the case of polarization by external fields, i.e., Equations (8) and (10) hold again, where, however,

$$\alpha = A / 2kT. \tag{14}$$

5. Again let $S = \frac{1}{2}$, $H = 0$. It has been shown in reference 6 that with a Hamiltonian

$$V = AS_z I_z + B(S_x I_x + S_y I_y) \tag{15}$$

mixing of states with different m takes place. In particular the state m, $M = \frac{1}{2}$ mixes with the state $m + 1$, $M = -\frac{1}{2}$ (M is the projection of the electronic shell spin on the z-axis). In the same reference the following corresponding energy levels were obtained

$$E_m = -\tfrac{1}{4}A \pm \tfrac{1}{2}\sqrt{A^2K^2 + B^2[(I+\tfrac{1}{2})^2 - K^2]} \tag{16}$$

where $K = M + m$.

Let B be much smaller than A and kT. We shall find f_2 up to terms quadratic in B, i.e., we shall keep terms of the order $(B/A)^2$, $(B/kT)^2$ and (B^2/AkT). We shall neglect terms of higher order. Calculation for $I = 3/2$ gives

$$f_2 = \operatorname{th}\frac{A}{2kT}\operatorname{th}\frac{A}{4kT} - \frac{3}{8\left(\operatorname{ch}\frac{3A}{4kT} + \operatorname{ch}\frac{A}{4kT}\right)^2} \times \left(\frac{B}{A}\right)^2 \phi\left(\frac{A}{kT}\right), \tag{17}$$

where

$$\phi(x) = (1 - x + 2/3\,x^2)e^{x} - (1 + x)e^{-x} - 2xe^{\frac{1}{2}x} - (1 - 2/3\,x^2)e^{-\frac{1}{2}x} + e^{3/2\,x} \tag{18}$$

6. To produce polarized nuclei an external field of a few hundred oersteds must be imposed on the refrigerated salt[1,6]. At very low temperatures this induces a considerable polarization shell spins of paramagnetic ions, which in turn produces a considerable polarization of nuclei.

We shall examine quantitatively the following simple case: A monocrystal of paramagnetic salt, $S = \frac{1}{2}$, $A \gg B$ [we neglect the B term in Eq. (13)], with the external field in the z-direction. Here the energy levels are given by

$$E_m = \pm\tfrac{1}{2}(Am + \beta g_{\parallel} H). \tag{19}$$

A simple calculation shows that the quantities f_k, with k even, are the same as in the case of polarization by external fields [α given by Eq. (14)]. The odd-index f_k are obtained by multiplying Eqs. (7) and (9) by tank $\frac{g_{\parallel}\beta H}{2kT}$ [α given by Eq. (14)].

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The Spontaneous Fission of Thorium

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In recent years there have been several references in the literature[1-5] to the spontaneous fission of thorium. According to the data of Segrè[5], the half life of the spontaneous process is 1.4×10^{18} years. We should like to point out that the probability of spontaneous fission indicated by these investigations is considerably too high.

In references 1,3, the spontaneous fission of thorium was observed by detecting the accompanying neutrons, the number of neutrons per spontaneous fission being presumably the same as the number per induced fission (i.e., 2-3). This method is suitable for the observation of spontaneous fission in uranium, but may be susceptible to error in the case of thorium, where the ex-

pected effect is very small. The chief sources of error involved in observing spontaneous fission by detecting the fission neutrons are the following: a) contamination of the thorium by traces of uranium, and b) contamination of the thorium by minute quantities of light elements. The first possibility can be easily controlled by carrying out special experiments to measure the amount of uranium in the thorium sample. Traces of light elements (Be, B, Si, etc.) in the material under investigation lead to neutrons through the (α, n) reaction in light nuclei. These processes are difficult to eliminate and are especially troublesome in thorium, where the energy of the α particles can be more than 8 Mev.

Segrè[5] detected spontaneous fission by directly observing the ionization due to fission fragments. Using this method, he conducted a long experiment in which 178 fission events were recorded in 6300 hours of operation with a chamber containing about 0.2 grams of effective thorium. Attributing these events to the spontaneous fission of thorium, the half life was calculated to be 1.4×10^{18} years, as noted above.

In 1940-41, attempts[6,7] to detect the spontaneous fission of thorium by using a large ionization chamber gave negative results. These investigations established a lower limit to the thorium half life of 10^{19} years.

In 1947, during a series of experiments on cosmic ray induced fission in heavy nuclei (uranium, thorium, bismuth) we found it necessary to know the half life of thorium more accurately. The spontaneous fission of thorium was observed by placing the substance to be investigated on plates in an ionization chamber and detecting the ionizing fission fragments. The sensitivity of the method was increased by using a multi-plate variant of the ionization chamber[6] which allowed us to increase the amount of effective thorium to 10-12 grams. Thorium oxide was used as the working substance on the plates. The amount of effective thorium was measured by comparing the fission rate in a thorium loaded chamber irradiated by fast neutrons from a Po + Be source, with the rate induced by the same source in the same geometry in a uranium loaded chamber. A measurement of the spontaneous fission rate in uranium gave the absolute amount of uranium present, while the ratio of the fast neutron fission cross section in uranium to that in thorium was taken to be 4.

The percent contamination of thorium by uranium was measured by comparing the fission rates in thorium and uranium loaded chambers irradiated by slow neutrons from a Raγ + Be source.

TABLE I

Chamber	Number of Fissions per Atom		Amount of Effective Substance in grams
	Po + Be Source	Without Source	
With thorium	98±6	—	11±1.5
With uranium	280±10	100±5	5±0.5

TABLE II

Chamber*	Number of fissions per hour (Raγ + Be source)		
	Surrounded by paraffin	Surrounded by paraffin and cadmium	Effect of thermal neutrons
With thorium	2.0±0.2	0.6±0.1	1.4
With uranium	24000	850	23150

* The amount of effective substance in the chambers was the same.

As can be seen from the tables, there were about 10 grams of effective thorium containing not more than 0.006% of uranium.

The smallness of the expected effect demanded special care in carrying out the measurements and the complete absence of any extraneous effects. Accordingly, the pulses at the amplifier output were registered in such a way that it was possible to record their size also. With this method of detecting spontaneous fission it was possible to monitor the apparatus continuously, which was very convenient, considering the long time of observation.

The results of experiments with the large thorium chamber (effective amount of thorium, 11 ± 1.5 grams) showed that the number of fission fragments counted per unit time depended appreciably on the external conditions of the experiment. These experimental results are shown in Table III.

TABLE III

Experimental Conditions	Time of observation, hours	Number of fission events	Number of fissions gram-hour	Half life
Laboratory attic	381	56	0.013	$1.5 \cdot 10^{19}$ yrs
Cellar (10 meters of soil above apparatus	392	8	0.002	10^{20} yrs

Both the dependence on external conditions (attic, cellar) and the absolute magnitude of the effect (0.002 - 0.013 fissions per gram-hour at sea level) agree well with the results of our experiments on cosmic ray induced fission in heavy nuclei at sea level and at high altitudes. As can be seen from Table III, the effect of fission in the chamber decreases by a factor of 6-7 when the apparatus is moved from attic to cellar. Hence the number of fission events in thorium which can be ascribed to the spontaneous mechanism is not more than 0.002 fission per gram-hour. It is well to note also that at least half of the effect in the cellar must be attributed to the spontaneous fission of uranium nuclei, which constituted 0.006% of the thorium sample investigated (see above).

In this way, our experiments with a big ionization chamber detecting fission fragments indicate that the probability of spontaneous fission in thorium is very small, the half life being more than 10^{20} years.

Our results on thorium fission at sea level differ from those of Segre, which were apparently carried out under the same conditions, by a factor of 10, approximately. If we discard the possibility of trivial mistakes in the work of Segrè, such as the contamination of his chamber by traces of artificial transuranium elements (for instance, Pu^{240}), or the improbable presence in his apparatus of vanishingly small quantities of natural transuranium elements, then considering our data it appears difficult to explain the fact that the rate of spontaneous fission in thorium observed by Segre was a whole order of magnitude larger than the rate induced in thorium by cosmic rays at sea level.

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The Momentum Distribution in the Statistical Model of the Atom

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1. In the statistical model of Thomas-Fermi, the distribution of the angular momentum over the particles can be determined. The number of particles with given angular momentum L is expressed by the equation[1]

$$n(L) = \frac{4L}{\pi} \int [r^2 P^2(r) \quad L^2]^{1/2} \frac{dr}{r^3}, \qquad (1)$$

where $P(r)$ is the maximum momentum for a given point. The mean value of the square of the orbital momentum, $\overline{L^2}$, has been determined by Jensen and Luttinger[2] from the momentum distribution (1). Taking the potential distribution of the atom to be that of the simple Thomas-Fermi model, the latter authors found $\overline{L^2}$, and compared it with the experimental data obtained for the electron level