Some applications of radioactive decay

a-Estimate the age of antiquities by carbon

Carbon enters the structure of living organisms and is generated due to cosmic rays in the atmosphere (as a result of bombing nitrogen in the atmosphere with cosmic rays). It is known that the organic matter reaches the level of balance between the carbon and carbon in the atmosphere, and after the death of the organism the natural balance comes out and the organism stops absorbing ^{14}C and begins Its contents from this isotope are decreasing according to the law of radioactive decay, so an antique, for example, can be estimated from its knowledge of the carbon percentage $^{14}_{6}C$

$$A = A_0 (e^{-\lambda t})$$

$$A/ A_0 = (e^{-\lambda t})$$

$$A_0 / A = (e^{\lambda t})$$

$$Ln (A_0 /A) = \lambda t$$

$$t = (\frac{1}{\lambda}) \ln (\frac{A_o}{A}) \quad \ldots\ldots\ldots\ldots\ldots(1)$$

$$\lambda = 0.693 / t_{1/2} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

$$t = \frac{t_{\frac{1}{2}}}{\ln(2)} \ln\left(\frac{A_o}{A}\right) \quad \ldots\ldots\ldots\ldots\ldots(3)$$

If we adopt the half-life of carbon equal 5568 year, and the radioactivity ratio of an old piece (A) is compared to that of a corresponding piece at the present time(A_0) (modern live), it is known that the antiquity of the artifact is easy to find from the equation (1)&(3).

EX: An archaeologist has found an antique piece of wood with a mass of 50 g and the radioactivity of carbon in it is 320Bq find the age of this piece if the specific radioactivity of a living piece of wood similar to it is 12Bq/gm, knowing that the half-life for $^{14}_{6}C$ 5568 year?

Sol. $SA = A_0/m$

$12\ Bq/g = A_0/50\ g$

$A_0 = 600\ Bq$

$\lambda = 0.693 / t_{1/2}$

$\lambda = 0.693 / 5568 = 1.245 \times 10^{-4}\ y^{-1}$

$$t = \left(\frac{1}{\lambda}\right) \ln\left(\frac{A_0}{A}\right) = [(1/1.245 \times 10^{-4}\ y^{-1}) \ln(600/320)] = \ln(1.875)/1.245 \times 10^{-4}) = 5052\ y$$

B- Estimate the age of the rocks

$^{238}_{92}U \longrightarrow {}^{206}_{82}pb$ $\quad t_{1/2} = 4.5\times10^{9}\ y \quad A = 4n + 2$

$$t = \frac{1}{\lambda_u} \ln\left(1 + \frac{N_{Pb}}{N_u}\right)$$

N_{pb} = العدد الكلي لنوى الرصاص

N_u = العدد الكلي لنوى اليورانيوم

λ_u = ثابت الانحلال لليورانيوم

t = العمر التقريبي للصخور

Introduction

Our understanding of the nature of nuclear radiation depends on how this radiation interacts with matter. This knowledge is necessary in establishing and using radiation detectors and measuring devices and in the various applications of radiation in science, medicine, industry and agriculture. Radiology is divided into four types:

1- Heavy charged particles, such as alpha particles, deuterons and protons

2-Light charged particles are electrons and positrons

3-Uncharged bodies

4-Electromagnetic radiation, such as gamma and x-rays

Interaction of electromagnetic radiation with matter

gamma rays (as well as x-rays) are electromagnetic and non-charged. They are a torrent of photons, the relationship between photons energy(E), frequency(v), and wavelength(λ):

.$E=hv=\frac{hc}{\lambda}$

In general, the most important reactions of gamm

a rays with the material are**:**

1-The photoelectric effect

The photoelectric effect is a reaction between a photon and an atomic electron bound inside the nucleus. As a result of this interaction, the photon will disappear (absorb) and one of the atomic electrons will be ejected outside the nucleus and is considered a free electron. This electron is sometimes called a photoelectron

Kinetic energy of a lost electron(T):

T=$E_{\gamma} - B.E$

Falling photon energyE_{γ}:

B.E: Electron bonding energy

$(\frac{1}{2}mv^2)max = hv - \Phi$

1/2mv^2: $The\ maximum\ kinetic\ energy\ of\ an\ ejected\ electron$

hv : falling photon energy

work functionΦ:

Compton effect

The Compton effect is a collision between the proton and the electron free (or almost free). Of course, in normal circumstances, the electrons in general are not free but rather restricted, but if the photon energy is large with limits (KeV) or more, while the energy of connecting the electron with limits (eV) in this case is possible The electron is considered free. The photon does not disappear after Compton's scattering, only its energy and direction will change if the interaction can be perceived as an elastic collision between the falling photon and the electron (usually the electron is considered static before the collision)

When applying energy conservation and momentum laws, we obtain:

$E_\gamma = E_{\gamma\backslash} + T$

$T = E_\gamma - E_{\gamma\backslash}$

T:Kinetic electron energy

=hvE_γ: Falling photon energy

h$v^\backslash E_{\gamma\backslash}$: Photon scattered energy =

P=hv/c

P= h$v^\backslash/c$

T=$m_0c^2(B-1)$

3-Pair protection

It is an interaction between the photon and the nucleus in general. As a result of this interaction, the photon (gamma rays) completely disappear and an electron and a positron are formed, so that this phenomenon occurs when the photon energy greater or equal to the sum of the two energy powers of both the electron and the positron. In addition, this phenomenon must occur near The nucleus of the atom until the .momentum is preserved that this phenomenon cannot occur in a vacuum

From the Energy Conservation Act we obtain (upon neglecting the recoil)

$\mathbf{Te^+ + Te^- = E_{\gamma-}(m_0c^2)e^+ - (m_0c^2)e^-}$

طاقة سكونية للبوزترون $\mathbf{(m_0c^2)e^+ = 0.511MeV}$

طاقة سكونية للالكترون$\mathbf{(m_0c^2)e^- = 0.511MeV}$

$\mathbf{Te^+ + Te^- = E_{\gamma-}0.511 - 0.511}$

$$Te^{+} + Te^{-} = E_{\gamma - 1.022}$$

اقل طاقة لازمة لانتاج الزوج :1.022MeV