MAGNETIC INTERACTION IN EuS, EuSe, AND EuTe

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In this letter the preparation, crystal structure and magnetic properties of EuS, EuSe and EuTe are described. We have found EuS and EuSe to be purely ferromagnetic, insulating compounds with Curie points of 16°K and 6°K, respectively, whereas EuTe probably is weakly antiferromagnetic with an asymptotic Curie point of - 5°K and a Néel temperature of about 6°K. EuO has already been described to be ferromagnetic with a Curie point of 77°K by Matthias et al. [1]. This has recently been confirmed by means of neutron diffraction [2].

These compounds were previously made by Klemm and Senff [3] from $EuCl_2$ and by Domange et al. [4] and Quittard et al. [5] from Eu_2O_3. We prepared EuS, EuSe and EuTe by a direct reaction between the elements in evacuated, sealed quartz tubes at temperatures of 445°C, 690°C and 1230°C, respectively. The products obtained were single phase and have the rocksalt structure. The lattice parameters a, determined from powder diagrams, are given in table 1. These values are somewhat larger than those reported in the literature [3-5].

Table 1

Compound	a (A)	θ (°K)	p	saturation moment μ_B
EuO [1]	5.141	77	7.9	7
EuS	5.968 ± 0.001	16	8.0	6.5
EuSe	6.197 ± 0.002	6	8.2	7.0
EuTe	6.603 ± 0.001	- 5 (T_N = 6)	7.4	–

The electrical resistivity at room temperature, as measured on pressed powders, was found to be about 10^7 Ωcm for all three compounds.

Measurements of the magnetic susceptibility as a function of the temperature are shown in fig. 1. Well above the Curie point the susceptibility variation can be described by the Curie-Weiss law $\chi = C/(T - \theta)$ with $C = Np^2 \mu_B^2/3k$. For EuS and EuSe the experimental points lay well on straight lines pointing to respectively θ = 16°K and 6°K, indicating that these compounds are ferromagnetic. For EuTe, however, a marked deviation at low temperatures is observed. This may be explained by assuming EuTe to be weakly antiferromagnetic, with a Néel temperature of about 6°K and an asymptotic Curie point θ = - 5°K. The values found for the Curie points θ and for the effective moments p are listed in table 1, together with the literature data for EuO [1]. The values obtained for p are in good agreement with the theoretical value $p = g\sqrt{S(S+1)}$ = 7.94, calculated assuming europium to be in the divalent state (g = 2, $S = \frac{7}{2}$).

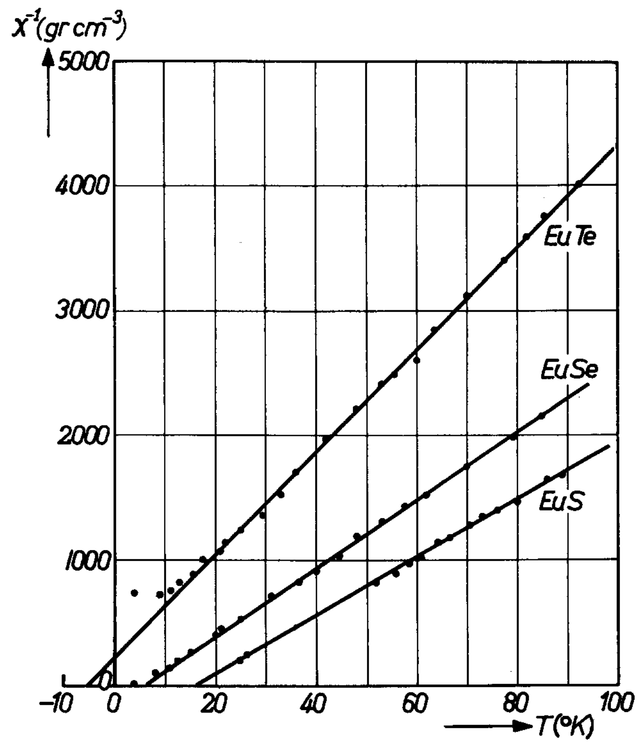

Fig. 1. Magnetic susceptibility as a function of the temperature. The measurements on EuS were made with a field of 640 Oe up to 40°K, with 1370 Oe from 50°K to 61°K and with 1820 Oe up from 62°K. The measurements on EuSe with a field of 1820 Oe up to 11°K, with 2700 Oe from 12°K to 40°K and with 4550 Oe up from 44°K and those on EuTe with 3080 Oe.

The magnetisation as a function of the temperature for several fieldstrengths (ranging from 8.2 kOe to 32.1 kOe) in the temperature region 4^{o}K - 100^{o}K was measured for both EuS and EuSe. It appears that the temperature and field-strength dependence of the magnetisation can be described satisfactorily by the Weiss field theory. Values for the Curie temperature T_c of 16^{o}K and 6^{o}K have hereby been found, which are equal to those found for the Curie points from the susceptibility measurements. For the saturation magnetisation per Eu-ion at 0^{o}K values of 6.5 μ_B and 7.0 μ_B have been obtained, which are in good agreement with the theoretical value $gS = 7.0$. These measurements and their interpretation will be described extensively in the Philips Research Reports [6].

It is interesting to relate the increase of the lattice parameter going from the oxide to the telluride to the decrease of the positive interaction and even the change of sign of this interaction for the telluride. In our opinion this provides strong evidence that there is in these compounds a competition between a positive direct exchange interaction and a weaker negative indirect exchange interaction, the former being dominant in the oxide, sulfide and selenide. It is likely that the direct exchange will decrease strongly with increasing lattice parameter. On the other hand it is generally found that the indirect exchange increases with increasing covalent character going from the oxide to the telluride.

Recently we learned that Busch et al. [7] are also working on the magnetic properties of these compounds.

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INCREASE OF MAGNETIC SATURATION INDUCTION OF HIGHLY SATURATED IRON

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The aim of this work is the study of the magnetic properties of highly saturated iron (with hydrogen contents up to 2% atom.).

It has been suggested by Galperin [1], that an increase in the lattice parameter of iron would cause an increase in the atomic magnetic moment.

Marburger [2] found that atomic magnetic moment in iron (ferromagnetic region) increases linearly with the temperature, showing in this way the dependence of atomic magnetic moment upon lattice spacing.

Therefore, the author has suggested that the magnetic saturation induction of a highly saturated iron should augment with the amount of absorbed hydrogen because interstitially entered hydrogen (in the form of protons) produces some change of the lattice spacing.

The first stage in this series of experiments was the saturation of the iron until the value 1% - 2% atom. of hydrogen was reached. The samples were 1 mm thick laminated sheets of commercial iron with 0.05% carbon content.

The difficulty of the iron saturation with such a high quantity of hydrogen was overcome by an electrolytic method. The electrolytic solution consisted of 20% H_2SO_4 and a small quantity of As_2O_3 dissolved in hot water. The current density was relatively high (0.16 A/cm^2) [3].

X-ray diagrams (fig. 1) show broader lines in the hydrogenated sample than in the sample that did not contain hydrogen, thus showing the lattice distortion due to the high proportion of hydrogen atoms present.

The quantity of hydrogen absorbed by the iron