

Structure of Matter – part I – MidTermTest2
March 12, 2020

PROBLEM 1. Many Electron Systems [19 pnts]

PROBLEM 2. Elementary Particles [21 pnts]

PROBLEM 1. Many Electron Systems

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

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

- c) Calculate the effective nuclear charge experienced by the 3d electron. [2 pnts]
- d) Why isn't the effective charge equal to 8+. [2 pnts]

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

- e) Determine all allowed terms. [2 pnt]
- f) Which term is the ground term? Explain your answer. [1 pnt]

Consider Dy, of which the electronic configuration is: $[Xe]6s^2 4f^{10}$.

- g) Determine the ground term and ground level of Dy. [3 pnts]

Consider a ground term with 6 fine structure levels.

- h) Determine the spin S of the term [2 pnts].
- i) Why is the fine structure splitting due to S and not L? [1 pnts]
- j) Determine the electronic ground configuration of this term [3 pnts].

PROBLEM 2. Elementary Particles [20 pnts]

Consider a charmed baryon with quark content dsc decaying into $p + 2K^- + \pi^+$. The quark composition of π^+ is $u\bar{d}$ and of K^- it is $s\bar{u}$.

- Determine the hypercharge and the azimuthal isospin of this baryon. [2 pnt]
- What is the most likely value of its isospin (lowest value) [1 pnt]
- Verify whether conservation laws for charge and baryon number are respected. [1 pnt]
- Which conservation law is violated? [1 pnt]
- What is the approximate time scale of the decay? Explain your answer. [2 pnt]

Consider π^+ and ρ^+ mesons

- Explain why π^+ pions are much heavier than their individual quarks [1 pnt]
- ρ^+ mesons are the second lightest mesons with the same quark content as π^+ mesons. What are the J value and parity of ρ^+ mesons? Explain your answer [2 pnts].
- Are ρ^+ mesons eigenstates of the charge conjugation operator? Explain your answer. [2 pnts]

Consider now a Σ^+ baryon (uus) with spin $3/2$.

- Indicate why the spin wave function is symmetric. [1 pnt]
- Explain why the spatial wave function of that baryon is symmetric too. [2 pnt]
- Why does the fact that both spin and spatial wave functions are symmetric require the existence of an additional set of color quantum numbers? [2 pnts]
- What is the color of the uus baryon, explain your answer. [1 pnt]
- What is the Y^C value of the uus baryon, explain your answer. [1 pnts]
- In the wave functions of many-electron systems only space and spin symmetry is considered. Explain why color is not considered? [2 pnts]