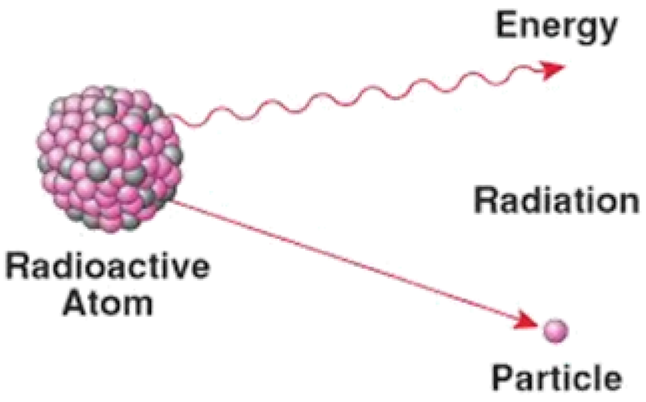
NUCLEAR ENERGY

RADİOACTİVİTY

- The spontaneous emission of radioactive rays by an unstable atomic nucleus is called radioactivity.
- Spontaneously disintegrating atoms are called radioactive atoms and the nuclei of these atoms are unstable.

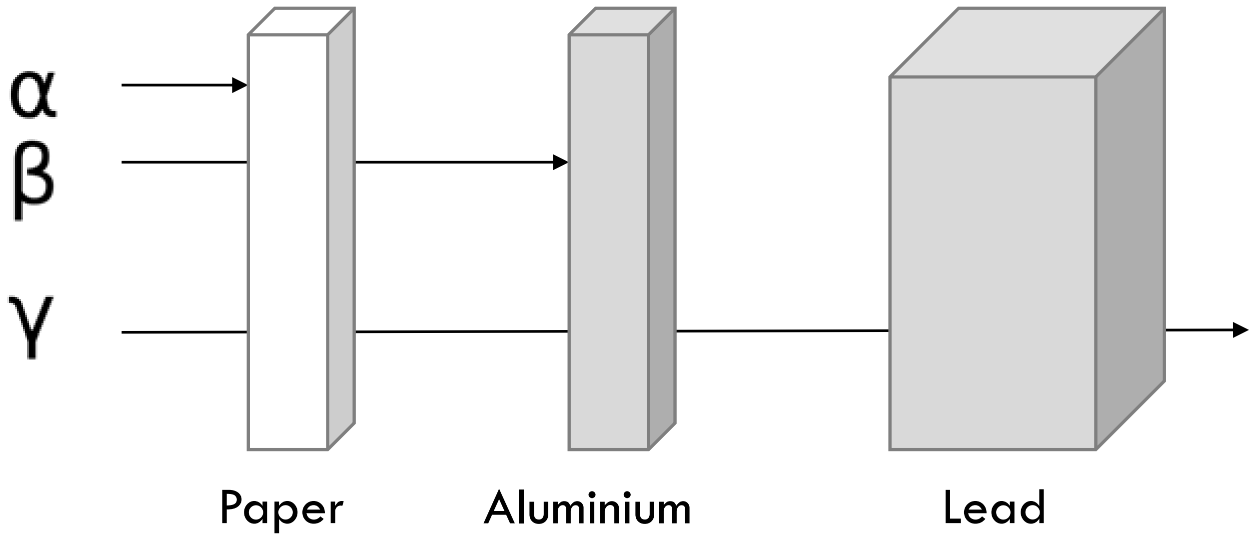


- The stability of the nucleus of an atom depends on the number of protons and neutrons.
- The nuclei of lighter atoms such as He, C, N and O have the same number of neutrons (N_n) and protons (N_p). Therefore, the ratio between the number of neutrons and the number of protons is 1 ($N_n/N_p = 1$) and such nuclei are stable. There are no atomic nuclei with the same proton and neutron numbers after the element ${}^{40}_{20}Ca$.
- Most radioactive elements have the following properties:
  1. The ratio between the numbers of neutrons and protons in a nucleus is greater than 1.5 ($N_n/N_p > 1.5$).
  2. The atomic number is bigger than 83.

i. Types of Radioactive Decays

- A radioactive substance decays by making mainly three types of emissions. These emissions are named as alpha, beta and gamma, and represented by symbols α, β, and γ respectively.
- Among them the effect of α rays is the lowest and γ rays affect the most whereas β radiation has the intermediate effect.

- A sheet of paper can block α particles but for blocking of γ particles thick lead plates are needed. The accidental injection of α particles can affect the internal organs and blood. Radiation is harmful only when it comes in direct contact with the body but, if the radiation is blocked, the presence of radioactivity is not destructive.



Alpha (α) Particles

- α particles are identical to the nuclei of helium atoms ($^{4}_{2}He$). Since they are 2+ charged particles, they are symbolized as $^{4}_{2}He^{2+}$. They are deflected by electric and magnetic fields because of their positive charge.

- For instance, if an $^{238}_{92}U$ isotope radiates one alpha particle, the nuclear equation can be expressed as shown below.

$$^{238}_{92}U \longrightarrow {}^{234}_{90}Th + \alpha$$

Beta (β) Particles

- β particles are represented by ${}_{-1}^{0}e$.
- An atom undergoing a beta decay, emits an electron (${}_{-1}^{0}e$.) from its nucleus. This emitted electron is produced as a result of the transmutation in the nucleus of one neutron into one proton.
- The equation of this process can be shown thus:

$$ {}_{0}^{1}n \rightarrow {}_{1}^{1}p + \beta^{-} $$

- For instance, when the ${}_{90}^{234}Th$ isotope radiates one β particle, it transmutes into the ${}_{91}^{234}Pa$ isotope. The nuclear equation can be expressed as shown below:

$$ {}_{90}^{234}Th \rightarrow {}_{91}^{234}Pa + \beta^{-} $$

Gamma (γ) Particles

- γ rays are a type of electromagnetic radiation with a very high energy. Generally, γ rays are not radiated alone.
- The mass and charge of γ rays are accepted as zero. Therefore, the atomic mass number and the atomic number of an atom remain unchanged when it radiates a γ ray.
- For example, when the element ${}^{234}_{92}U$ transmutes into ${}^{230}_{90}Th$ by radiating 1α ray, γ rays are also produced.
- The nuclear equation of this process is shown below;

$$ {}^{234}_{92}U \rightarrow {}^{230}_{90}Th^{*} + \alpha $$

$$ {}^{230}_{90}Th^{*} \rightarrow {}^{230}_{90}Th + {}^{0}_{0}\gamma $$

ii. Sources of Radioactive Pollution

Natural Sources

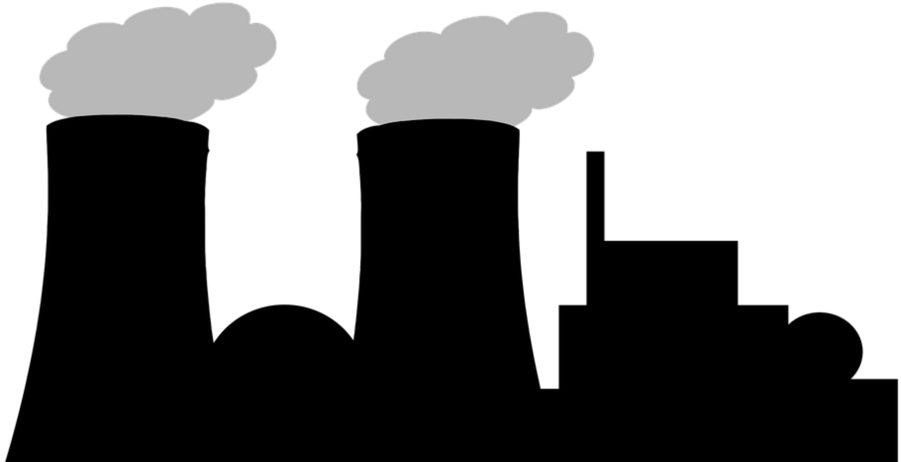
- Natural sources comprise cosmic rays and radioactive compounds in the soil and their residues emitted into the air, water and food.
- Our body cells also emit natural radiation in the form of K^{40}.
- At higher altitudes, the thinning of atmosphere provides lesser protection against the cosmic rays.

Anthropogenic Sources

- Nuclear power stations are responsible for production of radioactive waste.
- Mining and refining of ores of radioactive elements such as uranium and thorium involve crushing and processing of radioactive ores to generate radioactive by-products.
- This Nuclear fuel cycle is used in many industrial, medical and scientific processes.
- Nuclear accidents
- Industrial uses

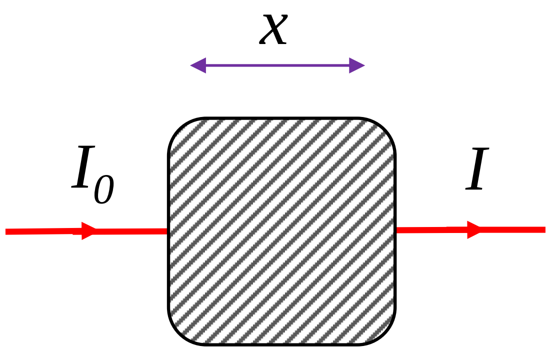
iii. Uses of Radiation

A. Electricity Generation (Nuclear Power Plants)
B. Medical applications
C. Industrial Applications
D. Agricultural Applications
E. Archaeological Applications
F. Applications in Consumer Products
G. Environmental Applications



iv. Units and Definitions

Half-value layer (HVL), or half-value thickness ($x_{1/2}$); is the thickness of the material at which the intensity of radiation entering it is reduced by one half.



$$I=I_0/2 \rightarrow x=x_{1/2}$$

	$X_{1/2}$, cm
Lead	1.25
Concrete	25
Water	30
Soil	25
Nickel, Chrome, Iron	2-2.5

- The depth and wall thickness of the tanks where the radioactive waste will be stored can be calculated according to the half-value thickness of the material to be used.

$I_0/I = e^{\mu . x}$ $\quad$ $\ln I_0/I = \mu . x$

$I = I_0/2 \rightarrow x = x_{1/2}$

$\ln 2 = \mu . x_{1/2}$

$\mu = 0.693/x_{1/2}$

μ: Attenuation coefficient

x: Layer thickness

The radioactive half-life ($t_{1/2}$); The half-life of an isotope is defined as the time it takes for half of the original amount of that isotope to decay into another element.

- The shorter the half-life of a radioactive decay, the higher the rate of radioactive decay.
- The half-life is the characteristic property of each element.

$$A = A_o \cdot (1/2)^{t/t_{1/2}}$$

Time

Half-life

Final amount

Initial amount