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Two Locally Chiral Dysprosium Compounds with Salen-Type Ligands That Show Slow Magnetic Relaxation Behavior

Li Zhang,^[a,b] Peng Zhang,^[a] Lang Zhao,^[a] Shuang-Yan Lin,^[a] Shufang Xue,^[a] Jinkui Tang,^{*[a]} and Zhiliang Liu^{*[b]}

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Two Dy compounds, $[Dy_4(\mu_4-O)L_2(C_6H_5COO)_6]\cdot 3CH_3OH$ (1) and $[Dy_2L(H_2L)(teaH_2)(o-vanillin)(H_2O)](ClO_4)_2\cdot 2CH_3OH + H_2O$ (2, teaH₃ = triethanolamine), were assembled by the reactions of the salen-type ligand N,N'-bis(3-methoxysalicylidene)-1,2-cyclohexanediamine (H₂L) and different dysprosium salts and bases. These compounds show both local chirality and slow magnetic relaxation. The former is induced by an unprecedented coordination mode of the ligand H₂L, in which the N₂O₂ pocket encapsulates one Dy ion. Compound 1, which has four Dy ions in distinct coordination envi-

Introduction

With potential applications in high-density information storage, quantum computing, and molecule spintronics, single-molecule magnets (SMMs) have flourished and become increasingly interesting in the field of nanomagnetic materials.^[1] For a transition-metal SMM, the reversal of magnetization is derived from a large high-spin ground state (S)in combination with an easy-axis-type magnetic anisotropy (D), which leads to an anisotropic energy barrier (U).^[1b,1c] To date, the largest anisotropic barrier reported for a transition-metal complex is found in an Mn₆ complex with an effective energy barrier of 86 K.^[2] Together with another antiferromagnetic Mn₆ cluster,^[3] it is noted that high spin and high magnetic anisotropy seem to be incompatible and that the strong anisotropy, which is mainly determined by the strength of spin-orbit coupling, plays an outstanding role in creating SMMs with high anisotropic barriers.^[4] In this regard, lanthanide ions, especially Dy ions, seem to be

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ronments, demonstrates the rare Dy_4 tetrahedron motif supported by a central μ_4 -O atom, which is akin to a chiral carbon atom in organic molecules, as revealed by single-crystal X-ray analyses. In contrast, the formation of **2**, which shows an unusual structural motif with a tail, is driven by the presence of triethanolamine. In spite of the low-symmetry coordination geometry around each Dy ion, both compounds display slow magnetic relaxation behavior, but with fast quantum tunneling relaxation, as indicated by alternating current (ac) susceptibility measurements.

attractive candidates for the construction of SMMs with high effective barriers, owing to their large magnetic moments and strong magnetic anisotropy, which arises from their large unquenched orbital moments.^[5] This has been indicated by a flood of groundbreaking results.^[1d,6] For example, the highest relaxation energy barrier for a multinuclear cluster, 528 K (more than six times of that in Mn₆), was observed in a Dy₅ pyramid cluster,^[6c] and the highest temperature at which hysteresis has been observed is 14 K (more than triple that in Mn₆, 4.5 K) in an N₂³⁻ radicalbridged Tb₂ complex.^[7] As a result, the assembly of Dybased SMMs represents a promising avenue to bring the goals of molecule-based information storage and processing closer to reality.

In addition, some SMMs have demonstrated their ability to incorporate more sophisticated functionalities, such as luminescence or chirality, thus leading to the design of advanced multifunctional materials, which have been the focus of much study in chemistry, physics, and materials science.^[8] In particular, the isolation of SMMs with chirality represents a formidable challenge. Such materials provide a great platform for the study of the cross-effects of circular dichroism (CD) and magnetochiral dichroism (MChD).^[8d,8e] Hitherto, a few examples of chiral lanthanide clusters have been reported with magnet-like behavior. In 2011, a lanthanide-based chiral SMM with a μ_4 -O-centered Dy₄ tetrahedron (**3**) was reported, in which the chirality is induced by the coordination of a twisted diazine bridge from a Schiff base ligand.^[9] Furthermore, lanthanide compounds with

[[]a] State Key Laboratory of Rare Earth Resource Utilization, Changchun Institute of Applied Chemistry, Department of Chemistry, Chinese Academy of Sciences, Renmin Street 5625, Changchun 130022, P. R. China Fax: +86-431-85262878 E-mail: tang@ciac.jl.cn

[[]b] College of Chemistry and Chemical Engineering, Inner Mongolia University, Hohhot 010021, P. R. China

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helical structures were obtained, which show the presence of two chiral configurations, Δ and Λ , in the crystal structure.^[10] In consideration of this, we have focused our attention towards the design of polynuclear 4f-only SMMs by using a multidentate salen-type ligand (H₂L) as a chelating agent. Therefore, a μ_4 -O-bridged Dy₄ compound (1), very similar to 3, and a Dy₂ compound (2) with a tail were assembled, both of which show coordination-induced chirality and slow relaxation behavior.

Results and Discussion

Here, one of the key aspects for achieving a chiral magnetic system is the special coordination mode of the salentype ligand N,N'-bis(3-methoxysalicylidene)-1,2-cyclohexanediamine (H₂L, Scheme 1d), in which the inner N_2O_2 coordination pocket accidently binds one Dy ion, which leads to the distortion of two ligands in different directions in 1 and the helical structure in 2. Scheme 1 presents the versatile coordination modes of the H₂L ligand reported previously. In 2010, Yan et al.[11] synthesized one mononuclear Eu^{III} complex in which the H₂L ligand adopts mode (a) in Scheme 1. Recently, starting from H₂L, a series of planar tetranuclear complexes with Nd^{III}, Yb^{III}, Er^{III}, and Gd^{III} ions have been self-assembled by Feng et al.,^[12] in which modes (b) and (c) are employed. Herein, a chiral Dy_4 tetrahedron compromising a rare μ_4 -O bridge, [Dy₄(μ_4 -O)- $L_2(C_6H_5COO)_6$]·3CH₃OH (1), as well as a Dy₂ compound, [Dy₂L(H₂L)(teaH₂)(o-vanillin)(H₂O)](ClO₄)₂·2CH₃OH· H_2O (2), display the peculiar coordination modes (d) and (e) of the H₂L ligand (Scheme 1), respectively. In general, it is very difficult for the inner N₂O₂ coordination pocket to encapsulate lanthanide ions owing to its relatively small size, but here the coordination of PhCOO⁻ and teaH₃ might push the lanthanide ions into the N₂O₂ coordination pocket of the H₂L ligand, thus resulting in the remarkable distortion of the ligand.

Crystal Structure of 1

The reaction of dysprosium(III) benzoate with H_2L in 2:1 methanol/dichloromethane in the presence of triethyl-

amine yields pale yellow single crystals of 1. The structural data and refinement details are summarized in Table 1, and selected bond lengths and angles are listed in Table S1. Single-crystal X-ray studies revealed that 1 crystallizes in the triclinic space group $P\overline{1}$ with Z = 2 (Figure S1). As illustrated in Figure 1a, the central μ_4 -O (O1) atom links four Dy^{III} ions with Dy–O1 distances of approximately 2.3 Å, and the geometry can be regarded as distorted tetrahedral. The dihedral angles between the underside (Dy1, Dy3, Dy4) of the Dy_4 motif and the other three sides are 58, 65, and 88°, respectively, and the edges are evidently distinct with Dy separations in the range 3.4525(9)-4.1049(9) Å. Three kinds of chelating modes of the benzoate ion coligands are presented in Scheme 2. Two adjacent Dy^{III} ions are bridged by deprotonated phenol oxygen atoms from an L²⁻ ligand. In addition, Dy1 and Dy4 (Dy2 and Dy3) are connected by a benzoate group in an $\eta^1:\eta^2:\mu_2$ fashion. Interestingly, $syn-syn-\eta^1:\eta^1:\mu_2$ -benzoate bridges connect diagonal Dy2 and Dy4 ions encapsulated by two ligands and Dy1 and Dy3 ions in the inverse directions, so that two ligands are constrained in the same side in a spiral

Table 1. Crystal data and structure refinement for 1 and 2.

	1	2
Empirical formula	C ₈₉ H ₉₀ Dy ₄ N ₄ O ₂₄	C ₆₀ H ₈₃ Cl ₂ Dy ₂ N ₅ O ₂₆
Formula mass	2249.65	1686.21
Crystal system	triclinic	monoclinic
Space group	ΡĪ	C2/c
Crystal color	pale yellow	yellow
a [Å]	14.957(2)	51.007(2)
<i>b</i> [Å]	15.886(3)	12.0967(5)
<i>c</i> [Å]	21.843(3)	22.8976(9)
a [°]	74.450(3)	90
β [°]	70.103(2)	107.0030(10)
γ [°]	84.368(3)	90
V[Å ³]	4701.4(13)	13510.7(9)
Z	2	8
$\rho_{\text{calcd.}}$ [Mg/m ³]	1.589	1.658
F(000)	2216	6816
R _{int}	0.0581	0.0313
$R_1 [I > 2\sigma(I)]$	0.0785	0.0301
wR_2 (all data)	0.2405	0.0790
GOF	1.041	1.023



Scheme 1. Binding modes of H₂L.

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twisted fashion. The resulting configuration of the ligands imparts a coordination-induced molecular chirality with the formation of a racemic mixture of enantiomers, as shown in Figure 1c. It is easily reminiscent of the Dy₄ tetrahedron molecule reported by Murugesu et al.,^[9] in which a twisted diazine bridge from a Schiff base ligand is forbidden to rotate freely, and thus conformational chirality is induced. Evidently, the packing arrangement along the crystallographic a, b, and c axes displays two stereoisomers alternately located in different layers (Figure S2). The coordination sphere of Dy1 (Dy3) is completed by a monodentate terminal benzoate anion. Each eight-coordinate Dy^{III} ion exhibits a distorted bicapped trigonal-prismatic geometry (Figure 1b) with an $\{N_2O_6\}$ coordination environment for Dy2 (Dy4) and an $\{O_8\}$ coordination environment for Dy1 (Dy3). However, the difference between the Dy1-O (Dy2-O) and Dy3-O (Dy4-O) bond lengths makes the coordination environments of the four Dy^{III} ions entirely different, and the O1 atom is the chiral center (similar to a chiral carbon atom, Figure 1) within the molecule. The average Dy–O distance is 2.369 Å, and the Dy–O–Dy angles are in the range 89.8(2)-126.1(4)°.



Figure 1. (a) Partially labeled molecular structure for 1 with hydrogen atoms omitted for clarity; (b) coordination polyhedra of bicapped trigonal-prismatic geometry for four Dy^{III} ions; (c) schematic representations of two different stereoisomers of the tetranuclear complex 1.



Scheme 2. Coordination modes of the benzoate groups in 1.

Crystal Structure of 2

A procedure similar to that for 1 except that $Dy(ClO_4)_3$. $6H_2O$ and triethanolamine replace $Dy(C_6H_5COO)_3$ and triethylamine, respectively, produces yellow crystals of 2, for which the asymmetric dinuclear unit, as determined by single-crystal X-ray diffraction, is depicted in Figure 2a (left). Compound 2 crystallizes in the space group C2/c with Z =8 (Figure S3). The metal centers (Dy1 and Dy2) in the dinuclear core are bridged by two phenol oxygen atoms (O3 and O2) and one alcohol oxygen atom (O1) from L²⁻, deprotonated o-vanillin, and tea H_2^- ligands, respectively; the Dy. Dy distance is 3.5492(2) Å, and the three Dy–O–Dy angles are 97.74(9), 94.19(8), and 103.55(9)°. The presence of o-vanillin probably results from the partial metal-ion assisted decomposition of H₂L. The Dy1 center is in the inner salen-type N2O2 coordination pocket of the L2- ligand, and the remaining coordination sites are filled by a phenol oxygen atom (O13) from an H₂L ligand and two methoxide oxygen atoms (O12 and O7) from H₂L and o-vanillin ligands. Discriminatively, the Dy2 center is chelated by a teaH₂⁻ ligand, and the coordination sphere is completed by the aldehyde group (O6) of the o-vanillin ligand, the methoxy group (O8) of the L²⁻ ligand, and a terminal H₂O molecule. The coordination arrangements of both nine-coordinate Dy1 and Dy2 ions are distorted tricapped trigonalprismatic geometries (Figure S4) with an $\{O_7N_2\}$ coordination sphere for Dy1 and an $\{O_8N\}$ coordination sphere for Dy2. Significantly, the L²⁻ and H₂L ligands bind two Dy^{III}



Figure 2. (a) Molecular structures of two configurations for 2; (b) illustration showing the hydrogen-bonding interactions (dashed lines) in 2, which produce a 1D supramolecular chain.

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ions in a double-stranded spiral twisted fashion, which leads to chirality that is induced by the coordination of achiral ligands to metal centers on each individual molecule. Both homochiral enantiomers are clearly shown in Figure 2a. One perchlorate ion and one methanol molecule (red circle in Figure 2b) as hydrogen-bonding connectors join the coordinated water molecule and teaH₂⁻ ligand from two adjacent Dy₂ molecules, respectively, the configurations of which are the same, through O11–H66···O20^{#2}, O18–H18···O19, and O4–H4···O18^{#1} (symmetry codes: #1: x, -y + 1, z + 1/2; #2: x, -y, z + 1/2; see Table S2 for details) hydrogen bonds to generate a 1D chain. Meanwhile, two 1D chains formed by two stereoisomers are connected by a "head-to-head" arrangement of a pair of enantiomers (Figure 2b).

Magnetic Properties

Direct current (dc) magnetic susceptibility studies were performed on polycrystalline samples of 1 and 2 under an applied magnetic field of 1000 Oe in the temperature range 300–2 K. As shown in Figure 3 (top), the $\chi_{\rm M}T$ value of 1 at 300 K of $53.36 \text{ cm}^3 \text{ K} \text{ mol}^{-1}$ is slightly lower than the expected value of 56.6 cm³ K mol⁻¹ for four non-interacting Dy^{III} ions (S = 5/2, L = 5, ${}^{6}H_{15/2}$, g = 4/3). The $\chi_{M}T$ product gradually decreases to 45.8 cm3 K mol-1 at approximately 10 K and then drops sharply to reach a minimum of 38.2 cm³ K mol⁻¹ at 2 K. The foregoing decrease should be a result of the depopulation of excited Stark sublevels, whereas the latter may be ascribed to weak antiferromagnetic interactions between the Dy^{III} spin carriers. In complex 2, the $\chi_M T$ value at room temperature is 29.4 cm³ K mol⁻¹ [Figure 3 (bottom)], which is in good agreement with the expected value of 28.34 cm³ K mol⁻¹ for two uncoupled Dy^{III} ions. With decreasing temperature, the $\chi_{\rm M}T$ product clearly decreases to 25.8 cm³ K mol⁻¹ at 9 K and then slightly increases below 9 K, which should arise from a combination of effects including the depopulation of excited Stark sublevels, the possibly weak ferromagnetic interactions between the Dy^{III} spin carriers, and significant magnetic anisotropy arising from strong spin-orbit coupling.^[13]

The field dependence of the magnetization of both complexes below 5 K reveals a relatively rapid increase of the magnetization at low fields and then a very slow linear increase without clear saturation through increasing dc field (inset of Figure 3). For 1, the magnetization value of $20.9 \ \mu_B$ at 2 K is in good agreement with the expected value of $20.92 \ \mu_B$ (4×5.23 $\ \mu_B$)^[1e] for four uncorrelated Dy^{III} ions under an applied field of 70 kG, but do not reach the saturation value of 40 $\ \mu_B$ (4×10 $\ \mu_B$), which suggests there might be significant magnetic anisotropy within the Dy₄ molecule. Complex **2** shows the same trend as **1** for the magnetization data. In addition, for *M* vs. *H*/*T* plots in **1** and **2**, the non-superposition on a single master curve below 5 K also confirmed the presence of significant magnetic anisotropy and/or low-lying excited states.^[14]



Figure 3. Temperature dependence of the $\chi_M T$ product at 1000 Oe and field dependence of the magnetization at low temperatures (inset) for 1 (top) and 2 (bottom).

To probe the dynamics of the magnetization, alternating current (ac) susceptibility measurements were performed for 1 and 2 under zero and nonzero dc fields as depicted in Figures 4 and 5, respectively. The frequency-dependent signals of the out-of-phase component (χ'') of the ac susceptibility were observed under a zero dc field below 6 K for 1 and indicate the onset of slow magnetic relaxation behavior, which is probably SMM behavior. However, the absence of frequency-dependent peaks under a zero dc field suggests that fast quantum tunneling of magnetization (QTM) in zero field may be an efficient pathway above 1.9 K. To reduce QTM, an optimal dc field of 1000 Oe was applied according to the field dependence of ac susceptibility (Figure S5). As a result, slow relaxation of magnetization was observed below 15 K, and the peaks in both the χ' (in-phase susceptibility) and χ'' (out-of-phase susceptibility) vs. T plots are observed at 1200 Hz for 1 under a 1000 Oe dc field, as seen in Figure 4 (right). It is clear that the χ'' signal is strongly enhanced, which further confirms the occurrence of QTM at low temperature.^[15] Unfortunately, the energy barrier could not be obtained by extracting the relaxation time characteristics because of the few peaks observed below the maximum frequency of our superconducting quantum interference device (SQUID). It is noted that the presence of fast quantum tunneling relaxation in the Dy₄ tetrahedron should originate from coordination geometry with low symmetry (approximately $C_{2\nu}$) on local Dy sites and weak intramolecular interactions between the Dy ions.^[16] This has been proved by some examples in the literature. In general, compounds with highly

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symmetric crystal-field environments, such as [LnPc₂] and Dy β -diketone compounds with close D_{4d} symmetry, display excellent SMM behavior with high effective barriers.^[1d,6d] Recently, the discovery of the highest measured blocking temperature of 13.9 K in an N_2^{3-} radical-bridged Tb₂ complex favors the fact that strong exchange coupling can mitigate quantum tunneling relaxation processes that lead to the loss of remnant magnetization under zero applied field. For 2, the frequency-dependent signals of the out-of-phase component (χ'') of the ac susceptibility were also observed without peaks under a zero dc field below 15 K (Figure 5), which indicates the onset of slow magnetic relaxation behavior. However, the preliminary ac susceptibility measurements at 997 Hz under applied dc fields suggest that the effect of a dc field on the relaxation is not important at 1.9 K (Figure S6).



Figure 4. Temperature dependence of the in-phase (top) and outof phase (bottom) ac susceptibility for **1** under zero dc field (left) and 1 kOe dc field (right).



Figure 5. Temperature dependence of the in-phase (top) and outof-phase (bottom) ac susceptibility for **2** under zero dc field.

To further investigate the dynamics of this system, a method applied to determine τ_0 in Mn₁₂ acetate and τ_0 and E_a in Dy₃ complex, which assumes that only one characteristic relaxation process of the Debye type exists in the system, can be used to attain the estimated energy barrier and τ_0 based on the following relation:^[10a,17]

$$\ln(\chi''/\chi') = \ln(\omega\tau_0) + E_a/k_BT$$

By using linear fits of plots of $\ln(\chi''/\chi')$ vs. 1/T for different frequencies, estimates of the activation energy, E_a , of ca. 2.3 and 1.4 K and the pre-exponential factor, τ_0 , of about 9.4×10^{-5} and 1.7×10^{-4} s for 1 and 2, respectively, are extracted (Figure 6). The results are estimated but are reasonable when the frequency-dependent peaks are beyond the low temperature and high frequency limits (1.9 K and 1500 Hz) of our SQUID magnetometer. Compared with the E_a values of other Dy₄ compounds (linear or planar Dy₄), the barrier in 1 is low, which may be due to the low symmetry on local Dy sites and an effective compensation of magnetic contributions in the tetrahedral arrangement.



Figure 6. Plots of natural logarithm of χ''/χ' vs. 1/T for 1 (top) and 2 (bottom). The solid line represents a fit of the results over the range 3–1200 Hz.

Conclusions

Two coordination-induced chiral Dy-based aggregates (1 and 2) that feature slow magnetic relaxation behavior have been isolated by using a salen-type ligand under different synthetic conditions. Here, the special coordination mode of the salen-type ligand is one of the key aspects for achieving a chiral magnetic system. The four Dy^{III} ions of 1 are very weakly coupled, and ac susceptibility measurements indicate the presence of significantly fast QTM in zero dc

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field, which can be slowed down by the application of a 1 kOe dc field. A structure with a tail is demonstrated in **2**, mainly because of the presence of teaH₃ during the synthetic process, which pushes the lanthanide ions into the N_2O_2 coordination pocket of the H₂L ligand, and thus results in the helical distortion of the ligand. The original synthetic approach illustrated in this work may represent a promising new avenue for the generation of coordination-induced molecular chirality through the application of a typical salen-type ligand.

Experimental Section

General Procedures: All chemicals were used as received without further purification, and all manipulations were performed under aerobic conditions. $Dy(C_6H_5COO)_3$ was synthesized according to a previously reported procedure.^[18] Elemental analyses (C, H, and N) were performed with a Perkin–Elmer 2400 analyzer. IR spectra were recorded with a Perkin–Elmer FTIR spectrophotometer with samples prepared as KBr disks in the 4000–300 cm⁻¹ range. Magnetic susceptibility measurements were obtained in the temperature range 1.9–300 K with a Quantum Design MPMS XL-7 SQUID magnetometer equipped with a 7 T magnet. The variable-temperature magnetization was measured with an external magnetic field of 1000 Oe in the temperature range 2–300 K. Diamagnetic corrections for the compounds were estimated from Pascal's constants,^[19] and magnetic data were corrected for the sample holder and diamagnetic contribution.

Synthesis of H_2L : The Schiff-base ligand was prepared by condensation of 1,2-cyclohexanediamine and *o*-vanillin in a 1:2 molar ratio in methanol.^[12]

Caution! Perchlorate salts of metal complexes are potentially explosive. They should be handled with care and prepared only in small quantities.

[Dy₄(μ_4 -O)L₂(C₆H₅COO)₆]·3CH₃OH (1): H₂L (0.1 mmol, 0.038 g) was dissolved in MeOH (10 mL) and CH₂Cl₂ (5 mL), and Dy(C₆H₅COO)₃ (0.1 mmol, 0.053 g) and triethylamine (0.3 mmol, 0.042 mL) were added to give a clear yellow solution. This solution was stirred for 2 h and was then left undisturbed. After 6 d, pale yellow block-shaped crystals of the tetranuclear cluster were formed in 57% yield (32 mg). C₈₉H₉₀Dy₄N₄O₂₄ (2249.70): calcd. C 47.51, H 4.03, N 2.49; found C 47.20, H 3.95, N 2.47. IR (KBr): $\tilde{v} = 3391$ (br.), 3059 (w), 2938 (m), 2864 (w), 1628 (s), 1602 (s), 1563 (s), 1547 (s), 1493 (m), 1470 (s), 1417 (s), 1361 (s), 1302 (s), 1284 (m), 1225 (s), 1171 (w), 1101 (w), 1080 (m), 1036 (w), 1024 (w), 974 (w), 939 (w), 857 (m), 783 (w), 719 (s), 672 (m), 561 (w), 511 (w), 482 (w), 431 (m) cm⁻¹.

[Dy₂L(H₂L)(teaH₂)(*o*-vanillin)(H₂O)](ClO₄)₂·2CH₃OH·H₂O (2): A procedure similar to that for 1 was applied, except that Dy(C₆H₅-COO)₃ and triethylamine were replaced by Dy(ClO₄)₃·6H₂O (0.1 mmol, 0.057 g) and triethanolamine (0.2 mmol, 0.026 mL), respectively. Yellow single crystals suitable for X-ray diffraction analysis were formed after 9 d in 32% yield (27 mg). C₆₀H₈₃Cl₂Dy₂N₅O₂₆ (1686.24): calcd. C 42.74, H 4.96, N 4.15; found C 42.61, H 4.77, N 4.26. IR (KBr): $\tilde{v} = 3419$ (br.), 3062 (w), 2936 (m), 2858 (w), 1650 (s), 1617 (s), 1557 (m), 1506 (m), 1471 (s), 1454 (s), 1406 (m), 1366 (w), 1348 (w), 1289 (s), 1225 (s), 1171 (w), 1076 (s), 1038 (m), 949 (m), 903 (w), 858 (w), 781 (w), 738 (s), 692 (w), 660 (w), 624 (m), 564 (w), 493 (w), 479 (w), 416 (m) cm⁻¹.

X-ray Crystal Structure Determinations: Single-crystal X-ray data of the title complexes were collected at 106(2) K with a Bruker Apex II CCD diffractometer equipped with graphite-monochromatized Mo- K_{α} radiation ($\lambda = 0.71073$ Å). Data processing was completed with the SAINT processing program. The structures were solved by direct methods and refined by full-matrix leastsquares methods on F^2 by using SHELXTL-97.^[20] The location of the Dy atoms was easily determined, and C, O, N, and Cl atoms were determined from the difference Fourier maps. The non-hydrogen atoms were refined anisotropically. All hydrogen atoms were introduced in calculated positions and refined with fixed geometries with respect to their carrier atoms. CCDC-891144 (1) and -892815 (2) contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/ data_request/cif.

Supporting Information (see footnote on the first page of this article): Crystal structure representations (Figures S1–S4), magnetic measurements (Figures S5 and S6), bond lengths and angles (Table S1) and hydrogen bond details (Table S2).

Acknowledgments

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Single-Molecule Magnets

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Two Locally Chiral Dysprosium Compounds with Salen-Type Ligands That Show Slow Magnetic Relaxation Behavior

Keywords: Chirality / N,O ligands / Quantum tunneling / Dysprosium / Magnetic properties