Decadimento Radiattivo

- tempo di semivita = $t_{1/2}$ 10^{-14} secondi – 10^{15} anni

Leggi di Conservazione

$$X_1 + X_2 \longrightarrow X_3 + X_4$$

1. L'energia totale del sistema deve essere costante:

$$E_1 + E_2 = E_3 + E_4$$

2. Il momento lineare p = mv, deve essere costante:

$$p_1 + p_2 = p_3 + p_4$$

3. La carica totale del sistema deve essere costante:

$$Z_1 + Z_2 = Z_3 + Z_4$$

4. Il numero di massa del sistema deve essere costante:

$$A_1 + A_2 = A_3 + A_4$$

5. Il momento angolare nucleare totale p_I, del sistema deve essere conservato:

$$(p_I)_1 + (p_I)_2 = (p_I)_3 + (p_I)_4$$

Decadimento α

$${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}X + {}^{4}_{2}He^{++}$$

$Q(MeV) = -931.5\ \Delta M$ (ΔM = Difetto di massa)

$$Q_\alpha(MeV) = -931.5\ (M_{Z-2} + M_{He} - M_Z)$$

Es:

$${}^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

$Q_\alpha = -931.5\ (234.043583 + 4.002604 - 238.050770) =$
$= 4.269\ MeV$

$$Q_\alpha = E_{Z-2} + E_\alpha$$

$$E_{Z-2} = Q_\alpha \frac{M_\alpha}{M_Z} \qquad E_\alpha = Q_\alpha \frac{M_{Z-2}}{M_Z}$$

$E_{^{234}Th} = 0.072 MeV$ $\qquad$ $E_\alpha = 4.197\ MeV$

Dal ${}_{82}Pb$ in poi e parte ${}^{144}_{60}Nd$ ${}^{150}_{62}Sm$

In questi l'E_α sono comprese tra 3 e 9 MeV

Non attraversano la materia ma ne causano la ionizzazione

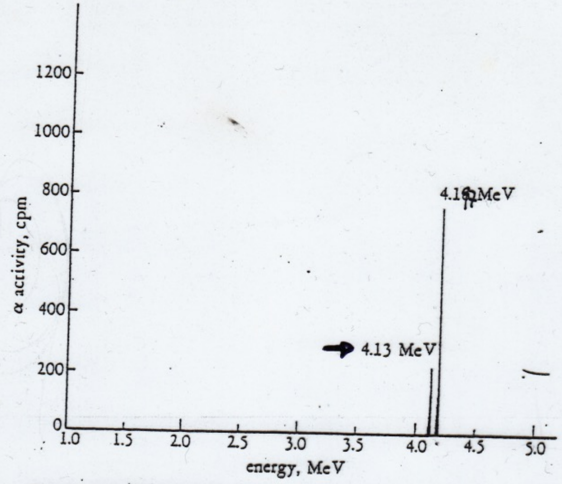


Figure 2–2 **Distribution of alpha particles emitted from U^{238} plotted as a function of their energies.**

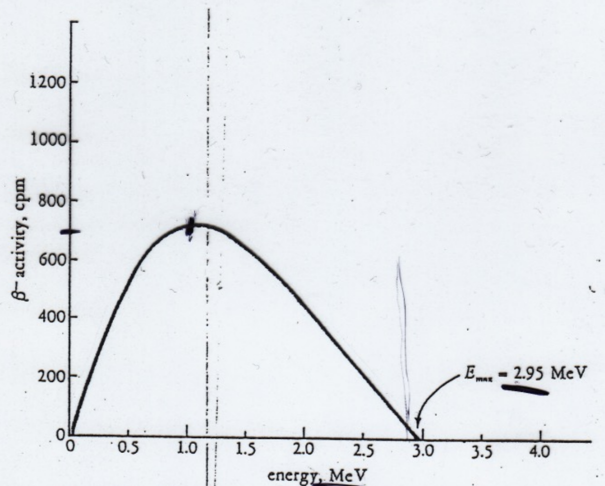


Figure 2–3 **Distribution of the negatron decay activity of In^{115} plotted as a function of the energies of the negative beta particles.**

Decadimento β

- Decadimento negatronico (β^-)

nuclei con un eccesso di neutroni

$$^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}X + {}^{0}_{-1}\beta^- + \bar{\nu}$$ (antineutrino)

$$n \longrightarrow p^+ + e^-$$

$$Q_{\beta^-}(MeV) = -931.5\ (M_{Z+1} - M_Z)$$

$$^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}X^+ + {}^{0}_{-1}\beta + \bar{\nu}$$ emissione di un elettrone

$$^{A}_{Z+1}X^+ + {}^{0}_{-1}e \longrightarrow {}^{A}_{Z+1}X$$ acquisto di un elettrone

Es:

$$^{116}_{49}In \longrightarrow {}^{116}_{50}Sn + {}^{0}_{-1}\beta + Q$$

$M_{116Sn} - M_{116In}$

$$Q_\beta = -931.5\ (M_{116In} - M_{116Sn}) = 931.5\ (115.94096 - 115.93779) =$$
$$= 2.95\ MeV$$

$$Q_\beta = E_{Z+1} + E_\beta$$

$$^{1}_{0}n \xrightarrow{10.6\ min} {}^{1}_{1}H + {}^{0}_{-1}e$$

$$Q_\beta = -931.5\ (1.007825 - 1.008665) = 0.782\ MeV$$

β^+

- Decadimento positronico (nuclei con un eccesso di protoni)

$${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}X^- + {}^{0}_{+1}\beta + \nu \longrightarrow {}^{A}_{Z-1}X + {}^{0}_{+1}\beta + {}^{0}_{+1}e + \nu \text{ (neutrino)}$$

$\rightarrow p^+ \longrightarrow n + \beta^+$

$$Q_{\beta+}(MeV) = -931.5\ (M_{Z-1} + 2\,M_e - M_Z)$$

per ogni elettrone positrone

$$931.5 \times 0.000549 = 0.511 \text{ MeV}$$

Es

$${}^{13}_{7}N \longrightarrow {}^{13}_{6}C + {}^{0}_{+1}\beta^+ + Q$$

$Q_{\beta+} = -931.5\,(13.003354 - 13.005738) - 2 \times 0.511 =$
$= 1.20$ MeV

$${}^{22}_{11}Na \longrightarrow {}^{22}_{10}Ne + 1e^- + {}^{0}_{1}\beta^+ + \nu$$

- Cattura Elettronica (EC)

$$^{A}_{Z}X \xrightarrow{EC} {}^{A}_{Z-1}X$$

$$p^{+} + e^{-} \rightarrow n$$

$$Q_{EC}(MeV) = -931.5\ (M_{Z-1} - M_{Z})$$

Es.:

$$^{195}_{79}Au \xrightarrow{EC} {}^{195}_{78}Pt$$

Nuclei con $Z < 30$ decadono per dec. β^{+}

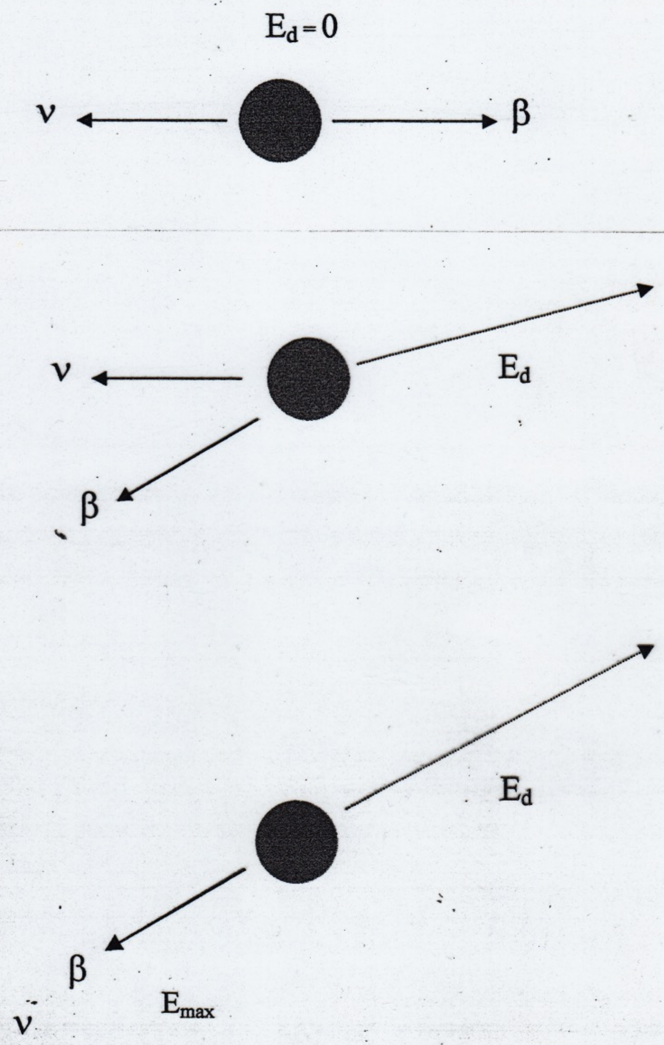
Nuclei con $Z > 80$ " " EC

Entrambi i processi sono osservati per Z fra $30 \div 80$

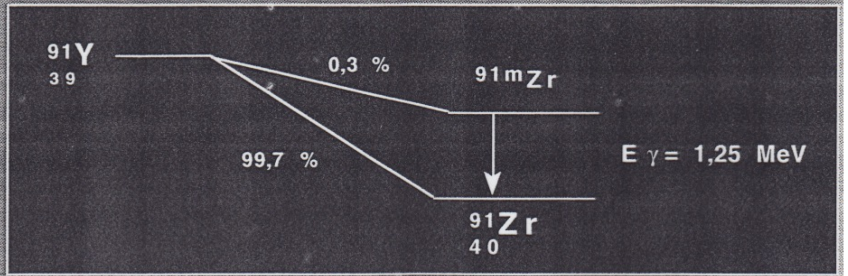
A seconda del guscio si avrà cattura K, cattura L ....

Questo processo crea una vacanza elettronica

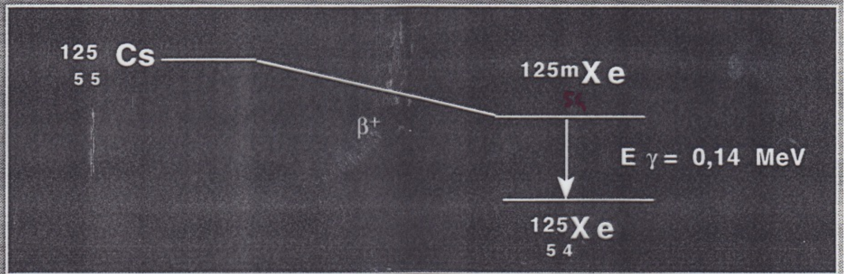
$$Q_\beta = E_d + E_{max}$$



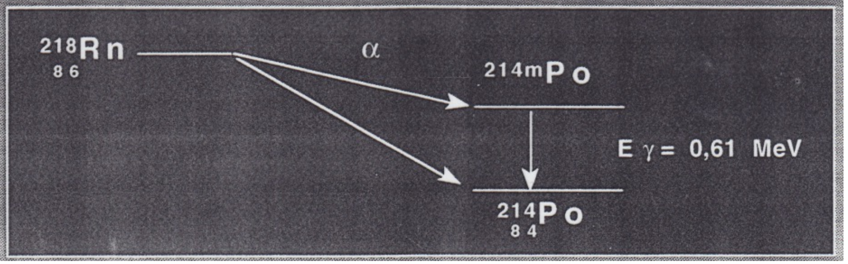
β^-



β^+



α



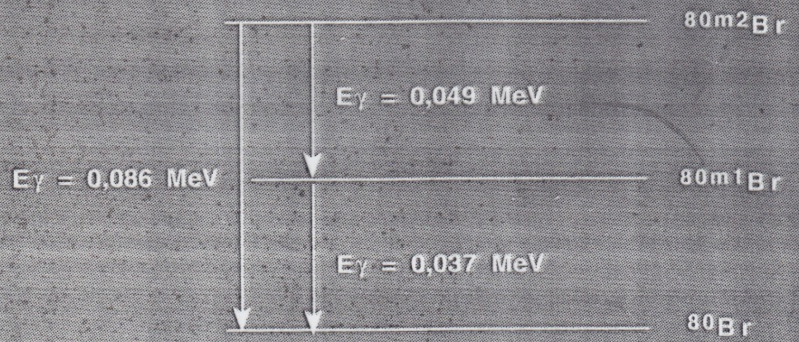
Emissione γ

$$^{Am}_{Z}X \longrightarrow {}^{A}_{Z}X + \gamma$$

(transizione isomerica)

$$^{34m}Cl \xrightarrow{33{,}2\ \text{min}} {}^{34}Cl + \gamma : \quad E\gamma = 3{,}22\ \text{MeV}$$

$$^{60m}Co \xrightarrow{10{,}5\ \text{min}} {}^{60}Co + \gamma : \quad E\gamma = 0{,}059\ \text{MeV}$$



t emissione molto breve ($\sim 10^{-12}$ sec)

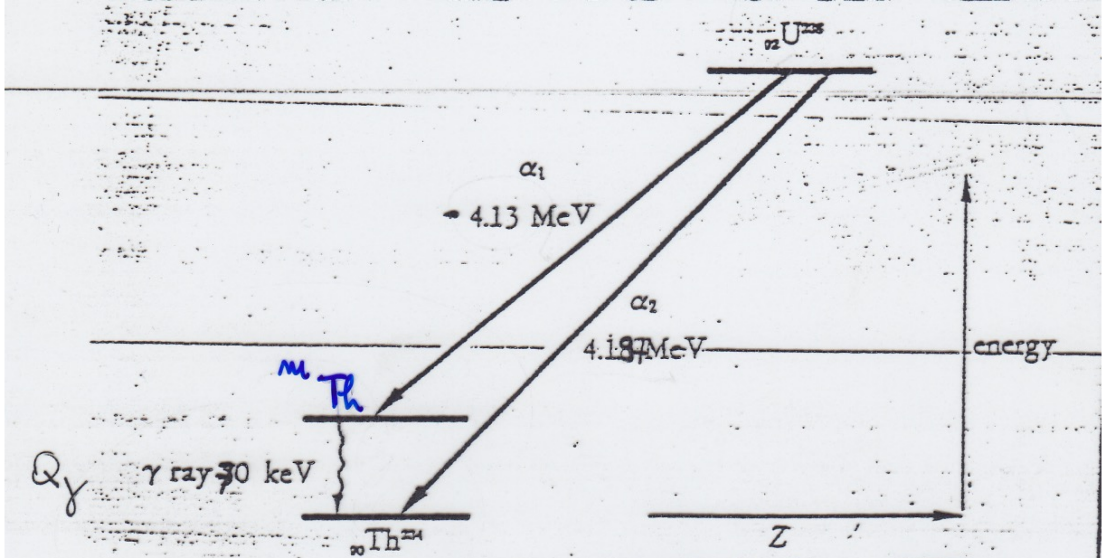


Figure 2–4 Energy relationships in the decay of U^{238} to Th^{234}. Alpha particles of 4.18 and 4.13 MeV and a gamma ray of 0.05 MeV are observed.

$$Q_\gamma = E_d + E_\gamma$$

$$E_d \leq 0{,}1\%\ E_\gamma$$

trascurabile

Conversione Interna

'E il processo alternativo ai raggi γ mediante il quale un nucleo eccitato trasferisce la propria energia a un elettrone di un orbitale interno (elettrone di conversione) che viene pertanto espulso con una certa energia cinetica.

$$Q_\gamma - E_{be} = E_d + E_e$$

trascurabile

elettroni di conversione sono MONOENERGETICI

Rapporto di conversione $= \alpha_i = I_e / I_\gamma$

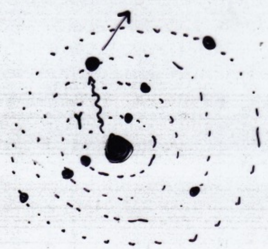
COMPETIZIONE TRA
- EMISSIONE FOTONE γ
- EMISSIONE ELETTRONE DI CONV.

$$\alpha_K = I_{eK} / I_\gamma$$

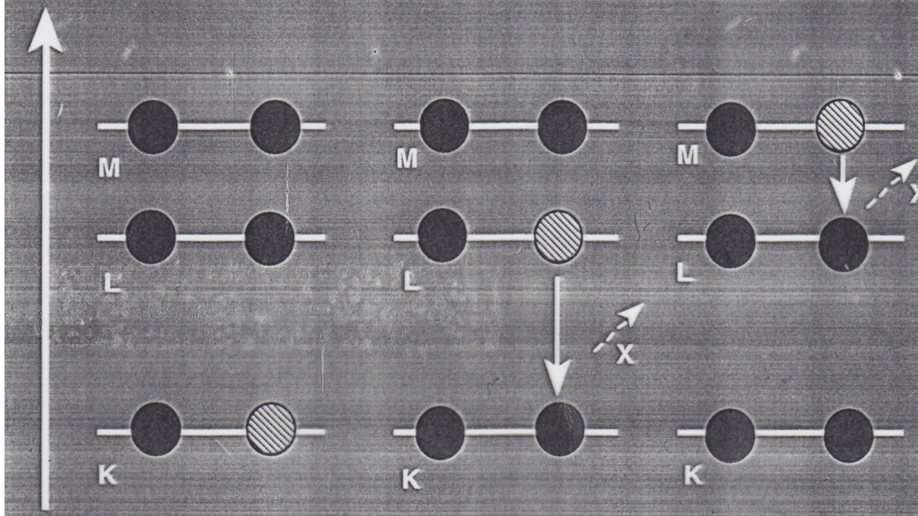
$\alpha_K > \alpha_L > \alpha_M > \ldots$

$${}^{Am}_{Z}X \longrightarrow {}^{A}_{Z}X^{+} + {}^{0}_{1}e \longrightarrow {}^{A}_{Z}X$$

Questo processo crea una vacanza elettronica



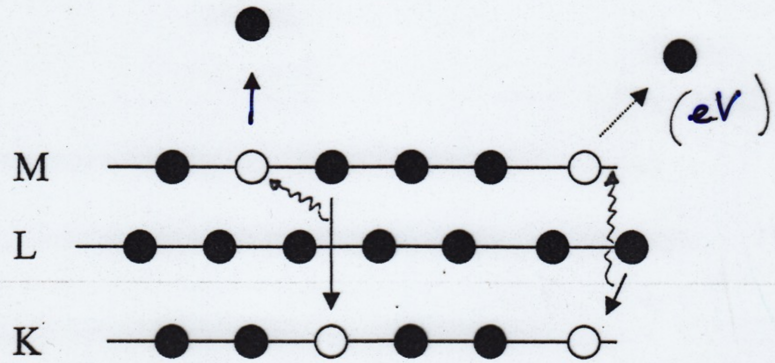
Fluorescenza a raggi X.
Effetto Auger.



$$\text{Resa di fluorescenza} = \frac{\text{n. di fotoni X emessi}}{\text{n. di vacanze elettroniche iniziali}}$$

Effetto Auger

(effetto fotoelettrico interno



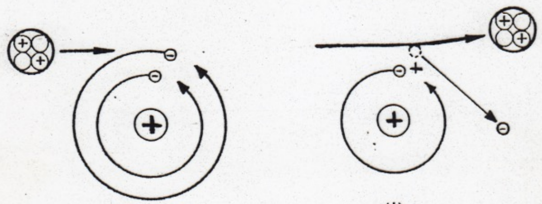
Lascia l'atomo in uno alto stato di carica

- è in competizione con l'emissione di raggi X (fluorescenza)

Interazione delle Radiazioni con la Materia

34 eV per coppia ionica formata

IONIZZAZIONE

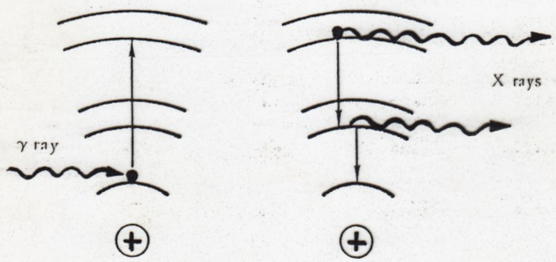


(a) (b)

Formation of an ion pair: (a) alpha particle approaches an orbital electron and (b) causes it to leave the atom, producing an ion pair.

L'elettrone emesso può portare alla emissione di elettroni secondari

FLUORESCENZA



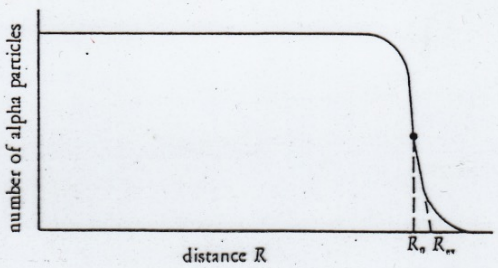
(a) (b)

Fluorescence: (a) the gamma ray excites the electron to jump to a higher energy level; (b) the electron falls back to the original level in two steps, with X rays or visible light emitted in each step.

> IONIZZAZIONE < CAPACITÀ DI PENETRARE LA MATERIA

Particelle α

$$R\,(cm) = 0.309\,E^{3/2}$$



Number of alpha particles plotted as a function of distance from their source. R_0 is the range calculated from the value of R at the inflection point on the range curve; R_{ex} is the range obtained from a line tangent to the curve at the inflection point.

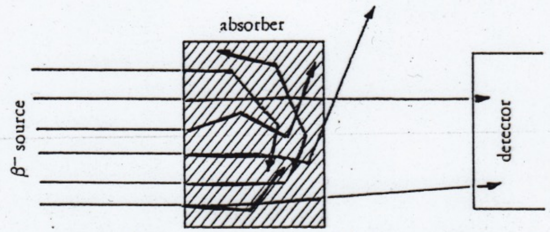
Sono poco deflesse

Viaggiano in linea

Basso potere penetrante (< liquidi > gas)

Alto potere ionizzante

Particelle β



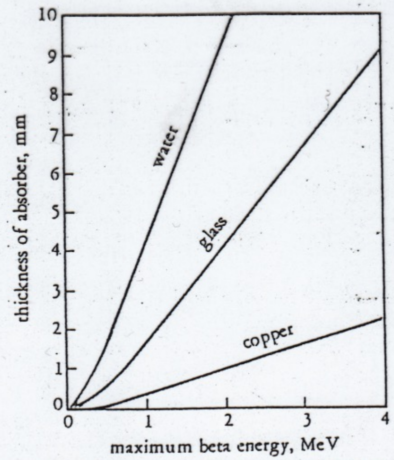
Scattering of beta particles in an absorber, illustrating that the range measured by the detector is not a measure of the total path traveled by the electrons because of the wide-angle deflections.

Perdono energia in 1 collisione

Sono molto deflesse

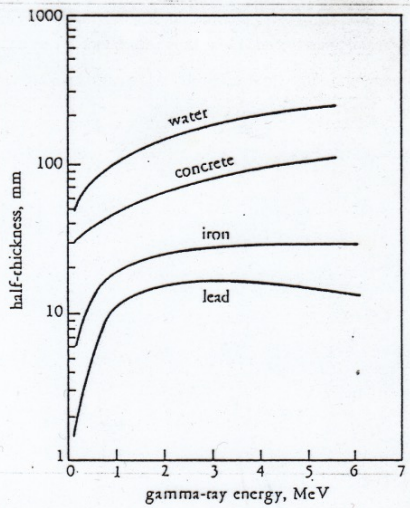
Buon ~~alto~~ potere penetrante

Alta ionizzazione secondaria (elettroni emessi ad alta energia) 70-80 %



Plot of absorber thicknesses required to stop beta rays completely.

Raggi γ



Plot of absorber thicknesses required to reduce gamma-ray intensity to one-half the original intensity.

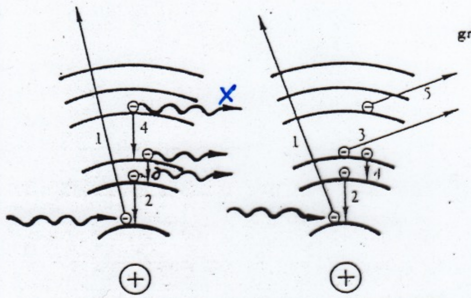
Alto potere penetrazione

Basso potere ionizzazione

Alto ionizzazione secondaria

Perdono energia in 1 collisione (ma è poco probabile)

$E_e = E\gamma - IP$

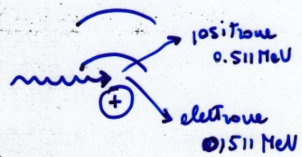


(a) X-ray emission (b) Auger-electron emission

The photoelectric effect: (a) following ionization of a K-shell electron (1), electrons from higher shells successively fall to the vacancies in the lower shells (2, 3, 4) with simultaneous emission of X rays; (b) following ionization, further electron emission occurs in competition with X-ray emission subsequent to the fall of electrons to lower energy levels.

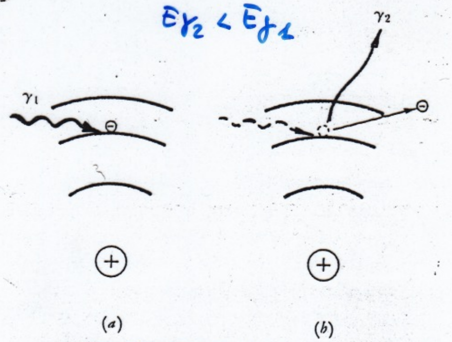
bone energie raggi γ e elementi pesanti

PAIR PRODUCTION



$E_\gamma > 1{,}02$ MeV

$E_{\gamma_2} < E_{\gamma_1}$

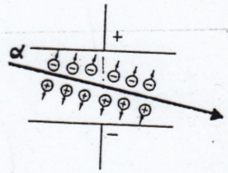


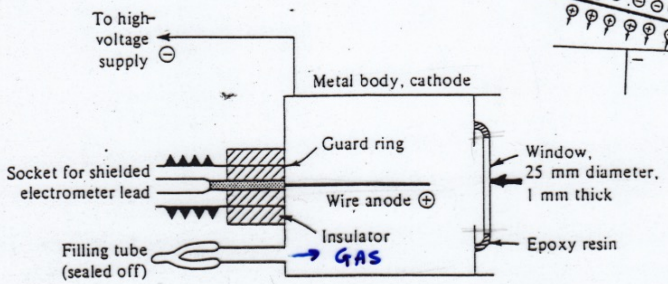
The Compton effect: (a) the gamma ray approaches the orbital electron and (b) excites it above the

Tecniche di Rivelazione delle Radiazioni

- Emulsioni fotografiche (producono tracce scure)
  si può distinguere tra α, β, γ

- Contatori a ionizzazione





per le particelle a prodotte nel decadimento dell'^{238}U aventi 4.18 MeV di energia, che formeranno 1.18×10^5 coppie ioniche:

$$Q = (1.18 \times 10^5)(1.6 \times 10^{-19}) = 1.9 \times 10^{-14} \text{ Coulomb}$$

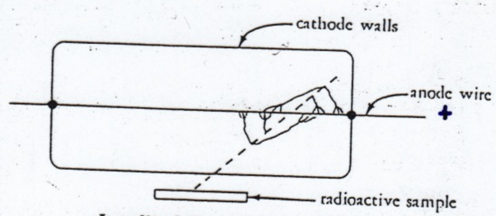
Deve essere amplificato.

- Contatori proporzionali

Distinzione α e β

non buono per γ

Amplifica 10^3-10^5 volte il segnale



Localized electron multiplication at the center anode wire in a proportional counter.

Ar/CH_4

- Contatori Geiger Müller

(non dà segnale continuo)

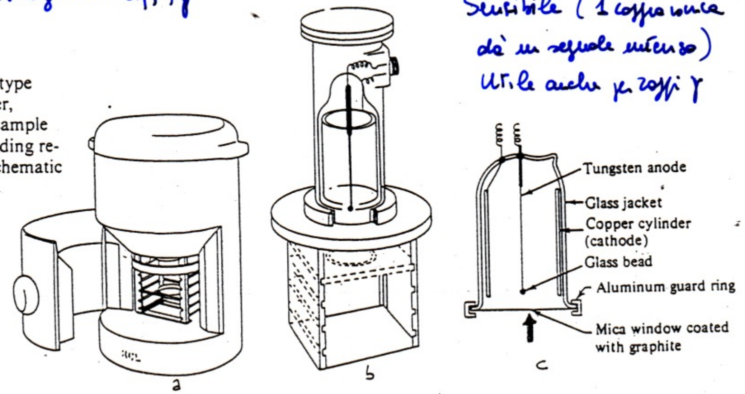
Non distinguono α, β, γ

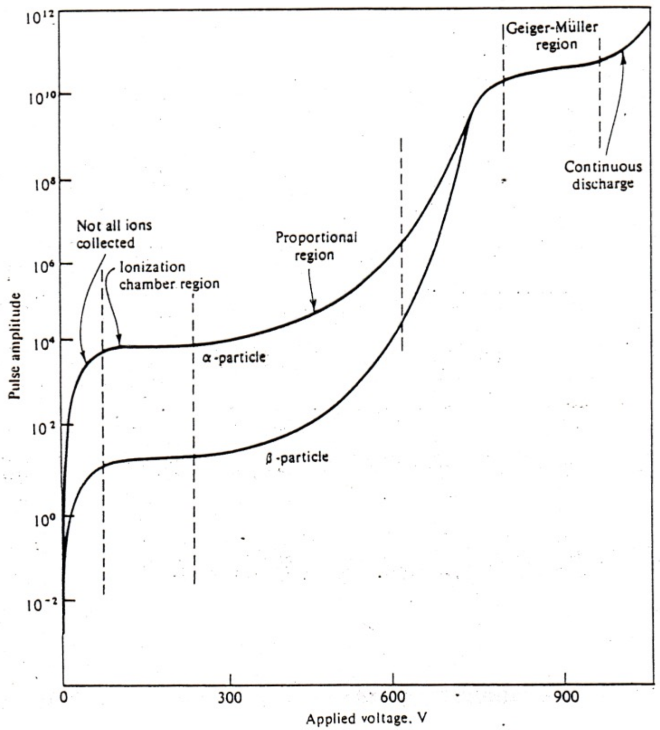
Sensibile (1 coppia ionica dà un segnale intenso)

Utile anche per raggi γ

(a) End-window type of Geiger counter, (b) counter and sample holder with shielding removed, and (c) schematic of counter.

Amplificazione 10^8





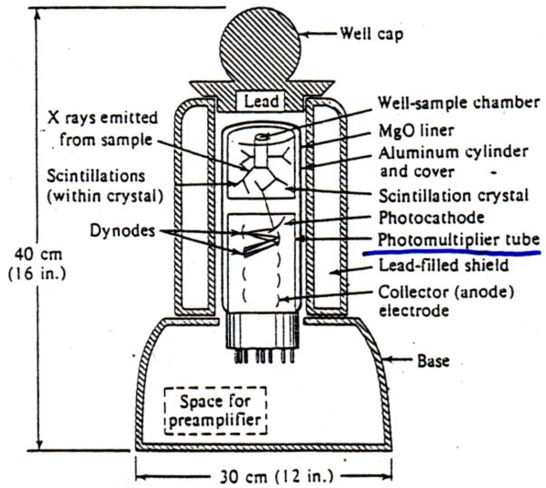
- Contatori a Scintillazione (α, β e soprattutto γ)

Alta velocità di conteggio.

NaI/Tl

ZnS (α)

Antracene (β)



- Rivelatori Semiconduttori

Creano vacanze elettroniche alterando la conducibilità della materia

	Counter			
	Ionization chamber	*Proportional*	*G.M.*	*Scintillation*
Normal detection state	gas	gas	gas	liquid or solid
Radiation usually counted	α, β	α, β	α, β, γ	α, β, γ
Multiplication of primary charge	1	10^4	10^8	10^8
Complexity of total system	medium	high	low	high
Particular advantages	simplicity; measurement of alpha energies	high count rates	simplicity; adaptability	high count rates; measurement of gamma energies