Structure of Matter – midterm I

March 4, 2021

Problem 1 – wave functions: 8 points
Problem 2 – effective nuclear charges and the independent particle model: 8 points
Problem 3 – LS coupling and Hund's rules: 8 points

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

You may use "Morrison" and this year's lecture and tutorial notes

1 - Wave functions

Consider a 7g electron in atomic hydrogen.

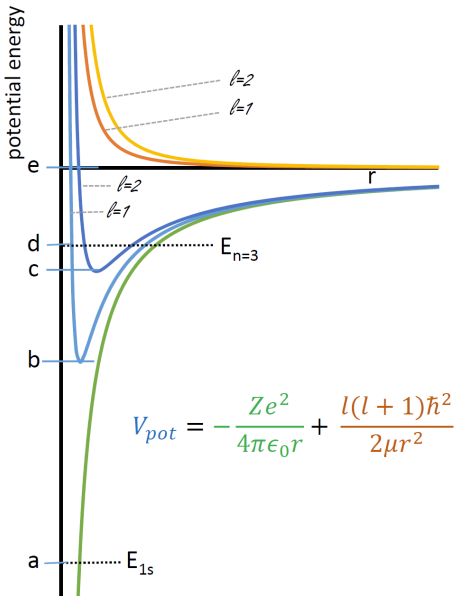
a) Calculate the polar angle of the angular momentum vector of a single 7g electron of which m=-3. [2 pnts]

b) Sketch the radial part of the 7g wave function (rR_{7g}). Explain your answer. [2 pnts]

Potential energy curves for hydrogen-like systems

c) Based on the figure explain why the 3s wave function is more compact or more extended than the 3d wave function. In the figure, the green curve depicts the Coulomb part of the potential energy while the orange/yellow ones represent the centrifugal potentials for l=1 and 2. The blue curves are the total potential energies for l=1 and 2. The energy of the n=3 shell is marked by $E_{n=3}$.[2 pnts]

d) Indicate the binding energy range in which the energy of the 2s state lies. Possible energy boundaries are marked by a, b, …., e on the energy axis. Explain your answer[2 pnts]



2 - Effective Nuclear Charges and the Independent Particle Model

Consider Fe^{7+}. The ionization potential of Fe^{7+} is 151 eV and its electronic configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 3d$.

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

b) Explain why the effective charge is not equal to 8+. [2 pnts]

Consider now a C^{4+} ion with its two electrons in the $3p^2\ ^1D$ term (all other shells are empty). The binding energy of this term is 100 eV.

c) Calculate the ionization energy of the $3p^2\ ^1D$ term, i.e., $C^{4+}(3p^2\ ^1D) \rightarrow C^{5+}(3p\ ^2P) + e$. [2 pnts]

d) Calculate the effective nuclear charge experienced by each of the electrons in the $3p^2\ ^1D$ term. Explain your answer. Hint: Independent Particle Model. [2 pnts]

3 – LS coupling and Hund's rules

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

a) Determine all allowed terms. Explain your answer.[3 pnt]

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

b) Determine the ground term and ground level of Tb. Explain every step in your solution [5 pnts]

Now that you finished your paper upload your file under assignments (do not use the dropbox!). If you are not using an electronic writing pad, take pictures of your answers (portrait, not landscape) and convert them to a single pdf document.