UCRL - 8312

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

DISCLAIMER

UCRL-8312

UNIVERSITY OF CALIFORNIA

Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

THE DECAY OF 13 HOUR Re^{182}

C. J. Gallagher, Jr., J. O. Newton, and Virginia S. Shirley

Printed for the U. S. Atomic Energy Commission

THE DECAY OF 13 HOUR Re^{182}

C. J. Gallagher, Jr., J. O. Newton, and Virginia S. Shirley

Radiation Laboratory and Department of Chemistry
University of California, Berkeley, California

August, 1958

ABSTRACT

An electron- and gamma-spectroscopic study of the levels of W^{182} populated by the 13-hour electron-capturing isomer Re^{182} has been made. The levels observed support previous studies on the W^{182} levels as observed in Ta^{182} decay. Evidence for weakly populated levels around 2 Mev is reported, which indicate that the decay energy of the isomer is greater than 2 Mev. On the basis of the spins and parities of the levels populated, the isomer is assigned spin 3, negative parity.

THE DECAY OF 13 HOUR Re^{182} †

C. J. Gallagher, Jr.,* J. O. Newton** and Virginia S. Shirley

Radiation Laboratory and Department of Chemistry
University of California, Berkeley, California

1. INTRODUCTION

The 12.7 hour isomer of Re^{182} which decays by electron capture to levels in W^{182} was first reported by Wilkinson and Hicks.[1] They were unable to tell whether this, or the 60 hour isomer, was the ground state. The value of 13 hours for the half life and the mass assignment obtained in the present study are in excellent agreement with the earlier results, but the question as to which isomer has lower energy has not been settled.

The energy levels of W^{182} have also been studied in detail by Murray, Boehm, Marmier, and DuMond,[2] who investigated the decay of Ta^{182}. With three exceptions all of the transitions observed in the present study were also observed in Ta^{182} decay; the interpretation of this work is therefore based largely on that given in the paper of Murray et al.

2. EXPERIMENTAL METHOD

Both the gamma spectrum and the conversion electron spectrum were studied. Owing to the relatively poor resolution of the gamma analysis and the complexity of the spectrum most of the useful data came from the study of the electron spectrum.

1. Electron Spectroscopy

The principal type of instrument used in this study was the 180° photographic recording spectrograph which has been previously described;[3] energy measurements can be made to an accuracy of at least one part in 10^3. For this spectrograph it is desirable to prepare carrier free sources which are usually

†This work was done under the auspices of the United States Atomic Energy Commission.

*Present address: Department of Physics, Calif. Inst. of Tech., Pasadena, Calif.

**On leave from the Atomic Energy Research Establishment, Harwell, Berks, England.

electro-deposited on to 0.01-inch diameter platinum wires.

The sources used in the study were produced in two ways. The first was to produce Re^{182} by the $Ta^{181}(\alpha,3n)$ Reaction. This method was unsatisfactory for two reasons: (1) The 60 hour isomer of Re^{182} is produced which decays through all of the W^{182} levels observed by Murray et al.[4] and hence might hide the presence of 13-hour Re^{182} if this isomer decayed through these levels alone.[2] (2) The presence of 20-hour Re^{181},[5] which appears to decay through a number of states of W^{181} and hence gives rise to a complex spectrum which decays with a half-life similar to that of 13-hour Re^{182}.

Therefore, it was thought necessary to make sources of the 13-hour Re^{182} free from the 60-hour isomer and, if possible, free from Re^{181}. Both of these possibilities were realized by producing Re^{182} from the decay of Os^{182}. Observation of the decay of some of the conversion lines in a double-focusing spectrometer and in a lens spectrometer and of the 1100-1200 kev gamma rays in a scintillation spectrometer showed that there was no 60-hour component in the decay of the Os^{182} daughter; the decay curve was consistent with that expected for a 13-hour daughter growing from 22-hour Os^{182}.[6] The Os^{182} was prepared by bombarding natural tungsten with 48 Mev alpha particles, the $W^{182}(\alpha,4n)$ reaction being principally responsible for its production. Carrier-free osmium sources were then prepared by dissolving the tungsten in alkali, acidifying with nitric acid and distilling the volatile OsO_4 so formed.[6]

The preparation of 13 hour Re^{182} from the decay of its osmium parent resulted in a source which was a mixture of the isotopes Os^{182}, Os^{183}, Os^{185}, and Re^{183} in addition to Re^{182}. Each of these isotopes has a complicated spectrum. Satisfactory analysis of the observed electron spectrum was made possible by the high resolution of the permanent magnet spectrographs. In many cases assignments of transitions could be made on the basis of the binding energy differences between the K, L, and M lines of rhenium and tungsten. Assignments could also be made by observation of the change of intensity of the various lines with time; series of 12 hour exposures, each for a given source, were made. The lines from Os^{182} and Os^{183} showed continuous decay, those from Re^{182} showed a characteristic rise followed by decay and those from Re^{183} showed an initial rise and then remained relatively constant due to the long half life of Re^{183}. Owing to the long half life of Os^{185} very few lines from this isotope were observed in these short exposures. The conversion electron spectrum of

Re^{183} had been studied previously[7] and a knowledge of this gave a further check on the assignments.

The relative intensities of the conversion lines were obtained by use of the method for relating photographic blackening to electron intensity given by Mladjenovic and Slatis;[8] the limits of error on the intensities are estimated to be about ± 20%. This intensity-error estimate is made relative to the correction curve for relating a densitometer trace to an actual intensity; any error in the shape of this curve could result in much larger errors in the intensities than the limits that we quote. The error in the correction for photographic efficiency as a function of energy has been measured and is not expected to introduce errors except at very low energies ($\leq$ 30 kev). We have not attempted to obtain intensities for low energy lines for this reason.

2. Gamma Spectroscopy

The gamma ray spectrum was investigated with 1-1/2 x 1 inch sodium iodide crystals together with 50-[9] and 100-[10] channel analyzers. Sources prepared in two different ways were used in these measurements. The first of these was prepared from the Os^{182} parent as described in the previous section.

The second source was prepared as follows. The form of the excitation function for a reaction of the type $Ta^{181}(\alpha,xn)Re^{185-x}$ is a fairly narrow peak, the energy for the peak cross sections being higher the higher the value of x. Thus, by choosing the bombarding energy correctly it is possible to obtain a source containing predominantly the isotope Re^{185-x}. A stack of 0.001 inch tantalum foils was bombarded with 48 Mev alpha particles. The mean alpha particles energy in the fourth foil was 36 Mev corresponding to the peak cross section of the $Ta^{181}(\alpha,3n)Re^{182}$ reaction. This foil was taken and the Re separated by a method similar to that of Meinke.[11] Both isomers were of course present together with some 20 hour Re^{181}. The spectrum of 60 hour Re^{182} was obtained by allowing the source to decay until essentially all of the 13 hour isomer was gone. This spectrum of the 60 hour isomer was then subtracted from the original composite spectrum thus leaving the spectrum due to the 13 hour isomers together with some contamination due to Re^{181}. Neither of these sources gave a trustworthy spectrum below about 900 kev because of the presence of gamma rays from other isotopes.

3. Experimental Results

The conversion line spectrum of 13 hour Re^{182} was compared with that

arising from the decay of the 60 hour isomer[4] and that from Ta^{182} decay,[2] which lead to the same final nucleus W^{182}. With two exceptions the lines observed were lines observed also in the decay of Ta^{182}. None of the transitions observed in the more complex decay of 60 hour Re^{182} which did not occur also in Ta^{182} decay were seen.

In Table I are listed all the transitions we have observed for Ta^{182} decay; with the exception of the two new transitions we report the energies are those of Murray et al. since the precision of their measurement was higher than ours. The relative intensities which we obtained for the various lines are also given. In Table I we have omitted several lines that Murray et al. report; these are probably present but would not have been observed in our experiment because of their lower intensity.

The gamma ray spectrum, above 800 kev, of 13 hour Re^{182} grown from the Os^{182} sample is shown in Fig. 1A. In Fig. 1B is shown the spectrum of 60 hour Re^{182}. It is immediately apparent that very little if any 1450 kev radiation is present in the spectrum from the 13 hour isomer whereas it is quite strong in that from the 60 hour isomer. Furthermore a peak corresponding to an energy of 1.99 ± 0.02 Mev appears in the 13 hour spectrum and not in the 60 hour spectrum. Its intensity relative to that of the 1100-1200 kev complex is about 0.03. It is likely that the 1.99 Mev peak is due to more than one gamma ray. This radiation was assigned to 13 hour Re^{182} since its intensity showed an initial rise followed by decay in the manner expected for this isomer.

The interpretation of the spectrum below 1 Mev was more difficult owing to the presence of gamma rays from other isotopes. However it was possible to set upper limits to the intensities of the 469.6 kev and 894.8 kev lines which were observed in the conversion line spectrum; these are 0.07 and 0.1 times the intensity of the 1100-1200 kev gamma-ray complex respectively.

The intensity of the K x-ray relative to that of the 1100-1200 kev complex was found to be 2.1.

Table I

Transitions in W^{182} following the decay of 12.7-hour Re^{182}

Initial and final states	Transition energy (kev) from Murray et al.	Conversion-electron intensities[a]								Multi-polarity
		K	L_I	L_{II}	L_{III}	M_I	M_{II}	M_{III}	N	
KJ	65.71		10	0.9		1.4				M1+E2
FD	67.74		32	14	16	9.1	3.4	2.1	2.5	E1
HF	84.67	b	26	11	7.4	7.0		3.0	5.6[c]	M1+E2
BA	100.09	b	24[c]	104	92		<49	<36	<16	E2
JH	113.66	15								M1+E2
KI	116.40	<0.1								(M1+E2)
HD	152.41	5.2	3.1[d]							E1
	469.6±0.4	1.6[e]								
	894.7±0.8	0.4[e]								
DB	1122	1.00[e]								M1+E2
FB	1189	0.6[e]	0.07±.03							E1+M2
DA	1222	0.6[e]	0.12±.04							E2
GB	1231	≤0.07[e]								M1+E2
FA	1289	0.19[e]								

a. The intensity units are arbitrary.

b. Line is in a region where intensity corrections are not reliable.

c. Line is on an intense background.

d. This very anomalous K to L ratio has been observed from two sources.

e. Intensities relative to that of transition DB. They are not directly related to the intensities for the lower energy transitions.

4. Decay Scheme

As has been stated in the previous section the electron lines observed in 13 hour Re^{182} are, with two exceptions, all observed in Ta^{182} decay; we therefore make use of the very detailed experimental data and analysis of the Ta^{182} decay scheme in interpreting the 13 hour Re^{182} scheme. In Fig. 2A is shown part of the decay scheme of Ta^{182} as reported by Murray et al.[2] In Fig. 2B is shown a schematic level scheme for W^{182} in which the intensities of the electrons depopulating the various states in Re^{182} decay are compared with those observed in the decay of Ta^{182}; the ratio for transition KJ is arbitrarily set equal to unity. Remembering that the errors of the intensities are about ± 20%, it is seen that the most striking differences between the two schemes is much lower relative population of level K in 13 hour Re^{182} decay as compared with that in Ta^{182} decay. In Ta^{182} decay, to within the accuracy of the measurements, level J is fed entirely from level K, thus there is little if any direct population of that level. The fact that transition JH is, relative to transition KJ, much stronger in 13 hour Re^{182} decay than in Ta^{182} decay shows that the 4-level J receives more population from other sources than from level K.

If we use our electron intensities together with the branching ratios and conversion coefficients of Murray et al. we can estimate the relative feeding intensities to the various levels of W^{182}. In doing this we reduce the values for the conversion coefficients of Murray et al. by 20% in order to allow for the correction due to finite nuclear size; Murray et al. derived their conversion coefficients by assuming the point nucleus value for a pure M1 transition. The results are shown in Table II. The upper limits to the intensities of the 469.6 and 894.8 kev gamma rays are of the same order of magnitude as the feeding intensities of levels J and K. Thus without furthering measurements we are unable to say whether these levels are fed by direct K capture, via either or both of the two gamma rays, or by both of these processes. The feeding intensity to "other states" arises from the excess of transitions BA over the calculated feeding of level B from levels F, H, J, and K; this value has little significance.

In addition to the levels discussed above it is likely, from the presence of the 2 Mev gamma ray that a level or levels in the region of 2 Mev must be excited also.

The partial decay scheme of 13-hour Re^{182} that we deduce from these data is shown in Fig. 3. The assignment of spins and energy levels is based on the data of Murray et al.[2] The assignment of K quantum numbers is based on the interpretation of the W^{182} level scheme by Alaga et al,[12] as modified by Gallagher and Rasmussen.[4] Other experimental studies which support this decay scheme are discussed in detail in reference 4.

Table II

Relative feeding intensities and estimated $\log_{10}$ ft values for decay to various states in W^{182}. See text for assumptions.

State	Spin I,π	Relative population (%)	$\log_{10}$ ft
F	2,-	46 ± 14	6.2 ± 0.2
H	3,-	29 ± 7	6.3 ± 0.3
J	4,-	8 ± 2	6.7 ± 0.3
K	4,-	4 ± 1	7.0 ± 0.4
G	3,+	< 1	> 7.5
others		13 ± 16	

The Coryell systematics[13] predict a value of ~1.2 Mev for the decay energy of Re^{182}. The presence of the 2 Mev gamma ray shows that the decay energy is in fact considerably greater than that of the Coryell prediction. In order to make an estimate of this we have assumed that the $\log_{10}$ ft value for decay to the "2 Mev state" is between 5 and 7. This assumption gives a value of 2.3 ± 0.2 Mev for the total decay energy, assuming a primary branching of 3% to the 2 Mev state. With the further assumptions that there is no direct population of the ground state and that all the states in Table II are directly populated, the $\log_{10}$ ft values of the table were calculated. The first of these assumptions is likely to be correct as will be seen later; the second is subject to the reservations discussed above.

The predominant decay to states of odd parity where states of similar spins and even parity are available suggests that 13 hour Re^{182} has odd parity. However, considerable care must be taken in interpreting $\log_{10}$ ft values in the regions of highly deformed nuclei. The fact that states of spin 2, 3, and 4

are populated suggests that the spin of 13 hour Re^{182} is 3. Here again however the conclusion is not absolutely certain since there is some doubt that the states of spin 4- are populated directly. Thus the data suggest strongly but not definitely a 3- assignment for 13 hour Re^{182}. If this isomer has a spin greater than 1 (which seems very likely), direct population of the ground state of W^{182} in appreciable intensity is most improbable, hence our assumption of the previous paragraph seems well justified.

It is interesting to note that a spin of 3- in Re^{182} can be explained in terms of the spin-spin coupling hypothesis of Gallagher and Moszkowski,[14] if the Nilsson states[15,16] with asymptotic quantum numbers 402↑ and 510↑ are used for the odd-proton and odd-neutron configurations, respectively.

REFERENCES

1. G. Wilkinson and H. G. Hicks, Phys. Rev. 77, 314 (1950).
2. Murray, Boehm, Marmier, and Dumond, Phys. Rev. 97, 1007 (1955).
3. W. G. Smith and J. M. Hollander, Phys. Rev. 101, 746 (1956).
4. C. J. Gallagher, Jr. and J. O. Rasmussen, Phys. Rev. (to be published).
5. Gallagher, Sweeney, and Rasmussen, Phys. Rev. 108, 108 (1957); C. J. Gallagher, Jr., (thesis) Electron-Spectroscopic Studies of Neutron-Deficient Rhenium Isotopes, UCRL-3928, Sept, 1957 (unpublished).
6. B. J. Stover, Phys. Rev. 80, 99 (1950); J. O. Newton and V. S. Shirley (unpublished data, 1957).
7. Thulin, Rasmussen, Gallagher, Smith, and Hollander, Phys. Rev. 104, 471 (1956).
8. M. Mladjinovic and H. Slätis, Arkiv Fysik 8, 65 (1954).
9. A. Ghiorso and A. E. Larsh, in Chemistry Division Quarterly Report, UCRL-2647, July, 1954.
10. Penco, Model PA-3, manufactured by the Pacific Electro-Nuclear Company, Culver City, California.
11. W. W. Meinke, Chemical Procedures Used in Bombardment Work at Berkeley, UCRL-432, August, 1949.
12. Alaga, Alder, Bohr, and Mottelson, Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd. 29, No. 9 (1955).
13. C. D. Coryell, in Annual Review of Nuclear Science, (Annual Reviews, Inc., Stanford, 1953) Vol. 2, p. 305.
14. C. J. Gallagher, Jr. and S. A. Moszkowski, Phys. Rev. (to be published).
15. S. G. Nilsson, Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd. 29, No. 16 (1955).
16. S. G. Nilsson and B. R. Mottelson, Kgl. Danske Videnskab. Selskab (to appear).

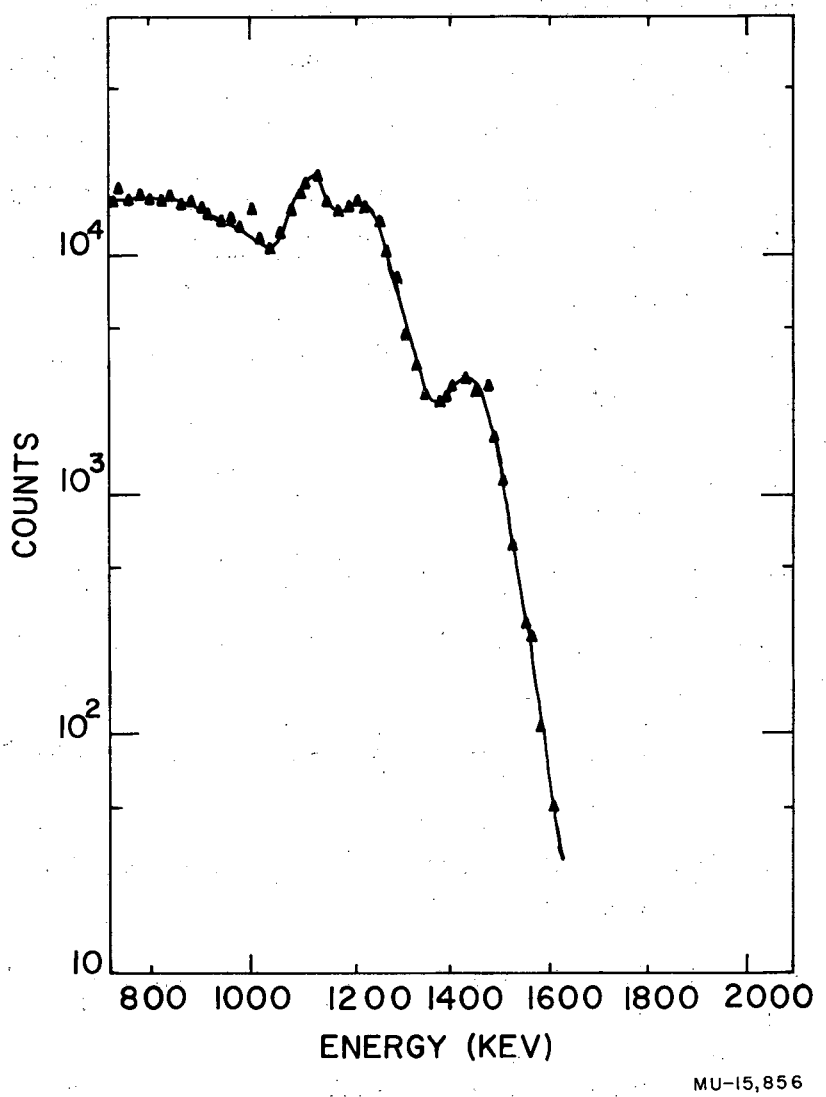

Fig. 1A. Gamma-ray spectrum of 60-hour Re^{182} above approximately 800 kev, measured with a NaI(Tl) scintillation spectrometer.

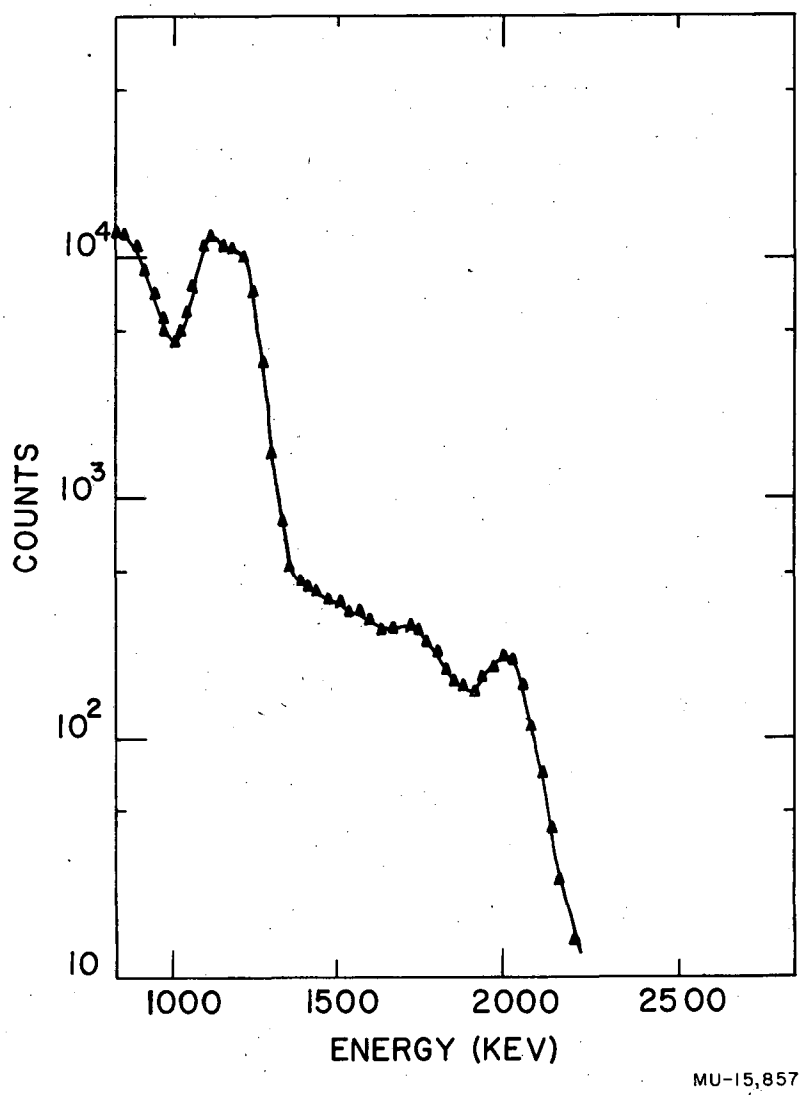

Fig. 1B. Gamma-ray spectrum of 13-hour Re^{182} above approximately 1 Mev, measured with a NaI(Tl) scintillation spectrometer.

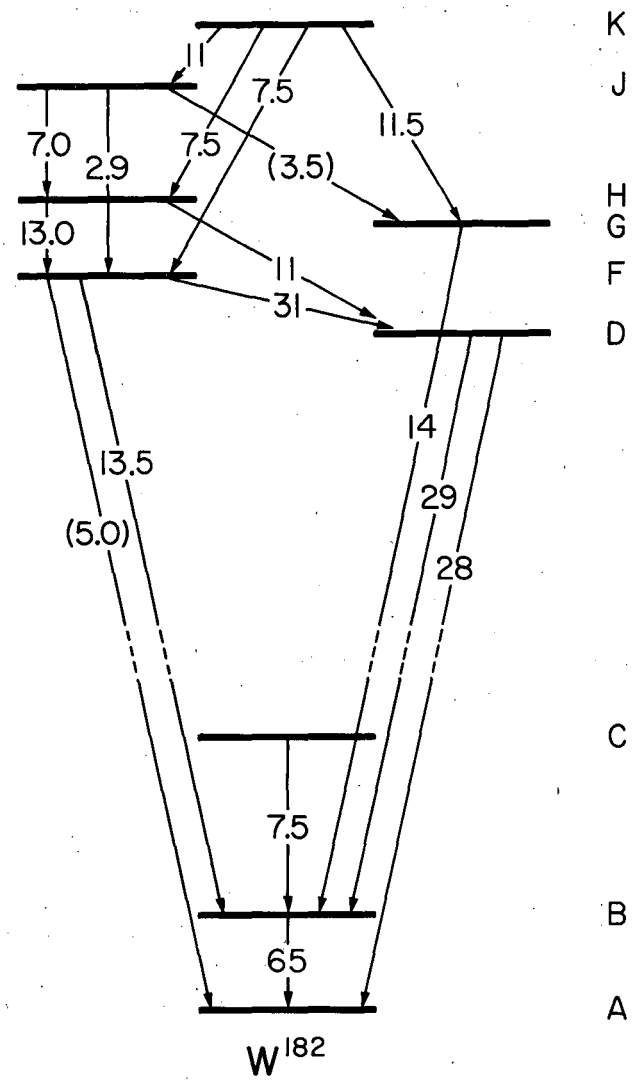

Fig. 2A. Transition intensities reported by MBMD for the transitions of W^{182} following Ta^{182} decay. The intensities are normalized so that a total of 100 populates the ground state.

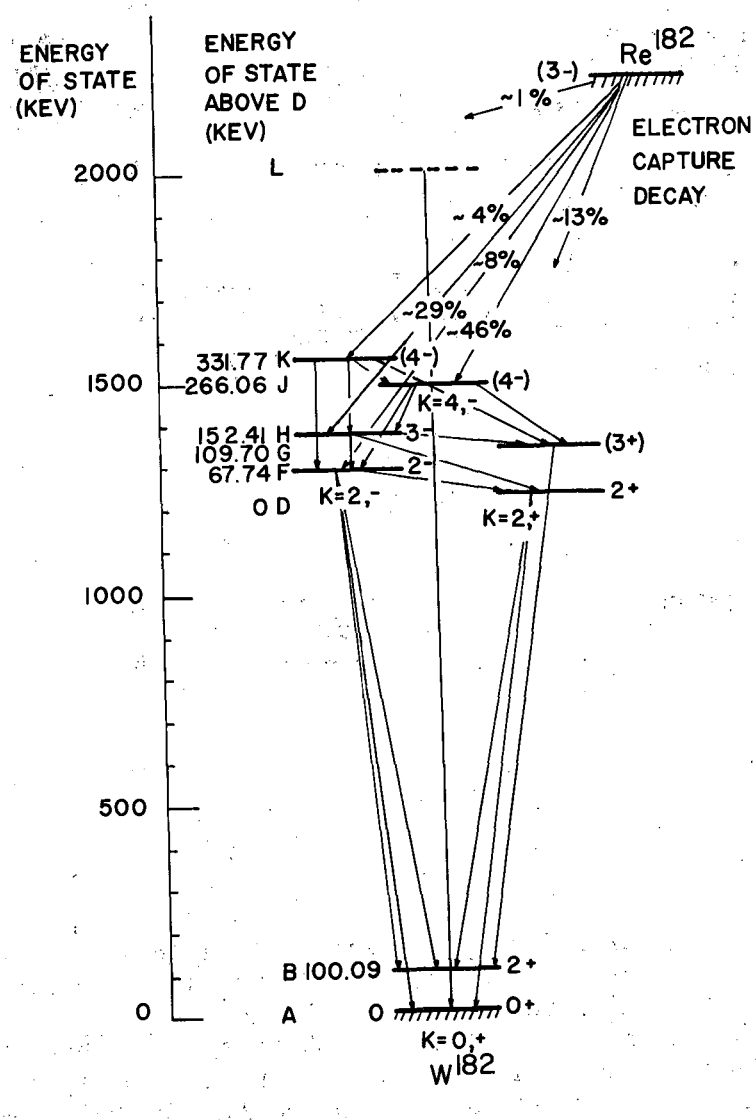

Fig. 2B. Comparison of electron intensities of transitions observed in both Ta^{182} and 12.7-hr Re^{182} decay. The ratios indicated on the transitions are normalized so that the ratio of the electron intensity of the L_1 65.71-kev transition observed following Re^{182} decay to that observed following Ta^{182} decay is 1.

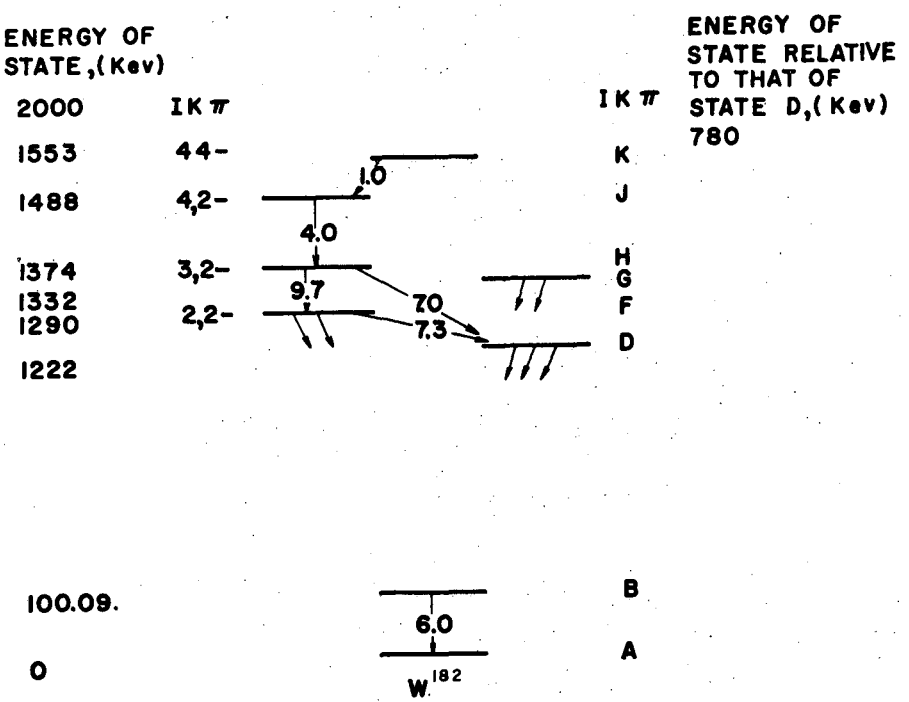

Fig. 3. A partial decay scheme of 13-hour Re^{182} and some of the levels of W^{182}. The energies of the levels (except L) were established by Murray et al.[2] The transitions shown were all observed in 13-hour Re^{182} decay. The assignment of K quantum numbers was originally made by Alaga et al.,[13] and modified by Gallagher and Rasmussen.[4]