FYS3500 - Problem set 11

Topic: β decay, γ decay

Make sure you have read the relevant chapters in the book and compendium before starting the exercises.

Concepts of the week

Explain these concepts: β-decay, double β-decay, neutrinoless double β-decay, γ-decay, multipoles, Weisskopf units

Problem 1 The basics of β-decay

a) Figure **??** shows the electron spectra measured on β-particles from decay of ^{210}Bi. What does this spectra tell about the nature of β-decay? How and what can we learn about the existence of neutrinos from this spectrum?

b) In what nuclei do we find double-beta decay (what would be prominent examples)? Argue eg. with the β-decay mass parabolas. Draw the Feynman diagram for double beta decay in the standard picture.

c) There are many experiments that look for physics beyond the standard model. If neutrinos were their own anti-particles (so-called Majorana particles), how would the Feynman diagram for this process look like?

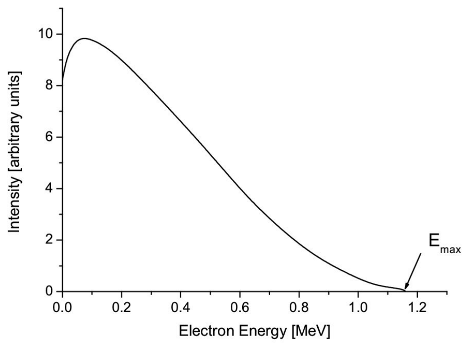

Figure 1: Electron spectra from β-decay of ^{210}Bi.

Problem 2 γ decay

When we describe nuclear γ ray resonances, we usually give the energy E_γ of an emitted photon is the difference E_0 between the initial excited state with energy E_1 and the final state with energy E_2, $E_\gamma = E_0 = E_1 - E_2$. This is not exact for free atoms or molecules, as it neglects the recoil energy of the nucleus.

a) Suppose that the nucleus was at rest before γ ray emission and find an expression for the exact γ ray energy. Calculate E_γ for ^{48}Ca when $E_0 = 1$ MeV. Can we neglect the recoil effect?

b) ^{60}Co is one of the most important γ ray calibration sources. By β-decay it feeds excited levels in ^{60}Ni. The $E = 1332.514$ keV level (with direct decay with $E_\gamma = 1332.501$ to the ground state) has a half-life $t_{1/2}$ below 1ps ($< 10^{-12}$ s). Compare the width of the state to E_γ and E_0. When one ^{60}Ni nucleus emits an the 1332.501 keV γ ray, can another ^{60}Ni nucleus absorb it directly? (Remember to convert half-life to lifetime)

c) (For the extra interested) Read up on the Mössbauer effect

Problem 3 γ-decay and Weisskopf units

a) For the following transitions between levels, give all permitted γ-ray multipoles and indicate which multipole might be the most intense in the emitted radiation.
I) $\frac{9}{2}^- \to \frac{7}{2}^+$ II) $\frac{1}{2}^- \to \frac{7}{2}^-$ III) $1^- \to 2^+$ IV) $0^+ \to 0^+$ V) $3^+ \to 3^+$

b) A nucleus has the following sequence of states beginning with the ground state: $\frac{3}{2}^-, \frac{7}{2}^-, \frac{5}{2}^+, \frac{1}{2}^-$ and $\frac{3}{2}^-$ Draw a level scheme showing the intense γ transitions likely to be emitted and indicate their multipole assignment. Which of the transition would you expect to be have the smallest chance to happen?

c) How are Weisskopf estimates calculated? If the experimentally determined transition rate deviates from the Weisskopf estimate, what does this indicate?

d) What do we mean with an isomeric state? (Also called: meta-stable)