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Half-Lives: Physical, Biological, and Effective

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Half-Lives: Physical, Biological, and Effective

• When planning to use the radioactive substance for both diagnostic and therapeutic purposes, there are three half-lives that are important and must be taken into account.

• both the physical and biological half-lives are important since they relate directly to the disappearance of radioactivity from the body by two separate pathways (radioactive decay, biological clearance), and the effective half-life takes into account not only elimination from the body but also radioactive decay.

Physical half Lives:

•Physical half-life is defined as the period of time required to reduce the radioactivity level of a source to exactly half its original value due to only radioactive decay.

•The physical half-life is designated $T_{\mathbf{phys}}$ or more commonly $T_{\mathbf{1/2}}$. There are a few things to note about the $T_{\mathbf{phys}}$:

Notes about the T_{phys}:

•The $T_{\mathbf{phys}}$ can be measured directly by counting a sample at 2 different points in time and then calculating what the half-life is.

•For example, if activity decreases from 100% to 25% in 24 hours, then the half life is 12 hours since a decrease from 100% to 50% to 25%, this mean there is 2 half live

Formula of the physical half life

$T_{½} = \ln2/\lambda$ Ln2= 0.963

Λ is decay constant (1/ time unit)

What is the decay constant

The radioactive decay law states that the probability per unit time, the decay of the nucleus is a constant, independent of time. This constant is called the decay constant and is denoted by λ, "lambda". This constant changes depending on the types of nuclei, leading to the different in decay rates.

Decay Constant and Half-Life

In calculations of radioactivity one of two parameters (decay constant an half-life), which characterize the rate of decay, must be known. There is a relation between the half-life ($t_{1/2}$) and the decay constant λ. The relationship can be derived from decay law by setting N = ½ No. This gives:

Where ln 2 (the natural log of 2) equals 0.693. If the decay constant (λ) is given, it is easy to calculate the half-life, and vice-versa.

Example for Half life and decay constant

Notes:

- The rate of nuclear decay (dN/dt) is also measured in terms of half-lives.
- Short half lives go with large decay constants. Radioactive material with a short half life is much more radioactive (at the time of production) but will obviously lose its radioactivity rapidly.
- No matter how long or short the half life after seven half lives have passed, there is less than 1 percent of the initial activity remaining.

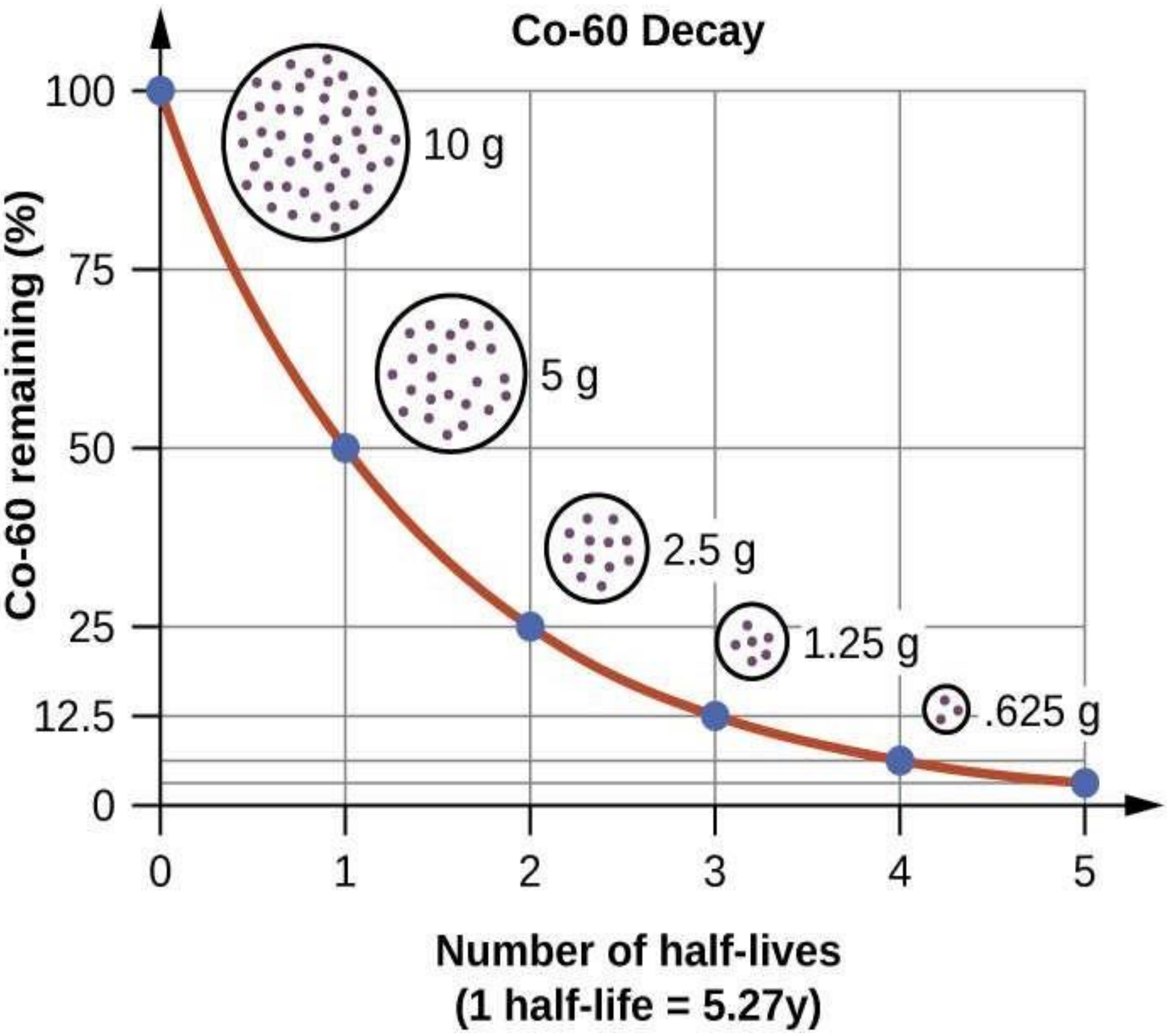


Figure of physical half life

Radioactive decay law

- The element that is emitted radiation in all directions transforms into a new element. The process is called a decay or a disintegration.

- The radioactive decay of certain number of atoms (mass) is exponential with the time.

N = N0 e-λt

- The radioactive decay law can be derived also for activity calculations or mass of radioactive material calculations:

- A= N λ, N(t) = N0 $e^{-\lambda t}$, A(t) = A0 $e^{-\lambda t}$, m(t) = m0 $e^{-\lambda t}$

- where N0 = total number of particles in the sample at t= 0, N(t)= number of particles at t=?, A0 =total activity (Bq) at t = 0, A(t)= activity at t =? , m0 = mass of radioactive material at t= 0, m(t)= mass of radioactive material at t.؟=

Note:

- The activity is the disintegration per second.

- The unit for activity is the Becquerel (Bq) where 1 Bq = 1 decay per second.

- Another unit is the curie, which is equal to 3.7 x 10 exp (10) Bq.

Biological half Lives

- Biological Half-life is defined as the period of time required to reduce the amount of a drug in an organ or the body to exactly half its original value due only to biological elimination.

- It is typically designated T_{biol} or T_b. There are a few things to note about the T_{biol}.

Notes about the T_{bio}:

- For radioactive compounds, we have to calculate the T_{bio} because the mass of the isotope is usually on the nanogram scale and, when distributed throughout the body, and especially in the target organ, concentrations are in the pictogram /ml range, this mean its much too small to measure directly.

- For non-radioactive compounds, we can measure the Tbio directly. For example, assuming that a person is not allergic to penicillin, we could give 1,000 mg of the drug and then measure the amount present in the blood and in the urine since we administered such a large amount of the drug.

Notes about the T_{bio}:

- T_{bio} is affected by many external factors. Perhaps the two most important are hepatic and renal function. If kidneys are not working well, we would expect to see a high background activity on our scans. Also important is level of hydration. A poorly hydrated patient, even with normal renal function, will have a high background activity since limited urine is being produced, making it difficult to eliminate isotope that has not localized in the target organ.

- Each individual organ in the body has its own T_{bio} and the whole body also has a T_{bio} representing the weighted average of the T_{bio} of all internal organs and the blood. It is therefore very important to have a frame of reference. For example, you need to know the T_{biol} of the drug in the liver or in the whole body.

Notes about the T_{bio}:

- All drugs have a T_{bio}, not just radioactive ones.

- Since the whole body has a T_{bio} representing the weighted average of the T_{bio} of all internal organs, it willnever equal the T_{bio} of an internal organ.

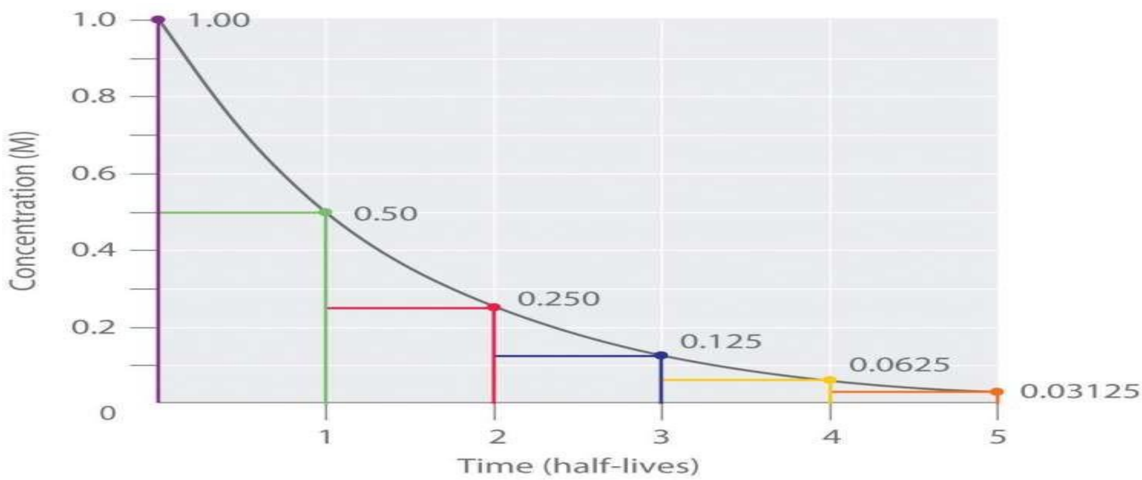
- The physical and biological half-lives can equal each other. For example, Tc-99m , both T_{phys} and T_{biol} are equal to 6 hours.

Biological half life formula

- T_{bio} = [(Ln 2)(Volume of Distribution)] /Clearance

- T_{bio} =[(0.693)(Volume of Distribution)]/ Clearance

- As demonstrated by the formula, a drug's half-life is directly dependent on its volume of distribution or how widely the drug spreads throughout the body. In other words, the more widely the drug distributes in your body, the longer it half-life. Furthermore, this same drug's half-life is inversely dependent on its clearance from your body. This means that when the rate of the drug's clearance from your body is higher, then the half-life is shorter



No. of half life

Activity after 1 half-life = ½ of the original

Activity after 2 half-lives = ½ x ½ = ¼ of the original

Activity after 3 half-lives = ½ x ½ x ½ = (½)3 = 1/8 of the original

Activity after 4 half-lives = (½)4 = 1/16 of the original

Activity after 5 half-lives = (½)5 = 1/32 of the original Activity after 6 half-lives = (½)6 = 1/64 of the original Activity after 7 half-lives = (½)7 = 1/128 of the original

Effective half-life

The effective half-life is the rate of accumulation or elimination of a biochemical or pharmacological substance in an organism; it is the analog of biological half-life when the kinetics is governed by multiple independent mechanisms. This is seen when there are multiple mechanisms of elimination, or when a drug occupies multiple pharmacological compartments. The complexity of biological systems means that most pharmacological substances do not have a single mechanism of elimination, and hence the observed or effective half-life does not reflect that of a single process, but rather the summation of multiple independent processes.

The sequence of events following radiation exposure may be classified as follows:

A. Prodromal Stage

Symptoms which appear quickly after radiation exposure are referred to as prodromal radiation syndrome. The severity of the symptoms experienced in this stage can give a rough indication of the magnitude of exposure and the clinical prognosis.

B. Latent Period

Following the initial radiation exposure, and before the full-blown biological effect occurs, there is a time lag referred to as the latent period. There is a vast time range possible in the latent period. The biological effects of radiation are arbitrarily divided into short-term and long-term effects on this basis. Those effects which appear within a matter of minutes, days, or weeks are called short-term effects and those which appear years, decades, and sometimes generations later are called long-term effects.

C. Period of Demonstrable Effects on Cells and Tissues

During or immediately following the latent period, certain discrete effects can be observed. The exact nature and range of effects depends on the dose received and area of the body exposed. One of the phenomena that is seen most frequently in growing tissues exposed to radiation is the cessation of mitosis, or cell division. This may be temporary or permanent, depending upon the radiation dosage. Other effects include breaking or clumping of chromosomes, formation of giant cells and/or other abnormal mitosis. It should be pointed out that many of these effects can be duplicated individually with other types of agents. However, the entire gamut of effects cannot be reproduced by any single chemical agent.

D. Recovery Period

Following exposure to radiation, recovery can take place to a certain extent. This is particularly apparent in the case of the short-term effects, i.e., those appearing within a matter of days or weeks after exposure. However, there may be a residual damage from which no recovery occurs, and it is this irreparable injury which can give rise to later long-term effects.