Alpha, Beta, and Gamma Decay

1) Determine whether these decay processes are possible.
   a) $^{212}_{84}\text{Po} \rightarrow ^{210}_{86}\text{Rn} + ^{4}_{2}\alpha$  
      (No)

   Charge: 84 ≠ 86 + 2
   Atomic Mass number: 212 ≠ 210 + 4
   This equation violates the laws of conservation of charge and of atomic mass number. Therefore, this decay process is impossible.

   b) $^{233}_{91}\text{Pa} \rightarrow ^{233}_{92}\text{U} + ^{0}_{-1}\beta$  
      (Yes)

   Charge: 91 = 92 − 1
   Atomic mass number: 233 = 233
   This equation is correct—both mass number and charge are conserved. Therefore, this decay process is possible.

   c) $^{14}_{7}\text{C} \rightarrow ^{14}_{7}\text{N} + ^{1}_{1}\text{H}$  
      (No)

   Charge: 6 ≠ 7 + 1
   Atomic mass number: 14 ≠ 14 + 1
   This equation violates the laws of conservation of charge and of atomic mass number. Therefore, this decay process is impossible.

2) Write the $\alpha$-decay process for these elements, and name the parent and daughter elements.
   All alpha decay processes fit the pattern $^{A}_{Z}\text{X} \rightarrow ^{A-4}_{Z-2}\text{Y} + ^{4}_{2}\alpha$.

   a) $^{230}_{90}\text{Th}$  
      [thorium, radium]

   For thorium-230, the daughter element is $^{230-4}_{90-2}\text{Y} = ^{226}_{88}\text{Y}$.
   On the periodic table, the element with Z = 88 is radium.
   $^{230}_{90}\text{Th} \rightarrow ^{226}_{88}\text{Ra} + ^{4}_{2}\alpha$

   b) $^{238}_{92}\text{U}$  
      [uranium, thorium]

   For uranium-238, the daughter element is $^{238-4}_{92-2}\text{Y} = ^{234}_{90}\text{Y}$.
   On the periodic table, the element with Z = 90 is thorium.
   $^{238}_{92}\text{U} \rightarrow ^{234}_{90}\text{Th} + ^{4}_{2}\alpha$
c) \(^{214}\text{Po}_{84}\)  

For polonium-214, the daughter element is \(^{214}\text{Po}_{84} \rightarrow ^{210}\text{Po}_{82} + ^{4}\text{He}\).

On the periodic table, the element with \(Z = 82\) is lead.

\[^{214}\text{Po}_{84} \rightarrow ^{210}\text{Po}_{82} + ^{4}\text{He}\]

3) Calculate the energy released during \(\alpha\)-decay of these nuclei:

a) \(^{230}\text{Th}_{90} \rightarrow ^{226}\text{Ra}_{88} + ^{4}\text{He}\)

\[E = 7.641 \times 10^{-13} \text{ J}\]

\[\Delta m = 5.12 \times 10^{-3} \text{ u} \times \left(\frac{1.66 \times 10^{-27} \text{ J}}{\text{u}}\right) = 8.5 \times 10^{-20} \text{ kg}\]

\[E = m \cdot c^2 = 8.5 \times 10^{-20} \text{ kg} \times \left(\frac{1.66 \times 10^{-27} \text{ J}}{\text{u}}\right) = 7.651 \times 10^{-13} \text{ J}\]

b) \(^{238}\text{U}_{92} \rightarrow ^{234}\text{Th}_{90} + ^{4}\text{He}\)

\[E = 6.839 \times 10^{-13} \text{ J}\]

\[\Delta m = 4.584 \times 10^{-3} \text{ u} = 7.60944 \times 10^{-30} \text{ kg}\]

\[E = \Delta m \cdot c^2 = 7.60944 \times 10^{-30} \cdot (3.00 \times 10^{8})^2 = 6.848 \times 10^{-13} \text{ J}\]

c) \(^{214}\text{Po}_{84} \rightarrow ^{210}\text{Po}_{82} + ^{4}\text{He}\)

\[E = 1.255 \times 10^{-12} \text{ J}\]

\[\Delta m = 8.409 \times 10^{-3} \text{ u} = 1.395894 \times 10^{-29} \text{ kg}\]

\[E = \Delta m \cdot c^2 = 1.395894 \times 10^{-29} \cdot (3.00 \times 10^{8})^2 = 1.256 \times 10^{-12} \text{ J}\]
4) Find the elements produced by $\beta^-$ decay of:

Use the pattern $\frac{1}{2}X \rightarrow Z_{-1}X + 0^+\beta^-$. The atomic number must increase by one without changing the atomic mass number.

a) $^{228}_{88}Ra \rightarrow ^{228}_{89}Ac^+ + 0^-\beta^-$

b) $^{212}_{82}Pb \rightarrow ^{212}_{83}Bi^+ + 0^-\beta^-$

5) For thallium-202:

a) What isotope will $\beta^+$ decay of thallium-202 produce? [mercury-202]

During $\beta^+$ decay, the atomic number decreases by 1. When the atomic number of thallium decreases by 1, it becomes $Z - 1 = 81 - 1 = 80$, which is the atomic number for mercury.

b) Write the process for this decay. $^{202}_{81}Tl \rightarrow ^{202}_{80}Hg + 0^+\beta^+ + \nu$

Use the general pattern $\frac{1}{2}X \rightarrow Z_{-1}Y + 0^+\beta^- + \nu$ for $\beta^+$ decay: $^{202}_{81}Tl \rightarrow ^{202}_{80}Hg + 0^+\beta^+ + \nu$

c) How much energy will be released by the decay of the thallium-202 nucleus if the mass of the thallium nucleus decreases by 0.001 463 u? [0.3400 MeV]

$\Delta m = 0.001463 u - 2(5.485799u \times 10^{-4})$

$\Delta m = 3.658402 u \times 10^{-4}$

E = 3.658402 u x 10^{-4} (931.5 MeV/u)

E=0.3408 MeV

6) Identify each type of decay in this series, and name the parent and daughter elements.

(a) $^{232}_{90}Th \rightarrow ^{238}_{90}Ra^* + 2\alpha$ [alpha, thorium, radium]

(b) $^{209}_{32}Na \rightarrow ^{209}_{32}Ne + 1\beta^- + \nu$ [beta, sodium, neon]

(c) $^{228}_{92}Ra^* \rightarrow ^{228}_{92}Ra + \gamma$ [gamma]

(d) $^{226}_{88}Ra \rightarrow ^{226}_{86}Ac + 1\beta^- + \bar{\nu}$ [beta, radium, actinium]

(e) $^{232}_{90}Ac \rightarrow ^{232}_{90}Th + 1\beta^- + \bar{\nu}$ [beta, actinium, thorium]

(f) $^{230}_{90}Th \rightarrow ^{230}_{90}Ra + 1\alpha$ [alpha, thorium, radium]

(g) $^1p \rightarrow 0n + 1\beta^- + \nu$ [beta, proton, neutron]