Experimental report

15/06/2022

Proposal: **5-31-2716**

Council: 10/2019

Title: The magnetic structure of the Eu2Xcompounds (X = In, Sn)

Research area: Physics

This proposal is a resubmission of 5-31-2663

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Samples: Eu2In
Eu2Sn

Instrument	Requested days	Allocated days	From	To
D20	4	3	18/06/2021	21/06/2021

Abstract:

A particularly sharp, strongly first-order ferromagnetic to paramagnetic transition at Tc=55K was recently discovered in the rare-earth intermetallic compound Eu2In. This transition is remarkable due to the combination of large latent heat, small lattice discontinuities and negligible hysteresis, which makes this material a nearly perfect candidate for magnetic refrigeration. Furthermore, the transition is not accompanied by a structural change and is purely magnetoelastic in nature, which is uncommon among rare earth intermetallics not containing d-elements. By contrast, Eu2Sn, which adopts a closely related crystal structure, exhibits a conventional second order antiferromagnetic transition at TN=31K. 151Eu Mössbauer spectroscopy confirms that the local magnetic behavior of the two compounds is completely different. While the spectrum of Eu2Sn shows a single Eu site and a conventional second order magnetic transition, Eu2In shows two, distinct, equal-area components and a clearly first order transition. The striking contrast between the properties of the two structurally similar compounds demand an in-depth investigation of their underlying magnetism by neutron diffraction.

Experiment report for 5-31-2716

A particularly sharp, strongly first-order ferromagnetic to paramagnetic transition was recently discovered in the orthorhombic rare-earth intermetallic compound Eu_2In at T_C = 55 K (see Fig.1). This transition is remarkable due to the combination of large latent heat, small lattice discontinuities and negligible hysteresis, which makes this material a nearly perfect candidate for magnetic refrigeration. Furthermore, the transition is not accompanied by a structural change (the structure type remains Co_2Si) and is purely magnetoelastic in nature.

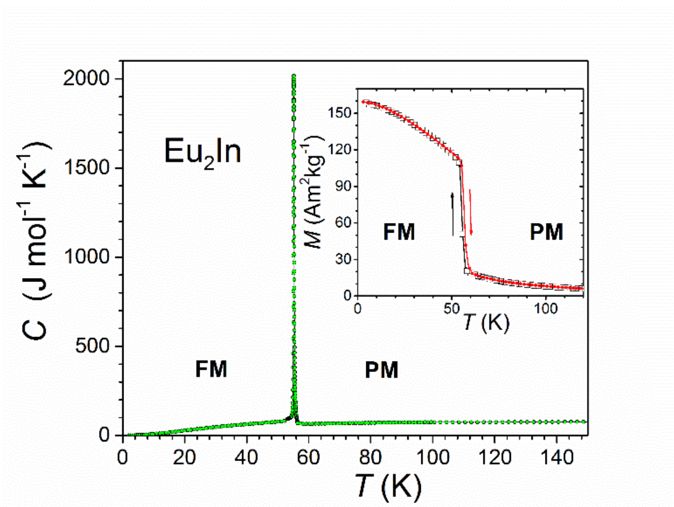

Figure 1 Heat capacity of Eu_2In measured in zero magnetic field. Inset: magnetization as a function of temperature measured in an applied field of 100mT on heating and cooling.

^{151}Eu Mössbauer spectroscopy (see Fig.2) confirmed the first-order nature of the transition and further showed that the two Eu sites in the structure have quite different hyperfine fields (B_{hf}) suggesting that the moments on the two sites are not the same.

Neutron diffraction measurements were made at a wavelength of 2.41Å on D20 using a large-area flat-plate geometry to offset the effects of the highly absorbing europium.

Fitting the magnetic-only pattern generated by subtracting data taken at 58K (in the paramagnetic state) showed that the europium moments adopt a ferromagnetic structure with the moments parallel to the a-axis (Figure 3a). Remarkably, the analysis also showed that the europium moments on the two sites are distinct, confirming the Mössbauer result. The two moments further exhibit different temperature dependences before they both vanish at the 55K first-order transition (Figure 3b). As noted in the earlier x-ray diffraction work, the neutron diffraction data confirm the a-axis expansion and b-axis contraction on heating through the first-order transition.

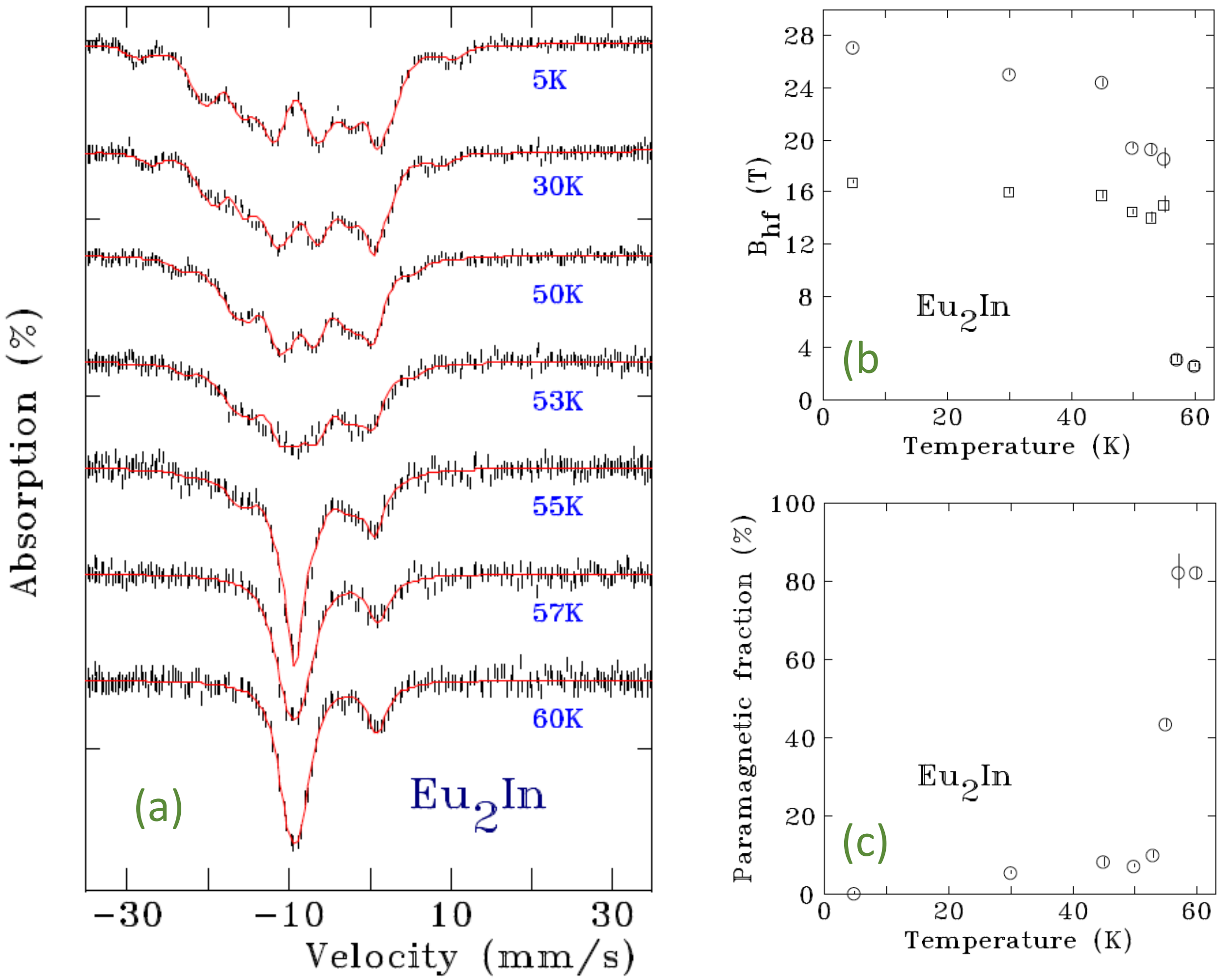

Figure 2. (a) [151]Eu Mössbauer spectra of Eu_2In showing the evolution of the magnetic order on heating through the first-order transition at 55K. (b) The temperature dependence of the hyperfine field (B_{hf}) showing the two distinct components and the abrupt collapse at 55K. (c) The paramagnetic fraction vs. temperature showing the brief coexistence at the first-order transition followed by the complete conversion.

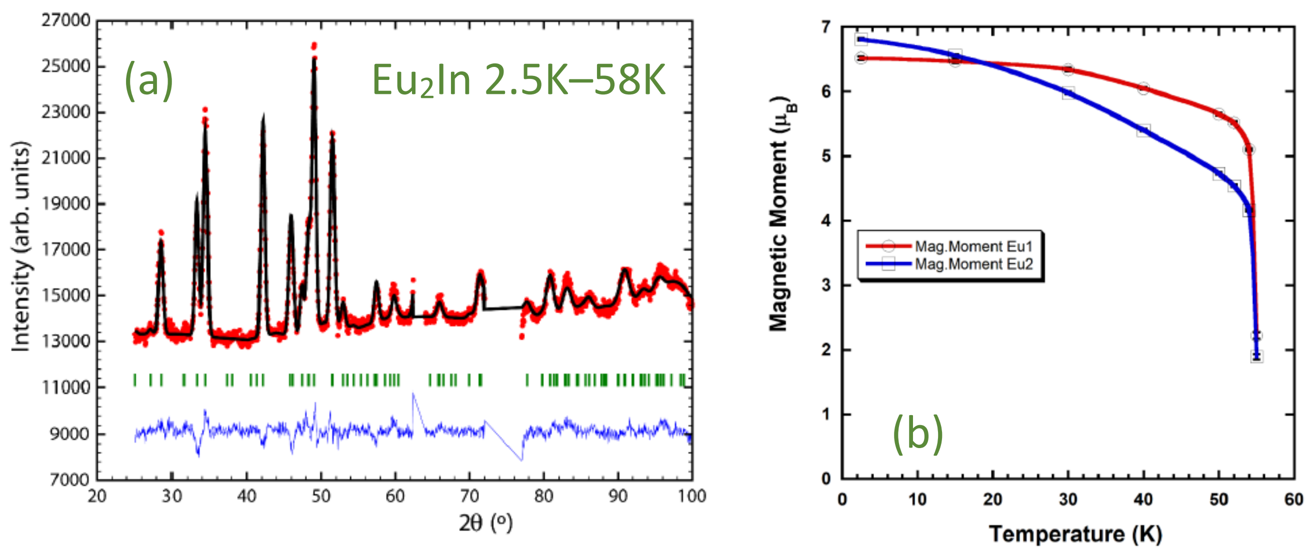

Figure 3(a) Neutron diffraction pattern of Eu2In showing only the magnetic contribution (generated by subtracting the paramagnetic pattern taken at 58K). (b) Temperature dependence of the two fitted europium moments showing their distinct values and different temperature dependences leading up to the first-order transition at 55K.