10^{-6} °K. Fröhlich and Nabarro[12] have investigated the behavior of the nuclear and electron spin systems below these temperatures including the slight change in population between the two electron spin states but neglecting the interaction Eq. (10). They conclude that below 10^{-6} °K the system of nuclear moments has ferromagnetic behavior. However, we see from Eq. (11) that the inclusion of the exchange interaction (which is essentially independent of the relative population of the electron spin states) makes the situation obscure. For nearest neighbors A_{ij} is positive and therefore gives a higher energy when spins are parallel than when antiparallel. This interaction energy is comparable to that from the Fröhlich-Nabarro effect. The exchange interaction varies at large distance as $R^{-3}\cos(k_m R)$, so that when the nuclear spins are ordered a nearest neighbor approximation is inadequate. We have made no attempt to calculate the nature of the lowest-energy state of the coupled-spin systems.

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Identification of Gadolinium and Terbium Radioisotopes as Fission Products of U^{235}

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The identification of Gd^{159} and Tb^{161} as products of the neutron-induced fission of U^{235} has been confirmed. By a comparison of counting rates with Mo^{99}, the fission yields have been estimated to be 1.1×10^{-3} and 8×10^{-5} percent, respectively.

THE radionuclides, Gd^{159} and Tb^{161}, have been found to be among the products of nuclear fission in numerous cation exchange resin separations[1] of rare earth fission products done over the past year. As expected from an extrapolation of the fission yield curve,[2] the fission yields of these radionuclides are rather low; however, development of quite efficient rare earth separation procedures[1] has made possible the ready identification of them among the other rare earth fission product radionuclides. Described below are summaries of experimental techniques used and preliminary estimates of yields of Gd^{159} and Tb^{161} formed in thermal neutron fission of U^{235}.

Table I. Fission yields of Gd^{159} and Tb^{161} relative to Mo^{99}.

Experiment	Fission yields Gd^{159} (in percent $\times10^3$)	Tb^{161} (in percent $\times10^5$)
1*a*	1.02	8.1
1*b*	1.07	(12.8)[a]
2*a*	1.19	7.6
2*b*	1.30	9.3
Average	1.14±0.13[b]	8.3±0.9

[a] Not included in average.
[b] Standard deviation.

Samples of both normal uranium and of uranium enriched in U^{235} were rigorously purified of rare earth impurities. (Gadolinium is of major concern here since neutron capture reactions in it lead to formation of the radionuclides being studied.) Purification was based on elution of uranium from a strongly acidic cation exchange resin with 1.0*M* ammonium lactate at *p*H 3.0. The uranium was eluted much ahead of any rare earth impurities.

The highly purified uranium samples were irradiated for one hour in the Materials Testing Reactor,[3] following which radiochemical analyses for rare earth radionuclides and Mo^{99} was performed. In addition to the previously known fission product radionuclides Nd^{147}, Pm^{149}, Sm^{153}, Eu^{156}, and Y^{91}, the radioisotopes of gadolinium and terbium, Gd^{159} and Tb^{161}, were also identified. Estimates of the fission yields of the latter were made by comparisons to Mo^{99}, whose fission yield was taken as 6.2 percent.[2] The values obtained in duplicate determinations on two different irradiated samples of uranium are given in Table I.

The fission yields of Gd^{159} and Tb^{161} lie on a smooth extrapolation of the previously established fission yield curve.[2] Although the standard error is about 10 percent, the absolute accuracy of the indicated fission yields may be no better than about 30 percent. Improvements in the absolute beta-ray counting measurements will materially improve the accuracy.

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