Mass and Q_β predictions of highly neutron rich Ga and As isotopes using Way-Wood diagrams

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Introduction

When nuclear masses are displayed as a function of N and Z, one obtains a surface in a three-dimensional space. However, due to the pairing energy this surface is divided into four sheets. The observed regularity of the mass sheets in all places where no new physics effects exist, can be considered as one of the properties of the mass surface. Thus, dependable estimates of unknown, poorly known and questionable data can be obtained by extrapolation from well-known mass values on the same sheet. Any coherent deviation could be an indication of new physical properties. Drawing the mass surface one may derive estimates for still unknown masses, either from interpolation or from short-range extrapolations. There have been quite a number extrapolation methods that were developed like the i) The quadratic isobaric multiplet mass equation (IMME) [1], the Atomic Mass evaluators [2] Way-Wood diagrams [3], Garvey-Kelson relations [4] and the Weighted slope method [5]. In this communication we have tried to show that the Way-Wood diagrams also are very useful for predicting the masses of highly neutron rich nuclides.

Method

Already back in 1954, Way and Wood [3] derived graphical presentations of nuclear decay data on the basis of the semi- empirical Bethe-Weizsa¨cker mass formula [6] . In the absence of nuclear structure effects as magic numbers, the lines connecting nuclei with constant N or Z ought be “straight” lines. Under the assumption that the atomic masses are smoothly varying functions. of N and Z (as the semi- empirical mass formula) the lines can be extrapolated to unmeasured nuclei. Q_β-values of neutron-rich isotopes with mass numbers around A = 90 are dis- played in Figure 1. known values were taken from the Atomic Mass Evaluation 2020 [2]. By extrapolating the lines connecting isotopes of 31Ga and 33As and the isotones N = 57, 59, 61, respectively, the Q_β-values of ^{88}Ga, ^{90}Ga and ^{94}As have been estimated.

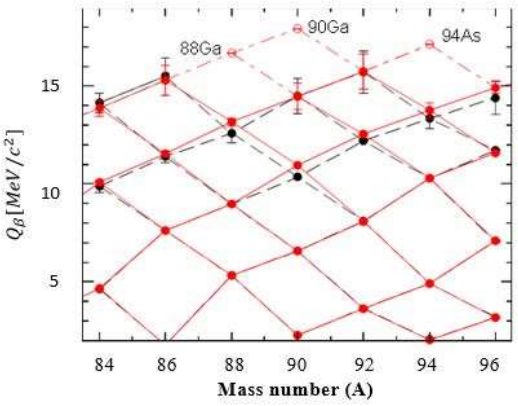

Figure 1:

Results ad discussion

The mass excess values and Q_β-values for ^{88}Ga, ^{90}Ga and ^{94}As calculated from the present Way-Wood diagram are compared with the most recent AME20 predictions (only one value for each is available) and the predictions using Garvey-Kelson relations and the most widely accepted mass models, FRDM12 [7] and HFB21[8] in Table 1 and Table 2 respectively. It is interesting to note the most recent version, AME20, of the Atomic Mass evaluators could not give the mass data on the highly neutron rich nuclides ^{90}Ga and ^{94}As from their extrapolations

where as the Way-Wood diagrams could predict their masses with reasonably good accuracy. The mass excess and Q_β predictions of the present method for the nuclides ^{88}Ga, ^{90}Ga and ^{94}As are in close agreement with a similar local extrapolation method of Garvey and Kelson. They are also very well agreeing with the mass model predictions of FRDM and HFB21. Even though present method may not be useful as a general extrapolation method, it would be of great help in predicting the masses of astrophysical interest highly neutron rich nuclei provided the masses of neighboring isotopes and isotones are available.

References

[1] Y.H. Lam. et al Atomic Data and Nuclear Data Tables 99.6, 680–703 (2013).

[2] M. Wang et al Chinese Physics C Vol. 45, 030003 (2021)

[1] K. Way. & Wood, Physical Review 94.1, 119 (1954).

[2] G.T. Garvey, I. Kelson, Physical Review Letters 16.5, 197–200 (1966

[3] K, Venkataramaniah et al, Scientific Data 9, 550 (2022)

[4] C.F. von Weizsäcker, Zeitschrif für Physik 96, 431–458 (1935).

[5] P. Möller, et al Nuclear Data Tables 109–110, 1–204 (2016).

[6] S. Goriely, et al Physical Review C 82.3, 035804 (2010)

Table 1: The mass excess values [in keV/c^2] calculated from the graphically extrapolated data from the-Wood diagram compared with those of Garvey-Kelson and AME20 predictions and FRDM and HFB21 mass model predictions

Nucleus	Mass excess values in keV/c^2					Differences of Way-Wood predictions with G-K, FRDM, HFB predictions			
	Way-Wood	Garvey-Kelson	AME20	FRDM12	HFB21	W-W – G-K	W-W – AME20	W-W – FRDM	W-W – HFB21
$^{88}_{31}Ga_{57}$	-23470	-22851	-22390	-22289	-22660	619	1080	1181	810
$^{90}_{31}Ga_{59}$	-11300	-11102	---	-10177	-10860	198	---	1123	440
$^{94}_{33}As_{61}$	-19700	-19683	---	-20334	-20670	17	---	634	970

Table 2: Q_β values [in keV/c^2] from Way-Wood diagram compared with those of Garvey-Kelson and AME20 predictions and FRDM and HFB21 mass model predictions.

Nucleus	Q_β values in keV/c^2					Differences of Way-Wood predictions with G-K, FRDM, HFB predictions			
	Way-Wood	Garvey-Kelson	AME20	FRDM	HFB21	W-W - G-K	W-W – AME20	W-W - FRDM	W-W – HFB21
$^{88}_{31}Ga_{57}$	16670	17071	17130	17356	17160	401	460	686	490
$^{90}_{31}Ga_{59}$	17920	18221	---	18895	18380	301	---	975	460
$^{94}_{33}As_{61}$	17100	17539	---	17162	16730	439	---	62	370