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SUPERCONDUCTIVITY WITH EUROPIUM

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$EuIr_2$ becomes superconducting at 0.2 K. Arc melting this compound raises T_c to 2.6 K, in an apparently different and unidentified structure. These are the first superconductors containing Eu.

Americium becomes superconducting below 1 K [1]. This happens, even though the element is right in the middle of the magnetic 5f elements. Superconductivity is not inhibited because it has a nonmagnetic configuration of its six 5f electrons, which through spin–orbit coupling form a singlet ground state [2].

Europium is the 4f analog of americum among the rare earths (RE) as far as its position is concerned. However, in the elemental state, it has seven 4f electrons one of which was removed from the usual RE three outer s–d electrons. It is therefore strongly magnetic and will not become superconducting.

When americium was seen to be superconducting, it became evident that europium would do the same if only the half filled 4f shell could be broken up. This would require pressures near 300 kbar and temperatures perhaps as low as 0.1 K, clearly a very difficult experiment.

However, another way out is to simply subject europium to the pressure of an intermetallic crystal lattice. There are intermetallic europium compounds in which the Eu has only six 4f electrons. This fact can easily be seen from its atomic radius since the lattice constants will then be very close to the corresponding samarium and gadolinium compounds.

Due to a long history [3,4], the compound which comes foremost to mind is $EuIr_2$. Here Eu is strictly in its trivalent, nonmagnetic state. Almost all iridium compounds with the rare earths of the form $(RE)Ir_2$ are of the cubic Laves phase and become either ferromagnetic or superconducting, depending on whether the RE element is either magnetic or superconducting by itself [5]. On the basis of these systematics, $EuIr_2$ had to become superconducting at low temperatures. In fact, it did just that at 0.2 K. This is a clear indication that pure europium once it is in its trivalent state will also become a superconductor at sufficiently low temperatures and at pressures > 250 kbar [6].

In fig. 1, the ferromagnetism and superconductivity of the known $(RE)Ir_2$ compounds is (now) shown. Just as in the case of americium, $EuIr_2$ is the lone superconductor right in the middle of strongly magnetic compounds. The strictly nonmagnetic character of europium becomes evident from magnetic susceptibility data over the whole temperature range, since $EuIr_2$ shows only an essentially temperature independent van Vleck paramagnetism.

Similar to the other superconducting $(RE)Ir_2$ compounds, the detailed superconducting behavior is quite complicated. Various values for critical temperatures are reported [7] and given in table 1. Whether this is due to a homogeneity range or a second phase

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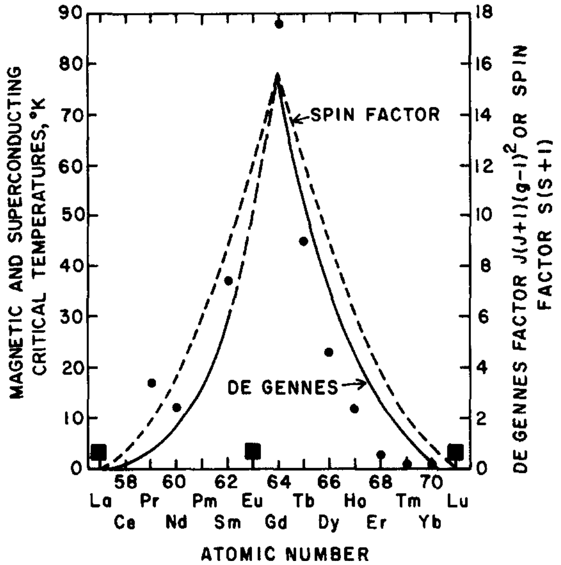

Fig. 1. Ferromagnetic (•) and superconducting (▪) transition temperatures of $(RE)Ir_2$ compounds.

is at present not clear. Similarly, when the sintered $EuIr_2$ is arc melted, the superconducting transition is raised to 2.6 K. Additional lines also appear in the X-ray picture. Therefore we believe that T_c of 2.6 K is due to another, as yet unidentified phase, rather than an extended homogeneity range.

In principle, however, this is not important now since we have been able to show that europium metal in its trivalent state will be a superconductor.

Table 1
Spectrum of superconducting transition temperatures for $(RE)Ir_{2+x}$ compounds.

$ScIr_2$	0.42,	1.03,	2.13,	2.46
$Y\,Ir_2$	1.09,	2.18		
$LaIr_2$	0.48,	2.32		
$LuIr_2$	2.47			
$EuIr_2$	**0.200;**	**2.64;**	**2.66**	

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