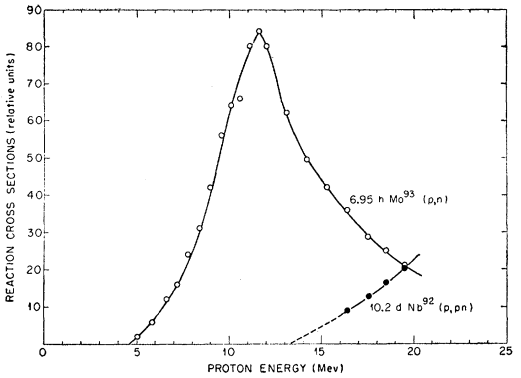

FIG. 2. Relative yields of Mo^{93} and Nb^{92} from Nb^{93}+20-Mev protons.

irradiated Nb showed the same 290-, 690-, and 1465-kev gammas from Mo as well as the 905-kev ray from 10.2-day Nb^{92} formed by a (p, pn) reaction.

The 7-hr Mo may be formed by either a (p, γ), a (p, n), or a $(p, 2n)$ reaction. The first of these alternatives seemed unlikely in view of the 3.7±0.2 Mev reaction threshold observed by Blaser *et al.*[3] However, the possibility of a $(p, 2n)$ reaction remained to be considered. Accordingly, an excitation curve was determined using a stacked foil technique in which one-mil Nb foils were bombarded for 90 minutes with a *ca* 10 μa beam of 20.1-Mev protons. The decay of the beta-activity produced in the Nb foils was resolvable into two periods only—the 6.95-hr Mo and the 10.2-day Nb^{92}. The yield of 6.95-hr Mo when plotted against the incident proton energy (Fig. 2) is seen to reach a maximum at about 11.5 Mev, after which it diminishes with increasing energy. The curve for the formation of 10.2-day Nb^{92} by a (p, pn) reaction shows a threshold at 13.3 Mev and has not reached a maximum at 19.5 Mev. The excitation curve for a $(p, 2n)$ reaction on Nb^{93} should resemble that for the (p, pn) reaction except that its threshold should be approximately 0.6 Mev lower. It seems necessary to conclude that the 6.95-hr Mo isomer is formed by a (p, n) reaction with Nb^{93} and hence must be assigned to mass 93.

[1] L. Dubridge, private communication to G. T. Seaborg; Revs. Modern Phys. **16**, 1 (1944).
[2] D. N. Kundu and M. L. Pool, Phys. Rev. **70**, 111 (1946).
[3] Blaser, Boehm, Marmier, and Sherrer, Helv. Phys. Acta **24**, 441 (1951). These authors find the 7-hr Mo to be formed with an abnormally small cross section.
[4] M. L. Wiedenbeck, Phys. Rev. **70**, 435 (1946).
[5] P. R. Stout and W. R. Meagher, Science **108**, 471 (1948).
[6] Kundu, Hult, and Pool, Phys. Rev. **77**, 71 (1950).
[7] R. B. Duffield and J. D. Knight, Phys. Rev. **76**, 573 (1949); see reference 3 also.
[8] L. Ruby and J. R. Richardson, Phys. Rev. **83**, 698 (1951); see also M. Goldhaber and A. W. Sunyar, Phys. Rev. **83**, 906 (1951), Table I.

Soft Radiation from Pu^{239}†

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THE radiations from Pu^{239} have been studied in the region 5–25 kev. For this purpose, a proportional counter, filled with argon to a pressure of 53-cm Hg and with methane to a pressure of 6-cm Hg, was employed in combination with a single-channel pulse analyzer and associated amplifying and counting circuits.

Advantage was taken of the fact that the plutonium sources used were capable of causing detectable quantities of fluorescent x-radiation in thin foils of various materials. By using a thin absorber of suitable material, there was obtained the spectrum from plutonium on which was superposed the peak resulting from the characteristic K x-radiation of the absorber material. Such a peak could then be used for purposes of calibration.

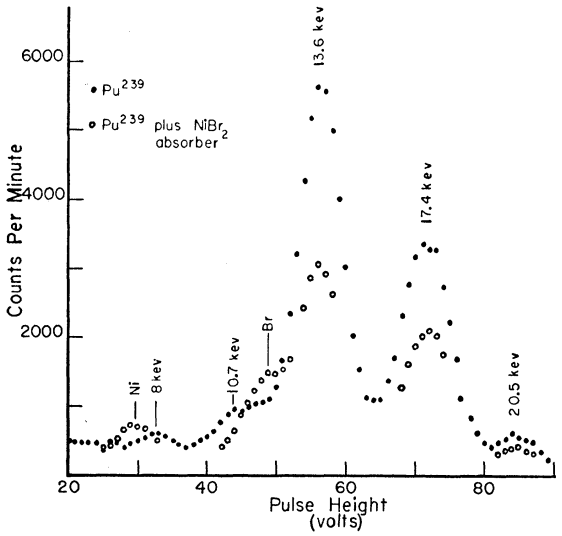

FIG. 1. Spectrum of soft radiation from Pu^{239}.

A typical result is shown in Fig. 1. The source, covered with sufficient Scotch tape to absorb all alpha-radiation, consisted of 0.164 mg PuO_2 on 2-mil Be and was approximately 2 cm^2 in area. The absorber used was a thin layer of $NiBr_2$ crystals put down on Scotch tape. The contribution of the absorber material to the spectrum can easily be noted.

The spectra obtained show peaks at 20.5±0.4, 17.4±0.3, and 13.6±0.3 kev. These values agree with the observed values for the L x-rays of uranium. The peak at 10.7 kev is assumed to be the escape peak for the 13.6-kev radiation, and the peak at 8 kev is considered to be the result of fluorescent radiation from a brass case in which the glass proportional counter was placed.

Using a collimated source, a determination of the L-photon yield was made. Calculations carried out in the usual way[1] gave the results shown in Table I. The total yield, 2.9×10^{-2} photons per alpha-particle, is in error by not more than 50 percent and is in agreement with that reported by Dawson and West.[2]

TABLE I. L-photon yield in Pu^{239} disintegration.

Photon energy (kev)	13.6	17.4	20.5
Photons/alpha-particle	1.2×10^{-2}	1.4×10^{-2}	0.3×10^{-2}

In all phases of the work, much valuable assistance was given by Simon Shlaer. The sources were supplied and prepared by John G. Povelites.

† Work done under the auspices of the AEC.
[1] W. Rubinson and W. Bernstein, Phys. Rev. **86**, 545 (1952).
[2] D. West and J. K. Dawson, Proc. Phys. Soc. (London) **A84**, 586 (1951).

Spherical Model of a Ferromagnet

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IN a paper having the above title[1] Berlin and Kac have presented a model for cooperative action in crystals to which statistical mechanics can be applied rigorously. We wish to point out that the mathematical manipulations of that paper can be reduced to almost nothing by the use of a grand rather than a canonical ensemble. We feel that this observation is of some consequence in a domain of research in which progress is largely impeded by mathematical difficulties.

The simplification consists in replacing the partition function (11) by the corresponding grand partition function in which the quantities ϵ_i are not restrained by a side condition:

$$Q_N=(2\pi)^{-N/2}\int_{-\infty}^{+\infty}\cdots\int_{-\infty}^{+\infty}\times d\epsilon_1 d\epsilon_2\cdots d\epsilon_N \exp[K\Sigma_{i,j}'\epsilon_i\epsilon_j-s\Sigma_i\epsilon_i^2]. \quad (1)$$

Here s is the conjugate variable to $\Sigma_i\epsilon_i^2$; after evaluation of Q_N it is to be adjusted at each temperature so that the Berlin-Kac condition holds:

$$\partial \ln Q_N/\partial s=-N. \quad (2)$$

This means that we satisfy the restraint of their model in the mean; this is sufficient by the principles of fluctuation theory, provided each member of the assembly is itself a macroscopic system. The evaluation of an expression of the form (1) also occurs in BK (C3). It is, however, followed by an integration in the complex plane which appears to play an essential role in the determination of the temperature singularity of the three-dimensional model.

In the present mode of computation we proceed entirely from (1) and (2). In evaluating (1) we follow BK [Eqs. (5) to (8)] with the one reservation that the lowest mode must be excepted from the smoothing-out process (this is familiar from the theory of Einstein condensation). Thus, we find

$$\ln Q_N=-\tfrac{1}{2}\ln(2s-12K)-\frac{1}{2}\frac{N}{(2\pi)^3}\int_0^{2\pi}\int\int\int\times d\omega_1 d\omega_2 d\omega_3 \ln[2s-4K(\cos\omega_1+\cos\omega_2+\cos\omega_3)]. \quad (3)$$

Equations (1), (2), and (3) are sufficient to yield

$$U=-\tfrac{1}{2}J\partial \ln Q_N/\partial K=(JN/4K)(1-2s). \quad (4)$$

This is BK Eq. (18), the key equation to most of the derived results. To complete our derivation, we must only show that we can also derive the correct dependence of s upon temperature. Applying condition (2) to (3), we get

$$1=\frac{1}{2N(s-6K)}+\frac{1}{2(2\pi)^3}\int_0^{2\pi}\int\int\int\frac{d\omega_1 d\omega_2 d\omega_3}{s-2K(\cos\omega_1+\cos\omega_2+\cos\omega_3)}. \quad (5)$$

For K sufficiently small, this equation yields for s a value substantially larger than $6K$; the first term is then negligible and Eq. (C23) of BK is obtained. As K increases, the boundedness of the integral comes into play, and s must approach $6K$ sufficiently closely so that the first term in (5) can make up the deficit. This feature leads to the "sticking" of s at the value $6K$ and yields the entire low temperature behavior of the model. All results of the BK paper are thus derived.

[1] T. H. Berlin and M. Kac, Phys. Rev. **86**, 821 (1952). In this letter it is referred to as BK.

Three New Neutron Deficient Xenon Isotopes*

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(Received September 17, 1952)

WHILE investigating the spallation reactions which occurred when iodine was bombarded with 240-Mev protons in the Rochester cyclotron, three previously unreported xenon isotopes were found.

About 200 mg of anhydrous lithium iodide (~99 percent pure, A. D. Mackay, Inc.), wrapped in a small envelope of 1-mil aluminum foil and clamped to the cyclotron probe, was exposed to the internal beam for one hour. Within 20 minutes of the end of the bombardment, collection of the xenon was completed and counting begun. The all-glass gas-collecting system consisted of a reaction tube containing a cold finger and an inlet for helium gas, a trap of potassium hydroxide-coated glass wool kept at dry ice temperature, and one or more charcoal traps held at liquid air temperature. The reaction tube contained about 10 drops each of frozen concentrated nitric and sulfuric acids, to which the target iodide was added, and was connected to the line by a ground glass joint. With helium slowly flowing through the system, the reaction mixture was heated until most of the iodine was collected on the cold finger (−78°C) and the xenon, carried by the helium, was adsorbed on the cold charcoal. All water and acid vapors were presumably removed by the potassium hydroxide trap. The charcoal trap, in the form of a small U-tube, was sealed, cut from the line, and cemented to a Lucite disk for counting.

Decay of the xenon activity, as counted through the glass wall (0.5–1.0 mm thick) of the U-tubes, was followed with a scintillation counter having a NaI(Tl) phosphor and also with a halogen filled GM tube. Resolution of a gross decay curve obtained with the latter yielded the following half-lives: ~35 minutes, 1.7 hours, 20.1 hours, and >20 days.

A xenon sample placed in our low resolution beta-ray survey spectrometer showed positrons of >2.8 Mev with ~1.8-hour half-life, and 3.1-Mev positrons of 20-hour half-life. The agreement between the latter positron energy and that of the reported[1] 3.6-minute I^{122} suggested that Xe^{122} with a 20-hour half-life had been produced, while the other activities indicated Xe^{121} and/or Xe^{123} were made.

Parent-daughter isolation experiments were performed to determine whether the 20-hour activity was the parent of I^{122} and to determine the half-lives of Xe^{121} and/or Xe^{123}. The separation was based on complete desorption of xenon from charcoal at elevated temperatures[2] and the retention of iodine daughters as solid iodide if silvered charcoal is used. A glass line consisting of a series of small U-tube traps, each filled with ~0.3 g silvered, activated charcoal held in place with glass wool, was used for making rapid periodic separations of the iodine daughters from the parent xenon. A large charcoal trap at −196°C, containing all the xenon collected from one target, was attached to the line by a ground glass joint and the system pumped down with a Cenco Hyvac pump. The xenon was transferred to the first trap of the series by cooling that trap with liquid nitrogen and warming the original large trap with an electric heater, after which the large trap was sealed from the line. This procedure was repeated at regular in-

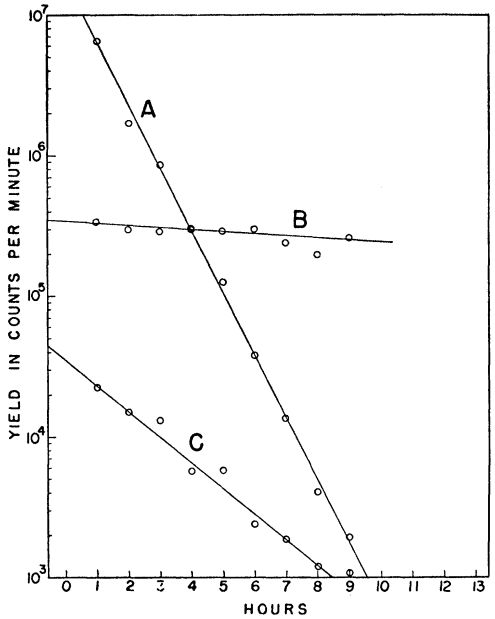

FIG. 1. Yields of iodine daughters at successive one-hour separations from xenon parent. Curve *A* (shelf 1, 2 mm from crystal), yields of I^{121}, shows the half-life of Xe^{121} to be 40(±2) minutes, and curve *C* (shelf 1), yields of I^{123}, gives 1.7(±0.2) hours for the half-life of Xe^{123}. Curve *B* (shelf 6, 80 mm from crystal) shows the yields of I^{122} to be compatible with 20(±1) hours for the Xe^{122} half-life, observed directly.