Atomic Mass Predictions of very neutron rich Br, Kr and Rb nuclei: A comparison between extrapolation techniques

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Introduction

In recent years, our knowledge on atomic masses far from the valley of stability has been increased due to the advent of new measuring techniques. Application of these masses, e.g. for astrophysical calculations, requires data for even far unstable isotopes which are generally derived from global mass models.

The ground state binding energy, and thus the mass of a nucleus, is one of its characteristic properties, revealing deep insight into the nuclear structure. Total binding energies 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.

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. Experimentally it has been observed that the four sheets run parallel in all directions meaning that the pairing energies Δnn, Δpp, Δnp vary smoothly and slowly with N and Z and each of the mass sheets varies smoothly also. 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. However, if one single mass violates the systematic trends, then one may seriously question the correctness of the datum.

Methodology

In order to make estimates for unknown masses (GKE) from trends in the mass surfaces, In 1966 Garvey and Kelson presented relations based on an independent particle model of the nucleus[1] which will be valid, independently of the actual variation of mass with atomic number and charge which are very useful because of their simplicity and greater accuracy in making ground-state mass predictions. For the Atomic Mass Evaluation, the interactive graphical program developed Audi et al [2,3] for extrapolations (AMEE) encompasses a “subjective” component in the form of individual judgments. Based on our Mass Excess data from Atomic Mass Compilation 2012[4], we have tried to study possibilities of avoiding the personal judgment in the extrapolations (AMCE) by applying “objective” techniques preferably based on algorithms

Overall, our knowledge of the mass surface has been significantly improved in the last decade. This suggests the need for a more plausible way of extrapolations using the modified mass surface for the extrapolation of masses toward the drip lines. In this report mass excess values from three different extrapolation techniques, GKE, AMEE and AMCE are compared for very neutron rich Br, Kr and Rb

Table 1. Garvey-Kelson relation (G-K) [11]. AME12, AMC12, HFB-21 (H) [9] compared. Deviations from HFB-21 are also shown as HFB-GKE, HFB-AMEE and HFB-AMCE. [Mass excess values in [keV/C^2].

Isotope	Extrapolated Mass Excesses				HFB –GKE	HFB – AMEE	HFB – AMCE
	GKE	AMEE	AMCE	HFB21			
^{91}Se	-50238	-50340	-50231	-50100	-138	-240	-131
^{92}Se	-46734	-46720	-46759	-46850	116	130	91
^{93}Se	-40951	-40720	-40950	-40860	-91	140	-90
^{94}Se	-37104	-36800	-36971	-37400	296	600	429
^{95}Se	-30761	-30460	-30589	-31250	489	790	661
^{94}Br	-47662	-47600	-47580	-47530	-132	-70	-50
^{95}Br	-43934	-43700	-44080	-44500	566	800	420
^{96}Br	-38240	-38160	-38620	-38800	560	640	120
^{97}Br	-33386	-34060	-33616	-35719	2333	1673	2103
^{98}Br	-27987	-28450	-28590	-29208	1221	758	618
^{99}Br	-23569	--	-25264	-25460	1891	--	196
^{99}Kr	-38913	-38760	-39284	-40313	1400	1553	1039
^{100}Kr	-34921	-35050	-35730	-36712	1791	1662	932
^{101}Kr	-28999	-29130	-29270	-30720	1721	1590	1450
^{100}Rb	-46524	-46550	-46431	-47646	1122	1096	1215
^{101}Rb	-42948	-42810	-43441	-44133	1185	1323	692
^{102}Rb	-37402	-37710	-37988	-38859	1357	1149	871

nuclei in the light of HFB-21 Hartree-Fock-Bogoliubov model predictions [5]

Garvey-Kelson-Relations (GKE): In 1966 Garvey and Kelson presented relations based on an independentparticle model of the nucleus which will be valid, independently of the actual variation of mass with atomic number and charge which are very useful because of their simplicity and greater accuracy in making ground-state mass predictions.

The AME extrapolations (AMEE): In order to make estimates for unknown masses from trends in the mass surfaces for the Atomic Mass Evaluations, an interactive graphical program was developed by Audi et a.

The Atomic Mass Compilation (AMCE) [5]: The interactive graphical program developed Audi et al [2,3] encompasses a “subjective” component in form of individual judgments. In this report we want to study possibilities of avoiding the personal judgment by applying “objective” techniques preferably based on algorithms. Table 1 presents a comparison of the three extrapolations along with HFB model predictions. AMC extrapolations seems to be more realistic in the light of HFB model calculations. This work is a part of a broader compilation to be published soon.

References

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