Tentamen Kaleidoscope Modern Physics

donderdag 8 november 2012, 9:00-12:00, Tentamenhal

- Answer all question short and to the point, but complete; write legible.
- Use of a calculator is not allowed.
- $hc = 1240$ eV nm ; $\hbar c = 200$ eV nm ; 1 u = 931.5 MeV/c^2.
- Put your name and student number on each sheet. Good luck!

1. Sketch the energy levels of a Li^{2+} ion ($Z = 3$). What is the ionisation energy in eV? Calculate the wavelength and frequency of a photon that can ionize a Li^{2+} ion in the groundstate and that gives the ejected electron a kinetic energy of 5 eV.
2. Neutrons (m = 940 MeV/c^2) are used in a diffraction experiment to determine the lattice structure of a solid. Their wavelength should be comparable to the distance between the atoms in the lattice, about 0.3 nm. Calculate the velocity of the neutrons in m/s.
3. Explain what the K_α-line is in an X-ray spectrum of atoms. Why does it hold that $E \sim (Z-1)^2$? Calculate the wavelength for a $n = 2$ to $n = 1$ transition in molybdenum (Mo, $Z = 42$).
4. Formulate the Pauli-principle for two electrons. Which quantum numbers for atoms determine the structure of the periodic system? Give the electron configuration of rubidium (Rb, $Z = 37$) and xenon (Xe, $Z = 54$).
5. Explain what β-decay is. When $^{23}_{10}$Ne (mass = 22.9945 u) decays to $^{23}_{11}$Na (mass = 22.9898 u), what are the minimum and maximum energy of the electron? What is the energy of the neutrino in each of these cases? Neglect the motion of the daughter nucleus.
6. Why does $^{235}_{92}$U fission easier with slow neutrons ($K \simeq 0$) than $^{238}_{92}$U? How many neutrons are produced in the fission reaction $n + {}^{235}_{92}\mathrm{U} \rightarrow {}^{133}_{51}\mathrm{Sb} + {}^{98}_{41}\mathrm{Nb} + ?n$? Estimate the energy release in MeV. The atomic masses for the U, Sb and Nb isotopes are 235.04 u, 132.92 u en 97.91 u; the neutron mass is 1.01 u.
7. What would be the constituents of an "anti-atom", build from the anti-particles of an atom? Which fundamental anti-fermions can be found in the "anti-atom" of deuterium? Is an anti-neutron stable? If so, why? If not, give the decay reaction.
8. Formulate the uncertainty principle for energy and time. In the reaction $\pi^+ + p \rightarrow N^* \rightarrow \pi^+ + p$ the unstable particle N^* is formed as a 'resonance' with a "width" $\Delta E = 100$ MeV. Estimate the lifetime of the N^* particle.
9. A cyclotron with radius $R = 0.25$ m accelerates protons ($m = 940$ MeV/c^2) in a magnetic field of $B = 1$ Tesla (1 T = 1V.s/m^2). For the velocity it holds that $mv = eBr$. If the protons leave the cyclotron at $r = R$, calculate their energy in MeV.
10. Fermi-problem: How much would the water level of the oceans rise if the ice caps would melt?