Lecture I.2
Nuclear Structure Observables

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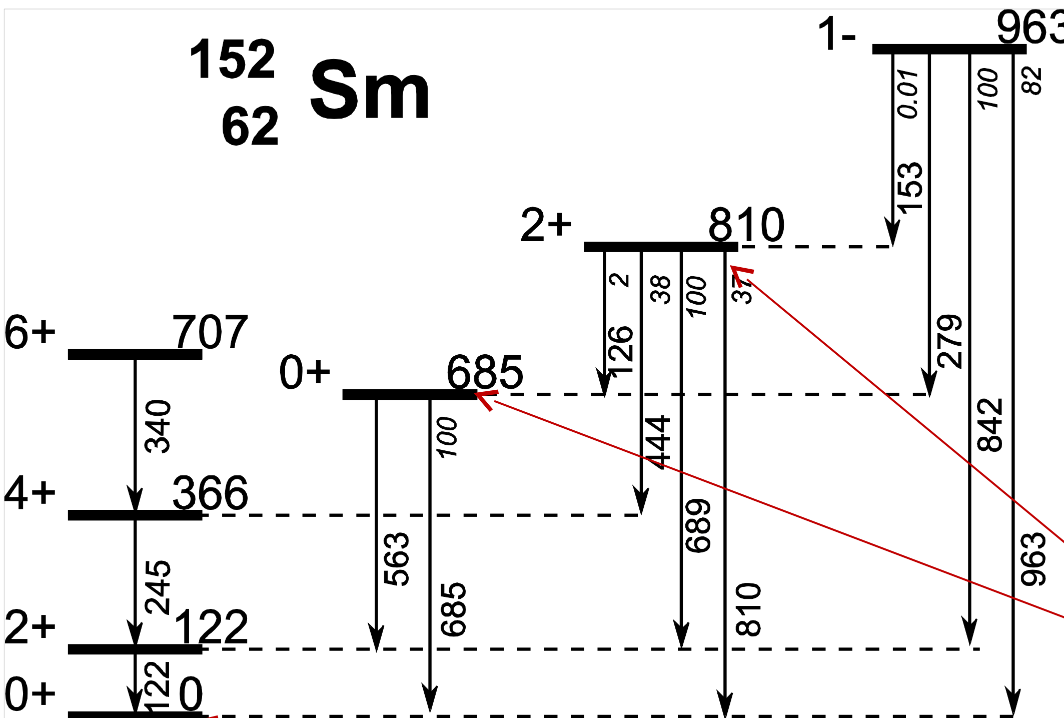
Outline

- The nuclear *level scheme*;
- The *gamma transitions*;
- The *energy* and the *intensity* of the gamma transitions; The *branching ratio*;
- The *coincidences*;
- The *lifetime* of a level; The *isomers*.

The nuclear levels. The level scheme



Ground state

A quantum system

N neutrons
Z protons

The nuclear force

⇩

The energy is quantified: ENERGY LEVELS

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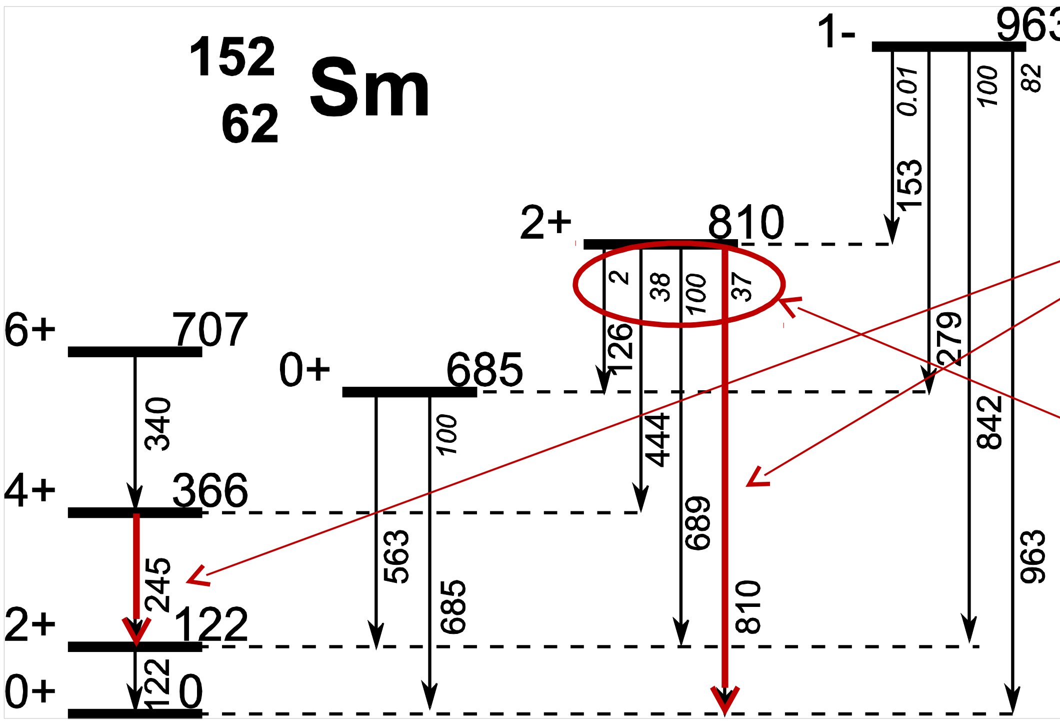
The gamma transitions



Deexcitation from one level to another => gamma transitions

$$E_\gamma \approx E_i - E_f$$

Branching ratio

Question

Why $E_\gamma \neq E_i - E_f = \Delta E$? How much is ΔE- E_γ?

Why ? How much is - ?

The RECOIL OF THE NUCLEUS:

$$\Delta E = E_\gamma + E_R$$

$$p_R = p_\gamma$$

$$\Delta E - E_\gamma = \frac{p_R^2}{2m_R} = \frac{p_\gamma^2}{2m_R} = \frac{(E_\gamma/c)^2}{2m_R} = \frac{{E_\gamma}^2}{2m_R c^2} \approx \frac{1}{20000}\, MeV = 0.05\ \mathrm{keV}$$

$$E_\gamma \approx 1\, MeV$$

$$m_R c^2 \approx Auc^2 \approx 10 \cdot 931.5\, MeV \approx 10000\, MeV$$

Lifetime of a level. Isomers.

$N(t) = N(t_0)e^{-t/\tau}$ — τ – lifetime of a level

$T_{1/2} = ln2 \cdot \tau$ — $T_{1/2}$ – half-life

Range of the lifetime of most nuclear levels: <1ps – 1 ns

If τ is of the order of 1μs or larger (ms, s, or larger) the nuclear level is an ISOMER.

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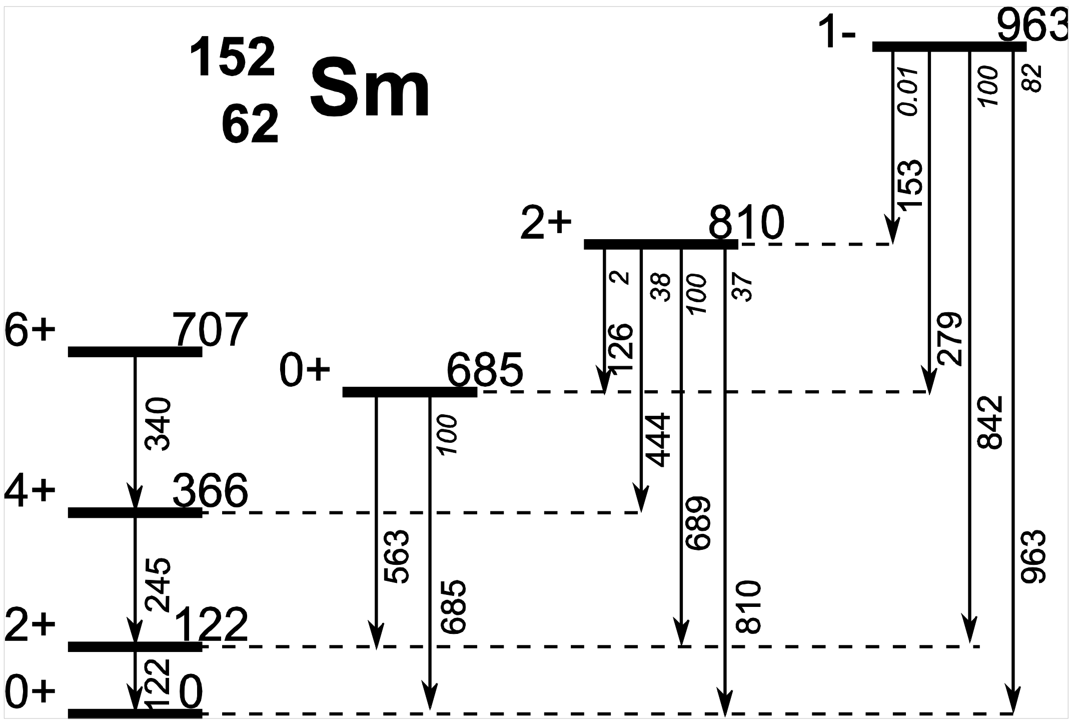
The coincidences



Time resolution of a detector:

- HPGe ~ 10 ns
- Scintillator ~ 0.5 ns

Exercise: Coincidences

	122	126	153	245	279	340	444	563	685	689	810	842	963
122		x	x	x	x	x	x	x		x		x	
126			x					x	x				
153								x	x				
245						x	x						
279								x	x				
340													
444													
563													
685													
689													
81													

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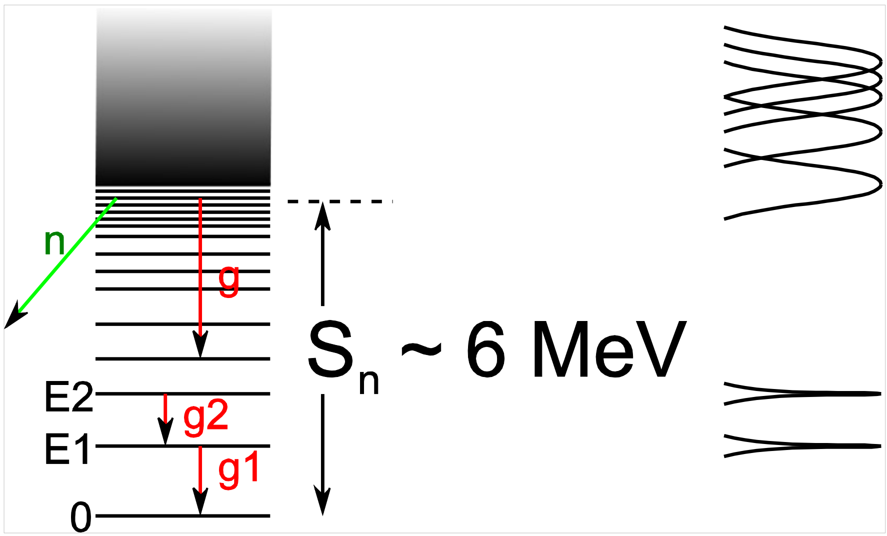
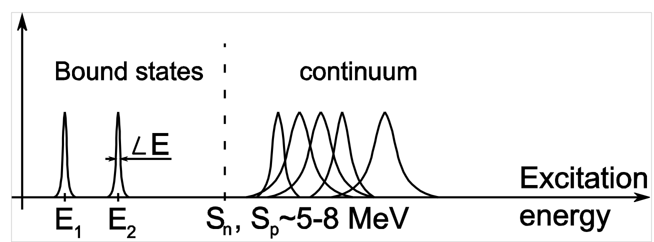
The discrete region and the continuum



$$\Delta E \cdot \Delta T \geq \hbar$$



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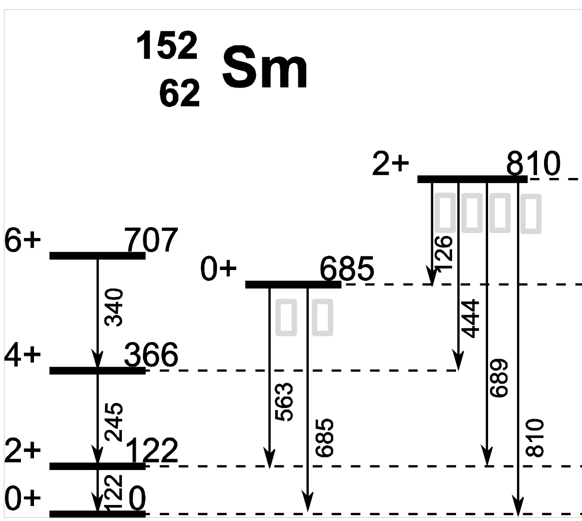
Exercise: calculate brancing ratios



E_γ (keV)	E_{level}(keV)	I_γ	Mult.
810	810	1.19 ± 1	(E2)

An Electron Capture experiment: th
^{152}Eu to ^{152}Sm.

Calculate the branching ratios for t
transitions starting from

-
-
-

Level: 685 keV
γ1: 563 keV 0.010 (5)
γ2: 685 not known

Level: 810 keV

γ1: 126 keV 0.06 (2)
γ2: 444 keV 1.22 (7)
γ3: 689 keV 3.20 (3) -> 100
γ4: 810 keV 1.19 (7)

- γ3: 689 keV 3.20 -> 100
  σ = 0.03 * 100/3.20 = 2

Branching ratio: 100(2)

- γ2: 444 keV 1.22 -> 1.22/3.20 *100 = 38.125

$f = \frac{a}{b} \times 100$ a=1.22(7), b=3.20(3)

$$\sigma_f^2 = \left(\frac{\partial f}{\partial a}\right)^2 \sigma_a^2 + \left(\frac{\partial f}{\partial b}\right)^2 \sigma_b^2 = \left(\frac{100}{b}\right)^2 \sigma_a^2 + \left(\frac{100a}{b^2}\right)^2 \sigma_b^2 \Rightarrow$$

$$(\dots) \Rightarrow \sigma_f = 2.216$$

Branching ratio: 38(2)

Summary

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