082–1083; **1987**, *109*, 316–321.
(8) (a) Feeney, J.; Partington, P.; Roberts, G. C. K. *J. Magn. Reson.* **1974**, *13*, 268–274. (b) Newmark, R. A.; Hill, J. R. *Ibid.* **1976**, *21*, 1–7. (c) Hawkes, G. E.; Randall, E. W.; Hull, W. E.; Gattegno, D.; Conti, F. *Biochemistry* **1978**, *17*, 3986–3992.
(9) Reuben, J. *J. Am. Chem. Soc.* **1985**, *107*, 1756–1759.
(10) Newmark, R. A.; Hill, J. R. *Org. Magn. Reson.* **1980**, *13*, 40–44.
(11) Christofides, J. C.; Davies, D. B. *J. Am. Chem. Soc.* **1983**, *105*, 5099–5105. (b) Reuben, J. *Ibid.* **1984**, *106*, 6180–6186.
(12) (a) Gagnaire, D.; Vincendon, M. *J. Chem. Soc., Chem. Commun.* **1977**, 509–510. (b) Bock, K.; Lemieux, R. U. *Carbohydr. Res.* **1982**, *100*, 63–74. (c) Christofides, J. C.; Davies, D. B. *J. Chem. Soc., Chem. Commun.* **1982**, 560–562; **1983**, 324–326. Christofides, J. C.; Davies, A. B. *J. Chem. Soc., Perkin Trans. 2* **1984**, 481–488. (d) Reuben, J. *J. Am. Chem. Soc.* **1983**, *105*, 3711–3713; **1984**, *106*, 2461–2462; **1985**, *107*, 1747–1755; **1985**, *107*, 5867–5870.
(13) Reuben, J. *J. Am. Chem. Soc.* **1986**, *108*, 1735–1738.
(14) Majerski, Z.; Zuanic, M.; Metelko, B. *J. Am. Chem. Soc.* **1985**, *107*, 1721–1726, and references cited therein.

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Table I. ^{13}C Chemical Shifts[a] (in ppm), Multiplicities,[b] and Deuterium Isotope Effects ($^{n}\Delta$)[c] (in ppb/deuteron) for Sugar Units and Ethylenediamine Units in Cobalt(III)-*N*-Glycoside Complexes

	C1	C2	C3	C4	C5	C6	en (a)	en (b)	en (c)	
1	97.83	87.40	77.00	91.20	63.96		53.92	46.20	46.70	45.74
	$^{2}\Delta$ d; 67	-	-	$^{4}\Delta$ d; 12	-		$^{2}\Delta$ d; 106	$^{2}\Delta$ t; 121	$^{2}\Delta$ t; 119	$^{2}\Delta$ t; 121
							$^{3}\Delta$ t; <15	$^{3}\Delta$ d; 27	$^{3}\Delta$ t; <21	$^{3}\Delta$ t, <15
2	97.65	88.68	76.12	87 27	69.24	21.70	53.67	46.38	46.88	45.57
	$^{2}\Delta$ d; 70	-	-	-	-	-	$^{2}\Delta$ d; 106	$^{2}\Delta$ t; 119	$^{2}\Delta$ t; 119	$^{2}\Delta$ t; 121
							$^{3}\Delta$ t; <20	$^{3}\Delta$ d; <24	$^{3}\Delta$ t; <18	$^{3}\Delta$ t; <15

[a] 2-Methyl-2-propanol was used as an internal reference with a chemical shift 31.9 ppm. Each chemical shift value is given for the all-protio form (lowest field component). [b] d = doublet, t = triplet, - = no isotope effect. [c] The magnitudes of all the isotope effects are negative (upfield shifts). Digital resolution is 3 ppb.

(III)-*N*-glycoside complexes in order to obtain the direct evidence of the C-N bond formation.

Partial deuteriation of coordinated NH_2 or NH groups can be easily achieved in a neutral H_2O-D_2O mixture. Generally hydrogen exchange of coordinated amino groups in aqueous solutions is expected to be slow on the NMR time scale. As a result, the isotope effects on the ^{13}C resonances of the α- (two-bond effect: $^{2}\Delta$) and β- (three-bond effect: $^{3}\Delta$) carbons to the coordinated nitrogens should give rise to distinct ^{13}C resonances for the individual isotopomers.[6] Some of the ^{13}C resonances of [Co(D-Rib-en[15])(en)]$^{+}$ (**1**)[4] were observed as multiplets in a neutral ca. 1:1 H_2O-D_2O mixture (Figure 1a). Partial deuteriation of a coordinated NH group produces two species, NH and ND, which cause ^{13}C resonances of α- and β-carbons to appear as doublets. On the other hand, partial deuteriation of a coordinated NH_2 group produces four species, NHH, NHD, NDH, and NDD, which cause ^{13}C resonances of α- and β-carbons to commonly appear as triplets.[6] The magnitude of the two-bond effect (55-128 ppb/deuteron) is usually greater than that of the three-bond effect (0-85 ppb/deuteron)[5,6,16] and that of the four-bond effect ($^{4}\Delta$) is commonly too small to be observed.[5,6] The resonances of carbon atoms with two possible isotope effects exhibit multiplicities analogous to those due to spin-spin couplings.[5-7,9-13]

The isotopic multiplet patterns in the ^{13}C NMR spectrum of **1** are expected as shown in Figure 1b on the basis of these empirical rules. Unlike the bidentate en ligand, the tetradentate *N*-glycoside ligand contains an NH_2 group and an NH group, which can give fingerprints of the formation of the *N*-glycoside bond. The carbon adjacent to the NH group of the en unit [en (a)] may appear as a doublet of triplets due to the two-bond effect by the NH group and the three-bond effect by the NH_2 group. The carbon adjacent to the NH_2 group of the en unit [en (b)] may appear as a triplet of doublets corresponding to the two-bond effect by the NH_2 group and the three-bond effect by the NH_2 group. C1 of the sugar unit may be observed as a doublet corresponding to the two-bond effect by the NH group and C2 as a doublet due to the three-bond effect by the NH group. The isotopic multiplet patterns for [Co(L-Rha-en[17])(en)]$^{+}$ (**2**)[4] are expected to be of the same manner.

All the ^{13}C NMR signals from the sugar units of **1** and **2** in D_2O were previously assigned completely by the ^{1}H-^{1}H and ^{13}C-^{1}H shift correlation 2D NMR spectroscopies. Assignments of the observed isotopic multiplets of **1** and **2** are listed in Table I. As expected, the resonances of C1 of the sugar unit and the carbons of the en unit of the *N*-glycoside ligand exhibit multiplet patterns that originate from the presence of the glycosidic NH group. These results reveal evidence for the presence of the C1-NH-C-C-NH_2 moiety. Thus the C-N bond formation on the Co(III) complexes is unambiguously proved by the application of the isotopic multiplets in the ^{13}C NMR spectra.

It has been difficult to identify the C-N bond formation by means of conventional NMR techniques. There is considerable obscurity in estimation by ^{13}C NMR chemical shifts or vicinal ^{1}H-^{1}H spin-spin couplings (H-N-C-H), and observation of ^{15}N-^{13}C spin-spin couplings commonly requires preparations of ^{15}N-labeled samples. In conclusion, the approach by use of the isotopic multiplet technique appears to be uniquely suited for such identification because of its clarity and simplicity.

(15) The full name is 1-(2-aminoethyl)amino-1-deoxy-D-ribose.
(16) The magnitudes of the two- and three-bond isotope effects are empirically greater for the less-substituted carbon atoms.[6,9,11] The magnitude of the three-bond isotope effect depends on the dihedral angle C(obsd)-C-X-H(D) (X = C or N).[6,14]
(17) The full name is 1-(2-aminoethyl)amino-1,6-dideoxy-L-mannose.

Synthesis and Polymerization of γ-Trichloroethyl-L-glutamate *N*-Carboxyanhydride: A Polypeptide That Can Be Functionalized with a Nucleophilic Agent

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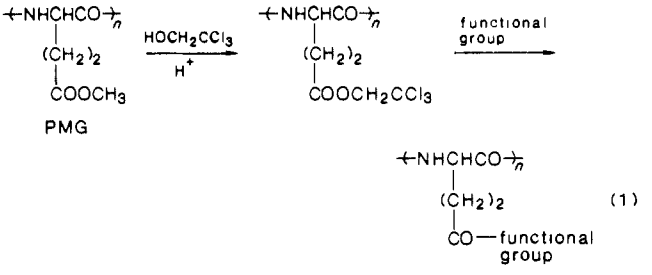
Poly(α-amino acids) are interesting as base materials in the synthesis of functional polymers because they can be induced to assume a conformation such as α-helix, β-sheet, and random coil under certain conditions. The synthesis of functional polymers utilizing these features of poly(α-amino acids) has been reported.[1,2] We have reported methods for the introduction of functional groups into poly(γ-methyl-L-glutamate) (PMG) by transesterification.[3] However, selective incorporation of a nucleophilic functional group into PMG, such as an amino group, is difficult due to low reactivity of the methyl ester and to the fission of the PMG main chain by nucleophilic attack by the amino group. Therefore, we have devised a method for incorporation amino functional groups into PMG (eq 1), where the methyl ester is



(1)

transesterified with trichloroethanol and the amino group is reacted without main chain fission. PMG functionalized with various groups has been prepared by applying these methods, and polymeric electron transport membranes containing redox functionality such as viologen and lipoic acid have been developed.[4-7]

If a glutamate *N*-carboxyanhydride with a highly activated ester such as trichloroethyl ester could be synthesized, it may be possible

(1) Maeda, M.; Kimura, M.; Hareyama, Y.; Inoue, S. *J. Am. Chem. Soc.* **1984**, *106*, 250.
(2) Sisido, M.; Egusa, S.; Imanishi, Y. *J. Am. Chem. Soc.* **1983**, *105*, 1041.
(3) Tanaka, H.; Endo, T.; Okawara, M. *Nippon Kagaku Kaishi* **1973**, 1770, 1775, 1780.

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