Transition:

Topic:

Arguements:

Transistion/summary:

**Transition:**

**Topic:** Energy spectrum

**Arguments:**

* Range from 0 to Q value
* Reaction products
* Energy distributed amond reaction products
* Gamma-ray carry majority, ICE remaining
* Gamma energy range from 0 to Q
* ICE lower end of spectrum, < 1MeV (?)
* Energy spectrum of reaction products is a superposition of a continuous component and a descrete component.

**Transition/summary:** The resultant energy spectrum is an overlap of …

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 resultant energy spectrum is an overlap of …

**Transition:** The resulting spectrum is an overlap of two basic components

**Topic:** Basic energy components

**Arguments:**

* Cont
* Discrete

**Transition/summary:**

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 is a set of discrete lines produced by low energy prompt gamma-rays, IC electrons, Auger electrons and X-rays. In other words, prompt gamma-ray emission add to both the discrete and continuous component, while the remaining reaction products supply the discrete component.

**Transition:** The spectrums form is closely related to the arrangement of Gds nuclear excitation levels.

**Topic:** Fig ? ,nuclear levels

**Arguments:**

* Density of energy levels increase with excitation energy
* Discrete and continuum levels
* Description of figure

**Transition/summary:**

The spectrums form is closely related to the arrangement of Gds nuclear levels.

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, they are discrete. As the excitation energy increases so does the nuclear level density, until high lying levels eventually become indistinguishable from one another and resemble a continuum. In fig. ?, the quasicontinuum domain 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.

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

**Topic:** continuous energy spectrum

**Arguments:**

**Comment:** 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. It is the transitions from initial states in the quasicontinuum that bring about the spectrum’s apparent continuity. Since there are endless state from which a nucleus can decay **The domain has an endless number of states , thus giving the gamma endless possibilities of emission energies**. Should rewrite, but how?

**Transition:**

**Topic:**

**Arguments:**

**Transition/summary:**

**Fermis Golden Rule**

**Transition:**

**Topic:** Discrete peaks, low-energy douplets

**Arguments:** discrete levers in low energy, values,

**Transition/summary:**

*A typical decay of Gd-156/Gd-158 has an average of 4-step gamma cascade [ref. only know for one, find for the other], though cascades with up to 12(?) gamma-emissions are also possible (?ref. simulations) a cascade of an average of 4 gammas (4-step gamma cascade). Cascaded with up to 10(?) steps have also been observed [ref?].*

In a multi-step cascade, most of the energy (how much%?) is carried by the first gamma and decreases with gamma generations. As the nucleus de-excites and approaches ground state it emits gammas from the discrete domain. There is a limited amount of discrete levels, consequently the number of possible gamma-emission energies are finite, in contrast to the continuum. This results in discrete peaks near the lowest part of the energy spectrum.

A close up of a map

Description automatically generated

T spectrum is dominated by two peaks in the lower end of the spectrum In a purely isotopic material of either Gd-156\* or Gd-158\* a set of two energy pairs is emitted, {88.97 keV, 199.22 keV} and {79.51 keV, 181.94 keV}, respectively. The lowest energy of each set is characteristic for the transition between first excited state 2+ and ground state 0+, while the larger energy is characteristic for transitions between second excited state 4+ state and first excited state 2+. **Add illustration** [C.W. Reich, Nuclear Data Sheets for A = 156, Nucl. Data Sheets 113 (11) (2012) 2537–2840.] Similar peaks can be observed in the prompt gamma spectrum of natural Gd, merely a combination of the aforementioned isotopic spectrums.

A representation of the complete prompt-gamma spectrum is illustrated in figure ?. Where discrete peaks are located in the lower energy range and the continuous spectrum broadening over the remaining spectrum.

**Electron spectrum (and biproducts)**

**Transition:**

**Topic:** IC electrons

**Arguments:**

* An orbital electron
* Competes with gamma-decay (expect when atom fully ionized, i.e. no orbital electrons)
* Internal conversion coefficient (tot and shell)
* Finite probability of finding the electron within the nucleus

**Transition/summary:**

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 electron 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 finite probability of penetrating the nucleus. The probability of IC in a shell becomes less likely the further it 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 shell coefficients:

**Transition:**

**Topic:** IC electron energy

**Arguments:**

**Transition/summary:**

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

Depending on which shell an electron is emitted from it will have energy in the range 29-182 (rewrite. Ambiguous sentence) keV.+K shell large binding, less energy available, low Ice are more common. (?)

* Binding E from erf. harms

Energies of IC electrons are discrete since the transitions take place in the discrete domain of energy levels.

**FORTSETT HER**

**Transition:**

**Topic:**

**Arguments:**

**Transition/summary:**