

RADIOACTIVE DECAY OF Re^{186}

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1. INTRODUCTION

THE radioactive isotope Re^{186} with 89h half-life had attracted the attention of a number of workers,¹⁻⁵ as it contains a first forbidden non-unique beta transition. The decay scheme is very simple as shown in the top corner of Fig. 2, and was thoroughly investigated.⁶⁻⁹ The decay fraction to W^{186} is very small. Almost all the activity decays to Os^{186} with about 76% decaying to the ground state and the remaining activity mostly going to the strongly converted 137 keV transition. The beta group feeding the 137 keV level has an end-point energy of 927 keV with a first forbidden non-unique shape. Os^{186} lies in the transitional region between the strongly deformed nuclei and those of spherical equilibrium shape. Further, the spin sequence of the levels is 0^+ , 2_1^+ and 2_2^+ . A ratio of 5.6 of the energies of the 2_2^+ to 2_1^+ states enables these levels to be classified as vibrational excitations in non-spherical nuclei. The properties of the first and second phonon vibrational states above the ground state are compared with the predictions of asymmetric rotor model.¹⁰⁻¹⁵ Mainly the photoelectron spectra were studied and the high energy gamma rays are 0.2% or 0.024% intense of the total intensity.^{7,9} So far, no complete scintillation gamma spectrum in the decay of Re^{186} containing the high energy gamma rays appears to have been published. It is the interest of the present work to study the gamma spectrum including the high energy gamma rays and to determine the relative intensities. Further, the relatively simple decay scheme and the very weak high energy gamma rays ideally suit the 4π sum-peak coincidence method¹⁶ from which fractional intensities of crossover and cascade can be determined. The experimental method for the branching ratios is based on the qualitative comparison of spectra taken with sum (adder) and 4π geometry sum-peak mode. The measured attenuation factors f_m 's for zero bias ($B=0$) are qualitatively compared with f_γ 's for corresponding energies and with general ranges of $f_{\gamma\gamma}$ and $f_{\gamma\gamma\gamma}$. This comparison reveals immediately all peaks due to singles (not

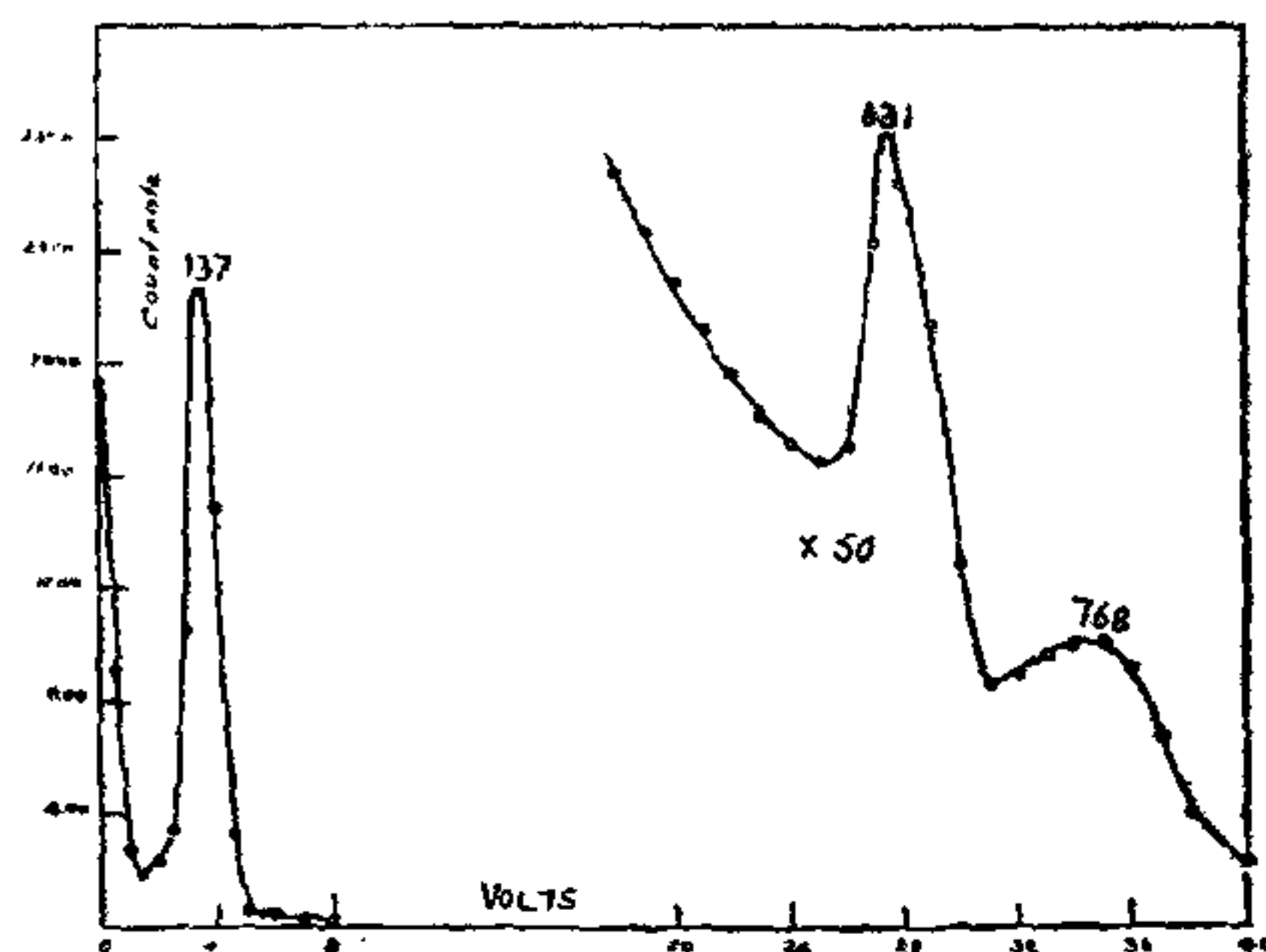
summed) gammas and gives at least a qualitative information on types of sum peaks and on magnitudes of mixtures of cascades and crossovers involved. In the simple case of a crossover and one cascade the procedure is quite simple and the fractional intensities can be determined with a knowledge of the experimentally determined respective photopeak efficiencies. Moreover, the experimental values afford a comparison with the theoretical values based on the vibrational as well as asymmetric rotor models.

2. EXPERIMENTAL DETAILS

The experimental set-up consists of two identical 4.45 cm. diam. \times 5.1 cm. NaI(Tl) crystals coupled to DuMont 6292 photomultipliers, whose outputs are added in a linear adding circuit after passing through amplifiers. The two crystals are placed face to face just touching each other, such that it forms approximately a 4π geometry. The integral discriminator outputs of both channels and the differential output of the adder channel are connected in a triple coincidence circuit. Since, the set-up is a simple modification of sum coincidence spectrometer, two de Waard stabilizers¹⁷ of the latter are included, each between the linear amplifier and the photomultiplier through a sine modulated pulse height analyser.

3. RESULTS

The source was obtained in a fine powder form with an activity of 50 mC and allowed to decay for several days to minimize Re^{186} content, usually present. A small quantity of the powder is sandwiched in between two films of cellotape. It is placed at a distance of 10 cm. from one of the spectrometers and the singles spectrum recorded is shown in Fig. 1. It shows prominent peaks at energies 137, 630 and 768 keV. The relative gamma intensities are calculated employing the experimentally determined peak-to-total ratios and the detection efficiencies as described by Bell.¹⁸ The gamma intensity of 137 keV transition is assumed to be 10% in the present work and the relative

FIG. 1. Singles spectrum of Re^{186} .

intensities computed are given in Table I. Along with these intensities, the total gamma transition intensities computed from the gamma branching ratio and the assumed beta intensities are also given.

TABLE I
Relative gamma intensities

No.	Gamma energy keV	Metzger and Hill %	Johns <i>et al.</i> %	Present work	
				Singles spectrum %	Adder and sum-peak spectrum %
1	137	9	10	10	10
2	637	0.2	0.024	0.368	0.306
3	768	0.2	0.024	0.176	0.204

The set-up is arranged in 4π geometry with the source in between the crystals. The adder and the zero bias sum-peak coincidence spectra are recorded as shown in Fig. 2. The sum-peak coincidence spectrum consists mainly of

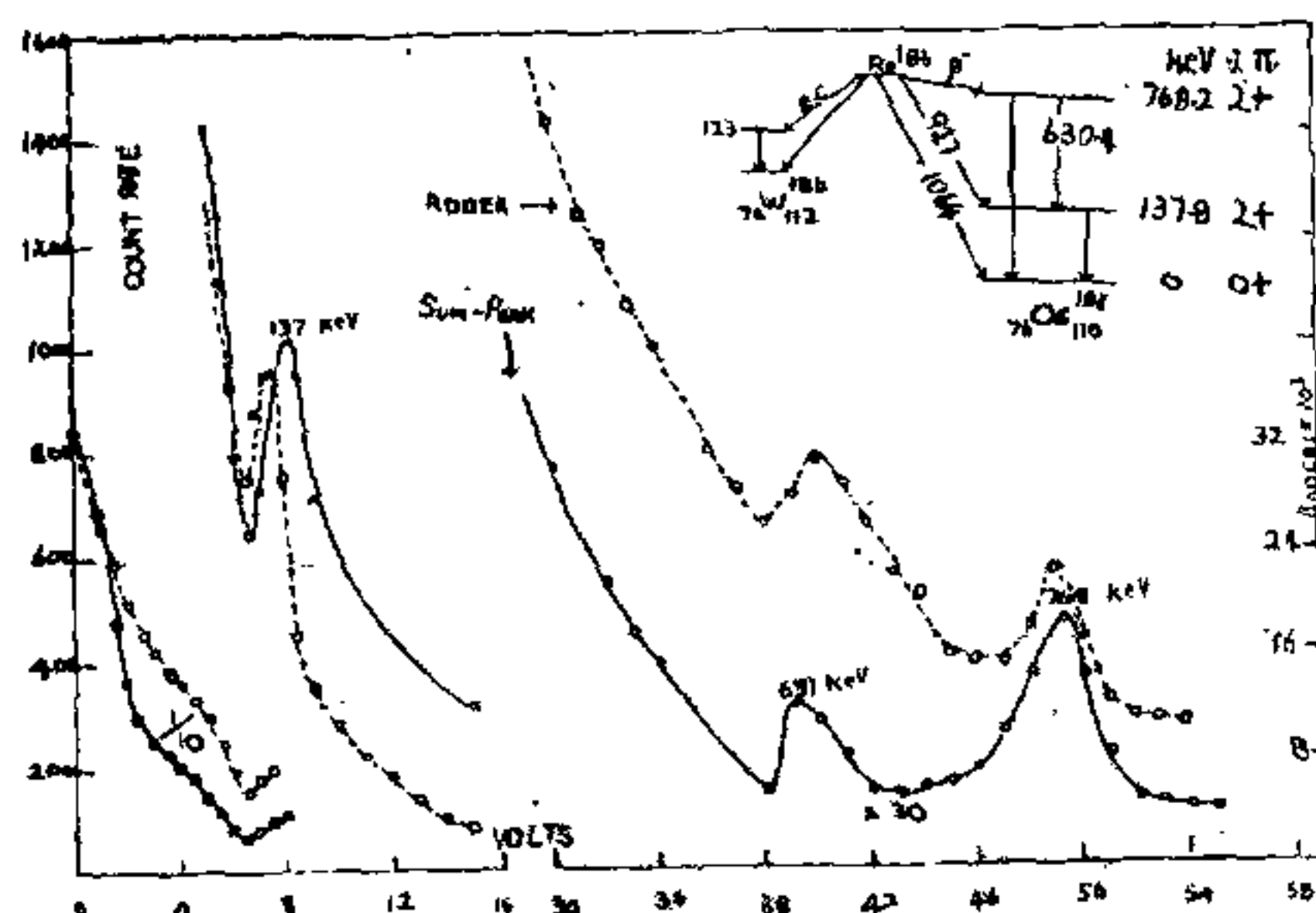


FIG. 2. Adder and zero bias 4π geometry sum-peak coincidence spectrum.

peaks at energies 137, 630 and 768 keV. The attenuation factors for these three transitions

are determined by drawing them on a bigger scale and measuring the areas of these peaks with a planimeter over the continuous pulse height distribution.¹⁶ The measured attenuation factor values (f_m) 0.023 and 0.077 for the 137 and 630 keV transitions are equal to the attenuation factors (f_γ) of single gamma transitions at those energies. The attenuation factors for single gamma transitions are determined for the present set-up in an energy range of 80–1330 keV employing Tm-170, Ce-141, Au-198, Cs-137, Co-60, Sc-46 and Cs-134 sources and a calibration curve is obtained. Further, the photopeak efficiencies are calculated from the given calculated intrinsic efficiency curves for zero distance¹⁹ and the experimentally determined peak-to-total ratios in the above energy range. It can be concluded that alternative decay modes do not exist in the above two cases of 137 and 630 keV transitions. The value (f_m) obtained for the 768 keV transition is 0.3423 which is significantly different from the corresponding attenuation factor ($f_{\gamma 3} = 0.084$) obtained for single gamma transition and that for the cascade ($f_{\gamma_1 \gamma_2} = 0.55$). The values of $f_{\gamma_1 \gamma_3}$ and f_{γ_2} are obtained from the respective attenuation factors f_{γ_1} , f_{γ_2} and f_{γ_3} by interpolation. But the value of the attenuation factor f_m is nearer to that of the cascade showing that the contribution of the cascade to the sum line is predominant. The value of the fractional intensity of the cascade is 0.5542 ± 0.06 . The estimates are expected to be accurate within 10% in general, an error of about 5% being in f_m and another 5% error arising from the errors and uncertainties of the photopeak efficiencies. When the above value for the fractional intensity of the cascade is corrected for the respective photopeak efficiencies, the value is 0.588 ± 0.06 and that for crossover is 0.412 ± 0.04 . The crossover cascade relative intensity ratio becomes 0.7.

The relative intensities of gamma transitions can be obtained from the total branching ratio, obtained by multiplying with $(1 + \alpha_{tot})$ of 768 and 630 keV transitions for internal conversion. But the absence of available total internal conversion coefficients for these transitions in literature because of their small intensities and the exact value of the beta intensity feeding the 738 keV level, render it difficult to determine the gamma intensities. Further, the relative gamma intensity of the 137 keV obtained from the singles spectra has the contribution from 123 keV gamma transition of W^{186} which is fed by ~ 2 to 3% in electron capture decay of Re^{186} . However, assuming the beta intensities

as 1% (300 keV), 19% (927 keV) and 76% (1064 keV) feeding the 768, 137 and 0 keV levels and the internal conversion coefficients to be equal, the relative intensities of gamma transitions are obtained as 137 keV 19.6%, 630 keV 0.6% and 738 keV 0.4% which normalized to 10% intensity for 137 keV transition are given in Table I.

Rotational levels of even nuclei have been treated¹⁰ under the assumption that the nuclei possess equilibrium shapes which are not axially symmetric. The transverse deformation parameter for Os¹⁸⁶ is 16.5°. The ratio of reduced transition probabilities is obtained as

$$\frac{B(E_2; 2_2^+ \rightarrow 2_1^+)}{B(E_2; 2_1^+ \rightarrow 0^+)} = 3.188.$$

In the Unified model²⁰ the same ratio is predicted as 1.43. In the asymmetric rotor model the ratio varies with the transverse deformation parameter (γ), at $\gamma = 0^\circ$, the ratio is 1.43 and at $\gamma = 30^\circ$, it is infinite. In general, the experimental values of this ratio are found to lie in between these two theories. In the transitional region, however, the Davydov and Filippov model is more successful in predicting this ratio. The experimental ratio in the case of Os¹⁸⁶ is

$$\frac{B(E_2; 2_2^+ \rightarrow 2_1^+)}{B(E_2; 2_1^+ \rightarrow 0^+)} = 3.83.$$

The experimental value shows better agreement with the asymmetric rotor model than with the vibrational model.

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CHELATING TENDENCIES OF FERRON WITH SOME BIVALENT METAL IONS*

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8-HYDROXY quinoline and its derivatives are of unusual importance in analytical chemistry. Ferron, 7-iodo 8-hydroxy quinoline 5-sulphonic acid has been widely recognised as a specific reagent for the spectrophotometric estimation of ferric iron.¹ Further, ferron has been used by Van Zijp² as a sensitive micro-chemical reagent in the detection of barium and strontium. Recently, Nasanen and Ekman³

have studied calcium-ferron chelate system as regards its stoichiometry and stability constant. However, the chelating tendencies of ferron with many other metal ions have not been investigated. The present communication describes a physico-chemical study of certain bivalent metal ions, Cu²⁺, Ni²⁺, Co²⁺, Mn²⁺, and Zn²⁺-ferron systems with a view to determine their stoichiometries and stability constants. Further, it has also been aimed to compare these bivalent metal ion-ferron chelate stability constants with those reported values⁴ of 8-hydroxy quinoline and 8-hydroxy quinoline 5-sulphonic acid chelates.

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