TABLE II. Tabulation of the resonances seen in this experiment and also the various parameters corresponding to the resonances. E_p is the incident proton energy (lab system), E_e is the corresponding excitation in N^{14}, J and π are the total angular momentum and parity of the levels, respectively, Γ is the full width at half-maximum of the resonances, and the last column gives the reduced widths of the levels relative to the reduced width for single-particle type excitation.

E_p, Mev	E_e, Mev	J	π	Γ, kev	γ^2 $\frac{3}{2}(\hbar^2/\mu a)$
2.00±0.02	9.39	1	−	25±3	0.10
2.12±0.02	9.51	3	−	32±6	0.11
2.33±0.02	9.72	1	+	15±3	0.005
2.90±0.04	10.29	···	···	80±30	···
3.12±0.03	10.51	···	···	80±10	···

where F and G are the regular and irregular solutions, respectively, of the Coulomb scattering problem evaluated at the radius of the nucleus, a.[18] The single particle reduced width is $3\hbar^2/2\mu a$, where μ is the reduced mass of the system and $a=(1.33A^{\frac{1}{3}}+0.77)\times10^{-13}$ cm.[19] It is quite apparent from these reduced widths that none of the three levels analyzed are formed through single-particle excitation.

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Capture of Protons in K^{39}

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Evaporated natural potassium metal targets were bombarded with protons from a Cockcroft-Walton generator. The excitation function was studied from 0.5 to 1.15 Mev. The gamma rays from a level found in calcium 40 at 9.29 Mev above the ground state were studied with single-crystal spectrometers and with a pair spectrometer. Gamma rays of energy 9.29±0.005 Mev, 5.93±0.005 Mev, 5.55±0.005 Mev, 3.73±0.005 Mev, and 0.500±0.005 Mev were found and suggest a decay scheme in agreement with the levels in Ca^{40} found by Braams by inelastic proton scattering.

THE doubly-magic nucleus Ca^{40} is of particular interest, especially in the light of the shell-model picture. One expects the first excited state to be rather high in energy above the ground state. The levels of Ca^{40} have been studied by inelastic scattering of protons by Braams,[1] who by magnetic analysis finds levels at 3.348 (0+), 3.730, 3.900, 4.483, 5.202, 5.241, 5.272, 5.606, 5.621, 5.901, and 6.029 Mev. See Fig. 1.

We have produced excited states in Ca^{40} by the capture reaction $K^{39}(p,\gamma)Ca^{40}$. Protons were accelerated in a conventional Cockcroft-Walton machine, resolved beams of 50–100 microamperes being used. Targets were prepared *in situ* by evaporation in vacuum of freshly cleaned, metallic potassium. Target thicknesses were 20–30 kev to 1-Mev protons. We have used two types of detection equipment. Firstly single-crystal spectrometers with NaI scintillators of cylindrical form of dimensions 2 in. diameter by $2\frac{1}{2}$ in. long, and $1\frac{1}{2}$ in. diameter by $1\frac{1}{2}$ in. long. Secondly a three-crystal pair spectrometer of the design of Bell, Graham, and Petch. Both detection systems were used in conjunction with an 80-channel Hutchinson-Scarrott kicksorter. The equipment was calibrated with the following sources: (i) Cs^{137} (0.627 Mev), (ii) Na^{22} (0.500 and 1.277 Mev), (iii) Rd-Th (2.62 Mev), and (iv) Po-Be (4.43 Mev), and with the reactions: (v) $F^{19}(p,\alpha,\gamma)$ (6.14 Mev), (vi) $C^{13}(p,\gamma)$ (8.06 Mev), and (vii) $Li^7(\alpha,\gamma)$ (9.276 Mev).

The excitation function has been studied from 0.2 to 1.2 Mev, and a number of resonances found. The yield was measured at two bias values, 4 Mev and 6.5 Mev. Resonances were found at incident proton energies of (i) 0.883±0.010 Mev, (ii) 0.925±0.010 Mev, (iii) 0.980 ±0.010 Mev, and (iv) 1.150±0.010 Mev. Relative cross sections are (i) 1.21, (ii) 1, (iii) small, and (iv) 10.1, respectively. These resonances correspond to levels in Ca^{40} at the following energies above the ground state: (i) 9.03±0.010 Mev, (ii) 9.07±0.010 Mev, (iii) 9.13±0.010 Mev, and (iv) 9.29±0.010 Mev.

A study of the γ-ray spectra by single-crystal spec-

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trometers and by a pair spectrometer at the 1.150-Mev resonance showed γ rays of energy 9.29±0.005 Mev, 5.93±0.005 Mev, 5.55±0.005 Mev, 3.73±0.005 Mev, and 0.500±0.005 Mev. All these can be accounted for by the following decay scheme for the 9.29-Mev level excited in Ca^{40}: (i) γ-ray (9.29-Mev) decay direct to ground state; (ii) γ ray (5.55 Mev) to 3.73-Mev level, which then decays to the ground state (3.73-Mev γ); (iii) γ ray (5.93 Mev) to 3.348-Mev level, which decays to the ground state by pair emission (indicated by 0.500-Mev γ ray).

The most intense of these transitions is the direct decay to the ground state. An accurate study of the relative intensities of the various γ rays is now in progress. A preliminary study has shown that the predominant decay for the 9.03-, 9.07-, and 9.13-Mev levels, is directly to the ground state. The ratio of the transition probabilities from the 9.29-Mev level to the 3.348-Mev level (0+) and to the ground state (0+), respectively, measured experimentally, is found to be approximately 0.21. By using single-particle model formulas, this ratio (for electric dipole transitions in both cases) is calculated to be 0.27.

An angular distribution of the γ rays corresponding to direct transition from the 9.29-Mev level to the ground state has been measured, and this indicates that the transition is an electric dipole one.

The Q value of the reaction $K^{39}(p,\gamma)Ca^{40}$ has been determined by a pair spectrometer. An accurate measurement of the high-energy γ rays at the 1.150-Mev resonance was made, in conjunction with the calibration points: (i) 9.276 Mev from $Li^7(\alpha,\gamma)$, and (ii) 8.06 Mev from $C^{13}(p,\gamma)$. The Q value was found to be 8.17 ±0.03 Mev.

A full report of this work will be published in the near future.

After completion of the work reported above, a private communication was received from J. H. Matthews of work by Towle, Berenbaum, and himself on $Cl^{35}(p,\gamma)$, $Cl^{37}(p,\gamma)$, and $K^{39}(p,\gamma)$ done in the Department of Physics, Imperial College, London, England. This is consistent with the findings and deductions from our work.

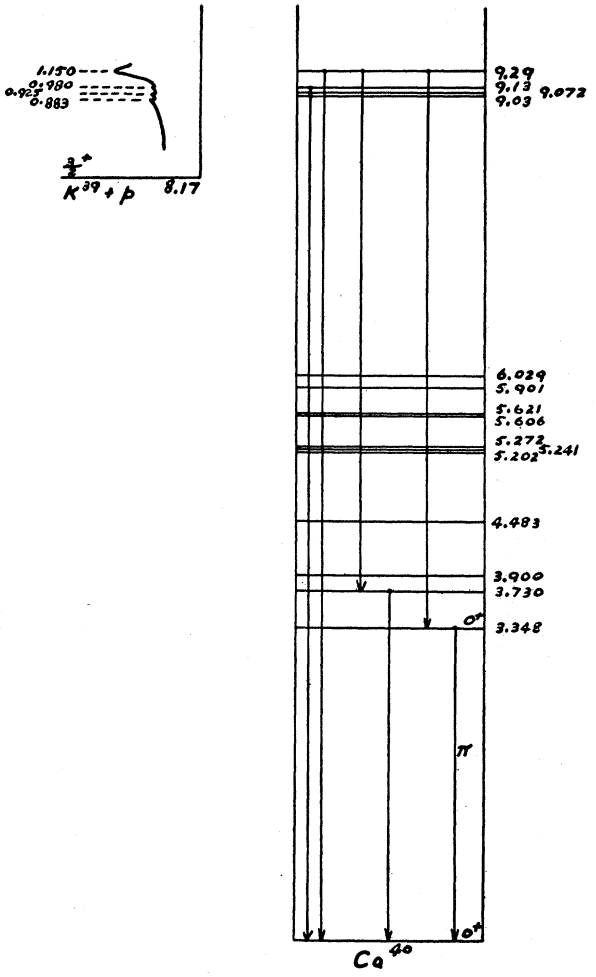

FIG. 1. Excitation function and gamma rays observed in the capture reaction $K^{39}(p,\gamma)Ca^{40}$. The energy level scheme is that obtained by Braams[1] from inelastic proton scattering on Ca^{40} and from this work.

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