STRUCTURE OF MATTER – Midterm Exam 1

March 7, 2024

Without explanation or calculation steps no points will be awarded to a sub-problem even if the answer is correct!

PROBLEM 1. One-electron wave functions [25 points]

a) Sketch the radial part of the 4s wave function (rR_{4s}). Explain your answer [6 pnts]
b) The 4s and 5p radial wave functions have the same number of nodes. Which one is stronger bound? What is the binding energy of the stronger bound electron? [7 pnts]
c) To which states can an electron in the 4s state of hydrogen decay? [6 pnts]
d) What will be the binding energy of a 4s electron in hydrogen-like mercury (Hg^{79+})? [6 pnts]

PROBLEM 2. Fine structure [25 points]

a) The fine structure levels are characterized by the quantum number j. What are the j values of a 4f electron? [4 pnt]
b) Calculate the energy of the fine structure levels w.r.t. to the unperturbed 4f energy. [9 pnt]

   Hint: $V_{SO} = \frac{A}{2}(j(j+1) - l(l+1) - s(s+1))$. The fine structure constant A=8 [cm^{-1}].
c) The shift of the j levels is asymmetric w.r.t. the 4f energy. Show that conservation of energy is not violated. [6 pnts]
d) Consider the lowest, strongest bound j level. This system is put in an external magnetic field B, sketch the behavior of the binding energies of the relevant m_j states as a function of B. [6 pnt]

for problem 3 Please Turn Over

PROBLEM 3. Many-electron systems [50 points]

a) To calculate energies and wave functions of many-electron atoms several approximations are made. Describe briefly the main assumption(s) underlying The Independent Particle Model and indicate what this implies for the representation of the wave function. [9 pnts]

Consider Mn^{6+}. The ionization potential of Mn^{6+} is 119.2 eV and its electronic configuration is [Ar]3d.

b) Calculate the effective nuclear charge experienced by the 3d electron. [7 pnts]

c) Why isn't the effective charge equal to 7+?. Explain your answer [7 pnts]

The ground electronic configuration of U^{4+} is $[Rn]5f^2$.

d) Determine all allowed terms. Explain your answer.[10 pnt]

e) Which term is the ground term? Explain your answer. [7 pnt]

Consider Ir, with the electronic configuration is: $[Xe]6s^2 4f^{14} 5d^7$.

f) Determine the ground term and ground level of Ir. Explain your solution steps [10 pnts].