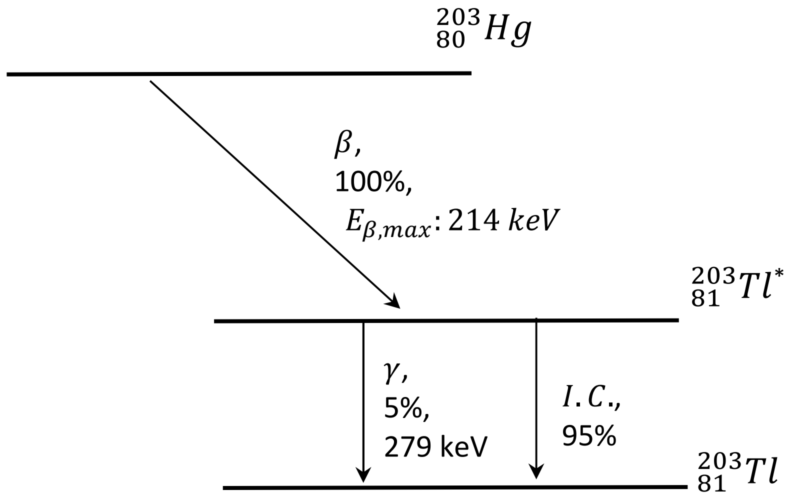
NPRE 441, Spring 2023
Quiz 1, 02-01-2023 Your Name:

**Q1.** (25 points): Plot the energy spectrum for all types of radiation emitted by $^{203}_{80}Hg$.

$$^{203}_{80}Hg \rightarrow \ ^{203}_{81}Tl + \ ^{0}_{-1}\beta + \ ^{0}_{0}\bar{\nu}$$




Note:

1. The binding energies for k-shell, L-shell, and M-shell electrons in a $^{203}_{81}Tl$ atom are given in the following table.

| Binding energies for $^{203}$Tl | |
|---|---|
| K | 85.529 keV |
| $L_I$ | 15.347 keV |
| $L_{II}$ | 14.698 keV |
| $L_{III}$ | 12.657 keV |
| M | 3.704 keV |

2. Within the energy spectrum, please draw all the sub-spectra corresponding to beta particles, conversion electrons, gamma rays, auger electrons, characteristics X-rays, etc. (25 points)
3. Whenever possible, please also mark on the individual sub-spectra with the following information: the energy characteristics and relative intensity (probability of emission per $^{203}_{80}Hg$ decay) of each type of particle. (25 points)

**Q2**: (25-points) Nuclide A decays into B by $\beta^+$ emission (24%) or by electron capture (76%). The major radiations, energies (MeV), and frequencies per disintegration are,

$\beta^+$: 1.62 max (16%), 0.98 max (8%)

$\gamma$: 1.51 (47%), 0.64 (55%), 0.511 (48%, $\gamma^\pm$)

Daughter X-rays

$e^-$ : 0.614

(a) Draw the nuclear decay scheme, labeling type of decay, percentage, and energies.
(b) What leads to the emission of daughter X-rays?

**Q3**. A 40-mg sample of pure $^{226}$Ra is encapsulated. (25-pts)

**(a)** How long will it take for the activity of $^{222}$Rn to build up to 10 mCi?

**(b)** What will be the activity of $^{222}$Rn after 2 years?

**(c)** What will be the activity of $^{222}$Rn after 1000 years?

**(d)** What is the ratio of the specific activity of $^{222}$Rn to that of $^{226}$Ra?

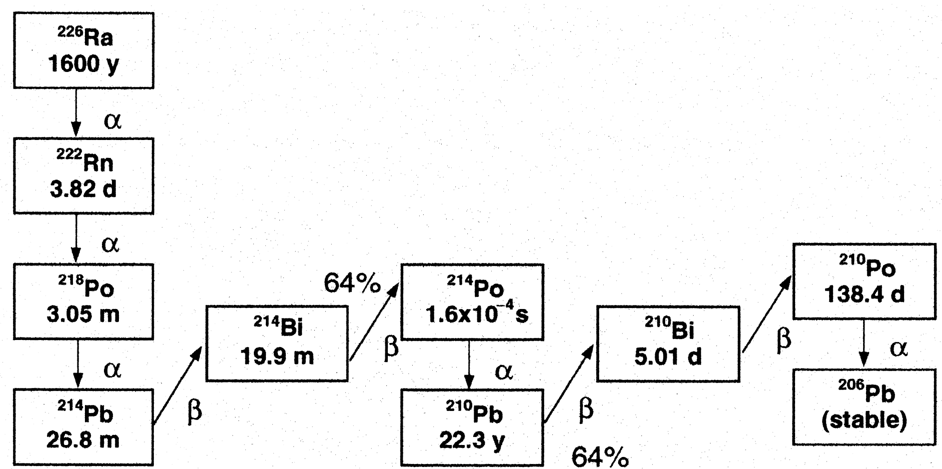



**Figure 3.11** The $^{226}$Ra decay series.

**Q4**. (25 points) Serial Decay

Consider a general case of serial decay scheme involving 4 isotopes, $A \overset{\lambda_A}{\rightarrow} B \overset{\lambda_B}{\rightarrow} C \overset{\lambda_C}{\rightarrow} D$, with the final product *D* being a stable isotope. The decay constants for isotopes *A*, *B* and *C* are $\lambda_A$, $\lambda_B$, and $\lambda_C$ respectively.

Assume that at *t*=0, there is only isotope *A* exists, whose activity is $Q_A$. Please derive the equations for the activities $Q_A$, $Q_B$, and $Q_C$ from *A*, *B* and *C* as a function of time.

Hint: For the first-order linear differential equation of the form

$$\frac{dy}{dx} + P(x)y = Q(x), \qquad (1)$$

and may be integrable by multiplying both sides of the equation by

$$e^{\int P\,dx} = e^{\int \lambda_B\,dt} = e^{\lambda_B t},$$

and the solution to Eq. (1) is

$$ye^{\int P\,dx} = \int e^{\int P\,dx} \cdot Q\,dx. \qquad (2)$$