significant applications of this relation are to cases of nuclei of the same spin and differing by two protons. In the only two known nuclear pairs of this type ($Cu^{65}-Ga^{69}$, $Ga^{71}-As^{75}$), Gordy's relation is in considerable error and in one case it gives the wrong sign for the quadrupole moment. Gordy has plotted the Cs^{133} quadrupole moment as $+0.3\times10^{-24}$ cm^2 and from this value derived other moments. However, known information on Cs^{133} allows only the conclusion that for this nucleus $|Q|\leq0.3\times10^{-24}$ cm^2. If the Cs^{133} moment is taken as zero or negative and if the predicted quadrupole moments are questioned, then no evidence appears to remain that completion of a neutron shell makes nuclear quadrupole moments more negative.

For the nuclei which contain closed proton shells plus or minus only one proton, the nuclear shell model gives not only a definite prediction of the sign of Q, but also, if the state of the odd proton is determined from the nuclear spin and magnetic moment, it gives a fairly definite value for the quadrupole moment magnitude. In the cases Li^7, N^{14}, and Bi^{209}, the calculated magnitudes are in substantial agreement with those observed. This model also gives roughly the proper ratios between the quadrupole moments of In^{113}, In^{115}, Sb^{121}, and Sb^{123} (protons differing by one from a closed shell of 50). However, in spite of the rather extensive success of this model, it appears difficult to reconcile the magnitudes of the In^{113}, In^{115}, and Sb^{123} quadrupole moments with a nuclear shell model including a closed shell at 50 nucleons. They are larger by a factor of four than can reasonably be produced by a single particle. In addition the very large quadrupole moments in the vicinity of $Z=71$ present difficulties to a nuclear shell model. To give Lu^{176} its quadrupole moment of 7×10^{-24} cm^2, approximately 35 protons in the most favorable orbits must contribute to Q. Since the first fifty protons are presumably in a closed shell and contribute nothing to Q, only 21 protons are available and even all of them could hardly be put in the few orbits which contribute most to a positive quadrupole moment.

Failure of the nuclear shell model to give correct quadrupole moments is in contrast to the situation with nuclear magnetic moments, which can all be accounted for by a suitable admixture of states of a single nucleon. In the shell model approximation, these large quadrupole moments must represent a considerable contribution from the protons in the closed shells. The polarization of this core would presumably require a sharing of angular momentum between the protons of the incomplete shell and those of the closed shells. The magnitude of the polarization, however, and the resulting large asymmetry of the nucleon distribution is hardly consistent with the single particle-central field quantization which is the basis of the shell structure model.

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The Sm^{151} Beta-Ray Spectrum*

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A LONG-LIVED samarium beta-emitter was first identified in mass spectrographic studies of R. J. Hayden and L. G. Lewis.[1] The half-life has been given recently by M. G. Inghram[2] to be about 200 years and independently by J. A. Marinsky[3] to be 1000±350 years. G. W. Parker and P. M. Lantz[4] have prepared sources of the activity and characterized its radiation by means of aluminum absorption curves. They report that maximum beta-energy to be approximately 65 kev.

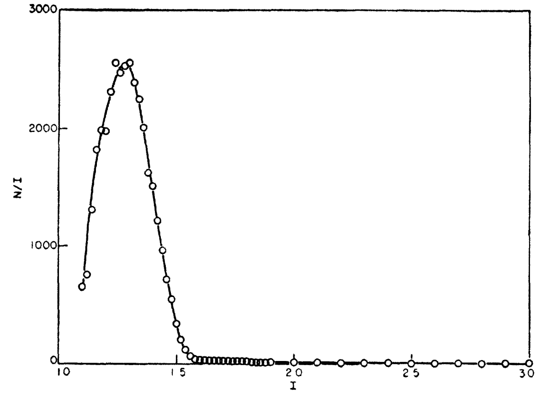

FIG. 1. Distribution of beta-rays of Sm^{151}. The counting rate per unit momentum is plotted against the coil current in amperes.

The source material used in this study was fission product samarium. Its chemical separation from the other fission products has been described elsewhere[4] in detail. The method consists of a gross separation of the fission products on an Amberlite IR-1 ion exchange column. This column effectively separates the trivalent cations from other cationic and anionic fission products and also separates the yttrium and cerium quite well from the other rare earths. After an intermediate separation of the cerium earths the fraction of eluate recognized by its gamma-activity to contain europium also contains the samarium and some element 61. Since the concentrations of other rare earth activities relative to the europium and samarium had been reduced, it was possible to achieve good separation of samarium from europium and element 61 by a final ion exchange column separation using optimum conditions for elution. The purified samarium was converted to the chloride and the aqueous solution was evaporated on a 50

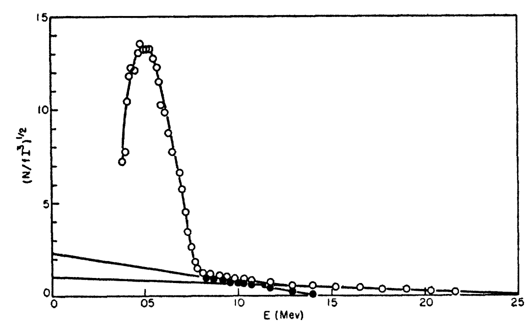

FIG. 2. Kurie plot of Sm^{151} source which contained Eu impurity.

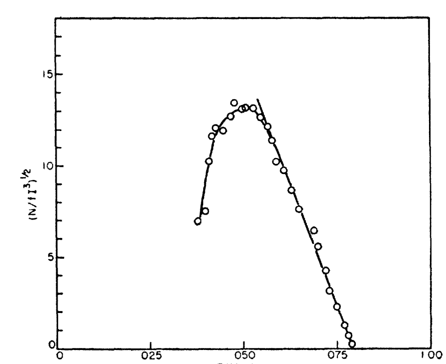

FIG. 3. Kurie plot of Sm^{151}.

μg/cm^2 laminated Formvar-polystyrene film. The source material itself was approximately 1 mg/cm^2 thick.

The beta-ray distribution curve shown in Fig. 1 was obtained on a thin lens beta-ray spectrometer similar to that described by Deutsch *et al.*[5] The counter tube window was 2 mg/cm^2-thick and no window corrections have been made. The Kurie plot of the data is shown in Fig. 2. There appear to be two higher energy components which are attributed to a small amount of Eu^{155} activity which was known to be present in the source. Figure 3 shows the Kurie plot of the samarium activity after the higher energy components have been subtracted. The beta-ray end point is 79 kev. Several determinations of the distribution give end-point energies which agree within three kilivolts of this value.

Because of the source thickness and the window cut-off an analysis of the shape of the spectrum would be meaningless and has not been attempted.

* This document is based on work performed under Contract Number W-7405 eng 26 for the AEP at Oak Ridge National Laboratory.

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Hyperfine Structure and Nuclear Spin of Kr^{83} and Ne^{21} Investigated with Separated Isotopes

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HIGHLY enriched samples of Kr^{83} and Ne^{21} have been prepared with a mass spectrograph[1] by collecting the ions of the separated isotopes in aluminum plates as previously described.[2] These plates were mounted as electrodes in Geissler tubes (volume $\sim$30 cc) filled with helium at a pressure of 5–10 mm in order to obtain the most favorable conditions for exciting the small amounts of isotopes to be investigated.[3] The isotopes were released from the electrodes by h.f. induction heating. When cooled with liquid air the tubes yielded intense Kr- and Ne-spectra without any impurities.

In earlier investigations of the spectrum of normal krypton, the nuclear spin of the only odd isotope Kr^{83} (11.53 percent) has been determined to be 9/2 with high probability.[4,5] However, due to the predominance of the even isotopes, certain h.f.s. components were masked, and it therefore seemed desirable to check the spin value from the interval rule by means of enriched Kr^{83}.

By using a tube containing about 2 μ moles of Kr^{83} (separated in a four-hour run), interferograms were photographed with a Fabry-Perot etalon showing the structures of the $1s-2p$ combinations in the infra-red. Measurements of the components of 8059A ($1s_3-2p_4$), from which the spin can be most simply deduced because of the spherical symmetry of the only splitting upper term $2p_4$, at first turned out to be in disagreement with the spin value 9/2, which should give rise to a h.f.s. pattern as shown in Fig. 1. This disagreement was later found to be caused by the presence of about one percent Kr^{82}, probably brought into the beam of mass 83 by the formation of $(Kr^{82}H)^+$ ions,[6] which brings about a slight displacement of the component b toward a.

The intervals x and y can, however, be indirectly determined by measuring the total splitting $x+y$, and by using the fact that the center of gravity must be located at a point Z in a distance y from a. This fact follows simply from interval and intensity rules. The center of gravity Z again coincides with the position of the line from the even isotopes, if no isotope shift exists.

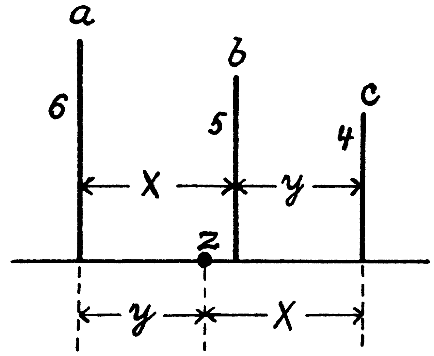

FIG. 1. Hyperfine structure of the Kr^{83} line 8059A.

In order to examine this last point, tubes containing very pure Kr^{82} and Kr^{84}, respectively, were prepared. By comparing interferograms taken alternately on the same plate with these tubes, an isotope shift of 0.002 cm^{-1} was detected for the line in question. This value is of the order of magnitude to be expected from Bohr's theory of the Rydberg constant, and consequently, the center of gravity Z for Kr^{83} must be situated symmetrically between the lines from Kr^{82} and Kr^{84}. By measuring interferograms taken in turn with Kr^{82}, Kr^{83}, and Kr^{84}, and by taking into account the isotope shift, the intervals x and y could be accurately determined. The final values were $x+y=0.192$ cm^{-1}, and $x/y=0.106/0.086$, which definitely give the spin value 9/2 (theor. val.: $x/y=0.1055/0.0865$).

An isotope shift of the same order of magnitude (0.002 to 0.004 cm^{-1}) was further found to exist for all measured $1s-2p$ combinations. In all cases the components of shorter wave-length belong to the heavier isotope. Finally, it should be mentioned that the intervals of the Kr line 7685A ($1s_2-2p_1$), for which only the lower term $1s_2$ splits up, were measured to be 0.138 and 0.108 cm^{-1}, which confirms the existence of a quadrupole moment of the Kr^{83} nucleus.[5]

The procedure here described was also used for investigating the h.f.s. of the rare isotope Ne^{21} (0.27 percent), since earlier experiments using neon, enriched by diffusion, showed no components from this isotope.[7] Interferograms photographed with a tube containing about 0.2 μ mole of Ne^{21}, collected in a ten-hour run, showed narrow h.f.s. structures of all $1s-2p$ combinations. Also in these experiments certain components were masked by a line originating from the lighter isotope (Ne^{20}), which in the final separation was present in nearly the same amount as Ne^{21}. This fact complicates accurate measurements of the structures, of which in most cases only one component could be observed, situated on the short wave-length side of the Ne^{20} line in distances of 0.05–0.07 cm^{-1}. However, by comparing intensities of the components of the lines 5852A ($1s_2-2p_1$), and 6266A ($1s_3-2p_5$), for which the structures are caused by the splitting of the lower and of the higher term, respectively, the magnetic moment was found to be negative and the spin to be 3/2 or possibly greater. The investigations with Ne^{21} will be continued, and further details for Kr^{83} will be published in the *Proceedings of the Royal Danish Academy of Science.*

We wish to thank Professor Niels Bohr for his continued interest in the present investigation. We should also like to thank Mr. F. Carlsen and Mr. S. Møller Holst for their help with the separation of the isotopes.

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