

1. Consider the atom denoted by  $^{183}_{79}\text{Au}$ .

The common name of this element is: **gold**

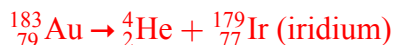
It has **79** electrons, **79** protons, and  **$183 - 79 = 104$**  neutrons.

This atom is radioactive and decays by alpha decay with a half-life of 49 seconds.

Determine the fraction of its atoms that decay in each second (i.e., determine its decay constant).

$$\lambda = (0.693)/t_{1/2} = (0.693)/(49 \text{ s}) = 0.0141/\text{s}.$$

Write down the decay of this atom and determine the new atom that results.



The new atom has **77** protons and **102** neutrons in its nucleus.

2. Consider the atom denoted by  $^{199}_{79}\text{Au}$ .

It has **79** electrons, **79** protons, and **120** neutrons.

This atom is radioactive and decays by beta decay with a half-life of 3.15 days.

Determine the fraction of its atoms that decay in each second (i.e., determine its decay constant).

$$\begin{aligned}\lambda &= (0.693)/t_{1/2} = (0.693)/(3.15 \text{ days} \times 24 \text{ h/day} \times 60 \text{ min/h} \times 60 \text{ s/min}) \\ &= 2.55 \times 10^{-6}/\text{s}.\end{aligned}$$

Write down the decay of this atom and determine the new atom that results.



The new atom has **80** protons and **119** neutrons in its nucleus.

Suppose you had a sample of  $1.00 \times 10^{20}$  atoms of  $^{199}_{79}\text{Au}$  at time  $t = 0.00$  days. Determine the number of atoms remaining after:

2 days:  $(1.00 \times 10^{20})e^{-0.693(2 \text{ d})/(3.15 \text{ d})} = (1.00 \times 10^{20})e^{-0.44} = 6.44 \times 10^{19}$

One week:  $(1.00 \times 10^{20})e^{-0.693(7 \text{ d})/(3.15 \text{ d})} = (1.00 \times 10^{20})e^{-1.54} = 2.14 \times 10^{19}$

One month (30 days):  $(1.00 \times 10^{20})e^{-0.693(30 \text{ d})/(3.15 \text{ d})} = 1.36 \times 10^{17}$

One year: The answer calculates to something times  $10^{-15}$  atoms! Just call it 0. This just means it is highly, highly unlikely that even one atom remains.

10 years and one century: Also 0, of course.

How many days will it take for 90% of the initial atoms to decay?

We need to find  $D$  such that  $e^{-0.693 D/(3.15 \text{ d})} = 1 - 0.90 = 0.10$ . Taking the natural logarithms of both sides,

$$-0.693 D/(3.15 \text{ d}) = \ln(0.10) = -2.30 \text{ so } D = \frac{-2.30}{-0.693/3.15} = 10.5 \text{ days}$$

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**3. The constituents of neutrons and protons are up and down quarks (no others). Each consists of three quarks. Determine the number of up and down quarks for each type of nucleon:**

**Neutron:** One up quark and two down quarks

The neutron is neutral, with total electric charge of 0. Since the up and down quarks have, respectively, charges of  $+2e/3$  and  $-e/3$ , the only way to combine three of these to have 0 total electric charge is to use one up quark and two down quarks.

**Proton:** Two up quarks and one down quarks

The proton has total electric charge  $+e$ . Since the up and down quarks have, respectively, charges of  $+2e/3$  and  $-e/3$ , the only way to combine three of these to have a total electric charge of  $+e$  is to use two up quarks and one down quark.

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