

What is Radioactive Decay?

Professional Personnel

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Fact Sheet #8A

Division of Environmental Health
Office of Radiation Protection



RADIOACTIVE DECAY

The atomic structure for certain isotopes of elements is unstable. Radioactivity is the natural and spontaneous process by which the unstable atoms of an isotope of an element transform or decay to a different state, and emit or radiate excess energy in the form of particles or waves called radiation. These emissions are energetic enough to ionize atoms and are called ionizing radiation. Depending on how the nucleus releases this excess energy, either a lower energy atom of the same form results or a completely different nucleus and atom are formed.

The unstable atoms of a radioactive substance decay in a random fashion but at a characteristic rate. The length of time this takes, the number of steps required and the kinds of radiation released at each step are well known and are unique to that isotope. For instance, an atom of phosphorus-32 decays to an atom of non-radioactive sulfur-32, accompanied by the emission of a beta particle (electron) with an energy up to 1.71 million electron-volts (MeV).

DECAY

Most nuclear decays occur spontaneously and randomly, where a given fraction of atoms decay in a known given time period, independent of the number of atoms present.

The change, due to decay, in the number of atoms, dN , during the time period, dt , is expressed as:

$$-\frac{dN}{dt} = \lambda N$$

This equation can be solved to form the following equation:

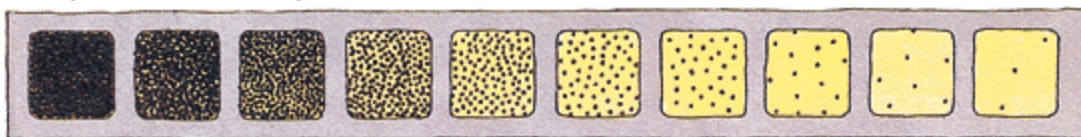
$$N(t) = N_0 e^{-\lambda t}$$

Where the number of atoms remaining (those that have not decayed) during a time period t is $N(t)$, the original number of atoms present at the start of the time period is N_0 , and λ is a proportionality constant known as the decay constant that equals $0.693/t_{1/2}$. The base of natural logarithm is e and e equals 2.718.

HALF-LIFE ($t_{1/2}$)

The half-life is the time required for a given amount of radioactive material to decrease by one half. After one half-life the amount of radioactive material is halved, after two half-lives it is reduced to one quarter, after three half-lives to one-eighth and so on.

Decay rate of radioactivity: After ten half lives, the level of radiation is reduced to one thousandth



Time: One half life two three four five six seven eight nine

The activity of any radionuclide is reduced to less than 1% after 7 half-lives.

This half-life is a time that is unique time to each radioisotope of an element. Half-lives can range from less than a millionth of a second to millions of years. The half-life can be mathematically expressed as the point in time when $N(t)$ is one half of N_0 .

Replacing this expression in the above equation, where $t_{1/2}$ is the half-life, gives:

$$1/2 = e^{-\lambda t_{1/2}}$$

Taking the logarithm of both sides of the above equation and solving for the half-life $t_{1/2}$ gives:

$$t_{1/2} = \frac{\ln(2)}{\lambda}$$

