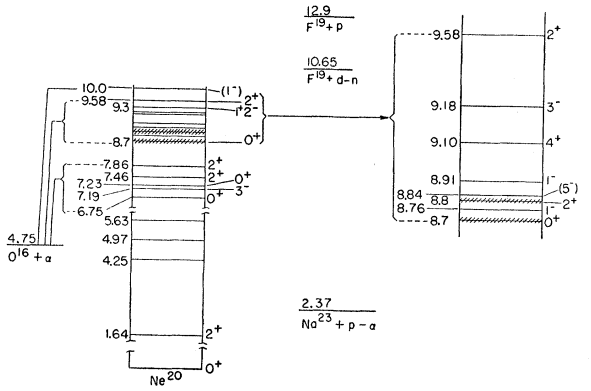

FIG. 5. Energy level diagram of Ne^{20}. The levels found in the present experiment are shown in an expanded scale on the right.

V. RESULTS AND CONCLUSIONS

As a result of this experiment, eight previously unobserved states in Ne^{20} in the region of excitation between 7.9 and 9.9 Mev have been found and identified. Six of the resonances are relatively sharp, while the two others overlap and are very broad. Interpretation of a phase-shift analysis of the data in the context of Wigner-Eisenbud dispersion theory has resulted in the assignment of the spins, parities, resonant energies, and widths of the levels. The characteristic energies and alpha-particle reduced widths have also been deduced and the latter have been compared to the Wigner single-particle limit of 3.66 Mev-cm. In addition to the broad 0^+ and 2^+ levels, an additional broad resonance in the region above the energy range of the data seems likely. The results of the analysis are shown in Table I and also in Fig. 5, which is an energy level diagram of Ne^{20} up to 10-Mev excitation. The five levels between 6.75 and 7.86 Mev were investigated by Cameron.[5] The positions of the four lowest excited states have been obtained from the work of Buechner and Sperduto.[14] The 9.2-Mev level reported by Ferguson and Walker[6] as 1^- does not appear.

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Isomerism of Silver-108

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A long-lived isomer of Ag^{108} has been detected in old Ag^{110m} samples. The isomer decays with a half-life $\geqslant 5$ years. Gamma- and beta-ray spectrometer data show that 90% of the disintegrations proceed by electron capture followed by a cascade of three gamma rays of 616-, 722-, and 434-kev energy, while 10% go by isomeric transition to Ag^{108}. New values are given for the branching ratios of 2.4-minute Ag^{108}.

I. INTRODUCTION

BASED on the data available for the even mass number isotopes of rhodium, silver, and indium, systematics indicate an isomer should be expected for Ag^{108} with a half-life comparable to the 270-day Ag^{110m} and with the isomeric level at $\sim$100 kev above the ground state. This isomer has been observed recently in a sample of Ag^{110m} obtained in 1951 from the Isotope Division of Oak Ridge, the Ag^{110m} activity having decayed by now to $\sim$0.05% of its initial value. A difference in neutron energy dependence for production of these two long-lived silver isomers could account for the discrepancies reported in the half-life of Ag^{110m}.

II. EXPERIMENTAL

The silver activities were studied with a one hundred-channel pulse-height analyzer and associated equipment described elsewhere.[1] The gamma-ray detector was a 3-in.$\times$3-in. NaI(Tl) crystal whose calculated photopeak efficiencies were checked by 4π beta counting.

The irradiations to obtain the 2.4-minute Ag^{108} were performed using the pneumatic tube facilities of the Ford Nuclear Reactor at the University of Michigan.[1] An irradiation time of two minutes at a thermal neutron flux of $\sim 1.4\times 10^{12}$ n cm^{-2} sec^{-1} was used and the shorter-

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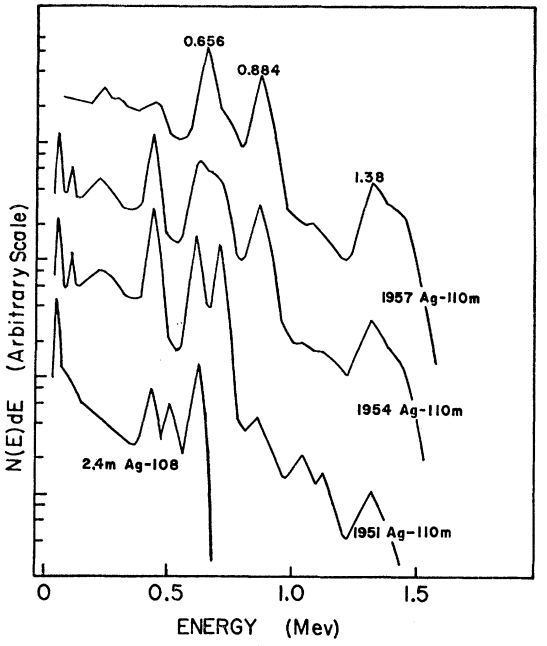

FIG. 1. Gamma spectra of Ag^{110m} are given along with their year of production. A spectrum of 2.4-minute Ag^{108} is included.

lived Ag activities allowed to decay for four minutes before any counting started.

III. RESULTS

Silver-108*m* Measurements

The gamma-ray spectrum of this new isomer, Ag^{108m}, is shown in Fig. 1 (designated as 1951 Ag^{110m}). The residual Ag^{110m} contributes less than 1% of the gamma activity of this sample. The figure includes spectra of Ag^{110m} samples produced in 1954 and 1957. The activities of the two isomers are seen to be about equal after 5 years of decay.

The relative gamma-ray intensities[2] in Ag^{108m} are 81 (5.9), 434 (100), 616 (100), 722 (100) kev. The 21-kev Pd K x-ray was found to be in coincidence with the 434-, 616-, and 722-kev gamma rays. No coincidences with the 81-kev gamma ray were detected in the gamma energy range of 20 kev to 2 Mev or beta energy range of $\sim$100 kev to 2 Mev. No annihilation peak was detected in the gamma spectrum or in the coincidence spectra. The energy of the 434-kev gamma ray in Ag^{108} and in Ag^{108m} was found to be the same within the limits of the measurement. The accuracy of the gamma-ray measurements is estimated to be ± 3 kev.

Beta-ray spectra taken with a plastic scintillator detector show a 1.65 ± 0.04 Mev beta ray, identical with that of Ag^{108}, of 11 (±1)% frequency relative to the cascade gamma-emission rate. Although the low-energy range is distorted from the gamma contribution, the spectra show a definite conversion line of $\sim$1% for the 434-kev gamma-ray transition relative to the gamma-emission rate. Since this transition is known to be $E2$,[3] the relative conversion-line areas were obtained by gating the beta detector with the Pd K x ray. The relative abundances observed (434, 1.0; 616, 0.41; 722, 0.21) indicate $E2$ or $M1$ character for all three gamma-ray transitions.[4]

The chemical assignment was confirmed by processing an aliquot of the 1951 tracer through the chemical separation procedure used by Hicks and Folger for the purification of fission product silver.[5] No change was observed in spectra taken before and after the separation. The final product contained 94 (±1)% of the carrier silver added and also of the initial activity, verifying the purity of the original silver tracer as well as providing proof of the activity being a silver isotope.

Silver-108 Measurements

The decay scheme of Ag^{108} as given by Strominger, Hollander and Seaborg[6] was checked. The gamma-ray spectrum is shown in Fig. 1 while measurement data are summarized in Table I. The beta counter detection efficiency was determined with a P^{32} sample standardized in the 4π counters. The new values differ by a factor of 2 from the beta calibration of the earlier experiment. The validity of the original spin and parity assignments[7] is not affected by this discrepancy. The bremsstrahlung corrections were determined using the standardized P^{32} activity. The K x ray to beta ratio was obtained from evaporated silver films of <0.01 mg cm^{-2} .The half-life was found to be 2.42 ± 0.02 minutes over 10 half-lives.

TABLE I. Transition energies and branching ratios in 2.4-minute Ag^{108}.

Isotope table value		New value	
1.77-Mev β^-,	97%	1.65[a] $\pm$0.04 Mev,	93.8%
0.63-Mev γ,	1%	0.632 $\pm$0.002 Mev,	1.90%
0.78-Mev β^+,	0.15%	0.83[b] $\pm$0.05 Mev,	0.36%
0.427-Mev γ,	0.06%	0.434 $\pm$0.002 Mev,	0.18%
0.61-Mev γ,	0.2%	0.615[c] $\pm$0.005 Mev,	0.42%
EC to ground state	1.5%	(1.85 Mev)	3.35%

[a] Determined by direct comparison with identical P^{32} sample.
[b] Obtained by taking K-shell fluorescence yield as 0.81 [C. D. Broyles, D. A. Thomas, and S. K. Haynes, Phys. Rev. **89**, 715 (1953)], L/K capture ratio as 0.11 [H. Brysk and M. E. Rose, Revs. Modern Phys. **30**, 1169 (1958)], and using calculated K/β^+ ratios of P. F. Zweifel [Phys. Rev. **107**, 329 (1957)].
[c] Energy measurement from coincidence spectra and from observed sum coincidence peak.

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[4] M. E. Rose, G. H. Goertzel, and C. L. Perry, Oak Ridge National Laboratory Report, ORNL-1023 (unpublished) (1951).

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[7] M. L. Perlman, W. Bernstein, and R. B. Schwartz, Phys. Rev. **92**, 1236 (1953).

IV. CONCLUSIONS

Mass Assignment

The long-lived isomer was shown to be an isotope of silver by the chemical purification procedure. The isomer has a half-life and levels consistent with predictions for Ag^{108m} based on systematics. The identity of the 1.65-Mev beta ray and of the 434-kev gamma ray in Ag^{108} and in the long-lived isomer is taken as proof of their relationship. Further, the K x ray observed in the decay of the long-lived isomer has been shown to be at 21 kev, being assigned as the K x ray of palladium.

The specific activity of the available sample is too low to obtain high resolution conversion line data. This information would be necessary to establish uniquely the postulated isomeric level.

Decay Scheme

The 81-kev gamma-ray transition for which no conversion line was detected is tentatively assigned in cascade with the isomeric transition. This gamma-ray is not observed in the decay of Ag^{108}. The total conversion coefficient is estimated to be ~ 0.5 from the relative 81-kev gamma-emission rate and the beta-emission rate of the 2.4-minute daughter, indicating a spin change of 0 or 1. From the lack of coincidence of the 81-kev gamma-ray with the K x rays, it is concluded that the isomeric transition has an energy less than the K-shell binding energy. This is consistent with the expectation from systematics of the isomeric level at ~ 100 kev. Gamma lifetime calculations indicate a spin change of 3 or 4 for the isomeric transition.

The logft value of about 5.8 for electron capture to the highest excited state of Pd^{108} indicates an allowed transition. From the cascade gamma-ray intensities and from calculated sum coincidence corrections, an upper limit of 1% is obtained for crossover transitions in the cascade. Calculated transition probabilities from the highest excited level of palladium show this to be consistent with a spin assignment of 4 to the level at 1154 kev. The parities of these levels are found to be positive from the measured K-conversion coefficients.

The second excited state of Pd^{108} from Coulomb excitation has been reported to be at 941 kev.[8] The level at 1050 kev observed in the decay of Ag^{108} is either 0+ or 2+, preferably 0+ from the absence of the cross-over transition.[7] The sequence of the 616- and 722-kev transitions in the cascade cannot be uniquely determined from the data obtained. The sequence given is arbitrary and based on level spacing considerations (see Pd^{106} and Cd^{110}) of the apparent triplet of close-lying levels 0+, 2+, 4+, at about 1 Mev above the ground state.

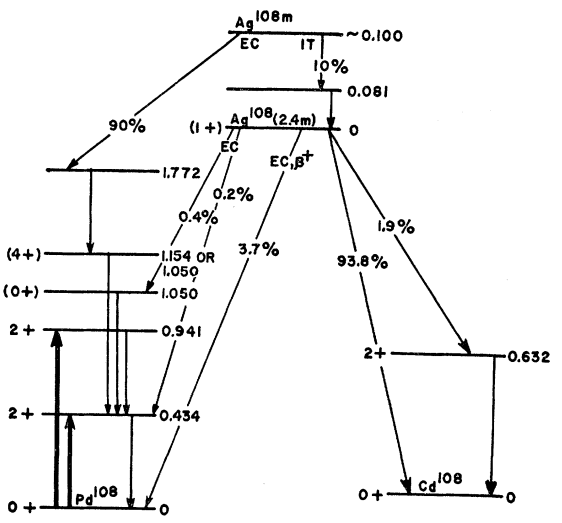

FIG. 2. Decay scheme and level diagram of Ag^{108m}-Ag^{108}.

From the preceding interpretation of data, the spin of the isomeric level of Ag^{108} must be 4, 5, or 6. The spins of the isomeric levels of Ag^{106} and Ag^{110} have been measured and found to be 6,[9] but experimental data on the level in Ag^{108} are insufficient to permit definite spin assignment. The data and conclusions are summarized in the decay scheme presented in Fig. 2.[10]

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[10] The soft gamma-ray spectra observed in thermal neutron capture by Ag^{107} as reported by V. V. Sklyarevskii and co-workers [J. Nuclear Energy, **10**, 69 (1959)] shows a prominent level at 82 kev which may be the same as the 81-kev gamma ray following the isomeric transition in Ag^{108m}.