International Journal of Physics and Mathematics

E-ISSN: 2664-8644
P-ISSN: 2664-8636
IJPM 2023; 5(1): 05-07

www.physicsjournal.net
Received: 07-11-2022
Accepted: 11-12-2022

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Modern method for determining the specific activity of natural radionuclides

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DOI: https://doi.org/10.33545/26648636.2023.v5.i1a.43

Abstract
The purpose of this work is to get acquainted with the basic properties and laws of interaction with the substance of gamma radiation. The practical part of the work includes an acquaintance with the technique and technique of gamma-ray spectroscopy by the example of recording the gamma spectrum of a Cs137 preparation with a spectrometer with a scintillation detector, followed by calibration of the energy scale. After that, on a calibrated spectrometer, it is proposed to determine the attenuation coefficient and estimate the energy of gamma quanta.

Keywords: Scintillation, radiation, chemical bond energy

1. Introduction

The term gamma radiation appeared in the analysis of types of radioactive radiation: this is how (γ is the third letter of the Greek alphabet) the radiation of radioactive nuclei, which is not deflected in a magnetic field, was named. Gamma radiation is electromagnetic radiation that accompanies the transition of nuclei from a state with a higher energy to a state with a lower energy. The energy range of photons (γ-quanta) conventionally begins with energies of the order of 103 eV ($\lambda < 10^{-9}$ м). Thus, the lower limit of the γ-ray energy range overlaps the X-ray energy range.

Gamma radiation is also called bremsstrahlung of fast charged particles; Electromagnetic radiation arising from the decays of elementary particles, during the annihilation of a particle and antiparticle: Electromagnetic radiation contained in cosmic rays. In these cases, the radiation is also gamma radiation, although there is often a name indicating the cause of its occurrence: bremsstrahlung, annihilation radiation, synchrotron radiation. The upper limit of the energies of gamma quanta emitted by nuclei - products of alpha and beta decays, is about 107 eV (λ ~ 10-13 m). 3) Photon participates only in electromagnetic interaction. The electric charge is equal to zero, as a result of which the effective cross section for the interaction of a photon with charged particles is much smaller than the cross section for the interaction between charged particles. The consequence of this is the greater penetrating power of gamma radiation compared to the penetrating power of the flow of charged particles.

Accordingly, radiation with characteristics 2^J and $P= (-1)^J$ is called electric 2^J - field (EJ) radiation, and radiation with characteristics 2^J and $P =(-1)^{J+1}$ - magnetic 2J - field (MJ) radiation. Radiations with J = 1, 2, 3, 4 are called dipole, quadrupole, octupole, hexadecapole, respectively.

The properties of the EJ and MJ radiations are similar to those of the radiations of macroscopic distributions of charge and currents, for example, a Hertz dipole (E1), a frame with a current (M1), antenna devices of various types.

Let us consider the main laws governing the gamma activity of radioactive nuclides. During radioactive decay, the product nucleus with a certain probability may appear in one of the excited states (Fig. 1). The transition of the nucleus to lower energy levels is accompanied either by the emission of a gamma quantum (radiative transition), or by the transfer of energy to an electron from one of the inner electron shells (K, L) of the atom, which is emitted from the atom with kinetic energy:

$$E_e = E - E_i$$

where E is the nuclear transition energy, E_i is the ionization energy of an electron. This process is called internal conversion, and the transition - conversion transition.

The ratio of the probability of a conversion transition to the probability of a radiative transition is called the internal conversion coefficient α. The range of possible values of the internal conversion rate: $0 < \alpha < \infty$.

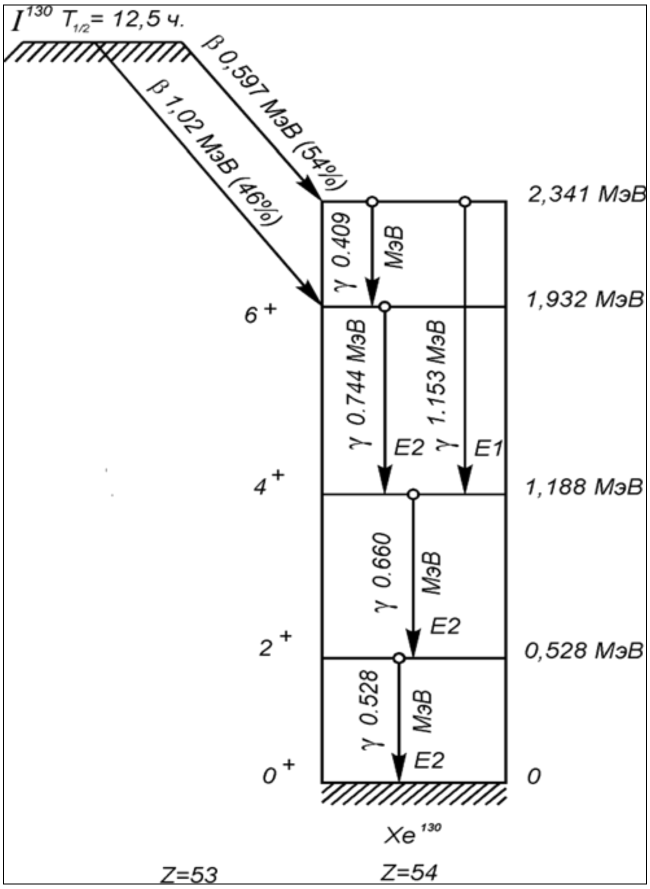

Fig 1: Schematic of the decay of the I^{130} Nucleus

Gamma absorption processes

The absorption of a photon by a free particle, without changing the rest energy of the latter, that is, when the photon energy is converted into the kinetic energy of the particle, is impossible, since the laws of conservation of energy and momentum are not simultaneously fulfilled. The electron has no excited states, its rest energy is unchanged, therefore, free an electron cannot absorb a photon at any energies of the last. Absorption processes gamma quanta occur with the participation of mediator particles. There are two mechanisms for the absorption of gamma quanta: the photoelectric effect and the production of electron-positron pairs.

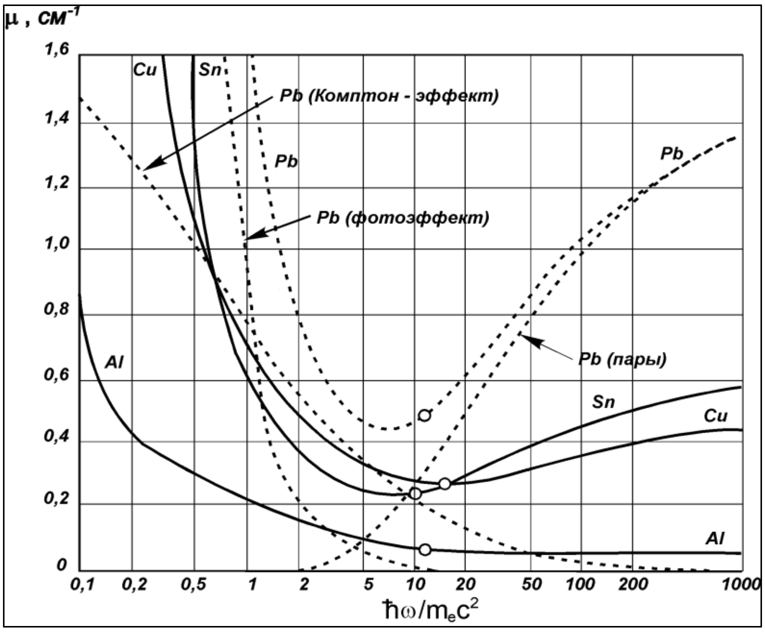

Fig 2: Dependence of the absorption coefficient on the energy of the γ-quantum.

To calculate the amount of energy transferred by gamma radiation to an absorbing medium, it is necessary to take into account that the contribution of each of the interaction processes is different. With FE, almost all the energy of a quantum is transferred by the photoelectron to the atoms of the medium; with Compton scattering, a significant part of the energy is carried away by the scattered quantum to the neighboring regions of the medium or beyond, some of the scattered quanta undergo secondary scattering or absorption; in the processes accompanying REPP.

Scintillation counter

The assembly of the scintillation counter consists in a rational combination of the scintillator and photomultiplier, which would provide the best resolution of the counter, both in amplitudes and in time, at the highest ratio of the amplitudes of electrical pulses from the detected particles to the amplitudes of the background pulses. A scintillator in the form of a cylinder or a disk is installed in front of the PMT cathode. For the fullest possible use of the light arising in the scintillator, the free surface of the latter is surrounded by a diffuse reflector, most often finely dispersed powder of magnesium oxide is used (reflection coefficient 90-97%).

A good optical contact is created between the scintillator and the photomultiplier photocathode using a substance with a refractive index intermediate between the glass and the scintillator substance. When registering low-energy particles, measures are taken to reduce the absorption of particles in the scintillator package.

Light flashes in scintillators when they are irradiated with γ-quanta arise as a result of the interaction of secondary electrons (appearing due to FE, REPS, and EC) with scintillator atoms. The intensity of the flares will be proportional to the energy of these secondary electrons. Let us consider the picture of the distribution of the energies of secondary electrons.

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