results of which we hope to publish in the near future, or by series expansions. If one solves by series expansion, one finds for the partition function:

$$f=2\left[1+\frac{3}{2}K^2+\frac{31}{8}K^4+\frac{5461}{240}K^6+\frac{2180851}{13440}K^8+\cdots\right], \quad (5)$$

which up to the K^6 term agrees with the exact expression as determined by one of us.[4]

From the partition function one can easily calculate the configurational energy and specific heat which are given by

$$E=-kT\cdot K\cdot\partial \log f/\partial K, \quad c_v=kK^2\partial^2 \log f/\partial K^2. \quad (6)$$

The series expansions for these two quantities are found to be:

$$E=-kT[3K^2+11K^4+(542/5)K^6+(107587/105)K^8+\cdots] \quad (7)$$

and

$$c_v=k[3K^2+33K^4+542K^6+(107587/15)K^8+\cdots]. \quad (8)$$

[1] H. A. Kramers and G. H. Wannier, Phys. Rev. 60, 252, 263 (1941).
[2] A preliminary account of the method was given at the New York meeting of the American Physical Society; see Phys. Rev. 75, 1298 (1949).
[3] E. Ising, Zeits. f. Physik 31, 253 (1925).
[4] D. ter Haar, Phys. Rev. 76, 176 (1949). The same result was also obtained by Dr. E. Trefftz and Dr. E. Somers. We are endebted to Dr. E. Trefftz and Dr E. W. Montroll for communicating to us these results prior to publication.

Nuclear Spin and Isotope Shift of Xenon Investigated with Separated Isotopes

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PURE samples of the xenon isotopes 129, 130, 131, 132, 134, and 136 have been prepared by using a mass-spectrographic technique previously described.[1] According to recent experiences with isotopes of neon and krypton,[2] Geissler tubes with aluminum electrodes were prepared containing some micromoles of xenon with helium as a carrier gas at a pressure of about 10 mm.

In order to reduce Doppler broadening the tubes were operated at liquid air temperature, which turned out to be possible without much loss of intensity. The interferometric investigations carried out by means of a Fabry-Perot etalon using 15–25-mm spacers, were especially devoted to the study of infra-red lines resulting from $1s-2p$ transitions.

Because of the high purity of the isotopic samples the interferograms of the magnetic structures of Xe^{129} as well as of Xe^{131}, did not show any lines due to impurities of even isotopes, which were checked to be present with less than one percent. Also the tubes containing the different even isotopes were prepared with great care in order to avoid any displacements of the observed lines.

From the exposures with Xe^{129} the spin value could at first sight be determined to be $\frac{1}{2}$, since all levels appeared split up into two levels, also for j-values 2 and 3. This result is in accordance with earlier determinations,[3] and also our measurements of term separation showed good agreement with earlier experiments, using normal xenon.[4,5]

Also in the case of Xe^{131} we could fully confirm[3] the spin value ($i=\frac{3}{2}$), but in this case by making use of the exact validity of the interval rule for a level ($2p_4$) having spherical symmetry. The two intervals for this level were measured directly by means of the line 8206A ($1s_3-2p_4$) for which only the upper term can split. The experimental values were found to be 0.1085 and 0.0655 cm^{-1}, closely agreeing with the calculated values 0.1087 and 0.0653 cm^{-1}.

Because of the high purity of the Xe^{131} tube with respect to other isotopes it was possible to measure the intervals directly for most of the $1s$ and $2p$ terms. Among these should be mentioned only the intervals of the term $1s_2$, which by means of the line 7887A ($1s_2-2p_1$) were measured to be 0.145 and 0.081 cm^{-1}, while the calculated values are 0.141 and 0.085 cm^{-1}. These deviations confirm the supposed existence of a quadrupole moment[6] of the same size as in Kr^{83}, but with opposite sign.

By using the method of alternating exposures previously described[2] the existence of an isotope shift between the even isotopes 130, 132, 134, and 136 was investigated. An isotope shift of the same order of magnitude as found in krypton[2] was measured under favorable experimental conditions (constancy of atmospheric pressure and temperature). However, the order was found to be reversed with respect to that of krypton, the heavier isotopes having the greatest wave-lengths. Further, in the present case no exact equidistance seems to be present, as shown in Table I.

TABLE I. Isotope shift of some even xenon isotopes expressed in 10^{-3} cm^{-1}.

Wave-length	Combination	132–134	134–136
8819A	$1s_5-2p_8$	2.5	3.6
8280	$1s_4-2p_5$	1.1	2.9
8231	$1s_5-2p_6$	2.4	3.5

Preliminary measurements indicate moreover that the center of gravity of the hyperfine structures for the odd isotopes Xe^{129} and Xe^{131} are situated close to the lines due to the even isotopes of one unit higher mass, i.e., Xe^{130} and Xe^{132}, respectively. All these results indicate that the isotope shift in Xenon is due to a nuclear volume effect rather than to a mass effect.

The investigation will be continued and further details will be published in the Communications of the Royal Danish Academy.

We wish to thank Professor Niels Bohr for his continued interest in this investigation. We should further like to thank Mr. S. Møller-Holst and Mr. K. O. Nielsen for having carried out several separation experiments.

[1] J. Koch, Nature 161, 566 (1948).
[2] J. Koch and E. Rasmussen, Phys. Rev. 76, 1417 (1949).
[3] H. Kopfermann and E. Rindal, Zeits. f. Physik 87, 460 (1934).
[4] E. Gwynne Jones, Proc. Roy. Soc. 144, 587 (1934).
[5] E. Gwynne Jones, Proc. Phys. Soc. London 46, 634 (1934).
[6] H. Korsching, Zeits. f. Physik 109, 349 (1938).

Possible Experimental Determination of Whether the Neutral Meson is Scalar or Pseudoscalar

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NEUTRAL mesons with a mass of ~300 Mev which decay into two photons have been reported.[1] It can be proved[2,3] on general grounds of rotation-inversion invariance that a particle which dematerializes into two photons cannot have spin 1. Furthermore,[3] if the neutral meson is a scalar meson, the two photons would always have parallel planes of polarization, while if the neutral meson is a pseudoscalar meson, the two photons would always have perpendicular planes of polarization. One is tempted to investigate whether this may possibly lead to an experimental determination of the symmetry nature of the neutral mesons. Some calculation along this direction has been carried out. The results are summarized herein.

The experimental set-up considered is schematically illustrated in Fig. 1. The two photons produce pairs at L and L'. The counters A and A' are supposed to be identical and symmetrically situated with respect to M. So are B and B'. The sizes of the counters have not been assumed to be small. Fourfold coincidence rate is recorded, and then the whole apparatus to the left of M is rotated

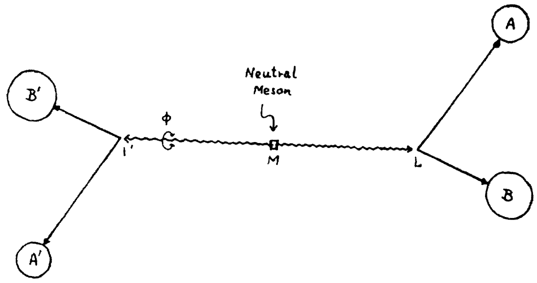

FIG. 1. Schematic diagram of experiment (angles ALB, $A'L'B'$ much exaggerated).

around the axis LML' through an azimuthal angle ϕ and the fourfold coincidence rate N plotted against ϕ.

The calculation of the theoretically expected dependence of N on φ is rather straightforward, but somewhat complicated. The result is

$$N=\alpha(1\pm\beta^2\cos 2\phi) \quad \begin{array}{l} +\text{ for scalar meson} \\ -\text{ for pseudoscalar meson,} \end{array}$$

where β^2 is a positive constant dependent on the geometry of the counters A and B with respect to the points M and L. One sees that

$$^N\phi=0^\circ > {^N\phi}=90^\circ \quad \text{for scalar meson,}$$
$$^N\phi=0^\circ < {^N\phi}=90^\circ \quad \text{for pseudoscalar meson.}$$

To get an idea of the order of magnitude of β^2, the hypothetical case that the counters A and B are infinitesimal in size is considered in detail. If the angles MLA and MLB are equal, the value of β^2 is approximately $\frac{1}{16}$ for all values of the angle MLA for which pair production is abundant. In such a case

$$\frac{^N\phi=0^\circ}{^N\phi=90^\circ}=\frac{17}{15}=1.13 \quad \text{for a scalar meson,}$$

$$\frac{^N\phi=0^\circ}{^N\phi=90^\circ}=\frac{15}{17}=0.88 \quad \text{for a pseudoscalar meson.}$$

[1] Bjorklund, Crandall, Moyer, and York, Phys. Rev. 77, 213 (1950).
[2] L. D. Landau, Dokl. Akad. Nauk USSR 60, 207–9 (1948). A summary in English of this article appeared in Phys. Abstracts A52, 125 (1949).
[3] C. N. Yang, Phys. Rev. 77, 242 (1950).

Neutron Capture Gamma-Rays from Be^9, C^{12}, and N^{14}

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MATERIALS containing carbon and nitrogen were exposed to a high flux of thermal neutrons in the Chalk River pile. The radiations emitted were examined with the aid of a coincidence pair spectrometer similar to that described by Walker and McDaniel.[1]

In our method the coincidence counting rate between two counters recording positrons and negatrons is obtained for a series of values of the magnetic field. The field is measured by means of a proton resonance magnetometer. In a plot of coincidence rate against field strength a homogeneous gamma-ray appears as a sharp peak which falls rapidly to zero toward high field strengths. The upper limit of the peak corresponds to pairs which are produced at the center of the radiator, the components having equal energy. The energy of the gamma-ray can be calculated, to a first approximation, from the distance between the inner edges of the slits covering the counters and the value of the magnetic field obtained by extrapolating the high field slope of the peak to zero. The true energy of the gamma-ray is obtained by adding a correction of about 25 kev computed from the pair production cross section and from the geometry.

With a graphite sample in the pile a conspicuous radiation was identified as resulting from neutron capture in C^{12} which must be the direct transition to the ground state of C^{13}. The energy of this radiation is 4.947 ± 0.008 Mev. Another value for this energy may be obtained by the addition of the following equations:

$$C^{12}+H^2=N^{13}+n-0.281\pm0.003\ \text{Mev}^2, \quad (1)$$
$$N^{13}=C^{13}+2m_0c^2+1.198\pm0.006\ \text{Mev}^3, \quad (2)$$
$$n+H^1=H^2+2.230\pm0.007\ \text{Mev}^4, \quad (3)$$
$$n-H^1=0.782\pm0.002\ \text{Mev.}^5 \quad (4)$$

The result is:

$$C^{12}+n=C^{13}+4.951\pm0.010\ \text{Mev.} \quad (5)$$

A recent measurement of the energy balance in the $C^{12}(d,p)C^{13}$ reaction gives $Q_0=2.729\pm0.009$ Mev.[6] From this result, together with (3), we find:

$$C^{12}+n=C^{13}+4.959\pm0.012\ \text{Mev} \quad (6)$$

in agreement with our own figures and with (5). Taking into account the probable errors of these three results the mean energy is:

$$4.951\pm0.006\ \text{Mev.} \quad (7)$$

Nitrogen was investigated with the aid of samples of beryllium nitride, urea, and beryllium oxide. From the spectra of these

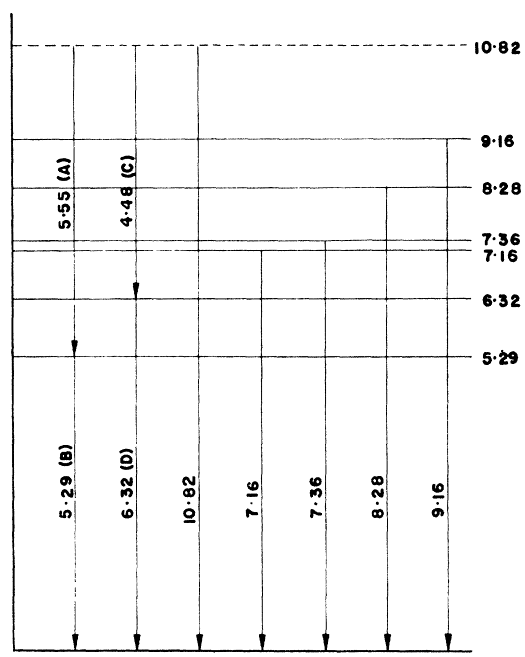

FIG. 1. Capture gamma-radiation from nitrogen.

compounds nine radiations due specifically to nitrogen were identified. These radiations are given in Table I and can be fitted to the level scheme of Fig. 1 which, with the exception of the levels at 7.16 and 9.16 Mev, has already been published.[7,8]

Rough values for the relative intensities appearing in Table I were obtained from the heights of the coincidence peaks after corrections had been made for the variation with energy of the pair production cross section and of the angular distribution of the electron pairs.

By comparing the intensities of the nitrogen and beryllium radiations from beryllium nitride we estimate that the radiative capture cross section of nitrogen is about 100 millibarns. This