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Detectors to Observe Various Radiations & Their Energy Calibration-I: Beta Ray Energy Calibration for Plastic Scintillation Detectors for the Range ~50 to ~600 keV

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A method is described to calibrate plastic scintillation counters for observing low energy electrons, using β-emitting radioactive sources. Some of the sources such as ^{63}Ni, ^{35}S, ^{45}Ca and ^{90}Sr of energies 63, 165, 256 and 556 keV, respectively, are used to calibrate a plastic scintillation counter with the help of a single channel and a 256-channel pulse height analyzers. The details of the electronics used and the method of calibration are presented. The importance and the need for such calibration of detectors for space science experiments are also discussed.

1. Introduction

Low energy electrons are expected to be present in the upper atmosphere. These electrons are albedos produced by high energy primary cosmic rays in their interaction with the atmosphere. High energy albedos have been observed by some workers[1,2]. Theoretical calculations of the flux and energy spectrum of electrons in the high energy region agree with various measurements[2]. Not much work has been done to observe the low energy electrons in the upper atmosphere. Their flux has been measured by a group of Russian scientists[3] around ~40 keV and has been found to be quite high but the details of their experiment are not available. Since the energy spectrum of the low energy electrons is not observed, one can have some idea about it indirectly by using the flux and energy spectrum of the low energy X-rays and γ-rays. The flux and energy spectra of these X-rays and γ-rays in the energy region of a few MeV have been observed by Ryan *et al.*[4]. Assuming that these X-rays and γ-rays are produced by the low energy electrons by Bremsstrahlung process, Verma[5] made an order of magnitude calculation of the flux and energy spectrum of the low energy electrons. This shows that substantial flux may exist with steep spectrum, the flux increasing at low energies. With the aim of observing these electrons, detectors of various kinds are being designed, fabricated and calibrated. The present paper gives the details of the method used to calibrate a plastic scintillation counter using β-emitting radioactive sources of various energies.

2. Method of Energy Calibration

In general, α particles and γ-rays from a radioactive source are used for calibrating detectors as they show unique peaks at definite energies, However, the calibration obtained by using α particles (or γ-rays) is not applicable for measuring the energy of β particles because the α and β particles of same energy do not produce same number of light photons in the scintillator. Therefore, a separate calibration is needed for β particles.

A method is developed to calibrate detectors using β-rays from radioactive sources. Unlike α- and γ-rays, β-rays do not show a definite peak in its energy spectrum. However, Fermi spectrum of β particles from any given radioactive source shows a definite maximum energy E_{max}. This E_{max} is obtained by observing the Fermi spectrum of the β particles (which has a negative slope on the high energy side) and extrapolating the straight line part of it to zero count at high energy. This method is used for energy calibration.

3. Experimental Details

Plastic scintillation detectors with photo-multiplier tubes (PMT) are used to detect β particles. The block diagram of the experimental set-up, with its electronics, is shown in Fig. 1. The output pulse from the PMT is given to the amplifier of the single channel analyzer (SCA). The count rates for different discriminator levels are observed by the scalar for a particular source. The count rates represent the number of particles and the discriminator levels are proportional to their energies.

In order to standardize the calibration, the discriminator levels of the SCA are calibrated using a pulse generator. Pulse of known magnitude (in mV) are used to determine the threshold levels of the discriminator for each setting. Thus the discriminator levels are calibrated in terms of mV.

The observed spectra of ^{63}Ni, ^{36}S and ^{45}Ca are

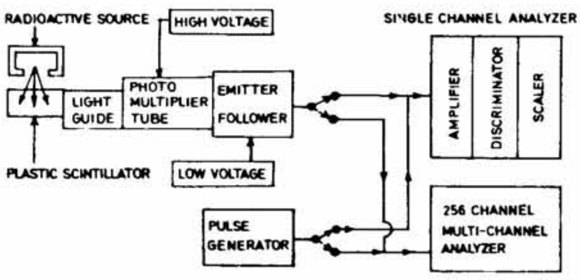

Fig. 1—Block diagram of the experimental set-up for energy calibration of a plastic scintillator detector by β-rays

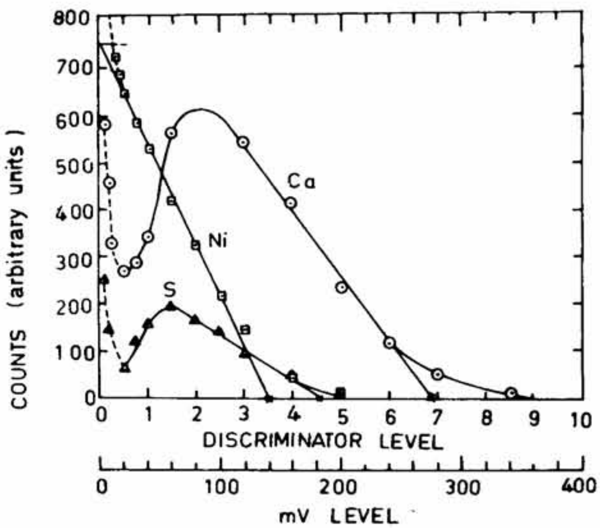

Fig. 2—Beta ray spectra of Ni, S and Ca

shown in Fig. 2. Spectra for ^{35}S and ^{45}Ca resemble the Fermi spectra of β particles except at low energy side. At low signal levels, there is a steep rise in count rate representing electronic noise*. This gives rise to a dip in the observed spectrum at the low energy side. However, ^{63}Ni, being a low energy source, does not show such a dip as the low energy end of the spectrum is merged with the noise. The straight line part of the spectrum, having negative slope, is extrapolated to give a cut-off on the mV axis which corresponds to E_{max} of the particles for that source. Various cut-off values in mV for different sources are obtained. The calibration graph is obtained by plotting the cut-off values versus E_{max} as shown in Fig. 3. Similar measurements on ^{90}Sr and ^{35}S are also taken on a 256-channel pulse height analyzer and the results are shown in the same Fig. 3.

*For plotting these spectra an attempt is made to remove the noise by subtracting the counts without source from the counts with source. However, this process of eliminating the noise is not a perfect one and the plots in Fig. 2 indicate some noise.

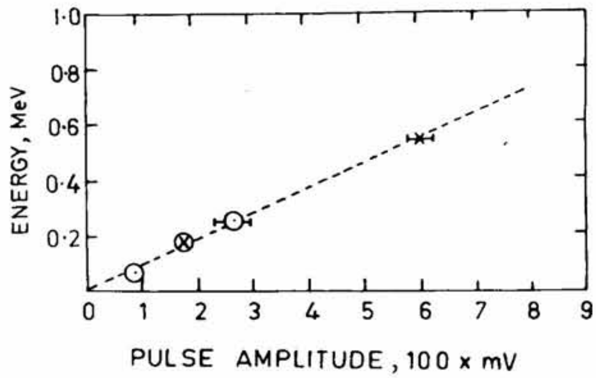

Fig. 3—Energy calibration of plastic scintillation counter for β particles [Circles (⊙) are for SCA results and crosses (×) are for 256-channel analyzer results]

4. Conclusion

Generally, the calibration for a β source is done by measuring its maximum range R_{max}. Since there is large uncertainty in measuring R_{max}, this method is not an accurate one. Another method is to find out the deflection of these particles in electric or magnetic field. Monoenergetic beams of electrons having different energies can also be used to calibrate detectors for β particles. However, in the absence of such beams, the method described in the present paper is quite a suitable one for measuring the energy of an unknown electron source. This has a useful application in the measurement of flux and energy spectrum of low energy electrons expected to be present in the upper atmosphere.

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