On the new GSI Atomic Mass Data Compilation

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Introduction:

The ground state binding energy, and thus the mass of a nucleus, is one of the characteristic properties, revealing deep insight into the nuclear structure. Total binding energies and derived quantities such as proton or neutron separation energies, Q-values, etc are needed for a basic understanding of the strong force, reaction kinematics and also applications in medicine, energy generation, nuclear waste transmutation and nuclear astrophysics. The atomic masses are important input data for fundamental as well as applied sciences. Compilations/evaluations of these quantities are indispensable tools for research and applications. An early attempt for a mass evaluation was of Livingston and Bethe [1]. The authors combined data from mass spectrometry and nuclear reaction and decay data up to ^{40}Ar. The first table of atomic masses using this method is dated 1955. Ever since the beginning of modern chemistry and physics, compilations of masses have been undertaken [2].The modern attempts on atomic masses which were initiated by A. H. Wapstra [3] are rather evaluations than compilations. The most recent version of such an evaluation is of AME03 [4]. The success of radioactive ion beams has lead to a notable increase in quantity and quality of data on atomic masses for exotic nuclides. Since the latest evaluation [4], a large number of new and quite important new data on mass measurements are available from direct and indirect measurements and reaction studies.

The GSI is contributing to the effort to collect and evaluate data on atomic masses to establish a follow-up of the 2003 Atomic Mass Table and the related NUBASE evaluation of nuclear properties as $T_{1/2}$, I^{π}, decay mode for ground and isomeric states.Quite some experiments at GSI have (and continue to) contributed many nuclear physics data related to ground state masses and decay properties: SHIP , FRS, ERS, LAND. Atomic masses of nuclides up to rather far removed from stability have recently been determined from their orbital frequency in a storage ring (ESR at GSI). At SHIP not only many new α and β decay energies were measured but also by particle-γ coincidences. Masses of more than 1100 nuclides were measured with Mass accuracy: SMS $1.5 \cdot 10^{-7}$ up to $4 \cdot 10^{-8}$, IMS $\sim 5 \cdot 10^{-7}$of which 350 are new masses and more than 300 improved mass values.

The present compilation is in response to the needs of nuclear physics community from fundamental physics to applied nuclear sciences, for a data base which contains values of the main basic nuclear properties, such as, masses, excitation energies of isomers, half lives, spins and parities. One of the applications of such a data base is atomic mass calculation in which it is essential to have clear identification of the states in a decay, a reaction or a mass spectrometric line. Further, more calculations requiring radioactive parameters for nuclear applications e.g. reactors, waste management, nuclear astro physics need to access this basic information on any nuclide. We have prepared a new compilation of atomic masses comprising the data from the evaluation of AME03 as well as results of measurements performed since then. Recommended values for the relative atomic masses have been derived and a comparison with results available in literature was performed.

Atomic Mass Compilation (AMC11):

We found it necessary to examine the literature, firstly, to revise several of the collected results in

ENSDF and ensure that the mentioned data are presented in a more consistent way; secondly, to have as far as possible all the available experimental data included. The scientific literature has been scanned for publications containing on nuclear masses, life times of ground and/or isomeric states. The Nuclear Science References (NSR) database of the National Nuclear Data Center at Brookhaven National Laboratory was browsed from the year 2000 until 2011. Recent volumes of relevant journals such as Physical Review A, C, Physical Review Letters, Nuclear Physics A, European Physical Journal, International Journal of Mass Spectrometry, Physics Letters, Journal of Physics G (London), Nuclear Instruments and Methods, Physics of Atomic Nuclei, Physica Scripta, Pramana, Metrologia, Chinese Physics, Chinese Physics Letters, Nature, Applied Radiation and Isotopes, Hyperfine Interactions, Physics of Particles and Nuclei, Bulletin of Russian Academy of Sciences, Europhysics Letters etc have been scanned regularly. Also data from non-refereed sources such as laboratory reports, preprints (mostly from the e-print archive (arXiv.org), diploma and Ph.D. theses and similar sources have been collected. Data previously available in the data base are checked for correctness and present validity.

The main table of the compilation presents all experimental data that were not included in AME2003 until 2003 and all experimental data from 2000 till 2011.. All input data are evaluated for calibrations and checked and compared with other results and with systematics. The accepted data allow calculation of the mass excess and atomic mass as weighted averages which are reported as adopted values in the table.

Results and Discussion:

The overall number of experimentally determined masses has increased from about 2200 to 2500. One can observe a replacement of less well determined mass values by higher precision ones. In all a total of 6156 (4953 AME03) data points corresponding to 3741 nuclides and isomers have been presented in the table. The number of ground state masses presented w are 2547 (2228 AME03) including the cases of 425 new nuclides and isomers 1194 (220 AME03) for which new atomic mass data is available while the number of nuclides for which no new experimental data beyond 2003 has been reported are 1753.

The mass surface has been significantly modified: Recent measurements by several groups with advanced techniques at the ridge of the valley of stability indicate to a general lift of the mass surfaces to higher masses(reduced binding energies),both on the n-rich and on p-rich wings, than those derived from the older data underlying theAME03. This rise is generally due to previously under-estimated Q data of exotic species resulting from missing levels. Some consequences of this change are expected in calculations using the nuclear masses as one of their ingredients. This will have an impact on the r-process nucleo-synthesis in astrophysics applications. For nuclides where no evaluated data was available in AME03, the extrapolated values of AME03 have been used for the calculation of percentage deviations. It has been observed that in most of the cases while the accuracy of the mass measurements almost seems to be maintained, the precision of masses of many nuclei has been improved. The main deviations from the AME03 data are clearly visible with the newly measured masses of p-rich and n-rich nuclides where the extrapolated mass values of AME03 have been used for comparison, suggesting the need for a more plausible way of extrapolations using the changed mass surfaces as these masses will impact future calculations through their influence on the extrapolation of masses toward the drip lines and future mass models.

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