Exercises to the Dark Matter lectures – series 1

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1. **Recoil energy**
   Calculate the recoil energy E_r, which a WIMP particle of mass m_χ with velocity $v_0 = 230$ km/s gives in a scattering process to a nucleus at rest of mass m_A, if the scattering angle in the center of mass system amounts to 180° (in this case equal to the scattering angle in the lab).
   Perform the calculation for WIMP masses of $m_\chi = 10$ GeV and $m_\chi = 100$ GeV and for nucleus masses of $m_A = 72.6$ u (Ge) and for $m_A = 131.3$ u (Xe). (We use the notation $c = 1$ and 1 u = 0.93 GeV).

2. **Interaction rate**
   What is WIMP nucleus interaction rate in a 1 t xenon target ($m_A = 131.3$ u) for WIMP masses of $m_\chi = 10$ GeV and $m_\chi = 100$ GeV? Assume a WIMP-nucleus interaction cross section of $\sigma = 10^{-40}$ cm^2, a local WIMP density of $\rho = 0.3$ GeV/cm^3 and a WIMP velocity of $v_0 = 230$ km/s.

3. **Radioactive contaminations:**
   A xenon detector has intrinsic contaminations of argon and krypton at the 1 ppt level (1 ppt= 10^{-12}). In natural krypton (average mass 83.8 u) and natural argon there are also the radioactive isotopes ^{85}Kr (released to the atmosphere by above ground atomic bomb tests and nuclear waste management, $T_{1/2} = 11$ y, $Q_\beta = 687$ keV) and ^{39}Ar (cosmogenically produced in the atmosphere by cosmic rays, $T_{1/2} = 269$ y, $Q_\beta = 565$ keV). The fraction of ^{85}Kr to natural krypton is $2 \cdot 10^{-11}$. The radioactivity of natural argon due to the ^{39}Ar fraction amounts to 1 Bq per 1 kg.
   What are the background rates in a xenon detector of 1 t target mass due to the ^{85}Kr and ^{39}Ar contaminations?