22.01 - Recitation #3

- Please grab a snack, get up off the sofa, look at something that isn't a screen for 5 mins!
- Please turn on your video (if possible) and mute yourself.
- These slides are at: *bit.ly/2201Rec3*

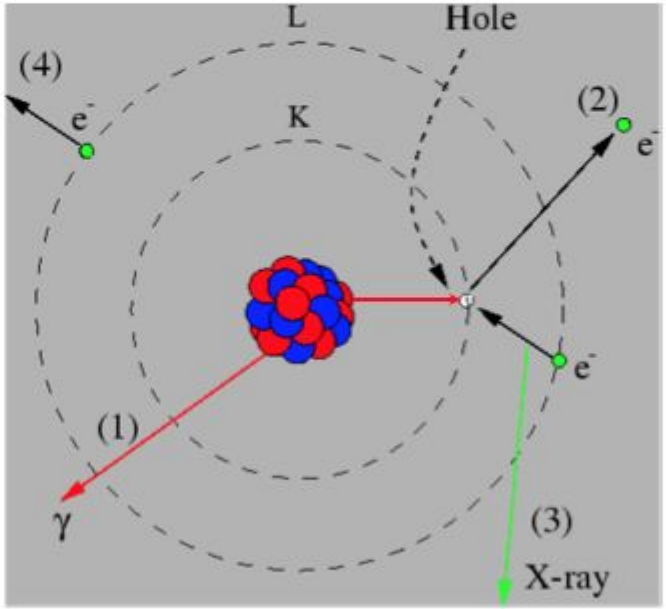
Outline + Intended Learning Outcomes (ILOs)

Decay processes

Decay particle energies

Semi-Empirical Mass Formula (SEMF)

Decay	Individual Particle Reaction	Full Nuclear Reaction
Alpha	a	${}^{A}_{Z}X_{N} \longrightarrow {}^{A-4}_{Z-2}X'_{N-2} + \alpha$
Beta -	$n \rightarrow p + e^{-} + \bar{\nu}$	${}^{A}_{Z}X_{N} \rightarrow {}^{A}_{Z+1}X'_{N-1} + e^{-} + \bar{\nu}$
Beta +	$p \rightarrow n + e^{+} + \nu$	${}^{A}_{Z}X_{N} \rightarrow {}^{A}_{Z-1}X'_{N+1} + e^{+} + \nu$
Electron Capture	$p + e^{-} \rightarrow n + \nu$	${}^{A}_{Z}X_{N} + e^{-} \rightarrow {}^{A}_{Z-1}X'_{N+1} + \nu$
Gamma (IT)	γ	${}^{A}_{Z}X^{*} \rightarrow {}^{A}_{Z}X + \gamma$
Internal Conversion	e^{-}	${}^{A}_{Z}X^{*} \rightarrow {}^{A}_{Z}X + e^{-}$


L
Hole
(4)
e⁻
K
(2)
e⁻
e⁻
(1)
γ
(3)
X-ray

Decay	Individual Particle Reaction	Full Nuclear Reaction
Alpha	a	${}^{A}_{Z}X_{N} \longrightarrow {}^{A-4}_{Z-2}X'_{N-2} + \alpha$
Beta -	$n \rightarrow p + e^{-} + \bar{\nu}$	${}^{A}_{Z}X_{N} \rightarrow {}^{A}_{Z+1}X'_{N-1} + e^{-} + \bar{\nu}$
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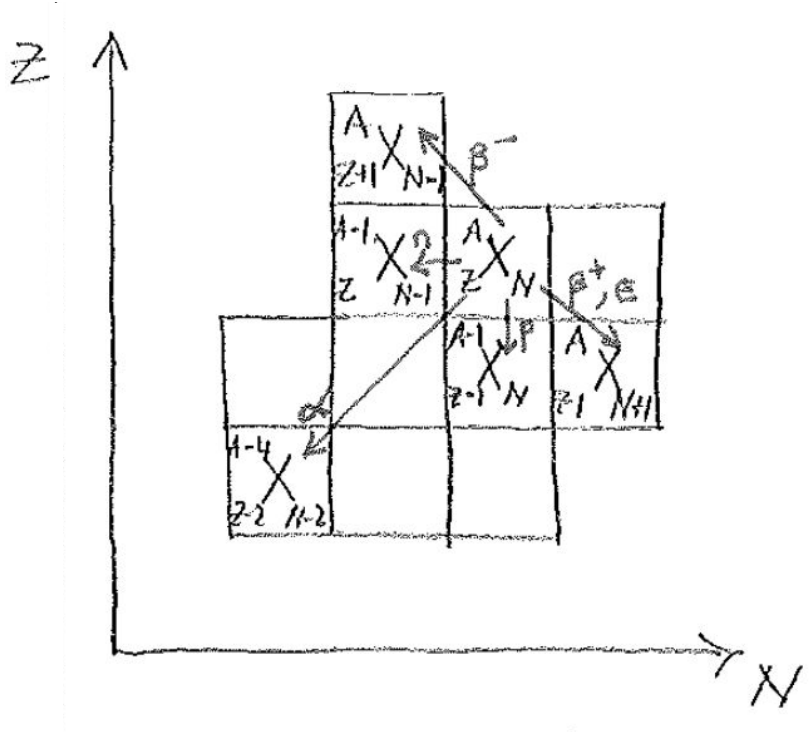
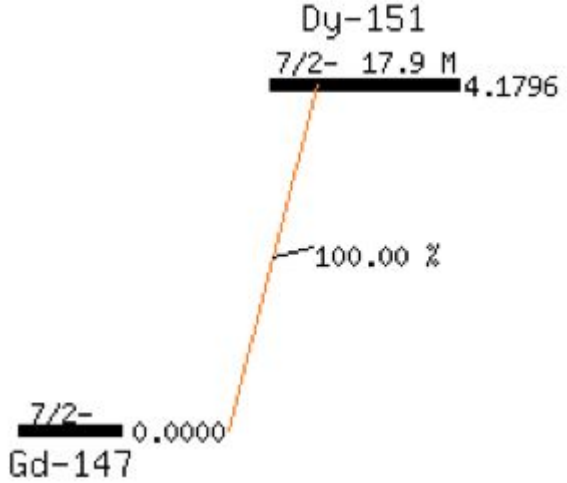
Gamma (IT)	γ	${}^{A}_{Z}X^{*} \rightarrow {}^{A}_{Z}X + \gamma$
Internal Conversion	e^{-}	${}^{A}_{Z}X^{*} \rightarrow {}^{A}_{Z}X + e^{-}$
...	*X-ray or Auger electron*	*N/A*

Decay Processes

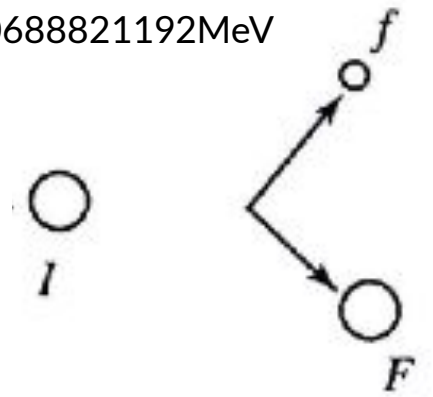


Energy spectra

Alpha: $${}^{A}_{Z}X_N \longrightarrow {}^{A-4}_{Z-2}X'_{N-2} + \alpha$$



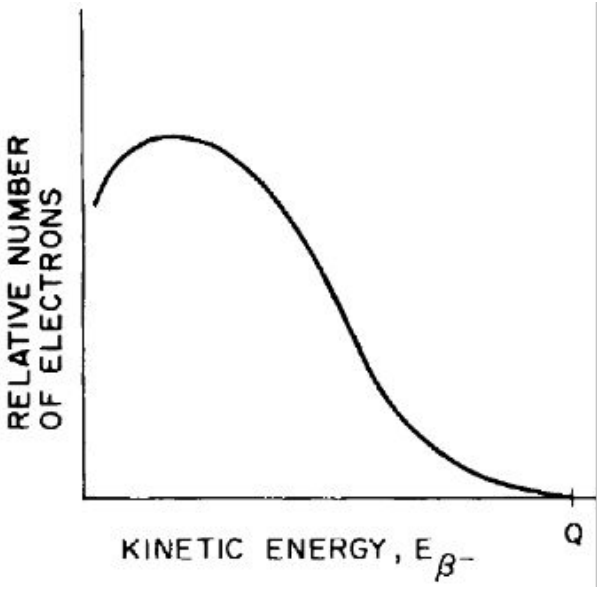
4.0688821192MeV

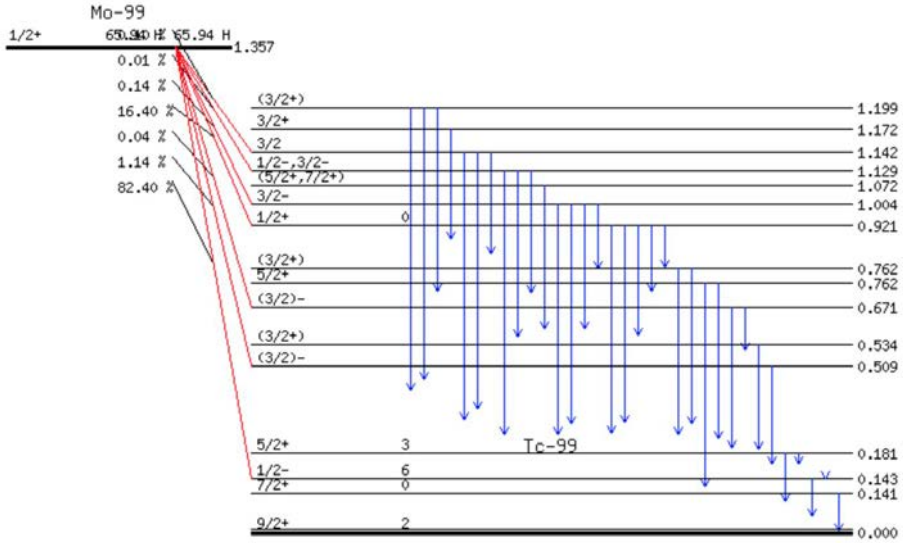


$$T_a = \frac{m_{X'}}{m_a + m_{X'}} Q$$

Energy spectra

Beta: $$ {}^{A}_{Z}X_N \rightarrow {}^{A}_{Z+1}X'_{N-1} + e^- + \bar{\nu} $$





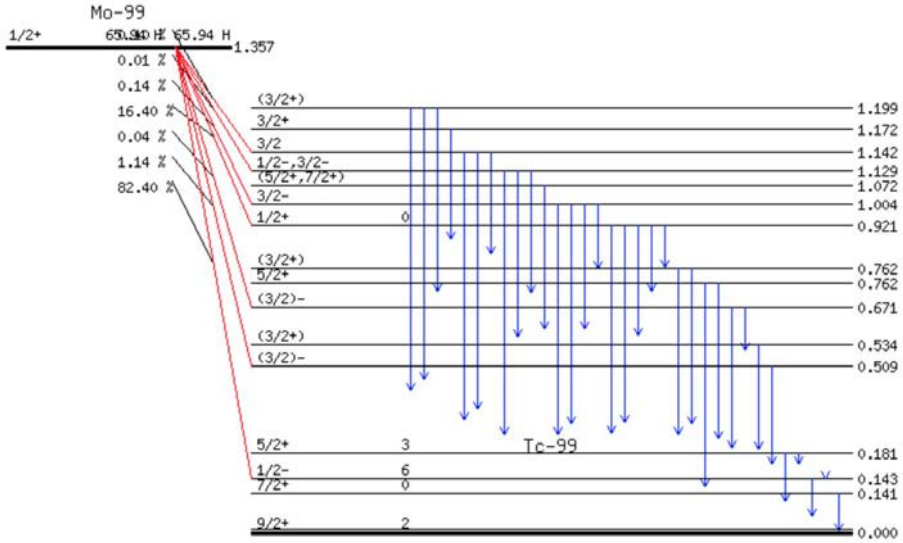
β⁻ rays:

Max. E (keV)	Avg. E (keV)	Intensity (rel)	Spin 1/2+
1215.1(-)	442.9(5)	82.2(4)	1/2-
848.7(-)	289.7(4)	1.16(2)	3/2-
686.3(-)	225.5(4)	0.057(3)	3/2-
437.2(-)	133.2(4)	16.4(3)	1/2+
353.7(-)	104.4(4)	0.146(5)	3/2(-)
228.7(-)	63.9(4)	0.012(1)	(3/2)-
215.9(-)	60.0(3)	0.111(3)	3/2+
185.6(-)	50.8(3)	0.0019(4)	3/2+
158.9(-)	42.9(3)	0.0021(4)	(3/2-)

•••

Energy spectra

Gamma: $${}^{A}_{Z}X^{*} \rightarrow {}^{A}_{Z}X + \gamma$$

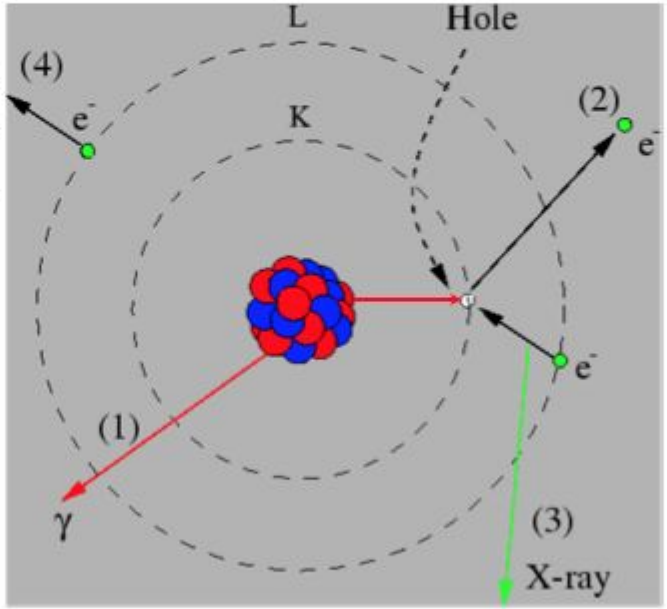


...

...

Auger electron emission

$\mathbf{KE = E_f - E_i - E_{Auger}}$



Internal conversion

$E_{e^-} = E_\gamma - E_b$

Normal *gamma ray* emission

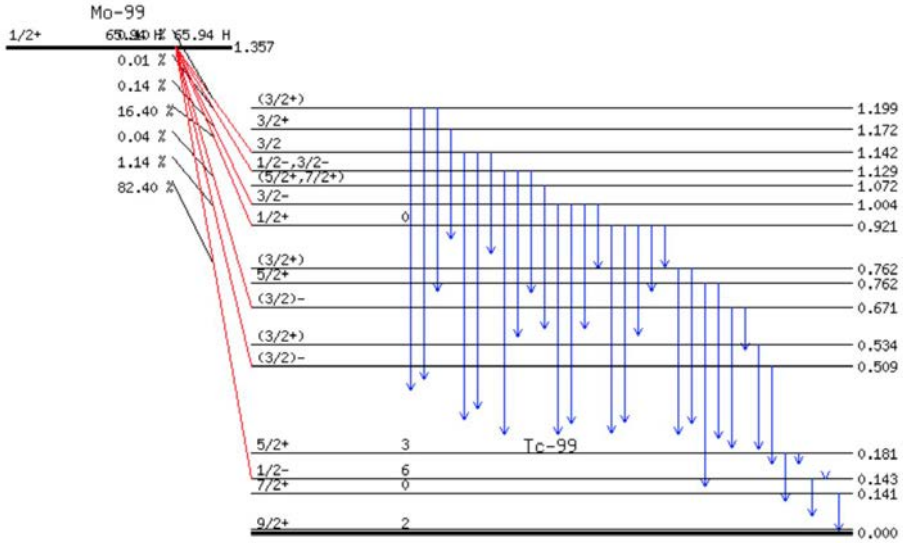
$\mathbf{E_\gamma = Q}$

Subsequent *x-ray* emission

$\mathbf{(K_\alpha, K_\beta, L_\alpha \ldots)}$

Energy spectra

Internal conversion:



...

Semi-Empirical Mass Formula

$$B(A, Z) = a_v A - a_s A^{2/3} - a_c \frac{Z(Z-1)}{A^{1/3}} - a_a \frac{(N-Z)^2}{A} + \delta \qquad (4.10)$$

a_v	a_s	a_c	a_a	a_p	
16	18	0.72	23.5	11	MeV

$\delta = a_p/\sqrt{A}$	even-even nuclei
$= 0$	even-odd, odd-even nuclei
$= -a_p/\sqrt{A}$	odd-odd nuclei

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Office Hour 3-**4**pm Monday

Questions?

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22.01 Introduction to Nuclear Engineering and Ionizing Radiation

Spring 2024