STRUCTURE OF MATTER – Midterm Exam 1

March 9, 2023

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 [5 points]

a) Sketch the radial part of an 3s wave function (rR_{3s}).
   Explain your answer [2 pnts]

b) 3s and 4p radial wave functions have the same number of nodes. Is there any difference between the two radial wave functions? If so what is/are the difference(s)? Explain your answer [3 pnts]

PROBLEM 2. Zeeman effect [7 points]

Consider a $^4D_{1/2}$ level.

a) Verify that a $^4D_{1/2}$ level does not split in a weak magnetic field (Zeeman regime). [2 pnts] *Hint:* $g_J = \left(1 + \frac{J(J+1)-L(L+1)+S(S+1)}{2J(J+1)}\right)$.

b) Of the $M_J=J$ state, calculate the polar angle of $\boldsymbol{J}$ with the z axis. [2 pnts]

c) What is the polar angle of the magnetic moment of a $^4D_{1/2}$ level. Explain your answer. [3 pnts]
   Advice: If you do not directly know how to solve this problem, please continue with problem 3 before spending too much time on 2c.

For problems 3 and 4 Please Turn Over

PROBLEM 3. Many-electron systems: Binding energies [8 points]

To calculate energies and wave functions of many-electron atoms several approximations are made. Describe briefly (2 to 3 sentences) the main assumption(s) underlying:

a) The Independent Particle Model and indicate what this implies for the representation of the wave function. [3 pnts]

b) The Central-Field Approximation. [1 pnts]

Consider Cr^{3+}. The ionization potential of Cr^{3+} is 49.1 eV and its electronic configuration is $[Ar]4s^2 3d$.

c) Calculate the effective nuclear charge experienced by the 3d electron. [2 pnts]

d) Why isn't the effective charge equal to 4+?. Explain your answer [2 pnts]

PROBLEM 4. Many-electron systems: LS coupling [10 points]

The ground electronic configuration of Zr is $[Kr]5s^2 4d^2$.

a) Determine all allowed terms. Explain your answer.[2 pnts]

b) Which term is the ground term? Explain your answer. [1 pnt]

Consider terbium (Tb). The ground electronic configuration of Tb is: $[Xe]6s^2 4f^9$.

c) Determine the ground term and ground level of Tb. Explain your solution steps [4 pnts]

Back to the $^4D_{1/2}$ level.

d) Explain why a $^4D_{1/2}$ level is never a ground level in LS coupling, no matter the l value of the electrons. You may limit your discussion to three equivalent electrons. Hint: Hund's rules. [3 pnts]