The excitation energy is distributed among reaction products; 99% of the energy is carried by prompt gamma-rays and 1.8% by IC electrons [?,?]. The energy spectrum ranges from 0 to the Q-value of the nucluear reaction. Energies of prompt gamma-rays lie all over the spectrum, while energies of IC electrons and their biproducts are mainly located at the lower end, below 0.2 MeV.

The resulting spectrum is an overlap of two basic components. The first is a continuous spectrum generated by prompt gamma-rays, in the medium to high energy range. The second component is a set of discrete. Its lines produced by low energy prompt gamma-rays, IC electrons, Auger electrons and X-rays. In other words, prompt gamma-ray emission adds to both the discrete and continuous component, while the remaining reaction products supply the discrete spectrum component.

The spectrums form is closely related to the nuclear level arrangement of Gd.

Figure ? illustrates excited states of an arbitrary nucleus. A low lying level have less excitation energy than a high lying level. Low lying levels are easily distinguishable, each with a known spin and parity, the levels are discrete. As the excitation energy increases so does the nuclear level density. Eventually high lying levels become indistinguishable from one another and resemble a continuum. In fig. ?, the quasicontinuum of energy states is represented by a gradient, where energy level density increases as the gradient darkens. Energy levels within the quasicontinuum are marked by dotted lines and the discrete domain with uninterrupted lines. There is no clear boundary between the continuous and discrete domain, but rather a smooth transition between the two. The highest energy level represents neutron capture state and the lowest level ground state, both are indicated by a bold uninterrupted line. A transition from one level to another is indicated by and arrow.

No finished?

A nucleus may transition once or several times before it reaches ground state.

Transitions can occur between (1) states in the continuous domain, (2) states in the discrete domain or (3) between the two. The quasicontinuum has an endless number of states from which the nucleus can decay, and it is transitions with initial states in this domain that bring about the spectrum’s apparent continuity. A cascade typically starts with a couple of successive gamma-rays and in some cases ends in one or more IC electrons. It is not before the nucleus approaches lower energy states that the decay processes truly start to compete with one another. Most of the excitation energy is therefore carried by the first gamma-ray, followed by the second gamma-ray, third gamma-ray and so on (%?) [hagiware [4,15]]. A cascade constitutes an average of 4 gamma-ray emissions [Hagiwara [21]]. IC electrons carry significantly less of the excitation energy than the first gamma-rays.

Do more research

**Fermis Golden Rule**

**Electron spectrum (and biproducts)**

A competing process to gamma-ray emission is internal conversion (IC), the direct emission of an orbital electron. IC is most probable for transitions from first state 2+ and to ground state 0+ and from second state 4+ to first state 2+. They are responsible for 96.7% of the energy carried by IC electrons. These transitions are also **responsible** for the discrete gamma-ray duplets {} and {}. In other words, there are two probable decay modes. The ratio of IC decay rate to gamma decay rate can be described by the internal conversion coefficient (ICC) :

In cases where gamma decay is preferred the coefficient is small, perhaps even negligible, and differently when IC is preferred the coefficient is large.

The probability of IC depends on the electron shell (K,L, M, …) and therefor each shell has its own ICC (. Inner shell electrons, such as those from the K shell, are more likely to interact directly with the nucleus since its wavefunction has a finite probability of penetrating the nucleus. The likelihood of IC lessen the further away a shell lies from the nucleus. In other words, it depends heavily on the atomic electron density inside the nucleus. (studie of the probability of IC from shells [ref?], table?). Consequently, odds of nuclear interaction with the K-shell is more likely than with the L-shell, than the M-shell and so on. (Observations of most K shells?)

The total ICC is the ratio of total number of IC electrons to gamma-rays emitted by a nucleus and it can be expressed as a sum of the shell coefficients:

***FORTSETT HER:***

*The energy of an IC electron is determined by the available transition energy and the binding energy of a shell .*

IC electrons contribute to lines in the range 29-182 keV of the spectrum.

*MORE HERE, come back to later*

**X-rays and Auger electrons**

Following the expulsion of IC electrons are X-rays and Auger electrons. A vacancy is left behind by the IC electron and is subsequently filled by a higher-level electron to release atomic energy (?). This energy is dissipated either by an X-ray or an Auger electron. Both have discrete energies, in the 4-50 keV range, and contribute to the discrete component of the total energy spectrum from neutron capture. [Dumazert 2016]

**Comparison of yields. Which deposit energy in solid state detectors?**

**Summary – take home message of section**

The complete spectrum resulting from reaction products and biproducts of neutron capture is superposition of a continuous spectrum and a discrete spectrum. The discrete lines appear in the lower end of the spectrum, while the continuum mid to high end of the spectrum. It is the discrete lines which play a prominent role in neutron detection.