# Atomic Mass Estimates of some Heavy Nuclei from their Beta decay Experimental Data

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## Introduction

The ground state binding energy and derived quantities, such as proton or neutron separation energies or Q-values, are needed for a basic understanding of the nuclear many-body problem, reaction kinematics, and also applications in medicine, energy generation, nuclear waste transmutation, and nuclear astrophysics. Compilations and evaluation of elemental masses have been undertaken [1]. Direct approaches to obtain binding energies of ground and excited states are Penning trap and time-of-flight mass spectrometry. The beta decay experimental data if measured with high precision would be of complimentary interest particularly for atomic mass evaluators, AME20 [2].

## Experiments:

The Seigbahn-Slatis intermediate image focusing beta ray spectrometer with plastic well-type detector used in the investigation described elsewhere [3] has been used for the present work. With this spectrometer it is possible to determine the end-point energy $W_0$ of beta groups of beta decaying nuclei very precisely by following the special Fermi-Kurie analysis of the experimental beta spectra.

An orderly sequence of fitting the beta spectrum is adopted to arrive at the correct end point energy. Firstly, for determining the $W_0$ and the second for finding the coefficients of the beta spectral shape factor. The shape factor varies as $\frac{N(W)}{(W_0-W)^2}$ where $N(W)$ is the beta intensity at a given energy $W$ and $W_0$ is the endpoint energy of the beta group, in the small region $W_0$. Since $N(W)$ goes to zero as $W$ approaches the true endpoint and $(W_0 - W)^2$ goes to zero as $W$ approaches the adopted value $W_0$, the shape factor is extremely sensitive to the choice of the $W_0$. Hence the shape factor goes either shooting up to infinity or down to zero and this behavior in the neighborhood of the end-point can be used to determine the true end point for the particular data. This method is more reliable and physically significant. For this purpose the computer program 'Beta Shape' is written which finds the approximate endpoint by extrapolating the Fermi-Kurie plot. It starts at an endpoint less than this approximate value by 20 keV and steps up $W_0$ by 1 keV each time. For each value of $W_0$, it computes

$\frac{N(W)}{pf(Z,W)(W_0-W)^2}$ vs. *W*, with *p*, the momentum corresponding to *W* and *f (Z,W)*, the Fermi-function, and plots all the forty shape factor curves simultaneously on the same figure (Figure1). From a detailed examination of these curves, the correct end-point energy $W_0$ can easily be determined.

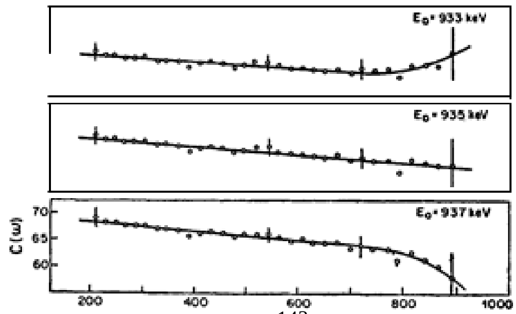


Fig.1: Beta Shapes of $^{143}$Pr beta spectrum
Fig.1:.F.K. Plot of $^{143}$Pr beta spectrum

Such procedure has been followed for determining the correct end-point energies of the highest energy beta groups and inner beta groups of some beta decaying nuclei.

These end-point energies have been used to calculate the ground state masses and hence their mass excesses using the standard relations and precise atomic mass data of the respective ground states from AME20 [2].

**Results and discussion:**

Table 1 shows our ground state atomic mass estimates in comparison with the most recent Atomic Mass Evaluation data, AME20 [2]. In the present case as the beta end point energies are determined very precisely, we could get very accurate atomic mass data. Precision measurements of beta decay energies would of complimentary importance in the atomic mass evaluations particularly in the case of accuracy of atomic mass data.

**References**

[1] A.H. Wapstra, G. Audi, C. Thibault, Nucl. Phys. A729, 129 (2003)

[2] M. Wang,W.J. Huang, F.G. Kondev G. Audi S. Naimi, Chinese Physics C Vol. 45, 030003 (2021)

[3] T. Nagarajan , M. Ravindranath, K. Venkata Reddy NucL Instr. Meth. 67, 77 (1969

Table1: Comparison of our atomic mass estimates with the available AME20[3] mass data

| Nuclide | $\beta^-$ energy + $\gamma$ energy (keV) | Atomic Mass (u) | | Mass excess (keV) | |
|---|---|---|---|---|---|
| | | Present work | AME20[2] | Present work | AME20[2] |
| $^{143}_{58}Ce$ | 1404.0 5 +57.36 | 142.9123914 | 142.9123920 2.6 | -81606.86 | -81606.4 2.4 |
| | 1110.0 5 + 351 | 142.912391 | 142.9123920 2.6 | -81607.22 | -81606.4 2.4 |
| $^{143}_{59}Pr$ | 935.0 5 + 0 | 142.9108236 | 142.9108226 1.6 | -83067.3 | -83068.2 1.8 |
| $^{152}_{63}Eu$ | 1481.0 5 +344.28 | 151.9217579 | 151.9217510 1.3 | -72882.04 | -72888.5 1.2 |
| $^{154}_{63}Eu$ | 1845.0 5 +123.07 | 153.9229858 | 153.9229857 1.3 | -71738.26 | -71738.4 1.2 |
| $^{166}_{67}Ho$ | 1771.0 5 + 80.58 | 165.9322889 | 165.9322912 0.8 | -63072.53 | -63070.3 0.8 |
| | 1845.0 5 + 0 | 165.9322818 | 165.9322912 0.8 | -63079.11 | -63070.3 0.8 |
| $^{188}_{75}Re$ | 1962.0 5 + 155.04 | 187.95811 | 187.9581137 0.8 | -39020.25 | -39016.9 0.7 |
| | 2120.0 5 + 0 | 187.9581132 | 187.9581137 0.8 | -39017.29 | -39016.9 0.7 |
| $^{198}_{79}Au$ | 966.0 5 + 411.80 | 197.9682483 | 197.9682437 0.6 | -29576.50 | -29580.8 0.5 |
| $^{204}_{81}Tl$ | 763.3 5 + 0 | 203.9738629 | 203.9738634 1.2 | -24346.52 | -24346.1 1.2 |