^{47}K MASS FROM THE REACTION ^{48}Ca(d, ^{3}He)^{47}K†

E. Newman and J. C. Hiebert*

Oak Ridge National Laboratory, Oak Ridge, Tennessee

and

B. Zeidman

Argonne National Laboratory, Argonne, Illinois

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The Q value for the reaction ^{48}Ca(d, ^{3}He)^{47}K was measured to establish the ^{47}K mass. The Q value was found to be -10.304 ± 0.012 MeV, which implies a ^{47}K mass excess of $-35\,707 \pm 21$ keV (^{12}C = 0). In addition, the first excited state of ^{47}K was established at 370 ± 15 keV and is tentatively identified as an s-hole state.

A 34.1-MeV deuteron beam from the Oak Ridge isochronous cyclotron was scattered from an 0.2-mg/cm^2 CaO target enriched to 95.6% in ^{48}Ca. The target had been evaporated onto a thin carbon backing at Argonne National Laboratory and had oxidized in transit to Oak Ridge. A semiconductor ΔE-E detector telescope was used for mass identification of the reaction products. For this experiment both detectors were transmission-mounted, surface-barrier detectors. The E and ΔE pulses were added at the amplifier input and ΔE vs $(E+\Delta E)$ spectra were recorded on a 20 000-channel, three-dimensional, pulse-height analyzer. The observed energy resolution for the reaction ^{48}Ca(d, ^{3}He)^{47}K was 90 keV (full width at half-maximum), with the cyclotron beam spread contributing about 80 keV.

A pulse-height spectrum of the ^{3}He particles observed at $\theta = 20°$ from the (d, ^{3}He) reactions on ^{12}C, ^{16}O, ^{40}Ca, and ^{48}Ca present in the target is shown in Fig. 1. Each ^{3}He group in Fig. 1 is identified by the state in the residual nucleus. The strongest three groups, corresponding to reactions proceeding to the ground state of ^{15}N, the ground state of ^{11}B, and the third excited state of ^{15}N, were used to calibrate the energy scale. Eight separate determinations of the Q value for the reaction ^{48}Ca(d, ^{3}He)^{47}K were made at laboratory angles ranging from $\theta = 14$ to 35°. From these measurements we obtained the value $Q = -10.304 \pm 0.012$ MeV for the ground-state reaction. Similarly, the first excited state of ^{47}K was established at 370 ± 15 keV. To determine the mass of ^{47}K from the measured ground-state Q value we rely on the ^{48}Ca mass. A recent measurement[1] has redetermined the mass excess of ^{48}Ca as $-44\,240 \pm 14$ keV, whereas the latest compila-

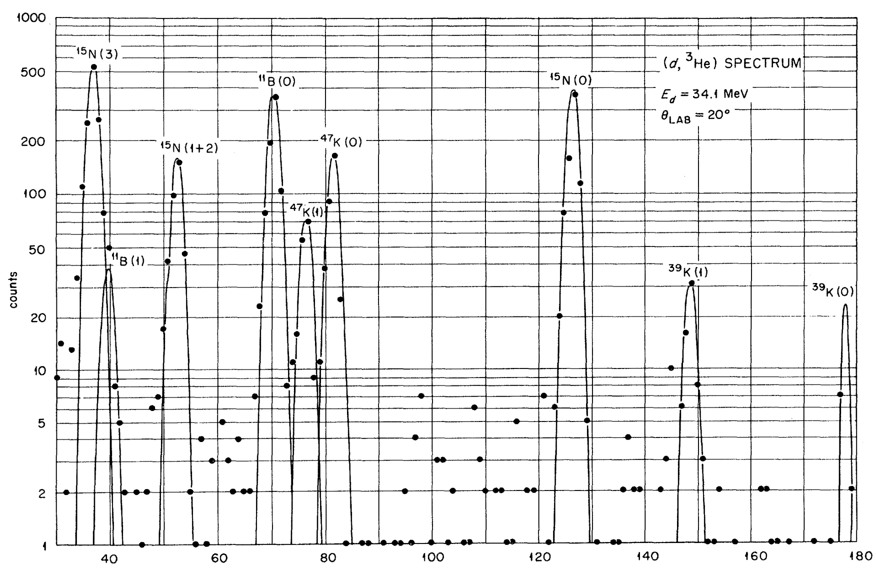

FIG. 1. Pulse-height spectrum of ^{3}He particles resulting from (d, ^{3}He) reactions in a ^{48}CaO target on a ^{12}C backing.

tion[2] of relative nuclidic masses reports the value $-44\,216 \pm 9$ keV. Using the latter value with the deuteron and helium-3 mass excesses,[2] we determined the mass excess of ^{47}K to be $-35\,707 \pm 21$ keV. The value presented in the compilation of Ref. 2 is $-36\,250 \pm 300$ keV.

The ground state of ^{47}K has an isobaric analog in ^{47}Ca, i.e., the lowest excited state in ^{47}Ca with $J^\pi = \frac{3}{2}^+$, $T = \frac{9}{2}$. Recently, Jänecke[3] has proposed a semiempirical formula which can be used to predict the excitation energy of any isobaric analog state, and thus estimate the masses of unknown nuclei. Using this formula, for odd-A nuclei,

$$\Delta E_{T,T'} = \frac{a(A)}{A} \,|\, T(T+1) - T'(T'+1) \,|,$$

and his empirical value of $a(47) = 63$ MeV, we find $\Delta E_{9/2,7/2} = 12.1 \pm 1.0$ MeV. The energy difference[2] between the mirror nuclei ^{39}K and ^{39}Ca was adjusted for radius to give the ^{47}Ca-^{47}K Coulomb energy difference.[4] From this value and the n-p mass difference, we find the predicted mass excess of ^{47}K to be -36.5 ± 1 MeV, which agrees with the experimental value. From our measurement of the ^{47}K mass and the Coulomb energy difference above, we are able to predict more accurately the lowest $T = \frac{9}{2}$, $J^\pi = \frac{3}{2}^+$ state in ^{47}Ca to be located 12.70 $\pm$ 0.12 MeV above the ground state.

Angular distributions for the $(d, {}^3\mathrm{He})$ reactions populating the ground and first excited states of ^{47}K are shown in Fig. 2. In analogy with the reaction ^{40}Ca$(d, {}^3$He$)^{39}$K,[5] we have assigned a $(1d_{3/2})^{-1}$ proton state to the ^{47}K ground state and a $(2s_{1/2})^{-1}$ proton state to the first excited state. The distorted-wave Born-approximation predictions shown in Fig. 2 use optical-model potentials extrapolated from optical-model analysis of deuteron and helium-3 scattering on nearby nuclei at the appropriate energies.[6] As expected, the quality of the fits is poor, but the spectroscopic factors extracted from comparing the predictions to the data, as shown, are $S(1d_{3/2}) = 3.55$ and $S(2s_{1/2}) = 1.15$. These numbers are in excellent agreement with the corresponding ^{40}Ca$(d, {}^3$He$)^{39}$K spectroscopic factors[5] and thus substantiate our assignment of a $(2s_{1/2})^{-1}$ proton configuration to the first excited state.

The appropriate elastic scattering and additional ^{48}Ca$(d, {}^3$He$)$ measurements are being made, better to assign spins and spectroscopic factors to these states and to more tightly bound proton states.

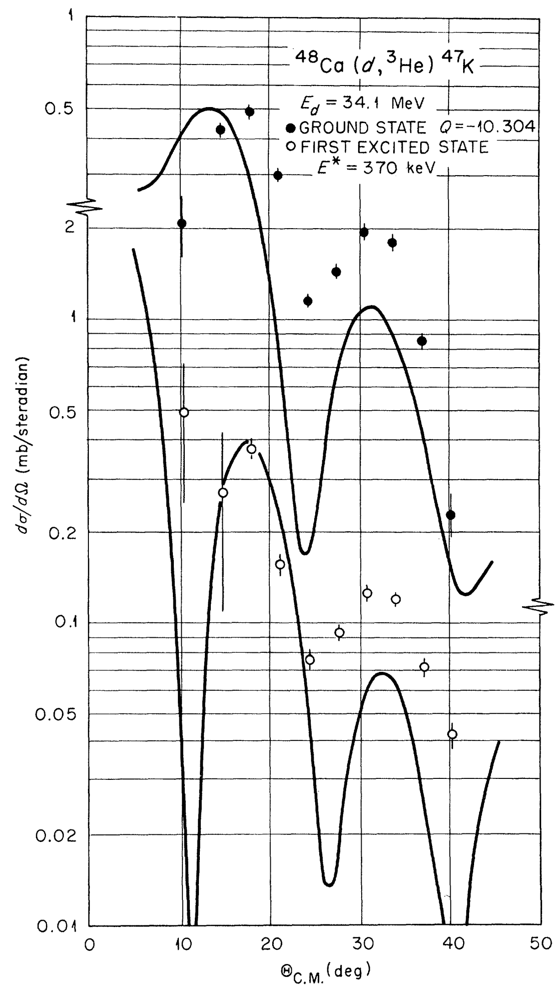

FIG. 2. Angular distributions for the reaction ^{48}Ca$(d, {}^3$He$)^{47}$K to the ground and first excited state of ^{47}K. The upper curve is an $l = 1$ distorted-wave Born-approximation prediction; the lower curve an $l = 0$ distorted-wave Born-approximation prediction.

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*U. S. Atomic Energy Commission Postdoctoral Fellow (1963-1965) under appointment from the Oak Ridge Institute of Nuclear Studies.

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PROPOSAL FOR AN EXPERIMENT ON ADIABATICALLY INDUCED COULOMB FISSION*

Eugene Guth
Oak Ridge National Laboratory, Oak Ridge, Tennessee

and

Lawrence Wilets
University of Washington, Seattle, Washington
(Received 18 October 1965)

Nuclear fission thresholds are fairly well known from the shape of cross-section curves as a function of energy. The thresholds yield directly the height of the saddle-point energy above the nuclear ground state. What is not so well known experimentally is the shape of the nucleus at the saddle point. Some information about this shape is known from (I) spontaneous fission lifetimes and the threshold behavior of the fission cross sections, and (II) the angular distribution of fission fragments. Both cases listed under (I) measure the quantity $\hbar\omega_f$, where $\omega_f = (C/B)^{1/2}$ is the inverted oscillator frequency at the top of the fission barrier. The position of the maximum does not enter. Both measurements yield[1] $\hbar\omega_f \approx 0.4$-$0.5$ MeV for even-even fissioners above the including uranium. Case (II) is model dependent and is based upon the variation in the statistical distribution of levels with deformation.[2] The purpose of this note is to propose an experiment which yields a measure of the saddle-point configuration in an easily interpretable manner.

To date, all induced (as distinct from spontaneous) fission experiments consist of depositing energy into a "compound nucleus," and then observing the decay through the fission channel. We propose introducing a Coulomb field which, ideally, distorts the "cold" nucleus up to a saddle point, after which the nucleus slides down the potential hill to scission. If the distorting potential is introduced sufficiently slowly, the interpretation of the experiments will involve only electrostatics and nuclear statics.

Consider a head-on collision between a projectile (1) and a target (2). Let the reduced mass and center-of-mass energy be denoted by mA_r and E. Then the classical turning point d (which we will choose to be outside the range of nuclear forces) is given by

$$E = Z_1 Z_2 e^2/d. \tag{1}$$

(This neglects the target distortion.) For present purposes, we calculate the electric polarization energy for a target assuming pure quadrupole distortion only; that is, the target contains only monopole and quadrupole moments. (The projectile is assumed to be unpolarized.) We will further consider only prolate, axially symmetric distortions, with the target axis perpendicular to the trajectory. (We ignore the tendency of the Coulomb field to introduce nonaxial symmetry or oblate deformation.[3]) The electric polarization energy is given by

$$V_Q = -\tfrac{1}{2} Z_1 e Q/d^3, \tag{2}$$

where Q is the expectation value of the operator qr^2P_2 for the target. If we further assume that the projectile moves very slowly (we present below calculations which do not make this assumption), then the condition for fission is that V_Q plus the target deformation energy $\epsilon(Q)$ have no maximum at closest approach. Since V_Q is linear in Q, it follows that the position of the inflection point in $V_Q + \epsilon$ is determined by ϵ. The threshold occurs for

$$\frac{Z_1 e}{2d^3} = \frac{d\epsilon}{dQ}\bigg|_{\text{inflection}} \equiv \epsilon' \tag{3}$$

or, taken together with (2), the "infinitely slow"