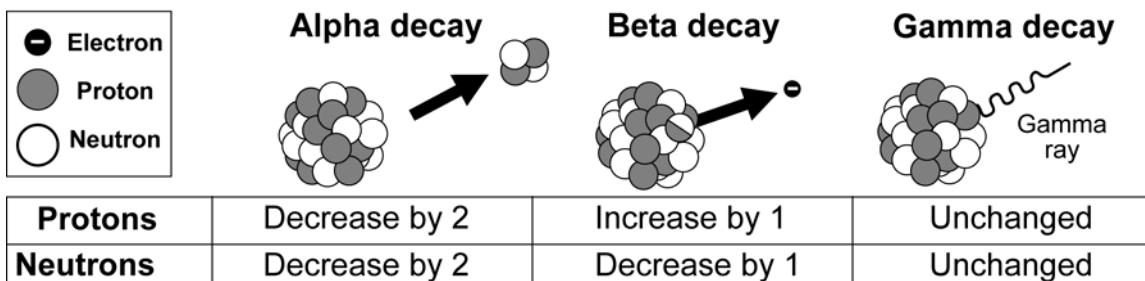


# Radioactivity



There are three main types of radiation that involve the decay of the nucleus of an atom:

- **alpha radiation** ( $\alpha$ ): release of a helium-4 nucleus (two protons and two neutrons). We can represent helium-4 using isotope notation:  ${}^4_2\text{He}$ . The top number, 4, represents the mass number, and the bottom number represents the atomic number for helium, 2.
- **beta radiation** ( $\beta$ ): release of an electron.
- **gamma radiation** ( $\gamma$ ): release of an electromagnetic wave.



## Half-life

The time it takes for half of the atoms in a sample to decay is called the half-life. Four kilograms of a certain substance undergo radioactive decay. Let's calculate the amount of substance left over after 1, 2, and 3 half-lives.

- After one half-life, the substance will be reduced by half, to 2 kilograms.
- After two half-lives, the substance will be reduced by another half, to 1 kilogram.
- After three half-lives, the substance will be reduced by another half, to 0.5 kilogram.

So, if we start with a sample of mass  $m$  that decays, after a few half-lives, the mass of the sample will be:

Number of half-lives	Mass left	
1	$\frac{1}{2^1}m =$	$\frac{1}{2}m$
2	$\frac{1}{2^2}m =$	$\frac{1}{4}m$
3	$\frac{1}{2^3}m =$	$\frac{1}{8}m$
4	$\frac{1}{2^4}m =$	$\frac{1}{16}m$

**PRACTICE** 

- The decay series for uranium-238 and plutonium-240 are listed below. Above each arrow, write “a” for alpha decay or “b” for beta decay to indicate which type of decay took place at each step.
  - $${}_{92}^{238}\text{U} \rightarrow {}_{90}^{234}\text{Th} \rightarrow {}_{91}^{234}\text{Pa} \rightarrow {}_{92}^{234}\text{U} \rightarrow {}_{90}^{230}\text{Th} \rightarrow$$

$${}_{88}^{226}\text{Ra} \rightarrow {}_{86}^{222}\text{Rn} \rightarrow {}_{84}^{218}\text{Po} \rightarrow {}_{82}^{214}\text{Pb} \rightarrow {}_{83}^{214}\text{Bi} \rightarrow$$

$${}_{84}^{214}\text{Po} \rightarrow {}_{82}^{210}\text{Pb} \rightarrow {}_{83}^{210}\text{Bi} \rightarrow {}_{84}^{210}\text{Po} \rightarrow {}_{82}^{206}\text{Pb}$$
  - $${}_{94}^{240}\text{Pu} \rightarrow {}_{95}^{240}\text{Am} \rightarrow {}_{93}^{236}\text{Np} \rightarrow {}_{91}^{232}\text{Pa} \rightarrow {}_{92}^{232}\text{U} \rightarrow$$

$${}_{90}^{228}\text{Bi} \rightarrow {}_{88}^{224}\text{Ra} \rightarrow {}_{89}^{224}\text{Ac} \rightarrow {}_{87}^{220}\text{Fr} \rightarrow {}_{85}^{216}\text{At} \rightarrow$$

$${}_{83}^{212}\text{Bi} \rightarrow {}_{84}^{212}\text{Po} \rightarrow {}_{82}^{208}\text{Pb} \rightarrow {}_{83}^{208}\text{Bi}$$
- Fluorine-18 ( ${}_{9}^{18}\text{F}$ ) has a half-life of 110 seconds. This material is used extensively in medicine. The hospital laboratory starts the day at 9 a.m. with 10 grams of  ${}_{9}^{18}\text{F}$ .
  - How many half-lives for fluorine-18 occur in 11 minutes (660 seconds)?
  - How much of the 10-gram sample of fluorine-18 would be left after 11 minutes?
- The isotope  ${}_{6}^{14}\text{C}$  has a half-life of 5,730 years. What is the fraction of  ${}_{6}^{14}\text{C}$  in a sample with mass,  $m$ , after 28,650 years?
- What is the half-life of this radioactive isotope that decreases to one-fourth its original amount in 18 months?