CHAPTER IV

DETAILS OF PRESENT EXPERIMENTAL INVESTIGATIONS

In this Chapter we give the details about the beta source, the targets used, the detector system, the experimental arrangement and the experimental procedure of the present investigations.

Source:

We have used a Sr-Y-90 source in our investigations, though all experimental results are relevant to Y-90 betas alone. The use of Y-90 beta source has the following advantages. It has a high end point energy of 2.26 MeV and is a pure beta emitter. Since Sr-90 and Y-90 are in secular equilibrium, the effective half-life of Y-90 source is quite large, so the same source can be used without any difficulty over a long period. The precise investigations on the beta spectrum of Y-90 by Johnson et al. have shown that between 0.5 MeV and the end point energy at 2.26 MeV, no other group of beta particles is present. Zr-90 gammas of 1.75 MeV are much too weak to affect the results. Though the Sr-90 beta spectrum is present, for photon energies above 0.5 MeV, it will not contribute to external bremsstrahlung at all. Bustard et al. have
shown that for photon energies above 400 KeV the contribution due to Sr-90 is negligible compared to Y-90.

A standard Sr-Y-90 pure beta source of strength 5 uC was obtained from the Isotope Division, Bhabha Atomic Research Centre (B.A.R.C.), Trombay, India, for the investigation of the Z-dependence of the integrated external bremsstrahlung intensity. As this source strength is very small for the measurements of external bremsstrahlung spectrum that is differential in photon energy, a carrier free 2 mC liquid source of high purity in nitrate solution was obtained from the Isotope Division, B.A.R.C., Trombay, Bombay. This source was further processed in our laboratory by slowly evaporating known aliquots of solution on a perspex disc of 2.5 cm diameter. The active solution was deposited in a small groove of 0.5 cm diameter, and was covered by 1.0 mg/cm² aluminised mylar sheet. The source was then sealed by keeping a thin perspex O-ring of I.D. 1.25 cm and C.B. 2.54 cm.

Targets:

The target materials used in this investigation were Copper, Selenium, Cadmium and Lead, covering an atomic number range of 29 to 82. The targets were 2.5 cm x 2.5 cm square foils of different thicknesses
ranging from 50 mg/cm² to 450 mg/cm². These thin foils were pressed together to provide targets of thickness up to 1.2 g/cm². The target thickness in mg/cm² were determined by weighing and by area measurements.

Target Foil Preparation of Selenium:

The selenium metal was available in the form of a fine powder. In a 2 in x 2 in x ½ in aluminum plate a 1 in diameter hole was drilled and a very thin Al foil (2.7 mg/sq.cm) was fixed on one side. Selenium metal powder of known weight was spread uniformly in the groove. Methyl alcohol was used to get a compact form of the powder and was evaporated by slow warming. Thus, by known weight of the powder and the area of the groove, the target thickness was determined.

The thicknesses of targets (in mg/cm²) used are given below:
<table>
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<tr>
<th>Element</th>
<th>Cu</th>
<th>Se</th>
<th>Cd</th>
<th>Pb</th>
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<tr>
<td>Z</td>
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<td>34</td>
<td>48</td>
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Detector System:

The external bremsstrahlung spectrum was measured using a NaI(Tl) scintillation spectrometer with a single channel pulse-height analyser. The spectrometer consists of a scintillation unit, an extra high tension unit, non-over load linear pulse amplifier, a single channel pulse height analyser, and a sealer with preset timer. A brief description of the electronic set up is given below:

The scintillation unit consists of a NaI(Tl) Harshaw crystal of type 4D4, 1 inch in diameter and 1 inch thick encased in an aluminum container which is optically coupled to a RCA 6199 photomultiplier tube. A thin packing of the magnesium oxide powder on the inside of the aluminum container acts as an efficient light reflector. A mu-metal magnetic shield is used to avoid the effects of external magnetic fields on the photoelectrons. The photomultiplier assembly with a cathode follower pre-amplifier is housed in a steel cylinder.

High Voltage Unit:

The high voltage power supply, +500 to +1500 volts at 1 mA maximum current furnishes the voltage necessary to operate the photomultiplier tube which requires an
extremely high degree of regulation. The electron multiplication factor of the photomultiplier strongly depends upon the applied voltage. A one percent change in voltage can cause as much as 15 percent change in electron multiplication. So a highly stabilised power supply is essential. The power supply used here is having the ripple and noise content less than 10 mV peak to peak.

The high stability of electronic instrument is further ensured by supplying the mains voltage to the spectrometer through an a.c. mains stabiliser, which provides a steady output within 1% variation even for a ±10 percent variation in mains voltage.

Pulse Amplifier:

The amplifier used is a non-over load linear pulse amplifier based on Chase and Higinbotham Circuit which fulfills the requirement of high gain to amplify these low level signal pulses, and whose output pulse height is proportional to the input pulse height over an output range 0 to 100 volts. If an amplifier is able to produce faithfully a small pulse even when a pulse large enough to drive the amplifier out of its linear region, it is said to have a good over load characteristic. The amplifier has a total gain A(B+C),
where A and B are coarse gain controls and C is a fine gain control. Gain setting A can be set to either 500 or 5000, and B can be set to any value from 0 to 0.8 in steps of 0.2; gain C can be varied from 0 to 0.2 smoothly. So that the gain can be changed continuously up to a maximum of 5000. The amplifier accepts either positive or negative pulses, but the output pulse is always positive.

Single Channel Pulse Height Analyser:

The single channel pulse height analyser gives an output only when the input pulse lies between two preset voltages. All voltages above the upper voltage level and below the lower level are rejected. The lower voltage level control (Discriminator Bias H) is a ten turn helical potentiometer which will not pass pulses that are below the setting of the dial or what is commonly known as the "Base line". The upper voltage control (window width ΔH) sets the limit above which all pulses will be rejected. The window width can be adjusted from 0 to 6 volts above the base line setting over the entire range of 0 to 100 volts of base line. The input pulses falling within the window width are obtained at the Differential socket with a constant output pulse of amplitude of +12 volts.
For integral operation pulses above the base line setting are obtained at the surplus socket with a constant output pulse of amplitude of +40 volts. Since the output pulses are positive the scaler should be set to accept positive pulses.

Experimental Arrangement:

The experimental arrangement employed for the measurements of integrated as well as differential external bremsstrahlung spectrum is shown schematically in Fig. 1. A stand was used to place the source in a fixed position and to place a perspex sheet of sufficient thickness to stop all particles from reaching the detector. The height of the stand was 13.5 cms on which the detector was placed with lead shield. The source was kept on 5th slot of the stand from below and the perspex beta stopper on 8th slot throughout all the measurements. The distance between the source and detector was 7.0 cms. All sides of the Sr-Y-90 beta source were covered by perspex so as to stop beta particles in all directions except in the forward direction, and thereby to minimise the extraneous external bremsstrahlung production from the surrounding materials. NaI(Tl) detector crystal was shielded by 2.0 cms of lead all around.
Calibration of the Spectrometer and the Test for Linearity:

Before recording any measurement the spectrometer was calibrated so that the full range of the discriminator bias level (0 to 100 volts) of the single channel pulse height analyzer represents an energy range of 0 to 2 MeV of the gamma rays. The 662 KeV gamma ray line from Ce-137 was used as a standard for calibration. The discriminator dial H was set to 32 volts and the window width dial was set to 2 volts so that the mean pulse height selected was 33 volts. The gain of the linear amplifier and the high tension of the photomultiplier were adjusted so that the pulse height due to total absorption of 662 KeV gamma becomes equal to 33 volts. This means that one volt of pulse height corresponds to 20 MeV of gamma energy.

Since the maximum pulse height obtained by the linear amplifier is 100 volts, this corresponds to a gamma energy range of 0 to 2 MeV. The linearity of the spectrometer was checked by determining the total absorption photopeaks of the following set of monoenergetic gamma lines: 145 KeV (Ce$^{141}$), 280 KeV (Ug$^{203}$), 662 KeV (Ce$^{137}$), 840 KeV (Mn$^{54}$), 1114 KeV (Tm$^{65}$) and 500 KeV and 1280 KeV (Na$^{22}$). A plot of pulse height corresponding to photopeak versus the incident gamma energy results
in a straight line as shown in Fig. 2, which establishes the linearity of the spectrometer over the entire range of energy of interest.

The scintillation spectrometer was switched on 2-3 hours before any data on bremsstrahlung was recorded. While recording the data on bremsstrahlung spectrum that is differential in energy, the spectrometer was kept on day and night so as to attain good electronic stability. The calibration was rechecked at the beginning and at the end of every set of readings. The variation in the energy calibration during a series of measurements was less than ± 1.6 percent. The proportionality between photon energy and pulse height was thus good to an extent of 2 percent throughout the energy range of interest. Similarly the window width was checked at the beginning and at the end of each set of readings, and was found to remain constant at 1 volt within about 1 percent.

Experimental Procedures:

A difference method has been adopted to eliminate the internal bremsstrahlung from the source and to determine the true external bremsstrahlung intensity produced in the target. The range of targets used were from 50 to 450 mg/cm$^2$ which is smaller than the range (1200 mg/cm$^2$) of beta particles of maximum energy from
FIG 2
LINEARITY OF PULSE HEIGHT IN VOLTS VERSUS THE GAMMA \gamma ENERGY IN MeV
Y-90. When the beta particles are not completely stopped in the target itself, it is necessary to prevent the transmitted beta particles from producing bremsstrahlung in the detector and the surrounding material. So a perspex sheet of 1.2 cm thick was used to stop all beta particles.

Correction for the internal bremsstrahlung from the source, has been made in the following manner. First the bremsstrahlung intensity was measured by keeping the target in position A; this intensity includes the internal bremsstrahlung attenuated in the target foil and in the perspex beta stopper, and the external bremsstrahlung intensity produced in the target attenuated in the perspex. Next the bremsstrahlung was measured by keeping the target in position B; this intensity is only due to the internal bremsstrahlung attenuated in perspex stopper and in the target. So, the difference of these two intensities gives the true external bremsstrahlung intensity produced in the foil, attenuated in the perspex stopper; this is free from both the internal bremsstrahlung and the cosmic ray background. Here we assume that when the beta particles fall directly on the perspex beta stopper the bremsstrahlung produced is negligible.

Perspex is a plastic derived by the polymerisation of the methylester of methyacrylic acid. Perspex has
the chemical structure $\text{C}_5\text{O}_2\text{H}_8$. From this structure we find the root mean square $Z$-value to be 4.6, which is comparable to $Z = 4$ of beryllium, the element of the lowest atomic number that can be used instead.
REFERENCES

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2. T.S. Bustard and J. Silverman, Nucl. Sci. and Engg., 