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Summary of the Research Progress Meeting of July 21, 1949

H. P. Kramer

August 26, 1949

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Measurement of the Cyclotron Magnetic Field by the Method of Nuclear Induction.

D. Bishop.

For the accurate measurement of the mass of the meson by $H\rho$ in the cyclotron and range in emulsion a precise knowledge of the magnetic field is necessary. By flip coil measurements in the past it was possible to measure the field with an error not exceeding one percent. With the present method, however, the field was determined with an error of less than 0.02 percent.

The measurements are based on the property of protons that causes them to behave like elementary magnets. When a proton is subjected to a magnetic field its magnetic moment aligns itself with the lines of force of the magnetic field. The application with an inductance coil in an L-C circuit of a varying magnetic field at right angles to the steady magnetic field causes a precession of the magnetic moments about the primary field direction. The orbit that is described by the moment vector is determined completely by the strength of the primary field H and the strength and frequency of the applied field. The motion of the elementary magnet when it is oscillating with its natural frequency can be detected by the current that is induced in a suitably placed coil when the coil is momentarily threaded by the flux due to the magnetic field of the proton. It is convenient to place the detector coil at right angles to both the field H and the applied field so that no electromotive force is induced in the detector coil by the variable applied field. To a given magnetic field H, and a detector coil placed at right angles to H and the rf field, there corresponds a definite known rf resonance frequency such

that the precession of the magnetic moments will induce a surge of current in the detector. One might therefore measure the magnetic field by varying the radio-frequency and noting for what frequency a surge is observed in the detector coil. Frequency modulation is however an awkward procedure. For this reason an alternative method of measurement was used. It is equally well possible to maintain the radiofrequency at a constant value and to vary the magnetic field until a surge of current is induced in the pick-up coil. This was done by superimposing on the field H a harmonically varying 60 cycle perturbation field.

For the clear exhibition and convenient manipulation of the quantities involved, a 60 cycle field signal synchronized with the perturbation field was imposed on the x-axis of an oscilloscope and the signal from the detector coil was placed on the y-axis. The frequency of the rf field was then adjusted so that the pip from the detector coil appeared at the zero the x-axis sweep. Since one factor that determines the accuracy of the measurement is the precise location of the center of sweep, that is the zero of the perturbation field, it is desirable to make the perturbation field small. The error in the determination of the center of sweep is a percentage of the sweep length and hence of the perturbation field. It was found convenient to use a perturbation field of 3 gauss amplitude.

Other factors that affect the accuracy of the measurement are the degree of homogeneity of the field H over the sample, the certainty with which the frequency of the rf field can be determined and finally the accuracy with which the magnetic moment of the proton is known.

A schematic drawing of the experimental arrangement is shown in Fig. 1.

Excitation Functions for Spallation Reactions. G. C. Wick.

The excitation functions that have been determined in recent years by Kelly and Segrè[1] and Meinke and Seaborg[2] indicate the existence of a

characteristic energy of bombardment which corresponds to maximum yield. An attempt has been made to analyze the dependence of yield on excitation energy on the basis of a simple probability model and a promising inclination to agreement between the results of analysis and experiment has resulted.

Because of the difficulty of manipulating a compound nucleus, the liquid drop model was used. For concreteness of image the theory will be illustrated by means of the excitation of the reaction Th^{232} (p,6n)Pa^{227} which is discussed by Meinke and Seaborg.[2] The relative yield of the reaction is equal to its probability, that is, the frequency with which this reaction occurs among all the reactions that are possible when protons of a certain energy E_0 impinge on a large number of Th^{232} nuclei. The reaction Th^{232}(p,6n)Pa^{227} is a compound event which consists of the separate events: one neutron is boiled off, then another, then another, until exactly six neutrons are boiled off in succession. For the purpose of simplifying computations, the probability of boiling off a proton is assumed to be negligibly small.

Let E_0 be the energy which the proton brings to the unimpaired Th^{232} nucleus. The temperature of the nucleus, T_0 is thenproportional to $\sqrt{E_0}$. It is assumed that the first neutron is boiled off with a Maxwellian energy distribution:

$$\frac{\epsilon_0}{T_0^2} e^{-\frac{\epsilon_0}{T_0}} d\epsilon_0$$

The energy that remains to effect the expulsion of a second neutron is $E_1 = E_0 - B - \epsilon_0$ where B is the binding energy of a neutron, and ϵ_0 is the energy that was imparted to the first neutron. The binding energy for a neutron was assumed to 6 Mev. It is then assumed that the second neutron is again boiled off with a Maxwellian energy distribution

$$\frac{\epsilon_1}{T_1^2} e^{-\frac{\epsilon_1}{T_1}} d\epsilon_1$$

The n'th neutron is expelled from the nucleus with an energy distribution

$$\frac{\epsilon_{n+1}}{T_{n+1}^2} e^{-\frac{\epsilon_{n+1}}{T_{n+1}}} d\epsilon_{n+1}$$

Let $p_n(\epsilon_n)$ be the probability function for the energy of emission of the n'th neutron, and define $\Sigma = \epsilon_1, + \epsilon_2 + \ldots + \epsilon_n$.

The probability function for the evaporation of at least n neutrons is $p_1 \cdot p_2 \cdot p_3 \cdot \ldots p_n$, so that the probability of boiling off at least n neutrons with an energy dissipation of Σ is

$$p(\Sigma) = \int p_1(\epsilon_1)\, p_2(\epsilon_2) \ldots p_n(\epsilon_n)\, \delta\,(\Sigma - \epsilon_1 - \epsilon_2 \ldots - \epsilon_n)\, d\epsilon_1 \ldots d\epsilon_n$$

When the number of neutrons that are emitted is large it is possible to use a Guassian or Poisson distribution as a limiting case of the Maxwellian distribution.

In order to arrive at the excitation function for the reaction $Th^{232}(p,6n)Pa^{227}$, for example, one computes the probability that at least six neutrons are evaporated and subtracts it from the probability that at least seven neutrons are emitted for various values of the initial excitation energy E_o. The graph of Fig. 2 shows the result. The agreement with experiment is fairly good although the experimental curves are somewhat sharper.

<u>The Light α-Emitters in Au and Hg. J. Rasmussen.</u>

T. P. Kohman[3] has pointed out that most nuclides above A = 140 are energetically capable of emitting α-particles although heretofore naturally radioactive Sm^{152} was the only known α-emitter below Bi. The discovery of isotopes that decay by α-emission in the medium heavy region increases in difficulty with decreasing mass number since the half-lives become extremely short. A search for α-emitters is being carried out among the neutron deficient isotopes of the elements whose atomic numbers are less than 83.

Two such isotopes have been produced and identified by the bombardment of gold foil in the 184-inch cyclotron with protons and deuterons. They are:

$Au^{<190}$	4.3 min.	5.2 Mev
$Hg^{<196}$	0.7 min.	5.6 Mev

A clear chemical identification has been made of Z for both isotopes. The two isotopes have been observed to decay by K capture, β^+ and α-emission. On the basis of measurements of soft x-rays and a number of simplifying assumptions a preliminary estimate of the K/α branching ratio of the 4.3 min. activity has been arrived at: $K/\alpha \approx 10^4$.

The complete identification of the masses of the isotopes has not been possible. An attempt has been made to obtain a rough mass assignment for the Au activity by recording an excitation function for the reaction $Pt^{194}(p,xn)Au^{195-x}$. The threshold for this reaction was located between 75 - 100 Mev and this, by analogy with Meinke's results, leads one to think that $7 \leq x \leq 10$, that is, that the 4.3 min. activity has a mass number between 185 and 188. A mass assignment by milking the Pt and Ir daughters must await the positive identification of mass number for the light Pt and Ir activities.

The search for α-emitters in the medium heavy region is being continued.

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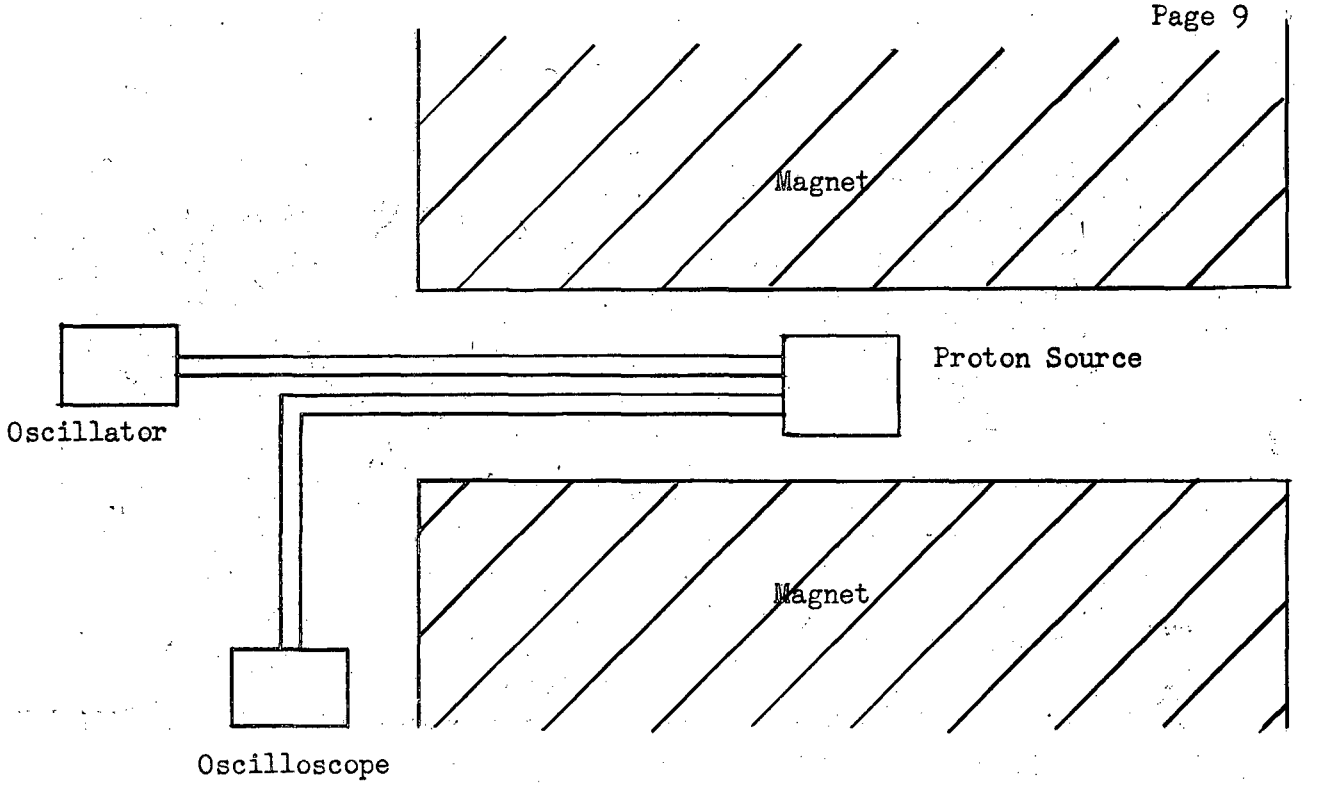
References

(1) E. L. Kelly and E. Segrè, Some Excitation Functions of Alphas and Deuterons on Bi, June 1947, MDDC-1145

(2) W. Meinke and G. T. Seaborg, Further Work on Pa^{235} and Some Excitation Functions, Chemistry Division Quarterly Report, March, April, May 1949, UCRL-382

(3) Truman P. Kohlman, Binding Energies of Alpha-Particles in Medium-Heavy Elements, May 1, 1948, AECD-2060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Oscilloscope

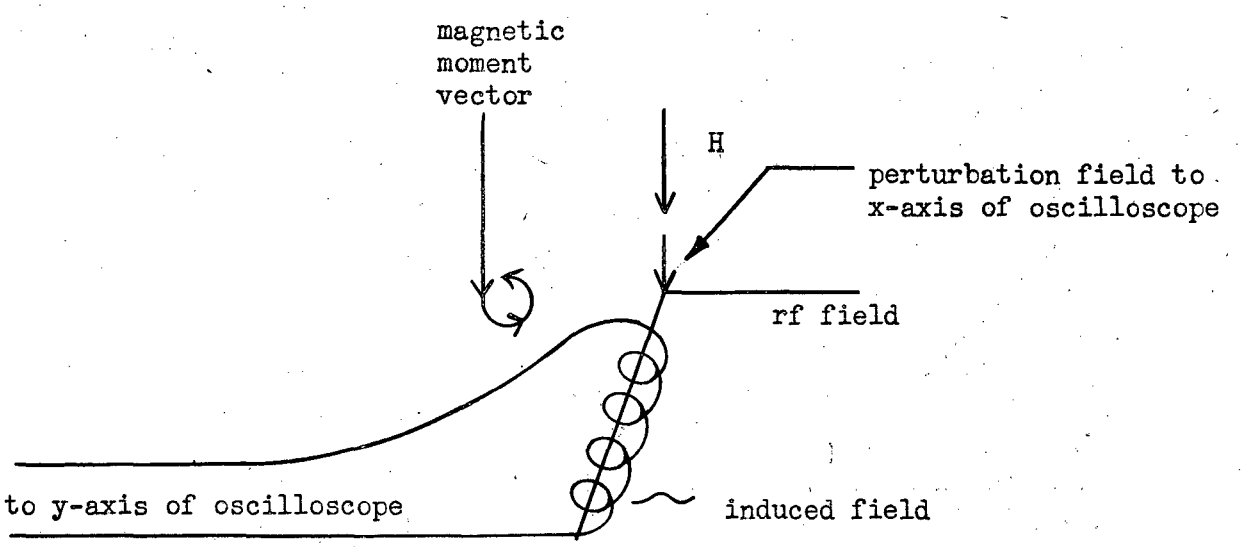
magnetic
moment
vector
H
perturbation field to
x-axis of oscilloscope
rf field
to y-axis of oscilloscope
induced field

Fig. 1

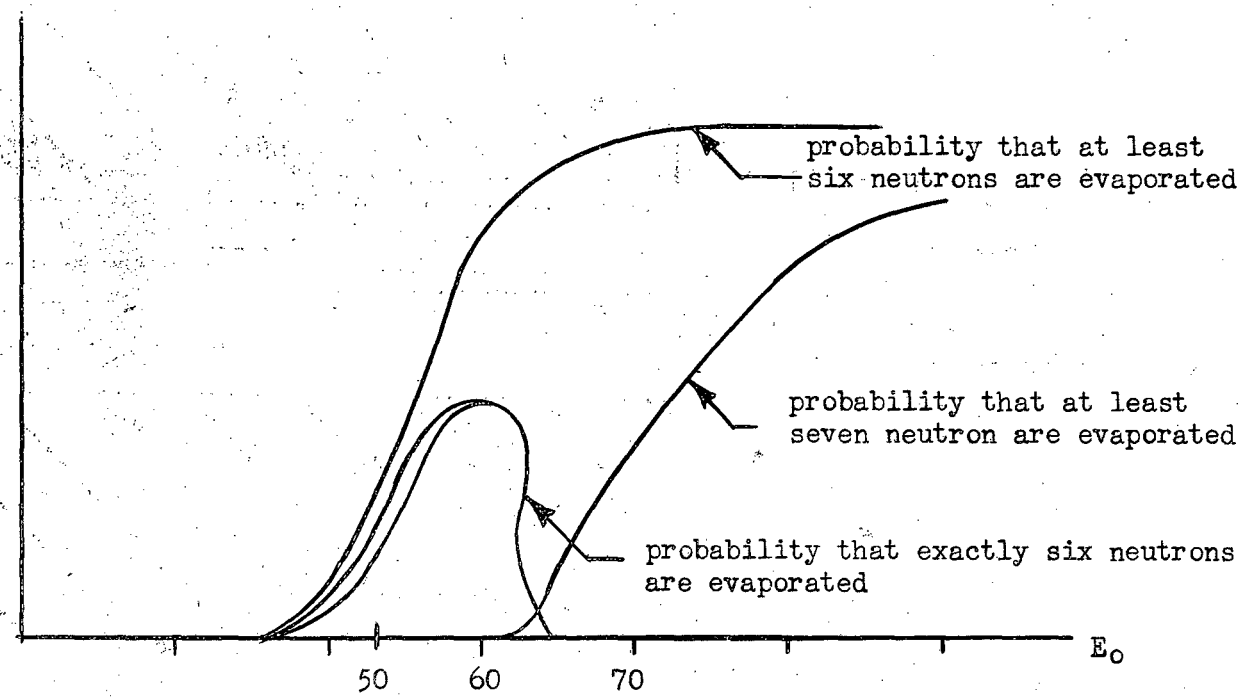
probability that at least
six neutrons are evaporated
probability that at least
seven neutron are evaporated
probability that exactly six neutrons
are evaporated
50
60
70
E_o

Fig. 2