ELEMENTARY PARTICLE PHYSICS AND FIELD THEORY

ONE MORE TIME ABOUT ATOMS

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An assumption of a possible relationship between the equilibrium shape of nuclei and structure of electronic shells of atoms is considered on the basis of an analysis of a number of theoretical and experimental works published in the literature.

INTRODUCTION

The chemical properties of atoms are repeated periodically. This law was discovered, put together and presented by D. I. Mendeleev in his periodic system of elements in 1869. According to a current formulation, the chemical properties of atoms are periodically related to the charges of their nuclei.

Physics of atomic nucleus has begun its development comparatively recently. Rutherford introduced a common concept of an atomic nucleus into nuclear physics in 1911 as a result of an analysis of his well-known experiments on scattering of α-particles passing through matter [11]. Further experimental and theoretical research resulted in a hypothesis that a nucleus can be compared to an incompressible equally charged droplet of nuclear liquid. It followed from that hypothesis that a nucleus, like a droplet, would have a shape of a sphere in an equilibrium unexcited state. In 1935, Schuler and Schmidt from the Institute of Solar Physics (Potsdam, Germany) obtained the first experimental results that did not conform to that hypothesis [2]. They examined the superfine structure of the spectral lines from In, Sb, Hg and 151,153Eu atoms. In the former three cases, the arrangement of lines from the multiplets followed the well-known Lande law of intervals, which testified to a spherical shape of their atoms. However, for 151Eu and 153Eu atoms, they found out a deviation from Lande rule. The authors interpreted the result as an indication of the fact that the nuclei of 151Eu and 153Eu atoms have a shape of ellipsoids of revolution. Later on, a notion was introduced of an electric quadrupole moment of a nucleus as a measure of the deviation of the shape of nucleus from spherical. The interest of physicists in researching the nuclear quadrupole moments has not subsided yet. The experiments of this kind make use of techniques based on, in particular, Coulomb’s excitation of nuclei and detection of the spectra from µ-mesoatoms and scattered electrons.

An analysis of the data on quadrupole nuclear moments may help identify certain regular features between the shape of nuclei and the structure of electronic shells of the respective atoms.

1. EQUILIBRIUM SHAPE OF NUCLEI AND PERIODIC SYSTEM OF ELEMENTS

It appears challenging to compare the experimentally modified quadrupole moments of a number of nuclei (Fig. 1) with the arrangement of atoms in the periodic system (Table 1). Figure 1 taken from [3] shows the experimental data [4] on quadrupole deformations δ for a number of heavy nuclei. The x-axis shows the atomic mass numbers, A, and the y-axis gives the deformation parameter, δ. For spherical nuclei δ = 0. Circles are for even-even nuclei, light triangles stand for nuclei with odd Z, dark triangles for nuclei with odd N, and crosses denote odd-odd nuclei. The dotted curve will be interpreted further in the text.
The aggregated data shown in Fig. 1 looks like a fragment of a certain periodic structure. Note that not only heavy but also light nuclei may possess ellipsoidal equilibrium shapes. Litherland et al. [5] obtained $\delta \approx 0.3$ for the quadrupole moment of $^{25}$Mg nucleus.