International Journal of Mass Spectrometry 349–350 (2013) 1–2

Contents lists available at ScienceDirect

International Journal of Mass Spectrometry

journal homepage: www.elsevier.com/locate/ijms

Preface

100 years of mass spectrometry

IJMS har utgitt et jubileumsnummer i forbindelse med 100års-jubileet for ms. Les interessante artikler på http://www.sciencedirect.com/science/journal/13873806/349

In 1913 J.J. Thomson reported on experiments with "Rays of positive electricity": Ion beams, as we would call them today, were deflected by electric and magnetic fields and, thus, were dispersed into separate parabolas on a photographic plate. In retrospect, this finding marked the birth of mass spectrometry, which was immediately recognized as an invaluable method for chemical analysis with highest sensitivity. Furthermore, by the discovery of the existence of neon isotopes, Thomson, more generally speaking, has discovered new nuclides. Soon after, his student F.W. Aston found out that the mass of an atomic nucleus M is smaller than its atomic mass number $A = Z + N$, which is an integer sum of the number of its composing protons Z and neutrons N. This is the famous "mass defect" of atomic nuclei, which directly reflects the binding energy of atomic nuclei and represents the result of the interplay of the strong, weak and electromagnetic fundamental interactions acting among the nucleons. The pioneering experiments by J.J. Thomson and F.W. Aston and in parallel by A.J. Dempster boosted the interest to atomic mass measurements. Ever since the first experiments and up to the present days, new results on atomic masses inspire the development of nuclear theories and are the basis for understanding of quantum many-body effects in nuclei, among which are the successful liquid drop model by C.F. von Weizsäcker, postulation of nucleon–nucleon pairing by W.K. Heisenberg, explanation of nuclear magic numbers by M. Goeppert-Mayer and H. Jensen and many others. It is therefore not surprising that the success of the meanwhile century-long mass measurement endeavor and thereupon-based discoveries is reflected by a number of Nobel prizes, beginning from F.W. Aston (NP, 1922).

Over the decades spanning its first century and still today, more and more mass-spectrometry methods were invented and refined. It is important to emphasize here the role of the double-focusing high-resolution mass spectrometers, developed first by J. Mattauch and R. Herzog, which revolutionized the mass spectrometry landscape in the 1930s and are still being used in numerous applications. Started with investigations of stable and long-lived easily available probes, the mass spectrometry went a long way forward and is being able today to address very short-lived and even unbound systems, which can only be produced in tiny amounts of sometimes only one particle per minute and less. A particular place has to be devoted here to the so-called "indirect" mass determinations through various reactions and decays, which is presently the only way to address unbound nuclear resonances beyond nuclear drip-lines. Time-of-Flight (ToF) spectrometers are irreplaceable facilities for studying short-lived systems. A new flavor is brought into this field now by the development of multi-reflection ToF spectrometers, which are small-size broad-bandwidth devices that are now widely employed starting from mass measurements of short-lived radionuclides to chemical analysis of dust particles in unmanned space missions.

The highest precision in mass determination can be achieved by measuring the frequency with which an ion of interest revolves in a magnetic field. The devices of choice are the ion traps and storage rings. The former have a volume of about one cubic centimeter while the latter have circumferences in excess of hundred meters. Quadrupole mass filters and radio-frequency ion traps were introduced by W. Paul and co-workers and the trapping of ions in a magnetic field was achieved by H.G. Dehmelt in the so-called Penning-trap named after F.M. Penning. The first ion-storage ring, employed for atomic mass measurements, was constructed in the 1990s by P. Kienle and co-workers. The frequency measurements in these "small" and "big" ion traps rely on sophisticated detection techniques like the ion cyclotron resonance (ICR) and the non-destructive Fourier transform ion cyclotron resonance (FTICR) in ion traps and the non-destructive resonant Schottky spectroscopy in storage rings. The striking feature of the ion traps and storage rings is their ability to conduct measurements on single stored short-lived ions. Furthermore, trap-assisted and in-ring decay studies became possible.

Along with these developments the range of applications was expanded. Mass spectrometry for environmental analysis, clinical research, or structural analysis of biomolecules has become a standard procedure in chemistry and medicine. In physics, high mass resolution allowed for detailed information on binding energies throughout the periodic table of elements including short-lived radioactive isotopes at extreme proton-to-neutron ratios and even beyond the drip lines. Mass comparisons of particles and the corresponding antiparticles serve as a stringent test of fundamental symmetries. Determinations of the masses of elementary particles, like electron or proton, represent an important part of our system of fundamental constants. New mass data, in particular of nuclides far off stability, provide an indispensable nuclear physics input for astrophysical models and thus for our understanding of the processes of element formation in the universe. Finally, attempts are under way to replace the present macroscopic standard for the mass unit by an atomic standard.

This special issue aims at reviewing the successful story of mass measurements over the last hundred years. A special emphasize was given to examples in atomic and nuclear physics research, although a few articles address applications of mass measurements

1387-3806/$ – see front matter © 2013 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.ijms.2013.07.005

in a broader context. The invited contributions are divided into two categories, namely (i) the historical overview covering the first experiments, the development of mass spectrometry techniques and methods, and the development of nuclear theories, and (ii) the examples of modern research which are split into the applications of mass data to nuclear structure, astrophysics, fundamental physics etc., the presently running experimental programs, and, last but not least, the envisioned future facilities and experiments.

Klaus Blaum
Yuri A. Litvinov
Available online 12 July 2013