Vortrag fuer Gamma Spektroskopie

Lektuere:

dieses buch

Germaniumdetektor Versuch 🡪 denk an p-n dotierung nicht so wie es scheint (mail von jens)

* Spectroscoy: studies of energy spectra of gamma rays
* The Identification of Gamma Emitting Radionuclides
* Photons enter matter and interacts with free or bonded (bound) electrons, nuclei or electric fields.
* Interaction processes depending on photon energy, Z of absorber atom
* Interactions important for gamma spectroscopy:
* inner photoeffect, Compton effect, pair production/annihilation
* photon loses energy while traversing through a medium (intensity = photons / (time and area) gets lower)
* intensity loss prop. Thickness, number of electrons and cross section (sigma)
* extinction coefficient mu = (sigma \* Z \* N\_L \* rho) / (A)
* N\_L = loschmidt’sche zahl
* 1/mu = mean distance of a photon in a medium with a proton number Z, cross section sigma and density rho and atom weight A

1. PHOTO EFFECT:

* Photon with E > E\_bind of K schale electron interacts with huellen electron
* Electron leaves the atom and has the remaining photon energy as kinetic energy
* Gamma + atom -> atom^+ + electron
* E(electron) = E(photon) – E(bind)
* „loch“ is filled in from electrons from higher orbitals recursively.
* The energy difference between orbitals are characteristic and the photons released are x-rays
* Rarely: the photons leave the absorber. Often excite other electrons inside the absorber and redo the process above
* Absorptionskante: unstetige aenderung des WQ

1. COMPTON EFFECT:

* Interaction of a photon with free pointlike electron
* Inelastic scattering of a photon at an electron “in ruhe”
* Photon transfers some of its energy to the electron and keeps remaining E; electron now moving
* E\_l = E\_photon \* (e \* [1 – cos phi] ) / (1 + e \* [1 – cos phi])
* E\_l = E electron after scattering
* e = E\_gamma / m\_0 \* c^2, m\_0 = electron mass
* E\_(l,max) = E\_gamma \* (2e / 1 + 2e) for phi = 180 deg (rueckstreuung)
* -> bad to have: only a fraction of E measured, cannot view full spectrum
* Non-isotropic angular distribution
* For small e (feasible since keV) thomson’sche streuquerschnitt sigma\_th = 8/3 \* pi \* r\_e^2 (r\_e = classic electronradius)
* d(sigma) / dE = … (show plot)

1. PAIR PRODUCTION:

* If E\_gamma > 2 \* m\_0 c^2 (photon can produce two leptons with electron mass -> electron positron pair)
* Pair production can only occur in the proximity of a nucleus or any other scattering partner to take the momentum from the gamma
* Why? Look at restframe photon mass = 0, 2e mass > 0 therefore created in nucleus
* Also possible if photon scatters at an electron -> need 4 m\_0 c^2
* Cross section depends on where pair production happens (K schale much coulomb field rejection, outer: other shielding effects)
* Low photon energy around core (coulomb case) 10 to 25 MeV photon energy:
* Sigma = alpha \* r\_e^2 \* z^2 (28/9 \* ln(2e) – 218/27)
* Full shielding out of the electron huelle with E\_photon > 500 MeV
* Sigma = const1 \* (const2 \* ln(183/cuberoot(z)) – 2/27), constants from sigma term above
* E\_photon line only when e+e- pair fully absorbed, possible that one or both escape
* Also lines at E\_photon – m\_0c^2 and E\_photon – 2 \* m\_0c^2
* Escaping leptons may do bremsstrahlung (accelerated particles emit radiation tangential to the acceleration)
* Annihilation peak = 511 keV (electron mass) or 1022 keV because of 2 electrons

1. How to detect gamma radiation? germanium detector

* Ge-detector is a semi-conductor
* Must have solid detector material since we want full radiation inside detector!
* Gas is bad since absorption not enough and photons or particles will escape with part of the energy
* Electron-hole pairs must be converted to electric signal -> supply electric field and sweep the particles out (only suitable if the material has electrical properties) that’s why semi-conductor
* Or use scintillators -> trap photons and use SiPMs

1. Band structure of solids (uff…)

* Electrons are in discrete/precise energy bands, each with fixed number of electrons
* Valence band: most outer band, for chemical reactions, most inhibited
* Electrons must move between bands to migrate inside the material

Insulator: full valence band, huge forbidden region (band gap E\_g 10 eV) to conduction band, no electrical current possible because electrons are immobile

Conductor: valence band not full, continuous with conduction band which is never empty, electrical field causes current to flow

Semiconductor: similar to insulator but band gap much smaller (roughly 1 eV), small amount of electrons in conduction band, limited conductivity. Electron migrating to conduction band goes up with Temperature T rising, down when cooled -> p(T) approx.. T^(3/2) \* exp(-E\_g/2 \* k\_b \* T)

Creating of charged carriers by gamma radiation

1. How a Ge-detector works:
   1. Semiconductor diode, 2 areas with p and n dotation
   2. Charge carriers diffundieren and recombinate
   3. At the meeting area: charge carrier poor zone
   4. Acceptor in p-zone, donator in n-zone -> electric field hinders carriers
   5. The bigger the poor zone the better the separation
   6. How? More U\_g
   7. If we can separate electrons and holes before recombination -> impulse -> quantification for electron energy and gamma energy as well
   8. Only possible if e-hole pairs generated in depletion zone (that is why it needs to be big) -> only there the field is strong enough to make separation possible
   9. To make depletion zone big: chose dotation wisely and sperrspannung U also
   10. D = d\_p + d\_n is roughly d\_p = \sqrt{2 \* \epsilon \* \epsilon\_0 / e\_0}(U\_D + U) \* 1/n\_A for n\_D >> n\_A
   11. -> only dotation in p zone interesting (asymmetric dotation)
   12. Keep it clean (easy with crystals), also make speerspannung U bigger. d prop. To \sqrt{U}
   13. Electrons able to random pass the U\_g gap -> noise (formular 18, put it in the slides) > n\_i proportional to const \* T^3 \* exp{-E\_g/k\_b T}, n\_i: electrons to cross gap that we don’t want. Keep that small!
   14. Cool detector (T = 77 K), make U = 5 – 6 kV and depletion thickness d = 3 cm
   15. -> easy measurements of MeV gamma rays possible
   16. Physical detector is a cylinder with aluminium case. (VETO energy = 40 – 50 keV)
   17. n-dotierung: Li-atoms on Ge, p-dotierung: Au-atoms in Ge
2. Advantages of gamma spec versus (radio chemistry)
   1. Less expensive
   2. Fast (measurement until result does not take long)
   3. Multinuclide analysis, all gamma emitters can be analyzed at once (distinct energy lines for different nuclides)
      1. Radiochemical analysis for one element only (e.g. U-234, U-235 and U-238)
   4. Non destructive for the source or anything (radiation hardness must be given)
   5. Can be performed remote where we don’t need a sample -> gamma rays from space
3. Disadvantages:
   1. Often less sensitive
   2. Often require larger sample masses
4. Include a table of radio nuclides
5. Make backup slides depending on how long the talk is (don’t need the whole calibration)
6. What is a semiconductor?