MAGNETIC HYPERFINE INTERACTION FOR Co^{60} *IN* Pt-Co *ALLOYS*

A. L. ERZINKYAN and V. P. PARFENOVA

Nuclear Physics Institute of the Moscow State University

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The magnetic fields at the Co^{60} nuclei in Pt-Co alloys are measured by the oriented-nuclei technique at Co concentrations between 8 and 90 at.%. The field strength at the nucleus is practically independent on the Co concentration. The results are compared with the previously-obtained corresponding data for Pd-Co alloys[1,2]. The experimental results point to a significant difference in the interaction of the magnetic moment of the Co atom with the conduction electrons in the two matrices.

MUCH attention has been paid recently to the investigation of the magnetic properties of alloys of Fe, Co and Ni with 4d and 5d transition metals. These properties become most clearly manifest in alloys of Fe and Co with Pd and Pt, for which the occurrence of "giant" localized moments and a transition to the ordered (ferromagnetic) states are typical even at very low concentrations of the 3d element. These phenomena are connected with the features of the electronic structure of the matrices (Pd, Pt) and with the polarization of the conduction electrons of the matrix as a result of the interaction with the magnetic moments of Fe or Co.

An investigation of the magnetic hyperfine interaction in alloys of the type Pd-Fe, Pd-Co, Pt-Fe, and Pt-Co makes it possible, in principle, to obtain information concerning the interaction of the magnetic moment of the 3d atom with the conduction electrons in matrices having high paramagnetic susceptibility.

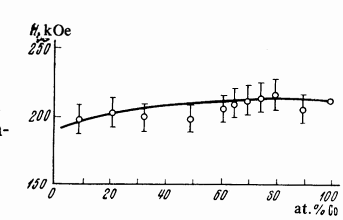
Investigations of the magnetic fields at the nuclei Co^{60} in Pd-Co alloys[1,2] have revealed a number of interesting properties of magnetic hyperfine interaction for Co and Pd atoms. It was observed that the field at the nuclei of the Co atoms in dilute solutions Pd-Co coincides with the direction of the magnetization of the matrix (positive)[1] and the absolute magnitude of the field depends strongly on the composition of the alloy, reaching a minimum at concentrations near 25–35 at.% Co[2]. These singularities of the magnetic hyperfine interaction were interpreted by us[2] as a consequence of the unusually large positive contribution made to the field at the nucleus of the Co atom by the polarized conduction electrons of the matrix.

Pt is frequently regarded as an analog of Pd. The observed differences between their processes frequently appear to be more quantitative than qualitative. Indeed, Pd and Pt occupy identical positions in group VIII of the periodic table. The magnetic properties of these metals are close: the magnetic susceptibility of Pt, although lower than that of Pd, is nevertheless quite high. The values of the localized magnetic moments in the Pt-Fe and Pt-Co alloys are equal to 6 and 4 μ_B respectively, whereas in the Pd-Fe and Pd-Co alloys they amount to 12 and 10 μ_B.

In this connection, it was of interest to investigate the magnetic hyperfine interaction on Co nuclei in Pt-Co alloys and to compare the results with the previously obtained corresponding data for the Pd-Co system.

The magnetic fields at the Co^{60} nuclei were determined by measuring the anisotropy of the angular distribution of the γ radiation of polarized nuclei. The samples for the investigation were obtained by alloying in vacuum the corresponding amounts of the components Pt and Co (the purity of the initial metals was 99.98%). The prepared alloys were homogenized in vacuum at a temperature of 1000°C for 10–12 hours. Samples in the form of discs of 2.5–3 mm diameter and thickness 0.2–0.3 mm were irradiated with neutrons in order to obtain radioactive Co^{60} nuclei. Alloys were prepared with the following Co concentrations: 8.7, 21.4, 31.8, 50.0, 59.8, 65.4, 69.7, 74.8, 80.4, and 89.7 at.%. The measurement procedure was analogous to that employed earlier[2,3]. The lowest temperature (0.025°K) was reached in the sample ~20 minutes after the demagnetization of the block of paramagnetic salt (potassium chrome alum). After two hours, the sample temperature rose to ~0.04°K.

The measurement results are shown in the figure. We see that the field intensity at the nuclei of the Co atoms is practically independent of the Co concentration in the alloy, and is close to the value of the field in pure metallic Co. The sign of the field at the nucleus was not determined in the experiment, but since the field was practically constant, it can be assumed that it has the same sign as in metallic Co, namely negative in the entire range of concentrations. This result differs strongly from that obtained for the Pd-Co system, where the absolute magnitude of the magnetic field depends strongly on the Co concentration



Absolute value of the magnetic field at the Co^{60} nuclei in Pt-Co alloys against the Co concentration.

and, according to[1], the field is positive at low Co concentration. In the interpretation of the corresponding data for the Pd-Co system[2], we have assumed, on the basis of the data of[1], that the field at the Co^{60} nucleus traverses sign at 25—35 at.% Co. A positive field at low Co and Pd concentration is due to the large contribution made to the field by the polarization of the conduction electrons, exceeding the negative contribution from the polarization of the electrons of the internal shells of the Co atom. The large positive contribution can be connected with the large susceptibility of the Pd matrix.

The results obtained in the present paper for the Pt-Co alloys allow us to assume that the interaction of the magnetic moment of Co with the conduction electrons in Pt and Pd is essentially different. If we regard Pt as an analog of Pd, then we might expect, for example, the effects connected with the interaction of the localized moment of Co with the conduction electrons to differ for Pt and Pd only to the extent that the electronic susceptibilities of the matrices are different. At the same time, the singularities of the magnetic hyperfine interaction, observed for Co in Pd-Co alloys, would be observed also in the Pt-Co alloys. The experiments show, however, that the difference between the Pt and Pd has a more fundamental character. In this connection, attention must be called to certain other experimental data, which also point to the appreciable difference between the properties of Pt and Pd.

Measurement of the temperature dependence of the Knight shift in transition metals makes it possible, as is well known, to determine the magnetic field H_d at the nucleus, due to polarization of the field shells of the atom by the magnetic moment of the d-electrons. In the analysis of these data, the Knight shift due to the d-electrons is usually attributed entirely to the intrinsic d-moment of the given atom, disregarding the contribution made to the hyperfine interaction by the neighboring atoms. This assumption, however, can hardly be regarded as valid; it is more natural to assume that the hyperfine interaction in this case is due (in analogy with the case of ferromagnetic matrices[2]) to the influence of both the intrinsic d-moment of the given atom, and to the d-moments of the neighboring atoms. This is indicated directly, for example, by the results of measurements of the Knight shift for Ag impurity atoms, which have no intrinsic moment, in the Pd matrix[4], namely, the ratio of the observed hyperfine field at the Ag nuclei to the atomic magnetic moment of the matrix turned out to be the same as for the impurity Ag atoms in ferromagnetic matrices Fe and Ni. Therefore, the values of H_d, determined for Pd and Pt in[5,6], must be corrected by taking into account the contribution from the neighboring atoms. This can be done, for example, by using the empirical formula derived in[7] for the fields at the nuclei of nonmagnetic impurity atoms. We find then that the values of H_d (referred to 1 μ_B of the d-moment of the atom) are $H_d(Pd) = -100$ kOe/μ_B and $H_d(Pt) = -600$ kOe/μ_B. These values can be compared with the value of H_d obtained in[8] from an analysis of the data on the hyperfine structure of the EPR spectra (inasmuch as these data pertain to insulators, they do not include the contribution made to the hyperfine field by the conduction electrons). Such a comparison shows that whereas for metallic Pt the value of H_d is close to the estimate obtained in[8], for Pd the value of H_d in the metal is smaller by approximately 2.5 times than H_d for 4d-elements in insulators. This difference can be attributed to the positive contribution made to the hyperfine field by the polarization of the conduction electrons.

Thus, both the analysis of the data on the Knight shifts, and data on the magnetic hyperfine interaction in Co alloys, obtained in[1,2] lead to the conclusion that there exists an appreciable positive contribution to the field, connected with the polarization of the conduction electrons by the proper moment of the atom in metallic Pd. This contribution, obviously, is missing (or else is very small) in metallic Pt, thus explaining the observed difference in the magnetic hyperfine interaction in Pd-Co and Pt-Co alloys.

The difference between Pd and Pt is indicated also by data on the low-temperature specific heat. Attention is called in[9] that the anomalies of the low-temperature specific heat observed in[10] for Pd do not appear in Pt.

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