DETERMINATION OF THE BETA ENERGY (E_{max}) USING THIN WINDOW INSTRUMENTS*

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The use of simple survey instruments for beta-energy analysis is complicated by large differences that exist in the beta spectra shapes. These spectral shapes are often complex and change continuously as the betas are absorbed in air. Changes are also caused by absorbing material between the source and the detector. One may frequently encounter a combination of beta energies, either from multiple emissions from a single isotope or from several isotopes in the sample being evaluated. There may also be monoenergetic conversion electrons present in the sample or low-energy X rays which are absorbed in a similar fashion to betas.

Obviously, a complete analysis of complex beta spectra cannot be performed using only survey instruments. We present two methods which will give the approximate E_{max} of the beta energy responsible for the most significant portion of the beta dose. Either technique should give adequate information about the beta spectra to provide necessary guidance for the health physics evaluation of the exposure.

Theory

If simple survey instruments are going to be used to determine the beta energy, the most reasonable approach would be to make absorption studies, but limit them to as few absorbers as possible. Three absorber thicknesses were used in this study.

Mantel published the calculated beta spectra shape for 59 beta emitters (Ma72). The absorption curve obtained from each spectrum depends upon its shape. We calculated the absorption curve for many of the spectra given by Mantel. When the shapes of the absorption curves were compared, significant differences were apparent. If analysis of E_{max} is to be based on absorption measurements (using the three filter thicknesses we chose earlier), the absorption curves have to be similar. Based on the shapes of the absorption curves obtained above, we divided the beta spectra given by Mantel into four spectra types. These spectra types are shown in Fig. 1.

Few beta spectra look exactly like the ones labeled as types 1 through 4 and we show the variation that occurs within each spectra. There is obviously an overlap region between types; for example, curves F and G are very nearly the same. By using the analysis technique we describe, the spectra type obtained for spectra that have shapes in this region could be identified as either Type 1 or Type 2 depending on the variations in count rate or instrument reading recorded for that source.

The Type 4 sources shown as Q, R and S are sources having two major beta energies being emitted by a single isotope or from two isotopes in a decay chain such as ^{90}Sr and ^{90}Y. Another kind of the Type 4 source category are those shown in curves T, U and V, where there is only one predominant beta. Using the technique described later, these spectra would be analyzed as having only the one predominant energy and therefore, the energy obtained experimentally may be different than the published E_{max}.

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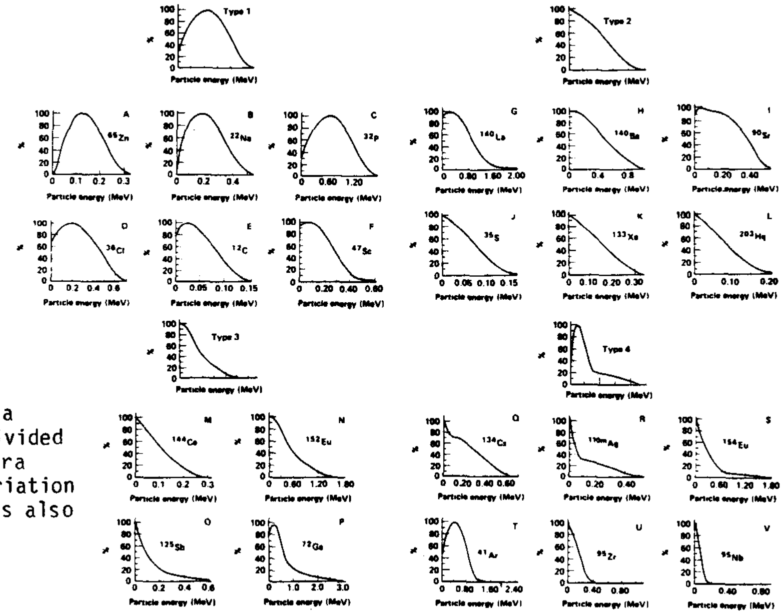

Fig. 1 The beta spectra were divided into four spectra types. The variation within a type is also shown.

A comparison of shapes of the absorption curves in the first decade shows that most of the Type 2 spectra are essentially straight lines, but the Type 1 and 3 spectra are curved with the Type 1 curves above and the Type 3 below the straight line curves of Type 2. The Type 4 sources have absorption curves (not shown) which have inflections in the curves and are obviously from two (or more) betas. The curves have a definite bend at the point where the first beta is absorbed. The absorption curves calculated for all the isotopes are different and we decided to use a typical or average curve for each source type. In Fig. 2 we show the average absorption curves used for the first three spectral types. These curves were used to develop additional curves, shown later, which were used to obtain the beta energy. The use of average curves will result in an error in the E_{max} evaluated for a specific beta depending upon how well the actual and average curves compare. This error is apparently small based on the good experimental results we obtained.

Experimental Method

To cover a wide range of dose rates, we used the Eberline Instrument Corporation Model RO-7 survey instrument and the Eberline Model E-120, GM equipped with the HP-210 pancake probe. The probe of the RO-7 has a window thickness of 7 mg/cm^2 and the window of the pancake probe varies from 1.5 to 2.0 mg/cm^2. The absorbers we used to distinguish between betas and gamma rays consisted of acrylic (Lucite). We used the $\sim$1 cm thick Lucite "beta filter" shown in Fig. 3 provided by Eberline with the RO-7 instrument. The pancake probe was used with two 0.48 cm-thick disks with an 8.8 cm radius (the o.d. of the probe housing), giving us a nominal 1-cm thick beta filter equivalent to the RO-7 beta filter. The readings of the instruments without the Lucite filters was assumed to be beta plus gamma and the filtered readings were the gamma readings. To determine the beta energies, aluminum absorbers of three thicknesses, 6.42, 33.4 and 277 mg/cm^2, were prepared for both instruments (Fig. 3).

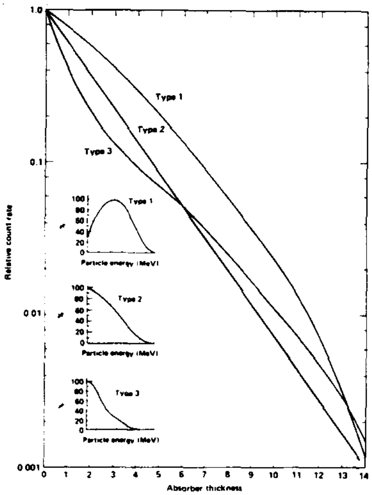

Fig. 2 Typical or averaged curves for each spectra type.

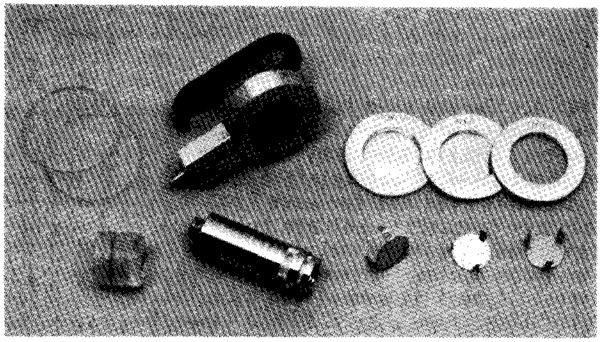

Fig. 3 Eberline HP-210 pancake probe and the Eberline RO7BM. The Lucite beta shields are on the left and the aluminum absorbers are on the right.

To determine the beta energy and spectral type of a source, five measurements of the dose rate or counting rates are required. These readings are made with the bare probe, Lucite-covered probe, and with each of the three aluminum absorbers.

The X- and gamma-ray component of the instrument readings must be removed first by subtracting the reading of the Lucite-covered probe from each of the other readings. Then, the ratio (or relative readings) of the beta readings with each aluminum absorber and the readings without absorber is determined. This is done by dividing the beta reading of the instrument with the aluminum absorbers by the beta reading of the instrument without absorber. The relative readings for each of the three absorbers is then plotted on the solid lines in Fig. 4 which was derived from the curves shown in Fig. 2.

If the source is a Type 1 source, the points plotted on the solid lines in Fig. 4 will be at the same beta energy. (If the relative reading is >0.95 or <0.05, that piece of data is probably not useful and does not need to be plotted.) If the data points do not give the same energy on the solid line, the source is not a Type 1 source. Then, in order to determine the type source, the points are plotted on the dashed curve for Type 2 sources and the dot/dash curve for Type 3 sources. The type of line on which the data points give the same energy (align vertically) is the type of source being evaluated and the energy where alignment occurs is the E_{max} of the predominant beta in the spectrum.

If the spectra is a Type 4 source, alignment will not occur. The results with the thin absorber indicate a low energy and the medium and thick absorbers indicate progressively higher energies. The fact that this is a Type 4 source can be useful in health physics work. One can use this technique to evaluate the higher energy component of Type 4 sources by removing the lower energy component with an appropriate absorber, (see complete text for details, HA82.

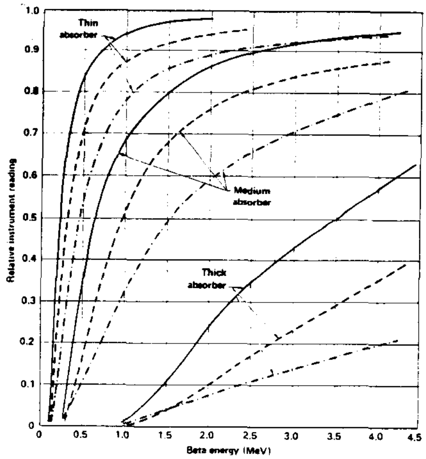

Fig. 4. Curves used to determine the energy and spectral type of beta sources. The beta energy and type is obtained when the relative instrument readings for each absorber thickness indicate the same energy (align vertically) on lines for one of the spectral types. Type 1 is symbolized by a solid line; Type 2 by a dashed line; and Type 3 by a dot/dash line.

The results obtained with numerous sources of all four types (see HA82) indicate that the known and evaluated source types and energies agree reasonably well and are adequate for health physics work. In most cases where differences were found, they could be explained by source shielding or other factors.

Field Surveys Using a Single Absorber

One goal of our study was to develop a technique where a single absorber thickness could be used to evaluate the exposure problems caused by beta particles in health physics field work. The field procedure consists of three dose-rate readings: (1) the bare probe, (2) the beta (Lucite) shielded probe and (3) the medium absorber reading. The reading with the beta shield (x and gamma rays) is subtracted from both the bare probe reading to obtain the beta dose rate and from the reading with the absorber. The beta dose rate and dose rate with absorber are compared and the amount of decrease caused by the absorber is determined. If it is small <25% the beta energy is high and is assumed to be >1.5 MeV. If the decrease is large, >75%, the beta energies are low <0.5 MeV. Readings between 25 and 75% would indicate beta energies between 0.5 and 1.5 MeV. Analysis of the beta energy using the single-filter technique gives a good estimate of the actual energy for the sources. However, its accuracy in a field location would depend upon the particular isotope or combination of several isotopes being evaluated, as well as the errors usually associated with field work. The technique is easy to use and a health physics technician making field surveys should be able to obtain the information necessary to evaluate protective clothing and personnel dosimetry requirements.

Ha82 Hankins, D.E., 1982, Evaluation of Beta Energy E_{max} and Spectral Type Using Survey Instruments, Lawrence Livermore National Laboratory, Livermore, CA UCRL-88275 [Submitted to Health Physics].

Ma72 Mantel J., 1972, "The Beta-Ray Spectrum and the Average Beta Energy of Several Isotopes of Interest in Medicine and Biology," International Journal of Applied Radiation and Isotopes 23, 407.