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Nuclear orientation in solids

Poppema, Okko Jan

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Bleaney (B5), $g_{//}$ = 6.45
ield H (temperature T) is
(temperature T_o), we can

in this way the value
ion, however, yields the
ly higher than the value
he errors in our measure-
there exist some indica-
ut 19 % instead of 12 %
ut the calculation under
occurs at a temperature
f its value by a magnetic
K1 axis. We then find
agreement with Bleaney's
ent of the field is also

etic moment of the ^{60}Co
he experimental results,
f the unexplained discre-
ound from the anisotropy
ted from the theory. How-
cally expected behaviour
region of interest than
amply wide at ± 5 %.
he value μ_{60} = 3.5 ± 0.5
,B8) as described in the
atively large error also
ch may be interpreted as
ation as found from the
anisotropy curves to the

t if the accuracy in the
re T of the crystals can
ise data can be obtained
the other hand, the expe-
ve nuclei having a well
n the anisotropy of the
rmometer in the tempera-

SUMMARY

In this thesis a report is given of the investigations on the orientation of atomic nuclei in solids, which have been carried out since 1948 in the Kamerlingh Onnes Laboratory of the University of Leiden in cooperation with the Physical Laboratory of the University of Groningen.

In Chapter I a brief survey is given of the methods for the production of nuclear orientation. The orientation can be described by parameters f_k, introduced to this end by Tolhoek and Cox (T2). Two kinds of orientation are possible: *polarization* and *alignment*.

When a strong magnetic field interacts with the weak nuclear magnetic moments a certain degree of polarization may result if the temperature of the nuclear spin system is sufficiently low (Gorter, 1934 (see D3), Kurti and Simon, 1935 (K2)). Temperatures of about 0.01°K are needed, but these have so far not been obtained in a constant field of about 20000 oersted. Gorter and Rose, independently suggested to utilize the h.f.s. coupling in paramagnetic ions. To obtain a resultant nuclear orientation the magnetic ions then must be oriented in one way or another. This may be performed by a relatively weak magnetic field (G3,G4,R1, R3) or by crystalline electric fields in a paramagnetic anisotropic single crystal, as suggested by Bleaney (B4). It was also proposed to use antiferromagnetism to this end (D2,G6). A suggestion to obtain nuclear orientation in a suitable single crystal by interaction between the nuclear electric quadrupole moments and the crystalline electric field is due to Pound (P3). In all methods mentioned very low temperatures (0.01-0.1°K) are needed, which must be obtained by adiabatic demagnetization of a paramagnetic salt. If no external magnetic field is present, then, generally, only nuclear alignment will be produced.

Chapter II deals with some theoretical aspects of experiments on oriented nuclei. An expression is derived for the absorption of thermal and resonance neutrons by polarized nuclei. In the case of a non-polarized incident neutron beam a second order dependence of the absorption on the degree of nuclear polarization can be expected.

A brief review is given of a number of papers, dealing with the angular distribution and polarization of gamma rays emitted by oriented nuclei (S4,S5,S6,S7,T1,T2,C5,C6). It is shown that at present it will be almost impossible to detect the circular pola-

rization of the gamma rays from polarized nuclei by means of Compton scattering by magnetized iron.

In Chapter III experiments on the absorption of non-polarized neutrons by polarized nuclei are reported. No positive effect could be shown with Gd and Sm, the statistical inaccuracy being 5 % and 3 % respectively. Some possible causes of the negative results are mentioned.

Chapter IV deals with experiments where the anisotropic angular distribution of gamma rays from oriented nuclei is used for the detection of the nuclear orientation. Essential parts of the electronic circuits for the counter devices are described. No detailed description of the cryogenic apparatus is given, but only some important features are indicated as far as needed for the discussion of the results.

No anisotropy in the angular distribution of the gamma rays was found when the sample consisted of powdered iron ammonium alum containing a small amount of the radioactive isotope ^{59}Fe, and in the case of powdered cobalt sulphate containing a small amount of the isotope ^{60}Co. Also in the case of an undiluted single crystal of cobalt ammonium sulphate the results were negative. Convincing positive effects were found using diluted single crystals of cobalt ammonium sulphate. Crystals in which 10-30 % copper was incorporated yielded maximum anisotropy effects of about 30 % in the angular distribution of the gamma rays from ^{60}Co, at temperatures of about $0.02^{\circ}K$. The experimentally found angular distribution is in good agreement with the 4-2-0 spin assignment to the ^{60}Ni levels concerned. From results obtained with a (Co 3.5 % Zn 96.5 %)$(NH_4)_2(SO_4)_2.6H_2O$ single crystal the value of the magnetic moment of the ^{60}Co nucleus was determined at 4.3 ± 0.2 nuclear magnetons. This value is given under restriction of small unexplained deviations between the (T, T^*)-relation found from the anisotropy measurements, and the theoretically expected (T, T^*)-relation (T = absolute temperature, T^* = magnetic temperature as found from Curie's law).