ON THE BOSONIC ATOMS – STRUCTURE AND PROCESSES

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We investigate ground state properties of atoms, in which substitute fermions – electrons by bosons, namely π^- - mesons. We perform some calculations in the frame of modified Hartree-Fock (HF) equation.

The modification takes into account symmetry, instead of anti-symmetry of the pair identical bosons wave function. The modified HF approach thus enhances (doubles) the effect of self-action for the boson case. Therefore, we accordingly modify the HF equations by eliminating the self-action terms “by hand”. The contribution of meson-meson and meson-nucleon non-Coulomb interaction is inessential at least for atoms with low and intermediate nuclear charge, which is our main subject.

As an example of simple processes with a pion atom, we consider photoionization and pion elastic scattering, comparing it to similar data for ordinary i.e. electron atoms.

To obtain these results, we have solved the following equation

$$-\frac{\Delta}{2}\chi_k(\mathbf{r}) - \frac{Z}{r}\chi_k(\mathbf{r}) + 2N_\pi^k(1) \int |\chi_k(\mathbf{r}')|^2 \frac{d\mathbf{r}'}{|\mathbf{r}-\mathbf{r}'|} = E_k\chi_k(\mathbf{r})$$

Here Z is the nucleus charge, $\chi_k(\mathbf{r})$ is the pion wave function, N_π^k is the number of pions on the level k . In calculations we put all pions on the lowest possible $1s$ level.

According to the data obtained, the total binding energy of a pion atom is much bigger than that for an ordinary atom, and the size of the pion atom is several times bigger than the size of a normal atom. Sizes and energies we express in pionic and normal atomic units, respectively. The ionization potential ($-E_{1s}$) of a pionic atom in these units is much smaller than that of a neutral atom.

An interesting feature of a pion atom is its ability to easily form negative ions. For pionic He , Ne and Ar we predict the possible formation of single negative pionic ions He_π^- , Ne_π^- , Ar_π^- . For Zn , the formation of Zn_π^- and Zn_π^{-2} becomes possible. Kr is able to form up to Kr_π^{-3} , while Xe is able to attach extra four pions that leads to Xe_π^{-4} . In general, the binding energy of pion negative ions A_π^- , pion atoms A_π , and the number of maximal extra bound pions ΔN_π increases with the growth of nuclear charge Z .

While for ordinary atoms, the $1s$ photoionization cross-section monotonically decreases with photon energy growth from the maximum value at threshold, for pion atom that cross-section, on the contrary, reaches its maximum value above ionization threshold, thus forming pronounced maxima, the height of which is decreasing while the width is increasing with Z growth. Formation of negative ions is reflected in corresponding behavior of its elastic scattering s-phase. Negative ion formation and resonances were observed in s-phase only.