A new weighted-slope method for extrapolation of Experimental Masses of Nuclei far from the valley of stability

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Introduction

A precise knowledge of nuclear masses in regions away from measured values is an important topic in nuclear physics, because of their importance in astrophysical calculations but many of these masses remain unknown. The values of the unknown nuclear masses are obtained through theoretical predictions but, unfortunately, there is a lack of consensus and most predictions differ drastically from each other, especially in the region of large neutron excess. For example, the two-neutron separation energies, S_{2n}(Z,A) have been computed from the ground state nuclear masses M(Z, A) and M(Z, A-2) from the AMC12 using

$$S_{2n} = -M(Z, A + M(Z, A-2) + m_n$$

The evolution of S2n, as a function of neutron number shows the well-known regularities. The curves of various isotopic chains are roughly parallel to each other. It was perceived that to follow the trend we have to consider point to point extrapolation by looking at the trends very closely.

The weighted slope method of computing the extrapolated S_{2n} values:

To obtain the extrapolated value S_{2n} value for a nuclide, we use the trend in the sheet by using the existing derivatives of the other elements. Consider the two – neutron separation energies entered in the table below. To extrapolate and find the $S_{2n_{10}}$ value, we use the trend in S_{2n} sheet by finding the slopes of the line joining the S_{2n} values for X_2 and X_1 of the next three elements. The slope for these three known set of values is calculated as

$$m_1 = \frac{S_{2n_{11}} - S_{2n_{21}}}{X_2 - X_1}, m_2 = \frac{S_{2n_{12}} - S_{2n_{22}}}{X_2 - X_1}$$

N/P	Y	Y	Y	Y	Y	Y
X						
X_2		$S_{2n_{20}}$	$S_{2n_{21}}$	$S_{2n_{22}}$	$S_{2n_{23}}$	
X_1		$S_{2n_{10}}$	$S_{2n_{11}}$	$S_{2n_{12}}$	$S_{2n_{13}}$	
X						

$m_3 = \frac{S_{2n_{23}} - S_{2n_{23}}}{X_2 - X_1}$. It is observed that in order to follow the trend of the next nuclide mass more closely it was necessary to have more weightage for the slope of the immediate next nuclide than the others. So the slope M was found as

$$M = 0.5\, m_1 + 0.3\, m_2 + 0.2\, m_3$$

The C - intercept for the extrapolated value was obtained by substituting the slope, m to the already known S_{2n} value for the nuclide which is $S_{2n_{20}}$ to obtain the extrapolated S_{2n} value as

$$S_{2n_{10}} = MX_1 + C$$

Using the intercept and slope M, the extrapolated S_{2n} are calculated for all nuclides of AMC12 and all the corresponding unknown atomic mass values are derived.

Results and discussion:

The weighted-slope method of extrapolation was validated by adopting for the calculation of known S_{2n} values of some random nuclides and shown in the Table 1 thus demonstrating the perfect predictions. Extrapolated mass excess values could be obtained with better precision for more than 1100 nuclei far from the valley of stability.. A sample data is presented in the Table 2 showing the comparison with AME12 [2] extrapolated mass excess data along with five of the most cited mass models [3-6]. The extrapolated experimental data of masses can be useful for assessing the impact of current and future experiments in the context of model developments..

Table:1 Validation of Extrapolated S_{2n} values with known S_{2n} values

Z	N	A	Elem.	Known S2n (keV)	Error (keV)	Extrapolated S2n (keV)	Error (keV)	Deviation (keV)
43	71	114	Tc	93270.78	19.94	93333.28	78.38	-62.50
44	48	92	Ru	11803.73	357.69	11779.67	356.82	24.06
47	51	98	Ag	10605.83	21.43	10569.14	96.25	36.69
61	74	135	Pm	10221.13	74.52	10164.59	58.98	56.53
66	103	169	Dy	25562.18	6.43	25486.27	29.59	75.91
81	97	178	Tl	24624.82	312.05	24695.01	353.69	-70.19
85	139	224	At	20713.47	109.92	20749.89	259.98	-36.41
89	119	208	Ac	21480.09	204.93	21405.41	173.11	74.69
90	147	237	Th	18893.34	129.48	18838.30	243.33	55.03

Table:2 Comparison of Extrapolated Mass Excess values with other Extrapolations and Mass Models

Z	N	A	Ele.	Extrapolated Mass Excess (keV)		Mass model Mass Excess (keV)			
				AMC-12 [1]	AME-12 [2]	DU-ZU [3]	FRDM12 [4]	HFB21 [5]	NIM [6]
34	30	64	Se	-26235 (360)	-26930 (500)	-26850	-26550	-27350	-30060
34	31	65	Se	-33400 (250)	-33160 (600)	-32899	-32480	-33400	-36210
34	57	91	Se	-50300 (110)	-50340 (600)	-51104	-49790	-50190	-49930
34	58	92	Se	-46460 (170)	-46720 (600)	-47595	-46470	-46910	-46340
34	59	93	Se	-40570 (280)	-40720 (800)	-41735	-40810	-40980	-40200
39	37	76	Y	-41162 (560)	-38600 (500)	-37313	-38870	-36770	-40090
39	38	77	Y	-48710 (270)	-46780 (500)	-45844	-47140	-45290	-47820
39	39	78	Y	-52990 (190)	-52530 (400)	-51066	-51940	-49620	-52400
39	65	104	Y	-53968 (58)	-54060 (400)	-53812	-54600	-53160	-54470
39	66	105	Y	-50880 (190)	-50820 (500)	-50550	-51560	-50230	-51910
51	51	102	Sb	-56310 (100)	-56180 (300)	-55719	-56570	-56120	-57540
51	87	138	Sb	-54320 (160)	-54540 (300)	-54765	-54090	-55310	-54710
51	88	139	Sb	-49930 (210)	-49790 (400)	-50394	-49760	-51160	-49950
51	89	140	Sb	-43540 (380)	-43940 (600)	-44724	-43640	-45050	-43330
58	63	121	Ce	-53300 (340)	-52770 (400)	-50222	-52940	-53240	-52850
58	64	122	Ce	-58190 (310)	-57870 (400)	-55421	-58000	-58460	-57920
58	65	123	Ce	-60660 (180)	-60290 (300)	-57961	-60470	-60800	-60520
58	66	124	Ce	-65190 (120)	-64920 (300)	-62639	-64970	-65260	-64900
58	94	152	Ce	-59210 (230)	-59060 (300)	-58075	-59490	-58990	-59210
69	80	149	Tm	-43750 (290)	-43880 (300)	-44024	-43910	-43490	-46090
69	81	150	Tm	-46670 (140)	-46490 (200)	-46741	-46560	-46020	-47420
69	108	177	Tm	-47615 (97)	-47470 (300)	-47602	-48150	-47430	-47750
69	109	178	Tm	-44590 (120)	-44120 (400)	-44351	-44890	-44060	-44270
69	110	179	Tm	-42120 (190)	-41600 (500)	-42177	-42660	-42050	-42130

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