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A NEW 20-HOUR ELECTRON-CAPTURING RHENIUM ISOTOPE, Re^{181}

Charles J. Gallagher, Jr., Michael Sweeney, and John O. Rasmussen

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During an investigation of neutron-deficient rhenium isotopes[1] produced by 48-Mev alpha particles on tantalum, a very prominent 366-kev gamma transition was observed which decayed with an approximately 20-hour half-life. Since a 17-hour activity had been observed when bombarding with alpha energies above 40 Mev in a stacked tantalum foil excitation function,[2] and since no isotope Re^{181} had been previously reported,[3] we assigned the activity to the electron-capture decay of a new isotope, Re^{181}. The 366-kev gamma associated with this decay is then a transition in W^{181}.

To verify this assignment two experiments were done. The first consisted of two stacked-foil excitation functions performed by bombarding a stack of 0.001-inch tantalum (99.98% pure) with a very low-intensity beam of alpha particles in the Berkeley 60-inch cyclotron.

In the first experiment the foils were counted directly in a sodium iodide counter with a 50-channel differential pulse-height analyzer. The intensity of the 366-kev gamma in each foil was then plotted against the energy of the alpha particle incident on each foil to give a rough excitation function. The threshold energy was approximately 33 Mev, and the curve was still rising at the full energy of the cyclotron, ~48 Mev. This threshold and the shape of the curve clearly must correspond to a Ta^{181} $(\alpha,4n)$ Re^{181} reaction. The excitation function is illustrated in Fig. 1.

The second stacked-foil bombardment was used to determine the half-life of the isotope. Much greater activities were produced, and carrier-free chemical separation to obtain pure rhenium was performed[4] on the first foil. The decay of the 366-kev transition was followed in a double-focusing beta-ray spectrometer at 0.3% resolution and on the previously mentioned 50-channel gamma analyzer. The results obtained by the two methods were in good agreement. The half-life determined was 20 ± 2 hours. In this experiment we determined a $K/L_1/M_1$ ratio of 5.7/1/~0.2 for the 366-kev gamma. The L_{II} and L_{III} lines were not observed.

The second experiment was conducted several weeks after the second

bombardment. Tungsten carrier was added to the previously separated pure rhenium activity. WO_3 was precipitated and the precipitate was gamma-analyzed. A single peak was observed at the energy of tantalum K x-rays. Since W^{181}, the only radioactive tungsten isotope in this region, has been observed to decay almost entirely to the ground state of Ta^{181},[5] and since the long-lived rhenium isotopes exhibit complex gamma spectra,[1] we feel that this experiment further establishes the activity first observed as Re^{181}. The half-life of the K x-ray peak is in agreement with the 120-day half-life reported for W^{181}, but we have not followed it for a long enough period to verify this value.

Dr. D. Strominger performed coincidence studies on the Re^{181}, using fast-slow coincidence pulse-analysis apparatus. He observed no coincidences between the 366-kev gamma and K x-rays, and from this result it was concluded that the half-life of the state giving rise to this gamma is greater than 10^{-7} sec.[6]

Recent studies of short-lived isomers produced by betatron excitation of natural tungsten[7,8] have revealed a 366-kev gamma transition with a half-life of 14.4×10^{-6} sec. The transition was reported[8] to have a K-conversion coefficient of $0.30 \pm .03$. These workers assigned the transition to W^{181}. Our work confirms this assignment, since the isomer is formed in decay of Re^{181}. Bureau and Hammer[8] (hereafter called BH) suggest that the multipolarity of the 366-kev transition, as determined by their absolute conversion coefficient, agrees with either a 28% E1 – 72% M2 or 65% M2 – 35% E3 mixture. From our failure to observe the L_{II} and L_{III} conversion electrons we can rule out the M2 – E3 assignment. Their mixing ratio was calculated using Rose's[9] theoretical conversion coefficients, which are now generally considered to be too high because of the neglect of a finite nuclear size correction. Using Sliv's[10] K-shell internal-conversion coefficients, we recalculate the mixture to be 14% E1 – 86% M2. Furthermore, the experimental limits of error given by BH do not eliminate a pure M2 assignment. The value of 5.7 we obtained for the K/L_I is in excellent agreement with the theoretical K/L_I ratio for a pure M2 transition. This is not a sensitive test for mixing, however, since the strong M2 conversion would mask small E1 contributions.

BH also advance an explanation of the isomeric W^{181} state in terms of nucleon states in a spheroidal well as calculated by Nilsson.[11] They suggest that the transition observed corresponds to a transition between two Nilsson odd-neutron states, 7/2- ——> 9/2+, the predominant M2 character resulting from a

high degree of cancellation of E1 transition matrix elements for the Nilsson states in question. Although retardation from single-particle formula rates[12] occurs generally for low-energy E1 transitions, the retardation (granting E1 admixture of 14% here) of about 10^{10} would be exceptionally large for E1 transitions not K-forbidden, retardations of $10^4 - 10^5$ being the general rule.[13] These lifetime considerations strengthen our alternative assignment of pure M2 character to the isomeric transition. The M2 transition is retarded by about a factor of 700.

Consideration of the Nilsson diagram for neutron states also shows a nearby 5/2- state which would give rise to a pure M2 transition to the 9/2+ ground state in W^{181}, and we favor this state assignment for the isomer.

Another test of the assignment of the isomeric state can perhaps be obtained from the Re^{181} studies if the log ft value for electron capture to the 366-kev state can be ascertained. This test is a consequence of the asymptotic-quantum-number beta-selection rules proposed by Alaga.[14] If we postulate that the 5/2+ odd-proton ground state, proposed for Re^{183},[1] Re^{185}, and Re^{187},[15] is also the ground state of Re^{181}, then decay to the 7/2- state proposed by BH should theoretically exhibit a larger log ft value then decay to the 5/2- state, since for electron capture to these states the 5/2+ ⟶ 7/2- beta transition is first-forbidden, hindered, while the 5/2+ ⟶ 5/2- transition is first-forbidden, unhindered. We have observed some additional weaker gamma transitions which may be associated with the decay of Re^{181}, but because of the complexity of the gamma spectra of the Re^{182} isomers with not too different half-lives, the isotope assignment of the weaker transitions in our samples is still quite uncertain.

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REFERENCES

1. Thulin, Rasmussen, Gallagher, Smith, and Hollander, Phys. Rev. 104, 471 (1956).
2. M. Sweeney and J. O. Rasmussen, Chemistry Division Quarterly Report, University of California Radiation Laboratory Report UCRL-2932 (1955).
3. J. M. Hollander, I. Perlman, and G. T. Seaborg, Revs. Modern Phys. 25, 469 (1953).
4. J. D. Giles, W. M. Garrison, and J. G. Hamilton, J. Chem. Phys. 18, 995 (1950).
5. Cork, Nester, LeBlanc, and Brice, Phys. Rev. 92, 119 (1953); A. Bisi, S. Ferrani, and L. Zappa, Nuovo Cim. 1, 651 (1955); ibid, 3, 661 (1956); Derbrunner, Heer, Kündig, and Rüetschi, Helv. Phys. Acta 29, 235 (1956).
6. D. Strominger, unpublished data (1956).
7. S. H. Vegors, Jr., and P. Axel, Phys. Rev. 101, 1067 (1956); M. G. Stewart, A. J. Bureau, and C. L. Hammer, Bull. Am. Phys. Soc. 1, 206 R2 (1956); also private communication to I. Perlman by P. Axel, S. H. Vegors, Jr., and R. B. Duffield of a list of (γ,n) reactions (as of Sept. 1956) producing metastable states in excited nuclei.
8. A. J. Bureau and C. L. Hammer, Phys. Rev. 105, 1006 (1957).
9. M. E. Rose, privately circulated tables. Also (with G. H. Goertzel) in "Beta- and Gamma-Ray Spectroscopy," edited by K. Siegbahn (Interscience Publishers, Inc. New York, 1955) App. IV, p. 905.
10. L. A. Sliv, privately circulated tables.
11. S. G. Nilsson, Kgl. Danske Videnskab. Selskab, Mat-fys. Medd. 29, No. 16 (1955).
12. S. A. Moszkowski, in "Beta and Gamma-Ray Spectroscopy," edited by K. Siegbahn (Interscience Publishers, Inc., New York, 1955) Chap. XIII, p. 391.
13. D. Strominger and J. O. Rasmussen, Nuclear Physics (in press).
14. G. Alaga, Phys. Rev. 100, 432 (1955).
15. B. R. Mottelson and S. G. Nilsson, Phys. Rev. 99, 1615 (1955).

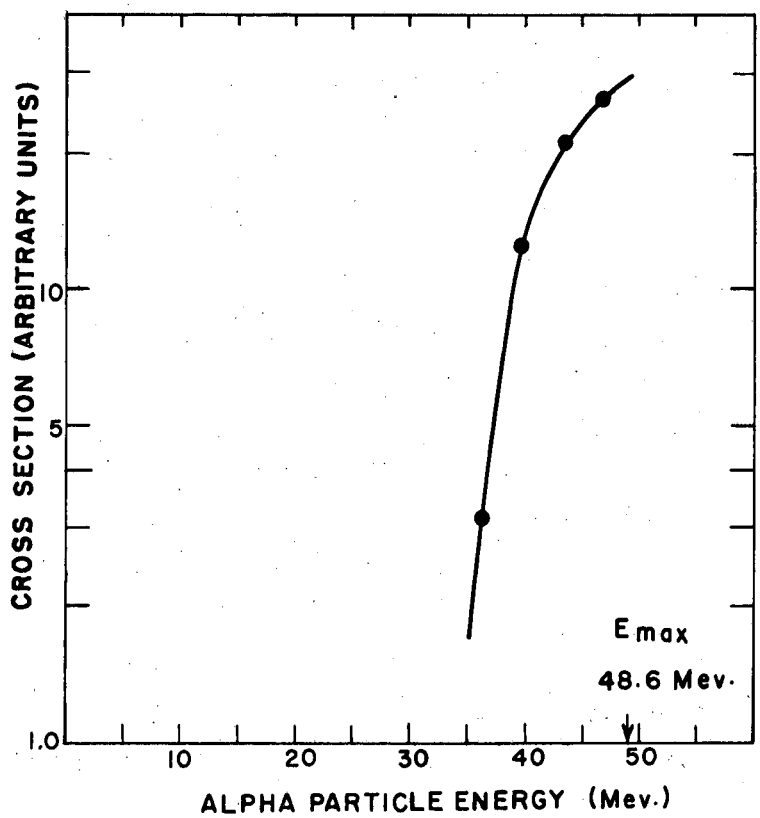

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Fig. 1. Excitation function (in arbitrary units of σ) for the Ta^{181} $(\alpha,4n)$ Re^{181} reaction. E_{max} indicates the maximum alpha particle energy produced by the cyclotron. The function was determined from the relative intensity of the 366-kev gamma in a series of .001-inch foils.