Exercises Physics VI (Nuclei and Particles)

Summer Semester 2009

Exercise sheet Nr. 3 Work out until 14.05.2009

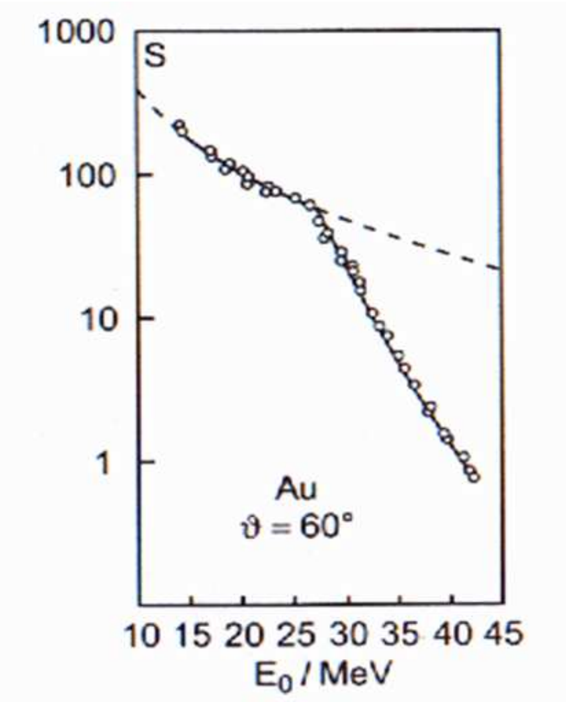
Exercise 1: Rutherford scattering (Points: 2)

a) A beam of α-particles with kinetic energy of $E_{kin} = 27$ MeV and 2 nA current crosses a Gold foil which is 2 mg/cm^2 thick. In a distance of 20 cm from the foil at 60° angle with respect to the beam is a detector with an active area of 4 cm^2. How large is rate of detected particles?

b) Leaving the detector at the same angle as above and varying the energy of the incoming beam, a deviation from the Rutherford scattering formula can be observed for energies $E_\alpha \geq 27$ MeV. Based on energy and orbital momentum conservation one can find for minimal distance $r_{min}(\theta)$ of α-particles from nuclei

$$r_{min}(\theta) = \frac{Z_\alpha \cdot Ze^2}{8\pi\epsilon_0} \cdot \frac{1}{E_\alpha} \cdot \left[1 + \frac{1}{\sin\theta/2}\right].$$

Apply this formula to calculate the radius parameter r_0 ($R = r_0 \cdot A^{1/3}$) and the radius of gold nuclei. Take the size of both target and projectile into account.



<u>Exercise 2</u>: Weizsäcker's formula (Points: 3)

a) From Weizsäcker's formula derive an analytic formula for a dependence of charge number Z of the stable Isobars on nucleon number A. In calculation take Z as continuous variable and neglect the pairing term.

b) What is the kinetic energy released in nuclear fission of ^{238}U to two symmetric nuclei?

c) Each of the products of ^{238}U fission will subsequently decay through β-decay until it reaches mass in valley of stability. Which stable element (nuclei) is obtained and how much kinetic energy is released in all β-decays?

<u>Exercise 3</u>: Mirror nuclei (Points: 1)

A ^{27}Si nucleus decays through β^+-decay to its mirror nucleus ^{27}Al. In the process, the sum of the kinetic energies of positron and neutrino is 3.80 MeV.

Which terms in Weizsäcker's formula is responsible for this energy? Calculate the radius R of the nuclei and the radius parameter r_0 ($R = r_0 \cdot A^{1/3}$) from the released energy. Assume that the charge inside the nucleus is distributed homogeneously in a sphere and therefore corresponds to the energy

$$E_c = \frac{3}{5} \cdot \frac{Q^2}{4\pi\epsilon_0} \cdot \frac{1}{R}$$

<u>Exercise 4</u>: ^{14}C method (Points: 3)

In the atmosphere, the isotope ^{14}C is produced at constant rate due to interaction of cosmic rays with the atmosphere. Through the decay of ^{14}C with a half-live of 5730 years, a constant ratio of ^{14}C and ^{12}C isotopes exist in the atmosphere. The same ratio exists also in all living organisms through carbon exchange in metabolism. The specific activity of ^{14}C in nature is 0.255 Bq per gram of carbon from tissue. Once on rganism dies its metabolism stops and the concentration of ^{14}C decreases through radioactive decay. This process can be used for dating in archeology.

a) How old is a sample of 2 g of carbon with an activity of 0.404 Bq?

b) How many atoms of ^{14}C were in the sample at that time? How many atoms are there now?

c) How long does one have to measure ithe activity of the sample to obtain its age with a relative statistical precision of 1%? Reminder: The statistical uncertainty of the measured number of events N is $\sqrt{N}$.