Extrapolated Experimental Masses of Some Nuclei far from the Valley of Stability

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Introduction

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 [1], 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 [1,2]. Extrapolation of masses can be useful for assessing the impact of current and future experiments where measurements are currently impossible. And also as nuclear physics input for modeling the nucleosynthesis processes in stars and understanding the composition of neutron stars. Helpful in investigating the evolution of shell closures and fundamental symmetries as well as the limits of nuclear existence. Most importantly, may be helpful for the authors of the massmodels in improving them.

Methodology and Results

The experimental mass data from the Atomic Mass Compilation – 2012 (AMC12)[3] has been analyzed for two-proton separation energies, two-neutron separation energies, double beta decay energies and four-beta decay energies and plotted against neutron number and mass number respectively. In order to estimate the unknown mass values, extrapolations were performed by independently following thetrends in four derivative sheets. To meticulously account for the local trends in the derivative sheets, it was noticed that point–to–point extrapolation had to be considered. In each of the sheets, trends from the three previous (or the following) derivatives were used to estimate the value of the unknown derivative. To further improve the accuracy of the extrapolated derivative, it was ensured that the local trends were closely followed by placing higher weightage to the trends from the closest neighbors to the derivative that was to be found. The details of the method used to find the extrapolated derivate and the error in corresponding extrapolated mass value is provided in reference [4]. As can be seen from the comparison in Table 1, with very recent new mass measurements, the deviations are well within the experimental uncertainties in most of the cases. Our extrapolations in majority of cases show very good improvement over the earlier extrapolations and can be useful for assessing the impact of current and future experiments in the context of model developments and also expected to impact research in the simulations of the astrophysical r-process.

References

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[4]C. Scheidenberger et al DAE-BRNS Nuclear Physics Symposium 64 (2019) 60

Table 1: Comparison present extrapolated mass excess (M.E.) data with new measurements

A	Element	Z	N	Present extrapolation		New measurement		Deviation (keV)
				M.E. (keV)	Error	M.E. (keV)	Error	
15	Be	4	11	49916	300	49826	166	90
19	B	5	14	59420	240	59770	525	-350
22	C	6	16	53291	450	53611	232	-320
29	F	9	20	40385	300	40150	525	235
34	Na	11	23	31630	630	31680	599	-50
30	Ar	18	12	21020	100	20931	206	89
31	Ar	18	13	11558	100	11325	200	233
48	Ar	18	30	-22627	100	-22281	307	-346
52	K	19	33	-17174	160	-17138	34	-36
53	K	19	34	-12645	200	-12296	112	-349
53	Ca	20	33	-29554	150	-29388	44	-166
54	Ca	20	34	-24985	250	-25161	48	176
56	Sc	21	35	-24362	450	-24852	587	490
57	Sc	21	36	-20490	500	-20996	1304	506
43	V	23	20	-18128	150	-17916	42	-212
64	Cr	24	40	-33150	320	-33480	440	330
68	Mn	25	43	-28415	300	-28380	400	-35
51	Co	27	24	-27273	110	-27342	48	69
55	Cu	29	26	-31820	115	-31635	155	-185
56	Cu	29	27	-38796	10	-38643	14	-153
82	Zn	30	52	-42345	20	-42314	3	-31
91	Se	34	57	-50426	140	-50580	433	154
100	Rb	37	63	-46150	150	-46247	20	97
105	Y	39	66	-51248	140	-51270	1337	22
82	Zr	40	42	-63818	40	-63631	11	-187
107	Zr	40	67	-53657	200	-54380	1122	723
84	Nb	41	43	-61181	50	-61219	13	38
110	Nb	41	69	-52017	180	-52309	839	292
115	Tc	43	72	-56149	53	-56320	789	171
121	Rh	45	76	-56268	110	-56250	620	-18
129	Cd	48	81	-63032	83	-63058	17	26
131	Cd	48	83	-55200	150	-55219	103	19
138	Sb	51	87	-54231	145	-54220	1064	-11
149	Ba	56	93	-53160	150	-53120	438	-40
150	La	57	93	-56211	160	-56129	436	-82
215	Pb	82	133	4374	43	4342	53	32
232	Fr	87	145	46103	53	46073	14	30
233	Fr	87	146	48893	82	48920	20	-27
201	Ra	88	113	11952	92	11937	20	15
221	U	92	129	24468	150	24520	51	-52
222	U	92	130	24350	120	24273	52	77
219	Np	93	126	29469	400	29457	88	12