

Preliminary Communication

# Successful isolation and X-ray crystal structure of {tris(*N*-*L*-rhamnosyl-2-aminoethyl)amine} (sulfate)nickel(II) hydrate trimethanol solvate: [Ni((*L*-Rha)<sub>3</sub>-tren)(SO<sub>4</sub>)] · H<sub>2</sub>O · 3CH<sub>3</sub>OH

Shigenobu Yano <sup>a,\*</sup>, Mayumi Doi <sup>a</sup>, Masako Kato <sup>a</sup>, Ichiro Okura <sup>b</sup>, Tetsuo Nagano <sup>c</sup>,  
Yasuhiro Yamamoto <sup>d</sup>, Tomoaki Tanase <sup>d,\*</sup>

<sup>a</sup> Department of Chemistry, Faculty of Science, Nara Women's University, Nara-shi, Nara 630, Japan

<sup>b</sup> Department of Bioengineering, Tokyo Institute of Technology, Midori-ku, Yokohama 227, Japan

<sup>c</sup> Faculty of Pharmaceutical Science, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan

<sup>d</sup> Department of Chemistry, Faculty of Science, Toho University, Funabashi-shi, Chiba 274, Japan

Received 30 May 1995; revised 3 October 1995

## Abstract

We have succeeded in the isolation and X-ray crystal structure determination of the octahedral nickel(II) complex [Ni((*L*-Rha)<sub>3</sub>-tren)(SO<sub>4</sub>)] · H<sub>2</sub>O · 3CH<sub>3</sub>OH (tren = tris(2-aminoethyl)amine; Rha = rhamnose) containing an *N*-glycoside derived from the reaction of *L*-Rha and tren. Crystal data: C<sub>27</sub>H<sub>62</sub>N<sub>4</sub>O<sub>20</sub>SNi, *M*<sub>r</sub> = 853.56, orthorhombic, space group *P*2<sub>1</sub>2<sub>1</sub>2<sub>1</sub>, *a* = 16.035(4), *b* = 16.670(7), *c* = 15.38(1) Å, *Z* = 4.

**Keywords:** *N*-Glycoside complexes; Nickel complexes; Sulfate chelate complexes; Crystal structures

Carbohydrates have a wide spread occurrence in nature and are indispensable compounds to living organisms [1]. Naturally rare carbohydrates have also proved to be involved in many glycoproteins, glycolipids and antibiotics, and play important roles in various biological processes [2]. Further, in some enzymatic reactions of carbohydrates, alkali, alkaline earth and some transition metal ions were suggested to act in cooperation with sugars [3]. In this regard, it is very important to elucidate the interactions between sugars and metal ions including the stereochemical behavior of sugars in transition metal complexes. It is an interesting subject to elucidate the interactions between sugars and metal ions including the stereochemical behavior of sugars in transition metal complexes in the fields of carbohydrate chemistry, bioinorganic chemistry and industry. We have extensively studied the synthesis and characterization of nickel(II) [4], cobalt(III) [5], and cobalt(II) [6] complexes containing *N*-glycosides derived from the reaction of sugars and polyamines. Here we wish to report a successful isolation and crystal structure of a novel nickel(II) complex containing *N*-glycoside derived from *L*-rhamnose (6-deoxy-*L*-mannose) and tris(2-aminoethyl)amine (tren).

100 ml of methanolic solution containing *L*-rhamnose (4 equiv., 2.19 g) and tren (1 equiv., 0.44 g) were incubated at 55 °C for 4 h. Then, NiSO<sub>4</sub> · 6H<sub>2</sub>O (1 equiv., 0.79 g) was added to the solution and the mixture was refluxed to give a blue–green solution, which was cooled to room temperature and allowed to stand overnight. The concentrated solution was purified on a Sephadex LH-20 gel permeation column using methanol as an eluent. The blue major band was collected and concentrated to give 0.82 g of a light-blue crystalline compound (**1**) in 34% yield based on the starting nickel(II) salt <sup>1</sup> [7].

The near-IR and visible absorption spectrum of this complex in solution showed three main bands with comparatively low intensities, which are characteristic of octahedral nickel complexes <sup>1</sup>. The transmittance spectrum (Nujol mull) also showed similar absorptions indicating no significant structural change around the metal on dissolution. In the circular dichroism spectrum, Cotton effects were observed in the

<sup>1</sup> Anal. Calc. for [Ni((*L*-Rha)<sub>3</sub>-tren)(SO<sub>4</sub>)] · 2H<sub>2</sub>O (C<sub>24</sub>H<sub>52</sub>N<sub>4</sub>O<sub>18</sub>SNi) (**1**): C, 37.17; H, 6.76; N, 7.23. Found: C, 36.70; H, 6.90; N, 7.23%. Near-IR and visible spectral data for **1** in dimethyl sulfoxide: ν<sub>max</sub> 9290 (ε 16.7), 12380 (3.6) (sh), 15970 (10.1), 25510 (15.1). Circular dichroism spectral data for **1** in dimethyl sulfoxide: ν<sub>max</sub> 10960 (Δε +0.068), 12860 (−0.027) (sh), 14040 (−0.027), 17080 (+0.057), 26460 (+0.013).

\* Corresponding authors.

d–d transition region<sup>1</sup>, suggesting coordination of the sugar moieties to the nickel atom. The value of effective magnetic moment of the complex is  $3.05 \mu_B$ , which falls within the range reported for octahedral complexes of nickel(II) [8].

Recrystallization from methanol of **1** gave good crystals suitable for X-ray crystallography. Crystal data:  $C_{27}H_{62}N_4O_{20}S$ ,  $M_r = 853.56$ , orthorhombic, space group  $P2_12_12_1$ ,  $a = 16.035(4)$ ,  $b = 16.670(7)$ ,  $c = 15.38(1)$  Å,  $V = 4111(3)$  Å<sup>3</sup>,  $Z = 4$ ,  $D_{calc} = 1.379$  g cm<sup>-3</sup>.  $\mu$  (linear absorption coefficient) =  $5.96$  cm<sup>-1</sup>. From 1752 independent reflections with  $I > 2.5\sigma(I)$  collected with Mo K $\alpha$  radiation ( $\lambda = 0.7107$  Å) within the sphere of  $2\theta < 50.2^\circ$  on a Rigaku AFC5S diffractometer at 23 °C, the structure was solved by direct methods with MITHRIL [9] and refined by full-matrix least-squares techniques to  $R = 0.084$  and  $R_w = 0.068$  ( $w = 1/\sigma^2(F_o)$ ). All calculations were performed on a Digital Vax station 3100 M38 with the TEXSAN-TEXRAY structure analysis package (Molecular Structure Corporation).

Fig. 1 shows the perspective drawing of the complex  $[Ni((L-Rha)_3-tren)(SO_4)]$ , where a sulfate anion and an *N*-glycoside ligand,  $(L-Rha)_3-tren$ , complete an octahedral coordination around the nickel atom. The sulfate anion attaches to the nickel atom through two oxygen atoms forming a four-membered chelate ring. The three *L*-rhamnosyl moieties form  $\beta$ -*N*-glycoside linkages with three primary amino groups of tren. It is well known that sugars possessing a free reducing group are able to react with primary and secondary amines to give, under mild conditions, *N*-glycoside derivatives (glycosylamines) in which the glycosidic hydroxyl group is replaced by an amino group. This is generally accepted as being the first step in the 'Maillard reaction' or non-enzymatic browning [10]. The real existence of C–N bonds between the C1 atom of aldose and the N atom of tren is clearly confirmed. The most remarkable feature is the coordi-

dination mode of the  $(L-Rha)_3-tren$  ligand, which binds to the nickel atom with only four points through four nitrogen atoms of the tren moiety, all the hydroxyl groups of the sugar residues being out of coordination although this ligand is a potentially heptadentate ligand as observed in the case of  $[Co((L-Rha)_3-tren)]SO_4 \cdot 3H_2O \cdot CH_3OH$  [6].

Our previous X-ray crystallographic study of nickel(II) [4] and cobalt(II) [6] complexes of *N*-glycoside indicated that the hydroxyl group adjacent to the glycosylated nitrogen atom of the glycosylamine ligand coordinated to the central metal atom, resulting in a five-membered chelate ring; the aldose unit binds to the metal atom at two points, through the hydroxyl oxygen atom on C2 and the glycosidic nitrogen atom on C1. In the present case, however, the complex has a unique structural feature where all the hydroxyl groups on C2 of the *L*-Rha residue are out of coordination. A preliminary study showed that the treatment of  $[Ni((L-Rha)_3-tren)(SO_4)] \cdot H_2O \cdot 3CH_3OH$  (**1**) with  $BaBr_2 \cdot 2H_2O$  yielded  $[Ni((L-Rha)_3-tren)]Br_2 \cdot H_2O$  (**2**) [11]<sup>2</sup>. *Anal. Calc.* for  $[Ni((L-Rha)_3-tren)]Br_2 \cdot H_2O$  ( $C_{24}H_{50}N_4O_{13}Br_2Ni$ ) (**2**): C, 35.10; H, 6.14; N, 6.82. Found: C, 34.81; H, 6.51; N, 6.58%. Therefore, the present complex could be regarded as one of the intermediates in the formation of **2**.

## Acknowledgements

This work was partially supported by a Grant-in-Aid for Scientific Research from the Ministry of Education of Japan (0731219, 08231251, 08404044, 07215252 and 07805079) and Grants from Iwatani, Nippon Itagarasu, Mitsubishi-Yuka, and Nagase Foundations.

## References

- [1] A.L. Lehninger, *Principles of Biochemistry*, Worth, New York, 1982.
- [2] J.F. Kennedy and C.A. White, *Bioactive Carbohydrates in Chemistry, Biochemistry and Biology*, Wiley, New York, 1983.
- [3] (a) E.A. Noltmann, *Enzymes*, 3 (1970) 271; (b) R.L. Root, J.R. Durrwachter and C.H. Wong, *J. Am. Chem. Soc.*, 107 (1985) 2997.
- [4] (a) S. Yano, *Coord. Chem. Rev.*, 92 (1988) 113, and Refs. therein; (b) T. Tanase, F. Shimizu, M. Kuse, S. Yano, M. Hidai and S. Yoshikawa, *Inorg. Chem.*, 27 (1988) 4085; (c) S. Yano, T. Takahashi, Y. Sato, K. Ishida, T. Tanase, M. Hidai, K. Kobayashi and T. Sakurai,

<sup>2</sup> Near-IR and visible spectral data for **2** in methanol:  $\nu_{max}$  9960 ( $\epsilon$  27.5), 12380 (7.5) (sh), 17300 (12.2), 26740 (18.4). Circular dichroism spectral data for **2** in methanol:  $\nu_{max}$  11030 ( $\Delta\epsilon$  -0.157), 12240 (-0.067), 14680 (+0.034), 17470 (+0.139), 25940 (+0.066). Without an X-ray crystal structure, the structure of  $[Ni((L-Rha)_3-tren)]^{2+}$  of  $[Ni((L-Rha)_3-tren)]Br_2 \cdot H_2O$  (**2**) is still ambiguous, as to whether **2** has a similar structure to that observed in the case of  $[Co((L-Rha)_3-tren)]SO_4 \cdot 3H_2O \cdot CH_3OH$  in which the sugar parts attach to the nickel atom at two points through the glycosidic nitrogen atom of tren and through the oxygen atom on C2 of *L*-Rha [6].

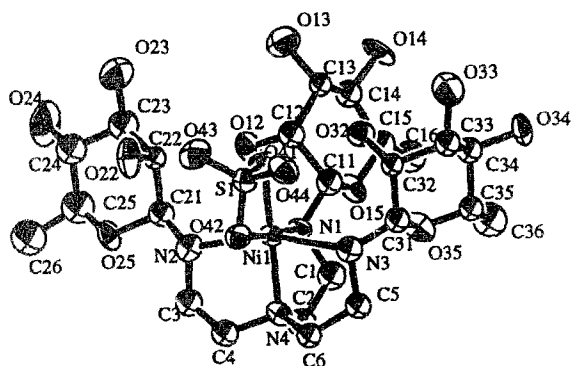


Fig. 1. A perspective drawing of the complex  $[Ni((L-Rha)_3-tren)(SO_4)]$ . Selected bond distances (Å) and angles ( $^\circ$ ): Ni(1)–O(41) = 2.07(1), Ni(1)–O(42) = 2.18(1), Ni(1)–N(1) = 2.13(1), Ni(1)–N(2) = 2.23(2), Ni(1)–N(3) = 2.36(2), Ni(1)–N(4) = 2.04(2), N(1)–C(11) = 1.44(3), N(2)–C(21) = 1.42(2), N(3)–C(31) = 1.48(2); O(41)–Ni(1)–O(42) = 67.7(5), O(41)–Ni(1)–N(1) = 174.6(6), O(42)–Ni(1)–N(4) = 164.9(6), N(2)–Ni(1)–N(3) = 158.0(6), N(1)–Ni(1)–N(4) = 86.5(7), N(2)–Ni(1)–N(4) = 85.4(7), N(3)–Ni(1)–N(4) = 80.1(7).

- Chem. Lett.*, (1987) 2153; (d) S. Yano, M. Kato, H. Shioi, T. Takahashi, T. Tsubomura, K. Toriumi, T. Ito, M. Hidai and S. Yoshikawa, *J. Chem. Soc., Dalton Trans.*, (1993) 1699; (e) T. Tanase, R. Nouchi, Y. Oka, M. Kato, N. Nakamura, T. Yamamura, Y. Yamamoto and S. Yano, *J. Chem. Soc., Dalton Trans.*, (1993) 2645.
- [5] (a) K. Ishida, M. Yashiro, S. Yano, M. Hidai and S. Yoshikawa, *J. Am. Chem. Soc.*, 110 (1988) 2015; (b) K. Ishida, M. Yashiro, S. Yano, M. Hidai and S. Yoshikawa, *J. Chem. Soc., Dalton Trans.*, 7 (1989) 1241; (c) K. Ishida, S. Nonoyama, S. Yano, M. Hidai and S. Yoshikawa, *J. Am. Chem. Soc.*, 111 (1989) 1599.
- [6] T. Tanase, M. Nakagoshi, A. Teratani, M. Kato, Y. Yamamoto and S. Yano, *Inorg. Chem.*, 33 (1994) 5.
- [7] L. Sacconi, *Trans. Met. Chem.*, 4 (1968) 210.
- [8] F.A. Cotton and G. Wilkinson, *Advanced Inorganic Chemistry*, Interscience, New York, 2nd edn., 1966.
- [9] C.J. Gilmore, *J. Appl. Crystallogr.*, 17 (1984) 42.
- [10] L.C. Maillard, *Hebd. Seances Acad. Sci.*, 154 (1912) 66.
- [11] T. Tanase, M. Doi, R. Nouchi, M. Kato, Y. Sato, K. Ishida, K. Kobayashi, T. Sakurai, Y. Yamamoto and S. Yano, *Inorg. Chem.*, submitted for publication.