Switching off the single-molecule magnet properties of the [Co\textsuperscript{II}(Me\textsubscript{6}tren)(OH\textsubscript{2})\textsuperscript{2+}] module by complexation with trans-[Ru\textsuperscript{III}(salen)(CN)\textsubscript{2}]\textsuperscript{−}\textsuperscript{†}

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The trinuclear complex [(Co\textsuperscript{II}(Me\textsubscript{6}tren))\textsubscript{2}(μ-NC)\textsubscript{2}Ru\textsuperscript{III}(salen)][NO\textsubscript{3}\textsubscript{2}]\textsubscript{3}CH\textsubscript{3}CN-H\textsubscript{2}O (2) (salen = \textit{NN}′-ethylenebis(salicylideneiminato); Me\textsubscript{6}tren = tris(dimethylamino)ethyl)amine) was synthesized by the reaction of trans-\textsubscript{−}(PPh\textsubscript{4})[Ru\textsuperscript{III}(salen)(CN)\textsubscript{2}] and two equivalents of [Co\textsuperscript{II}(Me\textsubscript{6}tren)(OH\textsubscript{2})][NO\textsubscript{3}\textsubscript{2}]\textsuperscript{−} (1). Magnetic susceptibility measurements of 1 reveal its single-molecule magnet behaviour whilst 2 shows no appreciable slow dynamics of the magnetization even under an applied dc field. A comparison of the electrochemical properties of complex 2 with the trans-(PPh\textsubscript{4})[Ru\textsuperscript{III}(salen)(CN)\textsubscript{2}] precursor reveals anodic shifts of the reduction and oxidation waves. The absorption spectrum of 2 obtained from surface optical reflectivity methods is also reported and discussed.

Introduction

With recent examples of mononuclear Co(II) and Fe(II) complexes exhibiting single molecule magnet (SMM) behaviour,\textsuperscript{1} our group has turned its attention to complexes of the amino based chelating ligand Me\textsubscript{6}tren.\textsuperscript{2} This tripodal tetraamine has the advantage of restricting the coordination sites of a metal centre, acting as a capping ligand, thus allowing the formation of controlled topologies.\textsuperscript{3−7} The Me\textsubscript{6}tren ligand can impose a trigonal bipyramidal environment around the coordinated metal centres,\textsuperscript{7,8} which is known to be a coordination geometry that favours SMM behaviour in Co(II) complexes.\textsuperscript{16}

Previously, we reported a number of cyanido-based complexes linking 3d, 4d and 5d metal ions to form polynuclear complexes as well as 1- and 2-dimensional networks.\textsuperscript{9−11} Some of these systems exhibit magnetic properties characteristic of single-chain magnets (SCMs).\textsuperscript{10,11} In our quest for new SMM and SCM systems, we have chosen to use the trans-[Ru\textsuperscript{III}(salen)(CN)\textsubscript{2}]\textsuperscript{−} module to link mononuclear Me\textsubscript{6}tren-based species.\textsuperscript{12} trans-[Ru\textsuperscript{III}(salen)(CN)\textsubscript{2}]\textsuperscript{−} complexes have relevance in a number of branches of coordination chemistry such as catalysis, electrochemical sensors and magnetism.\textsuperscript{9a,12−14} Most of these complexes exhibit two reversible redox processes arising from the II–IV oxidation states in which ruthenium is stable. Over the years the effect of the axial ligands (neutral or anionic) on both the redox potentials and catalytic activity of [Ru\textsuperscript{III}(salen)(CN)\textsubscript{2}]\textsuperscript{−} complexes has been demonstrated and studied.\textsuperscript{15,16} Leung and Che found that the catalytic activity of trans-[Ru\textsuperscript{III}(salen)(CN)\textsubscript{2}]\textsuperscript{−} complexes disappeared when X = CN\textsuperscriptr, due to its substitutional inertness.\textsuperscript{15} However, in the area of magnetism, having cyanido axial ligands might be beneficial as they open the possibility of coordination to other paramagnetic centres, thus providing an efficient path for magnetic coupling. Indeed, trans-[Ru\textsuperscript{III}(salen)(CN)\textsubscript{2}]\textsuperscript{−} has been used as a precursor in the synthesis of 0, 1 and 2-dimensional heteronuclear systems exhibiting interesting magnetic properties.\textsuperscript{9a,12,13} Its use in the preparation of molecule-based magnetic materials has the advantages that it is easy to synthesize and contains a paramagnetic 4d centre that can interact with other metal centres through the cyanido groups, whose trans-disposition also allows extendable coordination.

Herein we present the work developed from the use of the Me\textsubscript{6}tren capping ligand and the salt Co\textsuperscript{II}(NO\textsubscript{3})\textsubscript{2}.6H\textsubscript{2}O to yield the [Co\textsuperscript{II}(Me\textsubscript{6}tren)(OH\textsubscript{2})\textsuperscript{2+}] SMM (1), and its coordination to the trans-[Ru\textsuperscript{III}(salen)(CN)\textsubscript{2}]\textsuperscript{−} precursor to form the trinuclear complex [([Co\textsuperscript{II}(Me\textsubscript{6}tren))\textsubscript{2}(μ-NC)\textsubscript{2}Ru\textsuperscript{III}(salen)][NO\textsubscript{3}\textsubscript{2}]\textsubscript{3}CH\textsubscript{3}CN-H\textsubscript{2}O (2) for which the SMM properties are “switched off”. This new trinuclear species presents the novel structural feature of two pentacoordinate Co\textsuperscript{II} ions surrounding a hexacoordinated Ru\textsuperscript{III} ion through cyanido bridges. We here report the structural, spectroscopic, electrochemical and magnetic properties of complexes 1 and 2.

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Experimental

Me₆tren and trans-(PPh₃)[RuIII(salen)(CN)₂] were synthesized according to the literature.⁴⁻⁷,¹³,¹⁵ All the reagents used for the syntheses were purchased from commercial sources and directly handled without further purification. Complexes 1 and 2 were synthesized under argon using Schlenk techniques. Acetonitrile and diethyl ether were of reagent grade and were deoxygenated with argon before use. Caution! We did not encounter any problems during our studies; nevertheless, cyanido-based compounds are often toxic and should be handled with care.

Synthetic procedures

[Co²⁺(Me₆tren)(OH₂)](NO₃)₂ (1). 0.030 g (0.13 mmol) of Me₆tren was added to a Schlenk tube containing 0.038 g (0.13 mmol) of Co(III) precursor. The reaction mixture was then stirred for 2 hours before filtration. Dark blue single crystals suitable for X-ray diffraction were obtained after one week by Et₂O vapour diffusion. Yield: 0.046 g (80% based on Co). Anal. calcd (found) for C₁₂H₃₂CoN₆O₇: C: 33.41% (33.79%); H: 7.48% (7.41%); N: 19.48% (19.53%). IR/cm⁻¹: 2916 (m), 2108 (m), 1727 (s), 1665 (s), 1606 (s), 1545 (m), 1526 (m), 1483 (m), 1472 (s), 1411 (m), 1393 (s), 1290 (s), 1249 (w), 1184 (w), 1099 (m), 1037 (m), 1016 (w), 1003 (m), 945 (m), 935 (w), 911 (w), 826 (w), 808 (w), 776 (m), 744 (w), 739 (w), 599 (w), 574 (w).

[Co²⁺(Me₆tren)(μ-NC)]RuIII(salen)(NO₃)₂·3CH₃CN·H₂O (2). 0.057 g (0.13 mmol) of Co(III) precursor was dissolved in acetonitrile. To this solution was added 0.046 g (0.06 mmol) of trans-(PPh₃)₂[RuIII(salen)(CN)₂]. The reaction mixture was then stirred for 2 hours before filtration. Dark blue single crystals suitable for X-ray diffraction were obtained after two days by Et₂O vapour diffusion into the reaction mixture. Yield: 0.046 g (50% based on the Ru(III) precursor). Anal. calcd (found) for C₄₈H₈₅Co₂N₁₈O₁₂Ru: C: 43.57% (43.94%); H: 6.32% (6.68%); N: 19.05% (19.49%). IR/cm⁻¹: 3424 (b), 2916 (m), 2108 (m). υ(CN) at 2088 cm⁻¹.

Crystal structure determination

Single crystals of 1 and 2 were coated with N-paratone oil and mounted on a fibre loop. X-ray crystallographic data were collected on a Bruker APEX II Quazar diffractometer with graphite-monochromated Mo-Kα radiation (λ = 0.71073 Å) at 293(2) K. The program SAINT was used to integrate the data while the absorption correction was based on multiple and symmetry-equivalent reflections in the dataset using SADABS.¹⁷ The structures were solved with SIR92 and refined by full-matrix least squares on F² using SHELXL-97.¹⁸,¹⁹ All atoms, except hydrogen, were refined anisotropically. The H atoms were placed at calculated positions using suitable riding models except those on the coordinated water molecule, which were found directly on the difference Fourier map and refined using DFIX constraints. A summary of the crystallographic data and selected structural details (bond lengths and angles) are reported in Tables 1 and 2.

Table 1 Crystallographic data and refinement parameters for 1 and 2

| Complex | 1 | 2 |
|---------|---|---|
| Formula | C₁₂H₁₃CoN₄O₂ | C₄₈H₈₅Co₂N₁₈O₁₂Ru |
| FW (g mol⁻¹) | 431.37 | 1325.27 |
| Crystal colour | Green | Dark blue |
| Crystal size (mm) | 0.10 × 0.17 × 0.09 | 0.26 × 0.12 × 0.03 |
| Crystal system | Monoclinic | Monoclinic |
| Space group | P2₁ | P2₁/c |
| T (K) | 100(2) | 100(2) |
| a (Å) | 9.131(3) | 19.577(2) |
| b (Å) | 12.369(4) | 33.296(4) |
| c (Å) | 9.870(4) | 9.372(1) |
| α (°) | 90 | 90 |
| β (°) | 117.337(13) | 103.641(1) |
| γ (°) | 90 | 90 |
| V (Å³) | 990.2(6) | 5937(1) |
| Z | 2 | 4 |
| Total refls | 5808 | 10 943 |
| Unique refls (I > 2σ(I)) | 4808 | 8964 |
| Rint | 0.0615 | 0.0706 |
| Refined param./restr. | 247/3 | 745/0 |
| R₁(I > 2σ(I)) | 0.0414 | 0.0549 |
| wR₂ (all data) | 0.1185 | 0.1673 |
| Goodness-of-fit | 1.099 | 1.133 |

Table 2 Selected bond lengths (Å) and angles (°) for 1 and 2

| Complex | 1 | 2 |
|---------|---|---|
| Co₁-N₄ | 2.144(12) | Ru₁-N₁₂ | 2.011(5) |
| Co₁-N₃ | 2.115(9) | Ru₁-N₁₁ | 2.014(4) |
| Co₁-N₂ | 2.136(18) | Ru₁-O₁ | 2.015(4) |
| Co₁-N₁ | 2.179(3) | Ru₁-O₂ | 2.017(4) |
| Co₁-O₁ | 2.018(3) | Ru₁-C₂₅ | 2.032(6) |
| O₁-Co₁-N₁ | 177.12(10) | Ru₁-C₂₆ | 2.068(6) |
| O₁-Co₁-N₄ | 99.02(11) | Co₁-N₉ | 1.997(4) |
| O₁-Co₁-N₃ | 99.94(13) | Co₁-N₃ | 2.109(5) |
| O₁-Co₁-N₂ | 95.17(14) | Co₁-N₄ | 2.113(4) |
| Co₁-N₁ | 2.114(5) | Co₁-N₂ | 2.114(5) |
| Co₁-N₁ | 2.194(5) | Co₁-N₁ | 2.194(5) |
| Co₁-N₁ | 2.110(4) | Co₁-N₁ | 2.110(4) |
| Co₁-N₁ | 2.125(1) | Co₁-N₁ | 2.125(1) |
| Co₁-N₁ | 2.122(4) | Co₁-N₁ | 2.122(4) |
| Co₁-N₁ | 2.126(6) | Co₁-N₁ | 2.126(6) |
| Co₁-N₁ | 2.205(4) | Co₁-N₁ | 2.205(4) |
| C2₅-Ru₁-C₂₆ | 178.72(24) | N₉-Co₁-N₁ | 178.28(16) |
| N₉-Co₁-N₂ | 177.76(17) | N₁₀-Co₂-N₅ | 176.09(51) |
| N₁₀-C₂₅-Ru₁ | 176.14(51) | C₂₅-N₉-Co₁ | 171.92(44) |
| C₂₅-N₁₀-Co₂ | 167.64(44) |

Crystal colour Green Dark blue
FW (g mol⁻¹) 431.37 1325.27
Crystal system Monoclinic Monoclinic
Space group P2₁ P2₁/c
T (K) 100(2) 100(2)
a (Å) 9.131(3) 19.577(2)
b (Å) 12.369(4) 33.296(4)
c (Å) 9.870(4) 9.372(1)
α (°) 90 90
β (°) 117.337(13) 103.641(1)
γ (°) 90 90
V (Å³) 990.2(6) 5937(1)
Z 2 4
Total refls 5808 10 943
Unique refls (I > 2σ(I)) 4808 8964
R_int 0.0615 0.0706
R₁(I > 2σ(I)) 0.0414 0.0549
wR₂ (all data) 0.1185 0.1673
Goodness-of-fit 1.099 1.133

Electrochemical experiments

Cyclic voltammetry measurements were performed using a CHI 760c potentiostat, in a standard one-compartment cell under N₂, equipped with platinum wires for working/counter electrodes and a silver wire (Ag/Ag⁺) for the reference electrode. Solutions were prepared from 0.1 M tetraethylammonium tetrafluoroborate ([NEt₄]⁺[BF₄]⁻) in acetonitrile. Ferrocene was added at the end of each experiment and potentials are referenced to the Cp₂Fe⁺/⁰ couple.

CCDC 991663 and 991664 for 1 and 2, respectively. Fig. 1 and 2 were generated using CrystalMaker® (CrystalMaker Software Ltd, www.crystalmaker.com).
confirm the absence of ferromagnetic impurities. The field dependence of the magnetization was collected between 1.85 and 8 K while sweeping the magnetic field between 0 and 7 T at about 100 to 400 Oe min⁻¹. ac susceptibility experiments were realized at ac frequencies ranging from 10 to 10 000 Hz with an ac field amplitude of 1 Oe (PPMS) and from 1 to 1500 Hz with an ac field amplitude of 3 Oe (MPMS). Experimental data were corrected for the sample holder and for the diamagnetic contribution of the samples.

Results and discussion

Synthesis and structural characterization

The mononuclear complex 1 (Fig. 1) was obtained in good yield by the 1 : 1 reaction of Me₆tren with Co(NO₃)₂·6H₂O in acetonitrile. 1 crystallizes in the monoclinic space group P2₁ (Table 1). The Co-directional bipyramidal coordination sites are composed of four nitrogen atoms from the Me₆tren ligand accounting for three axial positions. The three equatorial 

Magnetic properties

The samples were checked by X-ray diffraction prior to any magnetic measurements. Magnetic susceptibility measurements were performed using Quantum Design MPMS-XL SQUID and PPMS-9 magnetometers. The measurements were carried out on freshly filtered polycrystalline samples introduced in a polyethylene bag (3 × 0.5 × 0.02 cm). dc measurements were conducted from 300 to 1.85 K and between ±70 kOe applied dc fields. The thermal dependence of the magnetic susceptibility was measured at 1000 Oe. An M vs. H measurement was performed at 100 K to

Optical properties

Surface optical reflectivity measurements were performed on a home-built system at different temperatures ranging from 10 to 300 K. Heating and cooling rates were maintained at 4 K min⁻¹ during the measurements. The setup collects the light reflected by the sample (sum of direct and diffuse reflected light), which was analysed using a high sensitivity Hamamatsu10083CA spectrometer between 480 and 1050 nm. The spectra were compared to a white reference obtained with a NIST traceable standard for reflectance (SphereOptics, ref SG3054). The background, acquired with the light source switched off, was subtracted from all measurements. The absolute optical reflectivity can be plotted as a function of temperature, time or wavelength.

Electrochemical properties

The redox properties of complexes 1 and 2 in acetonitrile were studied by cyclic voltammetry (Fig. S1 and S2, ESI†) and are reported vs. Cp₂FeCl⁻ in Table 3. The mononuclear complex 1 exhibits one irreversible oxidation wave at +0.98 V (Fig. S1, ESI†), likely corresponding to the oxidation of CoII to CoIII. The Ru precursor, trans-(PPh₄)[RuIII(salen)(CN)₂]⁺, displays a reversible reduction at E' = −1.05 V and a reversible oxidation at E' = +0.31 V (Fig. S3, ESI†), typical of trans-[RuIII(salen)X₃]⁺ complexes.
For trans-(Bu$_4$N)$_2$[Ru$^{III}$(salen)(CN)$_2$], the reported potential values ($E'$) of Ru$^{III}$ → Ru$^{II}$ and Ru$^{III}$ → Ru$^{IV}$ are −1.15 and +0.28 V, respectively, in good agreement with those (vide supra) obtained here from the trans-[Ru$^{III}$(salen)(CN)$_2$]$^-$ complex with a PPh$_4^–$ counter cation.

Complex 2 exhibits two redox processes, a reversible reduction at −0.64 V and a quasi-reversible oxidation at +0.65 V (Fig. S2, ESI†). The first can be assigned to the Ru$^{III}$ → Ru$^{II}$ reduction with a significant anodic shift in comparison with the Ru$^{III}$ precursor, due to the presence of the electron-withdrawing Co$^{II}$ centres. This shift, and the absence of characteristic redox waves for the Ru$^{III}$ precursor confirms the persistence of the trinuclear complex 2 under these solution conditions. The redox feature at +0.65 V could be attributed either to the Ru$^{III}$ → Ru$^{IV}$ oxidation anodically shifted due to the Co$^{III}$ centres, or to the Co$^{II/III}$ oxidation cathodically shifted due to the change in the Co coordination sphere from a neutral to an anionic axial ligand. The $E'$ calculated for the two redox processes from the Ru$^{III}$ mononuclear complexes and that of complex 2 are reported in Table 3. The similarity of these values suggests that the redox process observed at 0.63 V for 2 likely corresponds to the oxidation of the Ru$^{III}$ centre.

** Optical measurements **

The spectroscopic properties of complex 2 were probed by optical reflectivity (Fig. 3) in search of a thermal or photo-induced electron transfer process from the Co$^{II}$ → Ru$^{III}$ centres, an inherent feature of several cyanido-bridged mixed valence heterometallic complexes. When cooling the sample, a slight blue shift is observed from the reflectivity band at 960 nm to 890 nm; meanwhile the rest of the spectrum remains unchanged. This band shift was examined by plotting the thermal evolution of the absolute reflectivity at 920 nm (Fig. S4, ESI†) which indeed reveals a gradual increase between 300 and 10 K. This behaviour has already been reported for [Bu$_4$N][Ru$^{III}$(salen)(CN)$_2$]$^–$. Therefore, the optical modification exhibited by complex 2 can be attributed solely to the trans-[Ru$^{III}$(salen)(CN)$_2$]$^–$ site and not to any other electronic process occurring between the Co$^{III}$ and the Ru$^{III}$ centres.

** Dc magnetic susceptibility measurements **

The temperature dependence of the magnetic susceptibility of complexes 1 and 2 was measured under a dc field of 1000 Oe in the 1.85–300 K temperature range. The $\chi T$ product plotted as a function of temperature for 1 and 2 is shown in Fig. 4. Plots of magnetisation as a function of field for 1 and 2 are shown in Fig. S5 (ESI†).

The room temperature $\chi T$ product for 1 is 2.4 cm$^3$ K mol$^{-1}$, which is higher than the value of 1.875 cm$^3$ K mol$^{-1}$ expected for an $S = 3/2$ spin with $g = 2$. This high value is the result of the orbital contribution typical of a high spin Co$^{III}$ metal ion. Upon decreasing temperature, the $\chi T$ product remains relatively unchanged until around 15 K when a rapid decrease to a value of 1.68 cm$^3$ K mol$^{-1}$ at 1.85 K is observed, as a signature of the Co$^{III}$ spin–orbit coupling.

At room temperature, the $\chi T$ value of 2 is 5.2 cm$^3$ K mol$^{-1}$, which accounts for three isolated spin centres: two high spin Co$^{II}$ with Curie constants of about 2.4 cm$^3$ K mol$^{-1}$ (on the basis of the magnetic properties of 1, vide supra) and one low spin $S = 1/2$ Ru$^{III}$ magnetic centre with a Curie constant equal to 0.4 cm$^3$ K mol$^{-1}$ ($g = 2.11$). As the temperature decreases, the $\chi T$ product remains unchanged until around 60 K. Below this temperature, the $\chi T$ product slightly increases to 5.3 cm$^3$ K mol$^{-1}$ at 14 K before experiencing a sharp decrease to reach a value of 4.4 cm$^3$ K mol$^{-1}$ at 1.85 K. The thermal behaviour of the

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**Table 3** Electrochemical data for 1, 2 and trans-[Ru$^{III}$(salen)(CN)$_2$]$^–$

| Complexes | Reduction $E'$ (V) | Oxidation $E'$ (V) | $\Delta E'$ (V) |
|-----------|-------------------|--------------------|----------------|
| 1         | −0.64             | +0.65              | 1.29           |
| 2         | −1.05             | +0.31              | 1.36           |
| trans-[PPh$_4$][Ru$^{III}$(salen)(CN)$_2$]$_2$ | −1.15 | +0.28 | 1.43 |

| Note: | stands for irreversible; Values for trans-[Bu$_4$N][Ru$^{III}$(salen)(CN)$_2$]$^–$ are referenced to Cp$_2$Fe$^{0+}$ according to ref. 21. |
\( \chi T \) product above 14 K suggests the presence of weak ferromagnetic interactions between Ru\textsuperscript{III} and Co\textsuperscript{II} magnetic sites mediated by the cyanido bridges. On the other hand below 14 K, weak intermolecular antiferromagnetic interactions and/or Co\textsuperscript{II} spin–orbit coupling effects are likely responsible for the decrease of the \( \chi T \) product.

**Ac magnetic susceptibility measurements**

Alternating current (ac) magnetic susceptibility measurements were performed on samples of both \( 1 \) and \( 2 \) at temperatures below 10 K. Neither complex showed an out-of-phase ac response in the zero applied field. However upon application of an external field above 200 Oe, complex \( 1 \) showed a high frequency relaxation mode at temperatures below 4 K.

The optimum field for \( 1 \) was determined by plotting curves of \( \chi' \) against frequency at 1.9 K with the application of different magnetic fields up to 7000 Oe (Fig. S6, ESI†). In the absence of a relaxation mode maximum, the optimum field was estimated at 1400 Oe, where the relaxation mode is the most intense. The temperature and frequency dependence of the ac susceptibility were thus measured at 1400 Oe (Fig. 5). Due to the absence of any maxima in the isothermal \( \chi' \) vs. \( \nu \) plots, a standard scaling method (inset Fig. 5)\textsuperscript{26} was used to estimate the temperature dependence of the magnetization relaxation time. Above 2.8 K, the relaxation time follows an Arrhenius law above 2.8 K as discussed in the text.

![Fig. 5](image.png)

**Fig. 5** Temperature (left) and frequency (right) dependence of the real (\( \chi' \), top) and imaginary (\( \chi'' \), bottom) parts of the magnetization susceptibilities, between 10 and 10 000 Hz and between 1.81 and 10 K, respectively, for \( 1 \) in the 1400 Oe dc-field (with \( H_{\text{ac}} = 1 \) Oe). Solid lines are visual guides. Inset: scaled frequency dependence of \( \chi'' \) (shown in the bottom left part of the main figure) normalized by the zero–frequency \( \chi'' \) (taken experimentally at 10 Hz) at different temperatures between 1.81 and 3.2 K (with \( H_{\text{ac}} = 1 \) Oe and \( H = 1400 \) Oe) for \( 1 \). The scaling parameter, \( z \), is equal to 1 for the data at 1.81 K.

A large magnetic field (Fig. S7, ESI†). Unfortunately, this result shows that the SMM properties of \( 1 \) are lost when the [Co\textsuperscript{II}Me\textsubscript{6}tren]\textsuperscript{2+} units assemble around the trans-[Ru\textsuperscript{III}(salen)(CN)\textsubscript{3}]\textsuperscript{2−} moiety.

**Conclusions**

We have shown that a mononuclear Co\textsuperscript{II} complex of Me\textsubscript{6}tren exhibits SMM properties with an energy barrier of about 18 K. Complex \( 1 \) is another example of the ever-expanding library of mononuclear pentacoordinate Co\textsuperscript{II} complexes that show SMM behaviour. Two units of \( 1 \) can be linked through a trans-[Ru\textsuperscript{III}(salen)(CN)\textsubscript{3}]\textsuperscript{2−} anion to form the trinuclear complex \( 2 \), which does not exhibit SMM properties even under dc field. Complex \( 2 \) presents structural and optical properties similar to those of its precursors. However, the electrochemical properties of complex \( 2 \) are distinguishably different from those of the Co\textsuperscript{II} and Ru\textsuperscript{III} precursors at both reduction and oxidation processes. These results echo what has been reported for cyanido-bridged complexes containing Co\textsuperscript{II} and Ru\textsuperscript{III} centres bearing weak ferro- or antiferromagnetic coupling.\textsuperscript{27–29} Work is currently underway to expand this area of research into other transition metals such as Fe(n).

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