Secondary Education

3rd year: Sections LH - SE

Physics

Chapter 4: Radioactivity

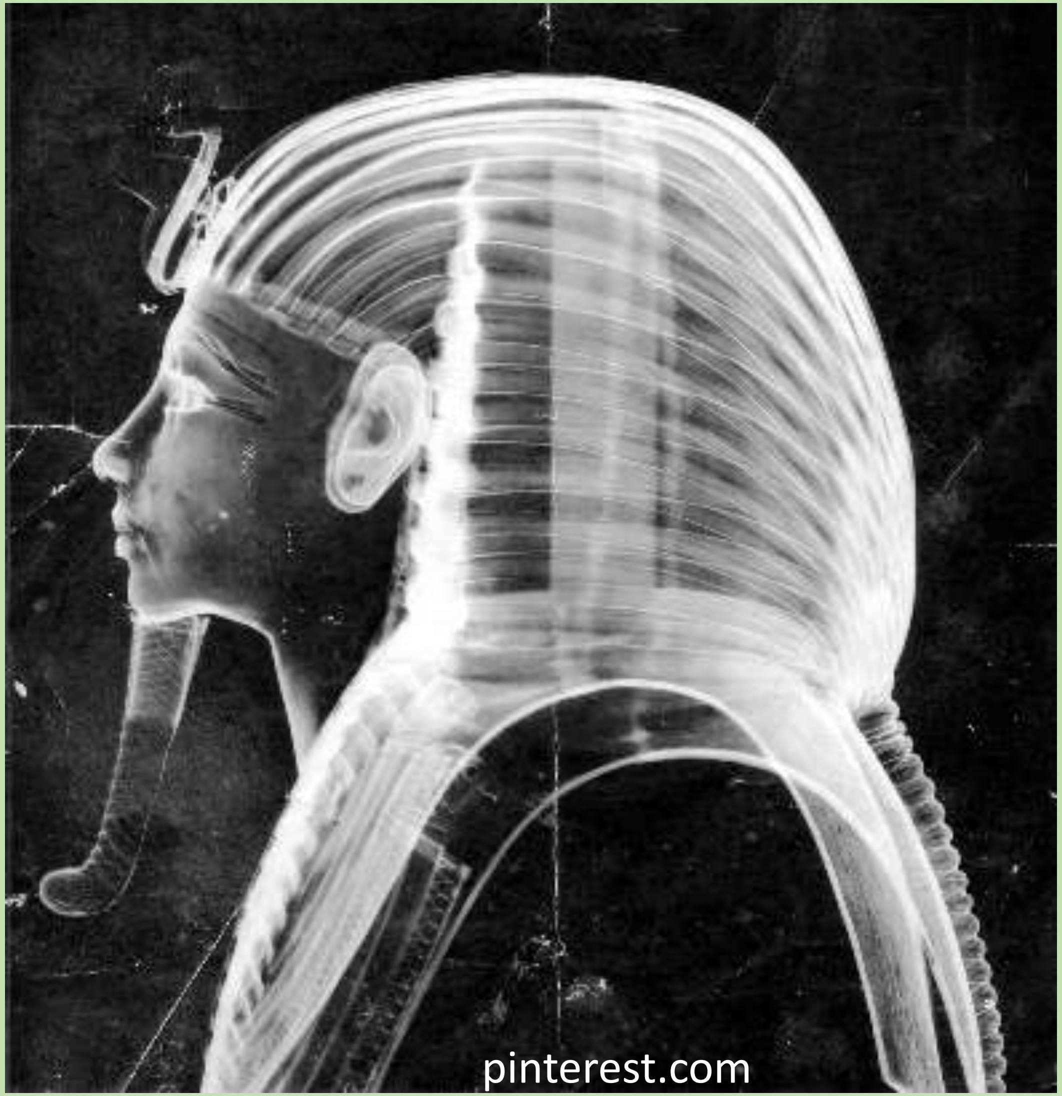
تم الاعتماد على الكتاب المدرسي الوطني الصادر عن المركز التربوي للبحوث والانماء

إعداد مصطفى سكرية

Chapter 4: Radioactivity

Objectives

- Define radioactivity.
- Name the types of radiations (α, β^- , β^+ and γ).
- Know the properties of the emitted radiation.
- Define the half-life of a radioactive substance
- Give some examples of spontaneous nuclear reactions.



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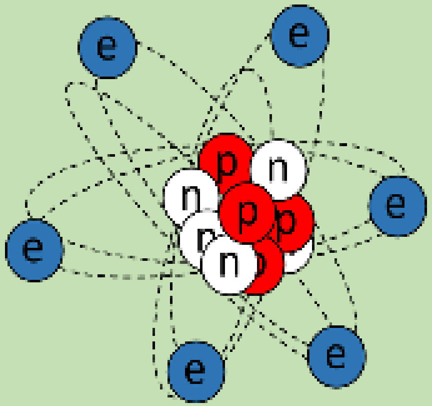
Chapter 4: Radioactivity

Atomic Nucleus



An atom with symbol X has a nucleus represented by $^{A}_{Z}X$ where:

Z is the atomic number or the number of protons in the atom.

A is the mass number or the number of nucleons in the nucleus.

Therefore, **(A – Z)** is the number of neutrons .

The **Nuclide** is the set of atoms that have the same mass number A and the same atomic number Z

The **isotopes** of a chemical element are the nuclides that possess the same atomic number Z but having different number of neutrons.

Application: Calculate the number of protons and neutrons in: $^{235}_{92}U$, $^{238}_{92}U$

Number of protons = Z = 92 for both isotopes;

Number of neutrons = (A – Z), so it's equal to 143 for the first and 146 for the second.

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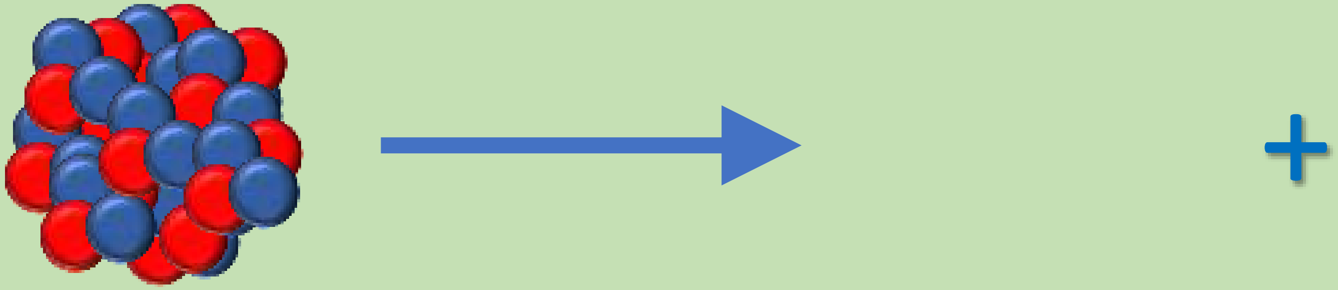
Radioactivity

Some isotopes are stable, that means their mass number and atomic number stay constant with time, while others are not.

We say that these isotopes are radioactive.

Radioactivity is the spontaneous transformation of an unstable nucleus X, called parent, into another nucleus Y, called daughter, with the emission of a radioactive radiation.



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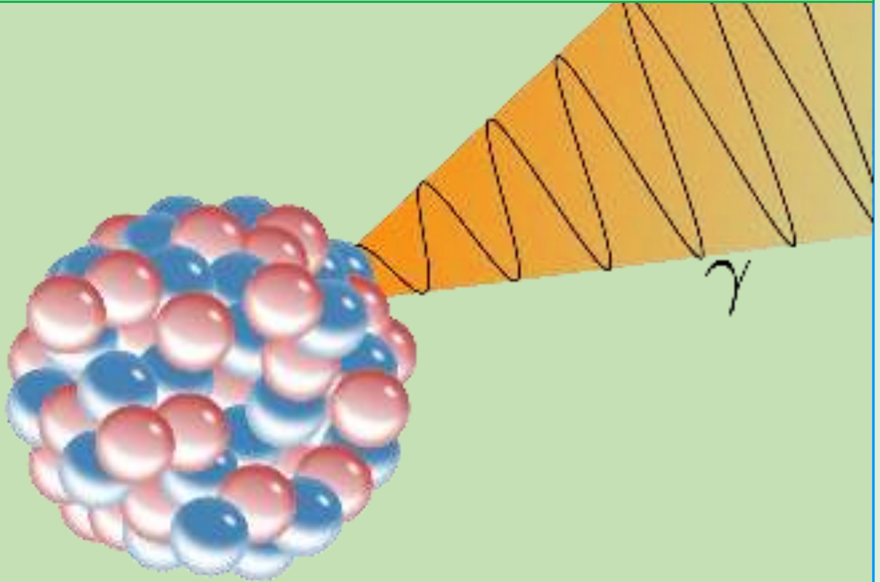
Types of radioactive radiations

There are four types of radioactive radiations, which are:
alpha (α), beta-minus (β^-), beta-plus (β^+)
and gamma (γ) radiations.



The γ radiation:

is an electromagnetic radiation (formed of photons).
is due to de-excitation of the daughter nucleus.
is very penetrating; it can easily cross several cm of lead;
is very dangerous;
is emitted with the speed of light that is 300,000 km/s.

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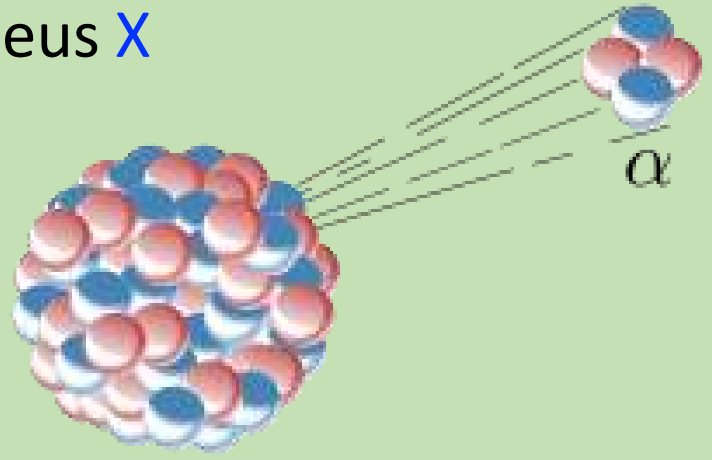
Types of radioactive radiations

Alpha decay is the spontaneous transformation of a nucleus X to a nucleus Y with the emission of an alpha **α** particle.



Alpha (**α**) particles

- are Helium nuclei $^{4}_{2}\mathrm{He}$; they are charged positively.
- are emitted by heavy nuclei (A > 200)
- are emitted with a speed about 20000 km/s;
- Have a very weak penetrating power; *a paper is enough to stop them*;
- are very ionizing;
- Thus, they are very dangerous.

The equation of this decay

$$^{A}_{Z}X \rightarrow \ ^{A'}_{Z'}Y + \ ^{4}_{2}He$$

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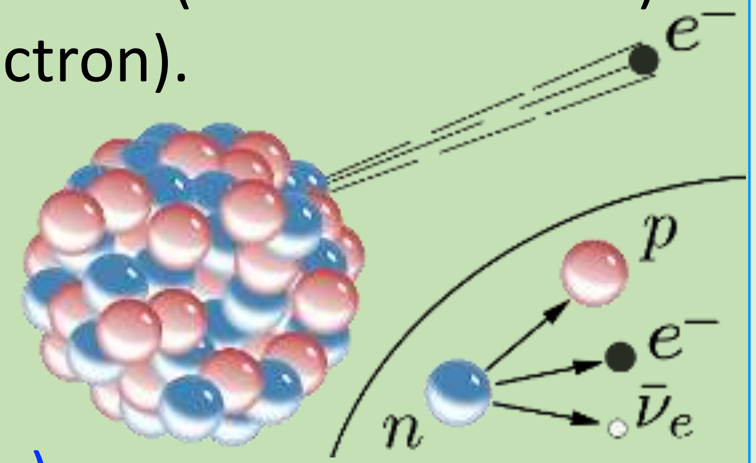
Types of radioactive radiations

Beta minus decay is the spontaneous transformation of a nucleus X (rich in neutrons) to a nucleus Y with the emission of Beta minus β^- particle (electron).



Beta-minus (β^-) particles

- are electrons ${}_{-1}^{0}e$.
- are very penetrating (several meters of air);
- can cross an aluminum foil of thickness 7 mm;
- are emitted at a high speed, about 280,000 km/s; (V = 0.9 c)

The equation of this decay

$$ {}_{Z}^{A}X \rightarrow {}_{Z'}^{A'}Y + {}_{-1}^{0}e $$

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Types of radioactive radiations

There is another type of beta decay, called the beta plus β^+.

This type of radioactivity only concerns certain artificial elements that are obtained by nuclear reactions in the laboratory, and that have an excess of protons.

Beta-plus (β^+) particles

- are positrons ${}_{+1}^{0}e$, of same mass and opposite charge of an electron.
- are very penetrating (several meters of air);
- can cross an aluminum foil of thickness 7 mm;
- are emitted at a high speed, about 280,000 km/s; (V = 0.9 c)

The equation of this decay

$$ {}_{Z}^{A}X \rightarrow {}_{Z'}^{A'}Y + {}_{+1}^{0}e $$

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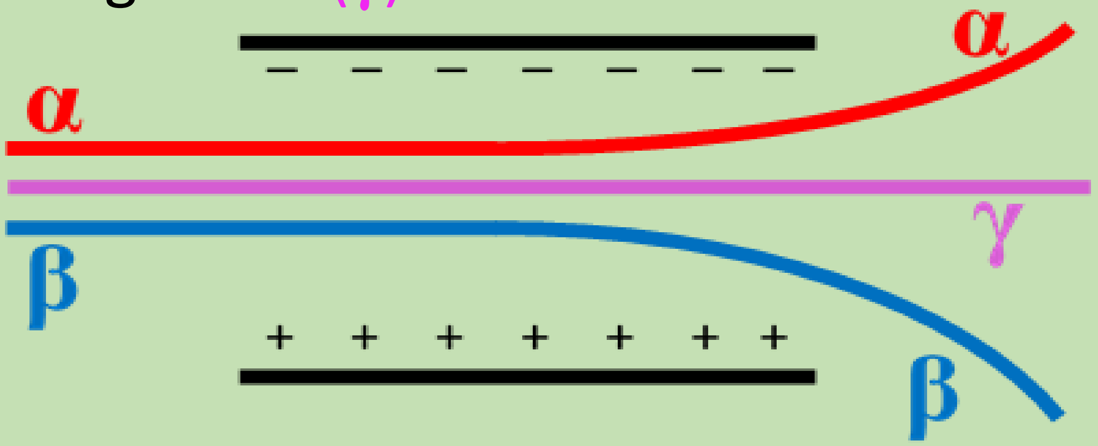
Types of radioactive radiations

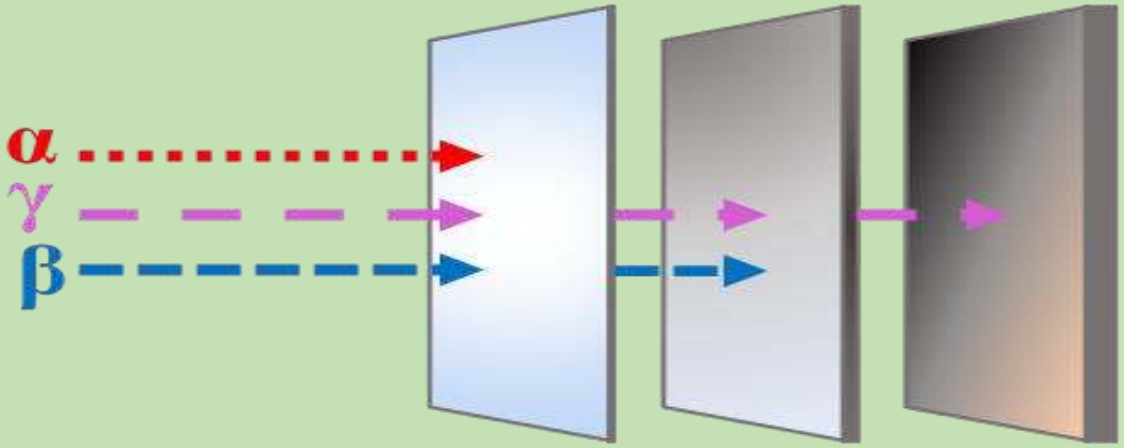
Comparison between alpha (α), beta (β^-) and gamma (γ) radiations.



Alpha positively charged and less penetrating.

Beta Negatively charged

Gamma has no charge, and is most penetrating



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Soddy's Laws: The laws of conservation

During the disintegration of a parent nucleus ${}^{A}_{Z}X$, a daughter nucleus ${}^{A'}_{Z'}Y$ is formed with the emission of a particle ${}^{a}_{z}p$.

$$ {}^{A}_{Z}X \rightarrow {}^{A'}_{Z'}Y + {}^{a}_{z}p $$

The laws of conservation, or **Soddy's Laws**, are applied in all Alpha (**α**) and Beta (**β**) radioactive transformations.

- Conservation of the mass number, A, or of the number of nucleons.
- Conservation of the atomic number, Z, or number of protons.

Application

Write the equation, and calculate A and Z of the daughter nucleus, then identify this daughter for each of the following Bismuth isotopes.

a) ${}^{212}_{83}\mathrm{Bi}$, is an alpha emitter.

b) ${}^{210}_{83}\mathrm{Bi}$ is a Betta minus emitter.

Given: Mercury ${}_{80}\mathrm{Hg}$, Thalium ${}_{81}\mathrm{Tl}$, Lead ${}_{82}\mathrm{Pb}$, Polonium ${}_{84}\mathrm{Po}$

Solution:

a) The first equation can be written as: ${}^{212}_{83}\mathrm{Bi} \rightarrow {}^{A}_{Z}\mathrm{Y} + {}^{4}_{2}\mathrm{He}$

Soddy's laws give: 212 = A + 4 then A = 208, and 83 = Z + 2 then Z = 81

The daughter is identified by its atomic number Z = 81, then it is the Thalium.

b) The second equation can be written as: ${}^{210}_{83}\mathrm{Bi} \rightarrow {}^{A}_{Z}\mathrm{Y} + {}^{0}_{-1}\mathrm{e}$

Soddy's laws give: 210 = A + 0 then A = 210, and 83 = Z + (-1) then Z = 84

The daughter is identified by its atomic number Z = 84, then it is the Polonium.

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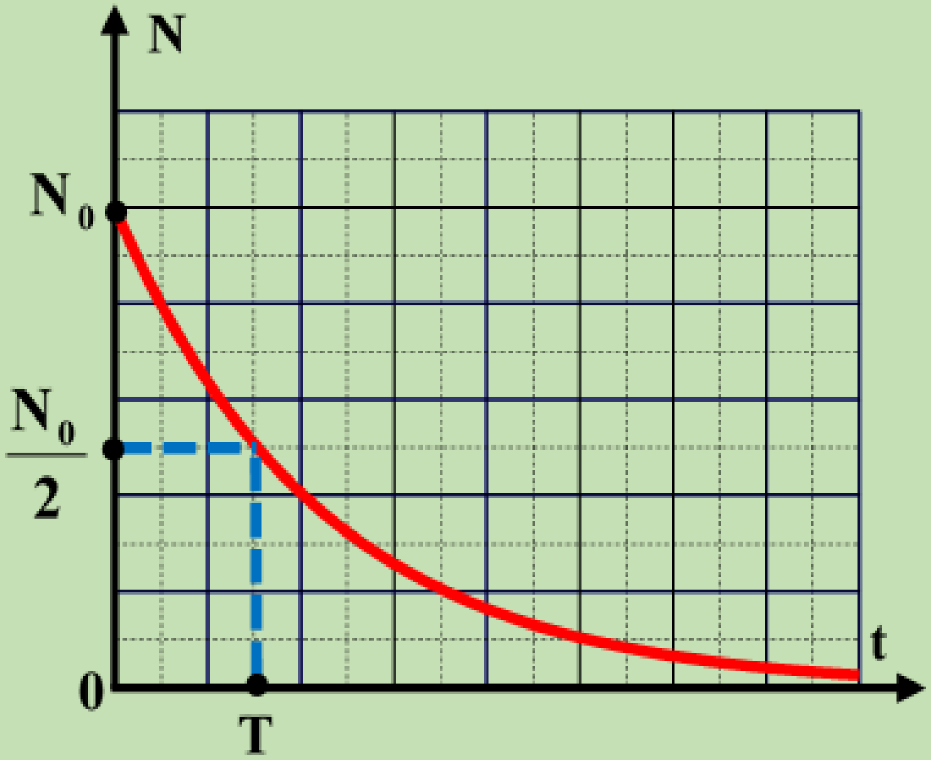
The half-life of a radioactive substance

Radioactive isotopes disintegrate at different rates. This rate of disintegration is measured by a characteristic time called the half-life of a radioactive substance.

The half-life of a radioactive substance is the time it takes for half of the radioactive substance to decay.

The rate of decay of a radioactive sample is described by its **activity**, which is the number of atoms that disintegrate per unit time.



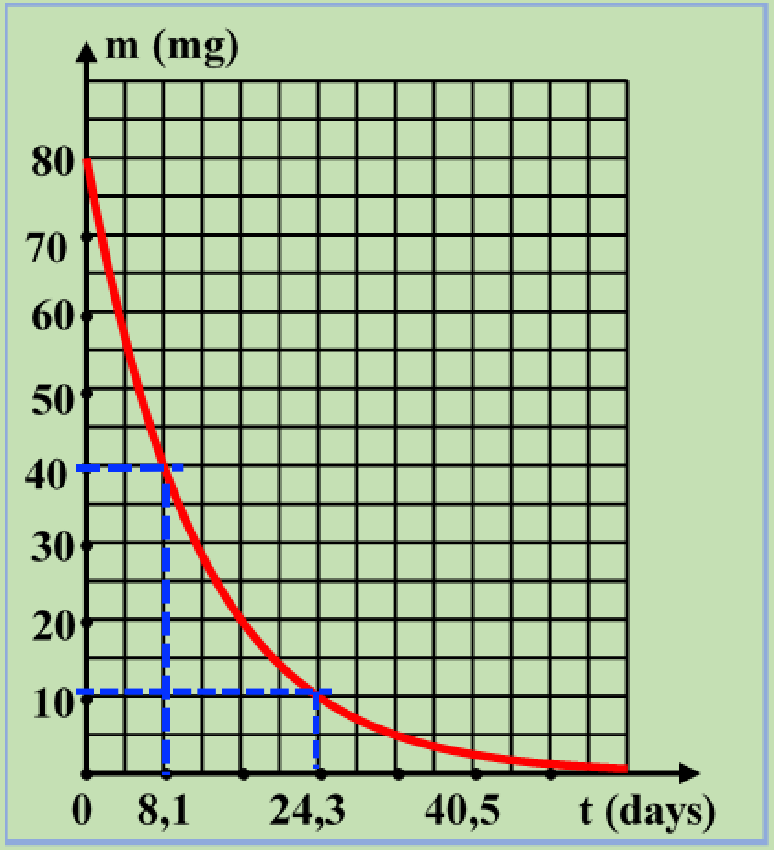
Half-lives of some radioactive elements

Astatine $^{217}_{85}At$	Nitrogen $^{16}_{7}N$	Iodine $^{131}_{53}I$	Carbon $^{14}_{6}C$	Uranium $^{235}_{92}U$
3.2×10^{-2} s	7.4 s	8.1 days	5700 years	7.2×10^{8} years

Application:

Official exams: Session 2019-1

The adjacent document, represents the mass m (in mg) of a sample of iodine $^{131}_{53}I$ as a function of time t (in days).



1) Define the half-life T of a radioactive substance.
   The half-life of a radioactive substance is the time it takes for half of the radioactive substance to decay.
2) Using the document:
   a) specify the value of the half-life T of iodine $^{131}_{53}I$;
      The half-life corresponds to $m = m_0/2$
      Referring to document,
      when $m = m_0/2 = 80/2 = 40$ mg, we have T = 8.1 days
   b) indicate the remaining mass of the sample of iodine $^{131}_{53}I$ after three half-lives.
      At t = 3 T = 3 × 8.1 = 24.3 days, this corresponds to m = 10 mg.

youtube.com/watch?v=5oUagoF_viQ

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