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A line graph representing an alpha-particle spectrum. The x-axis represents energy or channel number, and the y-axis represents counts or intensity. The plot shows a series of peaks of varying heights. From left to right, there are several small peaks, followed by a larger peak, then a series of peaks that generally increase in height, with some smaller peaks interspersed. The highest peak is on the right side of the plot. The line is continuous and shows some noise or fluctuations.

CATALOGUE OF SEMICONDUCTOR ALPHA-PARTICLE SPECTRA

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CATALOGUE OF SEMICONDUCTOR ALPHA-PARTICLE SPECTRA

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ABSTRACT

This report presents the first compilation of alpha-particle spectra obtained with silicon surface-barrier detectors. Spectra are presented of 35 nuclides ranging from $Z = 83$ to 98. Included are nuclides of both the natural decay chains and a number of the most frequently encountered artificially-produced nuclides. A thin source preparation method, described in this report, was used.

In order that these spectra be useful for analytical purposes, all spectra were recorded under a standard set of conditions that can be readily reproduced in other laboratories. Conditions such as detector size, resolution, geometry, sample size, and gain scale were standardized. The spectra are presented in graphical as well as digital form. In addition, the electronics, use of detectors, and sample preparation techniques are described in detail. To further aid the user of the Catalogue, appendices are included listing nuclides according to Z , A , and alpha-particle energy, a table of specific activities, the natural radioactive series and a range-energy curve.

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I. INTRODUCTION

The use of silicon surface-barrier detectors for alpha-particle detection and spectroscopy is now enjoying more widespread use with the advent of improved detectors and the increased reliability of solid-state electronics. However, outside of a few research laboratories, there appears to be a general lack of information concerning the use of these detectors, the improved alpha-particle resolutions that are now routinely attainable and their potential as an analytical tool. In this report we present a summary of the techniques involved in alpha spectroscopy plus a collection of alpha spectra in hopes of stimulating the increased use of this technique of analysis.

The analytical applications for alpha-particle spectroscopy are numerous and include areas such as reactor operations to detect and identify sample breaks and contamination levels, analytical techniques involving reactor fuel analysis for the Nuclear Safeguards Program, health physics analyses, and dating of geological (including extra terrestrial), oceanographic and archeological samples. In the region of the alpha-emitting nuclides (the trans-lead region) the majority of gamma-ray transitions are of low energy and for many nuclides of near equal energy. Alpha-particle energies and patterns, however, are unique for nearly all the heavy elements. Consequently, alpha-particle analysis many times succeeds where other methods such as gamma-ray spectroscopy fail. In addition, since alpha backgrounds are typically $\ll 1$ event per minute, only small samples of material are needed for an analysis.

In this catalogue we present the first compilation of semiconductor surface-barrier alpha-particle spectra. Spectra are pre-

sented for 35 nuclides from Bismuth ($Z = 83$) to Californium ($Z = 98$). Included are nuclides of the natural decay chains and a number of the artificially produced nuclides most frequently encountered. A complete description of the spectroscopy system and the sample-preparation techniques used in this survey is presented. Both were developed in this laboratory.^[1,2] To aid in the analytical analysis of the heavy elements, the digital form of the data is included as well as tables of nuclide as a function of energy, energy as a function of nuclide, specific activities, and a range-energy curve in air. Additional alpha spectra will be issued in the future as supplements, the timing of which depends upon financial support.

II. EXPERIMENTAL APPARATUS AND TECHNIQUE

1. Alpha-Particle Spectrometer

The spectrometer, designed and built in the authors' laboratory, is shown in block diagram in Figure 1. This spectrometer was designed as a research tool to study the many parameters affecting high resolution alpha-particle spectroscopy. As such the design includes some features which may not be necessary for a routine analytical instrument. Consequently, a duplicate of the system described below is by no means necessary to reproduce the spectra in the survey, and the following description is included only to emphasize those criteria important to any spectrometer design.

A silicon surface-barrier detector is mounted in a chamber so designed that the detector may be kept cooled, in constant vacuum and at full bias while changing samples. A field-effect (FET) charge-sensitive preamplifier, low-noise amplifier, and biased amplifier are

Figure 1. Block diagram of alpha-particle spectroscopy system.

used with a 1024-channel pulse-height analyzer for signal amplification and pulse-height analysis.

1.1 Cryostat and Chamber

Before designing the counting chamber, the effects of scattering from the walls and other metal surfaces in the vicinity of the detector and sample holder were evaluated. None were observed, even under conditions to produce maximum scattering. Therefore, the volume of the chamber was only that necessary to contain the detector and associated electronics.

Figures 2 and 3 show the spectrometer assembled and in exploded view. The main portion consists of two brass cylinders which

Alpha-Particle Spectrometer

FIGURE 2

Figure 2. Alpha-particle spectrometer with cutaway view showing internal preamplifier components, detector, and sample holder.

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Figure 3. Exploded view of alpha-particle spectrometer.

house the detector and first stage components of the low-noise pre-amplifier. The detector and internal preamplifier components are mounted on a 3/8-in. diam. copper rod. The end of the rod is fitted with a Microdot connector to hold the detector. This rod provides cooling to the detector and the FET's in the preamplifier first stage by extending to the top of the chamber where it is soldered to the outlet of a 10-liter cold-storage Dewar (Linde CR-10). These FET's are mounted just above the detector on a brass ring attached to the copper rod. Thus, the detector and FET's are maintained at the same temperature. This arrangement gives optimum performance down to -130°C ; below this temperature FET noise begins to increase^[3] and the brass ring should be insulated from the copper rod with Teflon (Figure 3). Electrical connections are completed through a nine-pin "Kovar" seal in the upper chamber wall.

A 4-in. gate valve^[4] isolates the upper sections of the chamber from the removable sample holder. The gate valve is an important feature of the design. It keeps the detector at constant vacuum, in the dark, and at full bias during sample insertion and removal. Even when operated at ambient temperature, the detector performance is improved when the conditions are kept constant. For operation at cryogenic temperatures, the gate valve system is a prerequisite for sample rates above one per 4 hr.

The counting sample rests in a cup mounted on a 1/4-in. diam. steel rod which slides through O-ring seals in a brass plate. With the sample in place, the sample holder is positioned under the gate valve and held firmly against the O-ring seal. The holder is then evacuated through the pump-out line located in the side of the gate

valve. Because of its small volume, the sample holder can be evacuated and integrated with the rest of the system in approximately one minute. Neoprene O-rings are the vacuum seals.

The chamber and sample holder are evacuated by a fore or roughing pump. Oil vapors from the pump, detrimental to silicon surface-barrier detectors, are removed on a Vac-Sorb^[5] filter mounted in the pumpout line. The spectrometer is also equipped with a Varian vac-ion pump which will maintain the chamber at $<10^{-6}$ torr.^[5]

1.2 Electronics

The FET preamplifier constructed in this laboratory^[1] is a DC-coupled version of an earlier design.^[3] To obtain maximum resolution a portion of the preamplifier is inside the cryostat (Figure 4). This permits a short 1-in. wire between the detector and the preamplifier first stage with a consequent low capacitance. In the preamplifier, 4 FET's were paralleled in the input stage to further improve the resolution^[3]. This arrangement gave a noise level of 0.77 keV silicon equivalent at 0 pf plus 0.028 keV per pf of input capacitance (including detector and stray capacitance to ground). The higher gain and lower noise of currently available FET's provide comparable performance with one or two units. Rather than building the preamplifier, commercial units are now available with comparable noise and performance levels.^[6]

With operation of the cryostat at $\sim 0^{\circ}\text{C}$ the detector leakage current for 25 mm^2 detectors is only 1 to 2 nano-amperes so that a large ($10^9 \Omega$) bias resistor was used in the high-voltage input circuit. When using a high leakage current device it may be necessary to use a lower valued bias resistor (see Sec. 1.3.1).

Simplified Schematic Diagram Of FET Preamplifier

Figure 4. Partial schematic diagram of FET preamplifier. The portion of the preamplifier within the dashed lines is located inside the cryostat.

The preamplifier output feeds through a low-noise main amplifier with variable shaping constants, then a biased amplifier. Several commercial units are adequate; the Tennelec TC-200 main amplifier and TC-250 biased amplifier were used. The spectra were analyzed on a 1024-channel Nuclear Data ND-181 pulse-height analyzer and the data printed out on paper tape. The spectra were plotted using the Cal-Comp computer routine.

1.3 Detectors

Silicon surface-barrier detectors are the type most commonly used for the detection of low energy alpha particles. Since alpha

particles from radioactive decay rarely exceed an energy of 10 MeV depletion depths of 60-100 microns are adequate (Figure 5).

Surface-barrier detectors are available with a range of active areas. The large, up to 1000 mm² active area, detectors are particularly useful for gross alpha counting of low-activity samples. The resolution for these size detectors is about 70 to 100 keV at room temperature. The smaller detectors with higher resolution are preferred for analyses of mixtures of α -emitters.

All the spectra in this catalogue were obtained on 25-mm² detectors of 60-125 microns depletion depth. These units were purchased commercially and had factory quoted resolutions of 13-16 keV FWHM at the 5.468 MeV ^{241}Am line at room temperature. For the catalogue spectra the resolution was held at 13.0 ± 0.5 keV FWHM by varying the detector temperature between 0°C and 25°C.

1.3.1 Detector Bias

For the detector to function, a depleted region must be formed by the application of a reverse bias voltage across it. This bias voltage should come from a well-filtered, stable, and regulated supply equipped with a continuously variable voltage control. A 300-V supply is adequate when using surface-barrier detectors. The voltage to be applied is a function of such detector properties as the silicon resistivity, the leakage current and, in addition, the value of the bias resistor in the high voltage input circuit. The applied bias causes a voltage drop across the bias resistor such that the voltage on the detector is less than the voltage at the supply. This drop, caused by the detector leakage current, is expressed as:

Figure 5. Silicon Detector Parameter Nonogram - A straight edge connecting the detector resistivity and applied bias voltage gives the corresponding depletion depth. Similar to a nonogram previously reported by J. L. Blankenship, IRE Trans., Vol NS-7, Nos. 2-3, p 190 (June 1960).

$$V_{\text{Det}} = V_{\text{Bias}} - I_{\text{Det}} R_{\text{Bias}}$$

where V_{Det} is the voltage actually applied across the detector (Figure 6). Detector performance is not affected by this voltage drop unless insufficient bias reaches the detector. To ensure that the voltage applied to the detector is adequate, the detector noise is monitored until a plateau is attained (Figure 7).

Although maximum operating voltages are stated for commercial detectors, these voltages are usually determined using a megohm-range bias resistor. We used a 1000 megohm resistor with a correspondingly larger voltage drop. The correct operating voltage

Figure 6. Schematic arrangement for applying detector bias showing placement of ammeter and RMS noisemeter.

Figure 7. RMS noise as a function of bias voltage for a 25-mm² surface-barrier detector at 25°C and 0°C.

was determined by monitoring the detector noise at the amplifier output with an RMS voltmeter or oscilloscope (Figure 6). Monitoring is an essential precaution to detect microplasma breakdown. When observed the applied voltage should be decreased before the detector is permanently damaged. As a means of monitoring, reverse current is also useful (Figure 5). However, monitoring noise is a more sensitive method for determining maximum operating voltage since, near breakdown, the noise increases more rapidly than the reverse current.

1.3.2 Chamber Pressure

Surface-barrier detectors may be operated at atmospheric pressure. However, the inelastic scattering of alpha particles by air molecules decreases the resolution. To obtain maximum

resolution, a vacuum maintained at $\sim 10^{-3}$ by a roughing pump is recommended. Resolution as a function of chamber pressure is shown in Figure 8 for a source-to-detector distance of 2 cm. The resolution at half maximum and one-tenth maximum undergoes only a slight increase of $\sim 2\%$ and $\sim 7\%$, respectively, over the pressure range of 1 to 900 microns. For applications where maximum resolution is not required, the vacuum may be maintained toward the upper limit of this range. In fact, such a procedure is helpful in avoiding contamination of the detector by daughter nuclei recoiling from the source onto the detector [7].

Figure 8. Alpha-particle resolution of ^{244}Cm as a function of chamber pressure for a source-to-detector distance of 2 cm.

1.3.3 Detector Cooling

The resolution of semiconductor detectors is improved by cooling. Cooling reduces the noise generated in the detector by reducing both thermal noise and reverse current. The effect of temperature upon RMS noise is shown graphically in Figure 7; reverse current as a function of temperature shows a similar pattern.

Silicon detectors are cooled by a variety of methods including thermoelectric coolers, carbon-dioxide gas expansion, mixtures of solid carbon dioxide and organic solvents such as carbon tetrachloride or acetone, liquid nitrogen, and circulation of other solvents including water through cooling systems. The detectors used in this study were cooled by a small refrigeration unit which circulates methyl alcohol through a cold-finger type cryostat. This method of cooling allowed the operating temperature to be varied for different detectors in order to maintain 13.0 ± 0.5 keV FWHM resolution. When many samples are analyzed over short time periods atmospheric moisture tends to condense on the detector with consequent loss of resolution. When observed, the detector should be warmed to ambient temperature for several hours with the vacuum maintained. With this remedy, the detectors maintain their long-term stability.

The gold surface on the detector is slightly sensitive to the passage of large molecules. Environments in which contaminants such as mercury vapor, pump oil vapor, large quantities of water vapor, and organic solvents may be present should, therefore, be avoided. When not in use the detectors are stored in a desicator under vacuum in the dark. [8]

2. Spectrometer Calibration and Use

2.1 Energy Calibration and Gain Determination

A mercury switch pulser connected to the amplifier through a 0.5 pf test capacitor (Figure 1) is used for an approximate calibration of the system. The pulser is previously calibrated with an alpha source such as the 5.806 MeV alpha particle line of ^{244}Cm .^[9] For precise calibration, a standard alpha source such as the 5.3045 MeV alpha particle of ^{210}Po is generally used. Because of its short half life, other nuclides, such as ^{244}Cm or ^{241}Am , are more convenient. We are determining the energies of these longer lived isotopes to a higher degree of accuracy so that they may replace ^{210}Po for general use.

The gain of the system was established at 3.0 keV/channel using the alpha spectrum of a nuclide containing two or more lines of known energy separation. An even-even nuclide such as ^{244}Cm has several distinct advantages. It is a convenient energy standard, has only two prominent alpha energies (5.806 MeV-76.7% and 5.763 MeV-23.3%) so that short counting periods suffice and energy separation between these two alpha energies has been measured accurately by gamma-ray measurements as 42.88 keV^[9].

2.2 Noise Measurement

A procedure for determining the electronic noise is used which measures the equivalent noise charge (ENC) of the system. The RMS noise of the system is measured at the shaping amplifier output with no sources or pulser input for a specified set of conditions. The pulse amplitude (V_{out}) from the shaping amplifier is then measured

for a given pulser^[10] amplitude (V_{in}). The equivalent noise change (ENC) is given by^[11]

$$ENC \text{ (keV, silicon)} = 5.12 \times 10^{16} \frac{V_{in} V_{noise} C_{test}}{V_{out}} .$$

With voltages expressed in volts and the capacitance in picofarads, the noise is expressed in keV FWHM silicon equivalent. The value of C_{test} , the preamplifier test input capacitor (Figure 1), for our measurements was 0.5 pf. With the detector removed, the noise was 0.77 keV. This value is essentially that of the preamplifier because the noise generated by the amplifier was negligible. For a 25-mm² detector the typical range is 4 to 5 keV silicon equivalent at 25°C to 3.5 keV silicon equivalent at 0°C.

2.3 System Performance Verification

The spectra presented in this survey have been recorded with the best "state of the art" equipment available at that time. The resolution was maintained at 13.0 ± 0.5 keV FWHM. A warranted resolution at some particular energy, usually the 5.486 keV peak of ²⁴¹Am, normally is provided with each detector along with the conditions of measurements by the manufacturer. This resolution is affected by the conditions of the source. A thick source, for example, will degrade the resolution even with an optimum system.

Overall system performance is best evaluated by measuring the resolution with a standard source.* If subpar, the individual

* Such standard sources can be purchased commercially or prepared in one's own laboratory if extreme care is exercised (see Section II-2).

parameters such as pulser width, RMS noise (see Section II-2.2), vacuum and detector are checked. When a detector is installed, the RMS noise for a particular gain and bias level should be recorded as a base for future comparison.

In addition, from the energy separation (~ 43 keV) between the two main alpha groups an indication of the detector resolution can be obtained by measuring the peak-to-valley ratio. This ratio is determined from the peak height of the 5.806 MeV line and the height of the valley between the two main alpha groups. Since this ratio can be read directly from the display scope on the analyzer, a rough indication of detector resolution can be quickly made by reference to the curve in Figure 9. We have found these peak-to-valley measurements to be particularly useful in checking out new detectors and also in following the performance of a detector under varying conditions.

Figure 9. Resolution expressed as keV FWHM of the 5.806 MeV line of ^{244}Cm plotted as a function of the peak-to-valley ratio. This ratio is the peak height at 5.806 MeV divided by the valley height between the two main alpha groups (see text).

2.4 Geometry

Geometry considerations for alpha spectroscopy are straightforward and are controlled mainly by the source strength and the desired counting rate. The source-to-detector distance becomes critical only when the samples are at a distance of less than one or two detector diameters. At such distances, a decrease in resolution results when α -particles impact the detector at oblique angles, traverse different thicknesses of the gold layer, and thus experience an energy dispersion before reaching the active volume of the detector. From the practical standpoint, this distance varies as a function of the resolution of the detector. For example, a small effect noticeable at 12 keV FWHM may not be discernible at 15 keV FWHM. The foregoing assumes a source diameter about equal to the detector diameter. For larger diameter sources, a degradation in resolution becomes evident at greater distances.

The spectra in this catalogue generally were recorded at a source-to-detector distance of 2 cm which is ~ 4 detector diameters. The only exceptions were the long lived ^{235}U and ^{237}Np sources which were placed 1 cm from the detector.

3. Source Preparation

To obtain high resolution thin uniform sources are required. Crudely prepared sources such as those obtained by evaporation from aqueous solution are adequate in the range of 25 to 100 keV FWHM.

Many techniques are used to prepare alpha sources. Frequently used ones are vacuum sublimation from a hot filament^[12], electro-

spraying^[13], and electrodeposition^[14].^[a] These techniques are time consuming and, with the exception of electrodeposition, require elaborate apparatus. In addition, appreciable time is required to decontaminate the apparatus after each source preparation. The method developed and used to obtain the spectra presented in this catalogue is to extract the alpha-emitting isotope into a volatile organic liquid, centrifuge, transfer the organic phase to a platinum disc, evaporate to dryness under conditions to give a uniform deposit and flame to remove the organic matter. This method is rapid, uses simple and inexpensive apparatus which can be discarded, and produces thin, uniform deposits. The extractant was 0.25 M thenoyltrifluoroacetone (TTA) in benzene. Resolutions of 12 to 15 keV generally were obtained^[2].

The details of the working procedure are:

- (1) The nuclide or nuclides are chemically purified by conventional methods of ion exchange or solvent extraction.
- (2) The pH is adjusted to a value optimum for the extraction of the desired elements^[15], then extracted into 0.25 M TTA-benzene. The organic/aqueous ratio usually is 1:1 with a total volume of ~1 ml. A new 10 ml screw cap vial is used for each extraction.

[a] For a more complete review of sample preparation techniques, see: W. C. Parker and H. Slatis, "Sample and Window Techniques", in Alpha-, Beta-, and Gamma-Ray Spectroscopy, Kai Siegbahn (ed.), Vol. I, p. 370-407 (1965), and Proceedings of the Seminar on the Preparation and Standardization of Isotopic Targets and Foils, M. L. Smith (ed.) AERE-R-5097 (1965).

After 2 to 5 minutes of hand agitation the mixture is centrifuged for 1 minute.

- (3) A 1-in. diam. x 2 mil thick platinum disc* with a 4-mm diam. indentation in the center is centered ~3 inches under a heat lamp. The organic phase is transferred to the disc slowly with a small spitzer or medicine dropper with the heat lamp off.
- (4) After evaporation is complete, the disc is slowly heated to dull redness with a flame. Discs are not used that have any visible deposit.

Special care should be taken in the preparation of the TTA-benzene solution. Impurities in the solution could impair the quality of the sample. Care should also be exercised in transferring portions of the organic layer to the plates. Any trace of the aqueous layer will leave a residue with a resultant loss in resolution.

4. "Satellite" Peaks in Natural Chain Spectra

In the alpha spectra of several isotopes of the natural decay chains, a secondary or "satellite" peak appears 35-40 KeV above a main alpha peak. This satellite is usually 1/10 to 1/100 the in-

* Any highly polished metal that does not melt or oxidize upon flaming is satisfactory. Platinum discs, 1-in. diam. x 2 mil thickness, are used because a scratch-free depression is easily made with a fire-polished glass rod or the round end of a small test tube. Also, the melting point of platinum is high and it is resistant to oxidation. Aluminum is also satisfactory but melts at a lower temperature. Stainless steel slightly oxidizes during flaming to cause a decrease in resolution of 1 to 2 keV FWHM. Also, it is difficult to make depressions in stainless steel plates without the use of a die.

tensity of the adjacent main alpha peak as shown in Figure 10.*
 Since these peaks only appear in certain spectra an effort was made
 to determine the conditions under which they occur and how the
 satellites can be reduced or eliminated.

Figure 10. Alpha-particle spectrum of ²¹⁹Rn and ²¹¹Bi from a source of ²²⁷Th. Satellite peaks are marked with an asterisk (*).

* An asterisk is used to identify the satellite peaks in Figure 10 and throughout the catalogue.

Using several different detectors and sources prepared by different methods (liquid evaporation, electrodeposition, and recoil collection) it was shown that the satellite peaks are not a function of either the detector or the method of source preparation. Counting the samples at various distances and counting rates eliminated coincident summing or pulse pile-up effects as the source of the satellite peaks. Therefore, the peaks are a function of the source material.

These satellites are observed only for isotopes of $Z \leq 86$. Further, radon itself must be present in the source. For example, the alpha spectrum of ^{211}Bi in Figure 11 shows no satellites. The source

Figure 11. Alpha-particle spectrum of ^{211}Bi from a source of ^{211}Pb .

material in this case was ^{211}Pb whereas in Figure 10 above the source was ^{227}Th in which ^{219}Rn is a chain member. Even though radon is present in the source not all alpha lines show the satellite—only those of $Z \leq 86$. Thus, in Figure 12 of ^{224}Ra and daughters the 5.684 MeV ^{224}Ra line is not affected, whereas the rest of the chain members exhibit the satellite.

Reducing or eliminating the satellites involves preventing recoils from leaving the vicinity of the source. One method used involves placing a few micrograms/cm² of plastic film over the source. Although the alpha particles were degraded in energy an average of ~ 7 KeV, the satellites were essentially eliminated (Figures 13 and 14)

Figure 12. Alpha-particle spectrum of ^{224}Ra and daughters.

Figure 13. Normalized alpha-particle spectra of ^{219}Rn and ^{211}Bi with and without a thin film over the source.

with no loss in resolution. In addition, the low energy tailing of the prominent alpha lines is appreciably reduced.

An alternate method of reducing the magnitude of the satellite peaks involves increasing the counting chamber operating pressure. In essence this produces the same effect as the plastic film, i.e., places a finite mass between the source and detector. As shown in Figure 15, satellite peaks progressively lower in intensity as the pressure is raised to 900 microns. The effect upon resolution is small as discussed in Section 1.3.2.

For the catalogue spectra the satellites were not removed, and each is marked with an asterisk (*).

Figure 14. Normalized alpha-particle spectra of ^{224}Ra and daughters with and without a thin film over the source.

5. Analysis of Alpha-Particle Spectra Recorded from Thick Sources

Spectra recorded from sources that are not mass free are quite different in appearance from massless source spectra such as shown in this catalogue. Sources containing any quantity of mass resulting from either foreign materials or the nuclide itself tend to degrade the energy of the alpha particles. The spectral result is increased tailing and loss of resolution.

However, low resolution spectra can in some cases be quite useful. In instances where the qualitative composition is known an accurate ratio of activities can be obtained as long as the nuclides are well

Figure 15. Alpha-particle spectra of ^{224}Ra and daughters as a function of chamber pressure: a) 85 microns, b) 500 microns, and c) 900 microns.

separated in alpha energy. The direct evaporation of a solution of medium salt content (<100 mg/ml) containing ^{239}Pu and ^{241}Am results in such a system as shown in Figure 16. Although the internal structures are not resolved at this resolution (~ 81 keV FWHM), the 329 keV energy separation between the two main groups permits extrapolation of the low energy tails and quantitative determination of the two nuclides.

This type of alpha-particle analysis is rapid and sufficiently accurate for many routine analyses such as feed solutions or process streams and some health physics applications. In many instances such

Figure 16. Alpha-particle spectrum recorded from a thick source of ^{239}Pu and ^{241}Am .

as in health physics problems, a smear type sample can be analyzed even though the resolution may be ~ 200 keV. Obviously when looking for a low intensity component in a mixture of isotopes or when highly accurate quantitative results are desired, high resolution spectra are a prerequisite and thin samples are then required.

III. DATA PRESENTATION

The data are presented in both graphical and digital form (Appendices 7 and 6, respectively). Each spectrum is labeled for nuclide, half life, gain scale, and geometry. In addition, each alpha line is identified by energy (in MeV) with relative intensities in parenthesis following the energy. Energies and relative intensities are quoted from References (9 and 16).

As explained in Section II.4, "satellite" peaks are labeled with an asterisk.

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APPENDIX I

Table of Alpha-Particle Energy vs. Alpha-Particle
Abundance, Nuclide, and Half Life

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
4.035	0.23	U-238	4.51 x 10 ⁹ y
4.147	23	U-238	4.51 x 10 ⁹ y
4.157	~0.5	U-235	7.1 x 10 ⁸ y
4.195	77	U-238	4.51 x 10 ⁹ y
4.216	5.7	U-235	7.1 x 10 ⁸ y
4.266	0.6	U-235	7.1 x 10 ⁸ y
4.323	3	U-235	7.1 x 10 ⁸ y
4.333	0.3	U-236	2.39 x 10 ⁷ y
4.344	1.5	U-235	7.1 x 10 ⁸ y
4.366	18	U-235	7.1 x 10 ⁸ y
4.396	57	U-235	7.1 x 10 ⁸ y
4.415	4	U-235	7.1 x 10 ⁸ y
4.441	0.03	Th-230	8.0 x 10 ⁴ y
4.442	0.05 §	Ac-227	21.8 y
4.443	26	U-236	2.39 x 10 ⁷ y
4.445	0.6	U-235	7.1 x 10 ⁸ y
4.474	0.12	Th-230	8.0 x 10 ⁴ y
4.493	74	U-236	2.39 x 10 ⁷ y
4.501	0.03	U-233	1.62 x 10 ⁵ y
4.502	1.2	U-235	7.1 x 10 ⁸ y
4.556	3.7	U-235	7.1 x 10 ⁸ y
4.573	0.05	Np-237	2.14 x 10 ⁶ y
4.586	0.01 §	Ac-227	21.8 y
4.591	0.015	Pa-231	3.25 x 10 ⁴ y
4.591	0.02 §	Ac-227	21.8 y

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
4.594	0.08	Np-237	2.14 x 10 ⁶ y
4.597	4.6	U-235	7.1 x 10 ⁸ y
4.598	0.06	Np-237	2.14 x 10 ⁶ y
4.598	5.5	Ra-226	1600 y
4.60	0.35	U-234	2.47 x 10 ⁵ y
4.617	24	Th-230	8.0 x 10 ⁴ y
4.624	0.1	Pa-231	3.25 x 10 ⁴ y
4.635	0.1	Pa-231	3.25 x 10 ⁴ y
4.638	4.6	Np-237	2.14 x 10 ⁶ y
4.654	58 §	Bi-210	5.01 d
4.658	0.57	Np-237	2.14 x 10 ⁶ y
4.660	0.06	U-233	1.62 x 10 ⁵ y
4.663	1.6	Np-237	2.14 x 10 ⁶ y
4.673	1.5	Pa-231	3.25 x 10 ⁴ y
4.683	0.4	Th-229	7340 y
4.684	76	Th-230	8.0 x 10 ⁴ y
4.691	42 §	Bi-210	5.01 d
4.693	0.18	Np-237	2.14 x 10 ⁶ y
4.697	0.08	U-233	1.62 x 10 ⁵ y
4.698	0.07	Np-237	2.14 x 10 ⁶ y
4.705	~1	Pa-231	3.25 x 10 ⁴ y
4.707	0.29	Np-239	2.14 x 10 ⁶ y
4.711	0.13	Np-237	2.14 x 10 ⁶ y
4.712	0.31 §	Ac-227	21.8 y
4.722	1.5	U-233	1.62 x 10 ⁵ y
4.722	28	U-234	2.47 x 10 ⁵ y

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
4.729	8.4	Pa-231	3.25 x 10 ⁴ y
4.735	0.09 §	Ac-227	21.8 y
4.749	0.3	U-233	1.62 x 10 ⁵ y
4.756	1.5	Th-229	7340 y
4.765	17	Np-237	2.14 x 10 ⁶ y
4.766	1.6 §	Ac-227	21.8 y
4.770	19	Np-237	2.14 x 10 ⁶ y
4.773	72	U-234	2.47 x 10 ⁵ y
4.778	14.6	U-233	1.62 x 10 ⁵ y
4.782	0.08 §	Ac-227	21.8 y
4.781	94.5	Ra-226	1600 y
4.787	0.04	Pa-231	3.25 x 10 ⁴ y
4.787	51	Np-237	2.14 x 10 ⁶ y
4.793	0.9 §	Ac-227	21.8 y
4.793	1.0	Th-229	7340 y
4.798	1.2	Pu-241	13.2 y
4.802	1.6	Np-237	2.14 x 10 ⁶ y
4.811	11.4	Th-229	7340 y
4.816	1.5	Np-237	2.14 x 10 ⁶ y
4.819	0.07 §	Ac-227	21.8 y
4.821	83.4	U-233	1.62 x 10 ⁵ y
4.842	58.2	Th-229	7340 y
4.845	1.4	Pa-231	3.25 x 10 ⁴ y
4.853	4.0 §	Ac-227	21.8 y
4.853	12	Pu-241	13.2 y
4.862	0.2	Np-237	2.14 x 10 ⁶ y

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
4.863	24	Pu-242	3.79 x 10 ⁵ y
4.870	0.9	Np-237	2.14 x 10 ⁶ y
4.870	6.5 s	Ac-227	21.8 y
4.872	0.4	Np-237	2.14 x 10 ⁶ y
4.896	83	Pu-241	13.2 y
4.897	0.11 s	Ac-227	21.8 y
4.899	10.7	Th-229	7340 y
4.903	76	Pu-242	3.79 x 10 ⁵ y
4.926	3.0	Pa-231	3.25 x 10 ⁴ y
4.930	0.25	Th-229	7340 y
4.938	38 s	Ac-227	21.8 y
4.940	0.25 s	Bi-214	19.8 m
4.943	22.8	Pa-231	3.25 x 10 ⁴ y
4.951	48 s	Ac-227	21.8 y
4.967	0.4	Pa-231	3.25 x 10 ⁴ y
4.967	6.0	Th-229	7340 y
4.971	1.1	Pu-241	13.2 y
4.977	1.4	Pa-231	3.25 x 10 ⁴ y
4.977	3.4	Th-229	7340 y
4.984	0.078	Rn-222	3.824 d
4.995	0.36	Pu-241	13.2 y
5.005	25.4	Pa-231	3.25 x 10 ⁴ y
5.009	~0.1	Th-229	7340 y
5.020	0.09	Pu-240	6580 y
5.022	20	Pa-231	3.25 x 10 ⁴ y

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
5.022	0.21 §	Bi-214	19.8 m
5.024	~2.5	Pa-231	3.25 x 10 ⁴ y
5.034	~0.2	Th-229	7340 y
5.036	18	Cm-248	4.7 x 10 ⁵ y
5.041	1.0	Pu-241	13.2 y
5.046	0.12	Bk-249	314 d (β-)
5.051	0.35	Pu-241	13.2 y
5.051	11	Pa-231	3.25 x 10 ⁴ y
5.054	6.7	Th-229	7340 y
5.067	0.2	Am-242m	152 y
5.080	82	Cm-248	4.7 x 10 ⁵ y
5.088	0.3	Am-242m	152 y
5.107	11.5	Pu-239	2.44 x 10 ⁴ y
5.109	2.7	Bk-249	314 d (β-)
5.123	24	Pu-240	6580 y
5.140	0.03	Th-228	1.913 y
5.140	0.32	U-232	72 y
5.142	6.1	Am-242m	152 y
5.145	15.1	Pu-239	2.44 x 10 ⁴ y
5.150	0.021	Ra-223	11.4 d
5.157	73.3	Pu-239	2.44 x 10 ⁴ y
5.168	76	Pu-240	6580 y
5.171	0.026	Ra-223	11.4 d
5.176	0.2	Th-228	1.913 y
5.181	1.1	Am-243	7.95 x 10 ³ y
5.183	0.61 §	Bi-214	19.8 m

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
5.207	89	Am-242m	152 y
5.211	0.4	Th-228	1.913 y
5.225	~0.02	Ac-225	10.0 d
5.234	10.6	Am-243	7.95 x 10 ³ y
5.234	0.042	Ra-223	11.4 d
5.246	2	Cm-245	9.3 x 10 ³ y
5.257	0.043	Ra-223	11.4 d
5.267	32	U-232	72 y
5.267	5.8 s	Bi-214	19.8 m
5.276	87.9	Am-243	7.95 x 10 ³ y
5.281	0.095	Ra-233	11.4 d
5.285	0.2	Ra-223	11.4 d
5.295	0.1	Ac-225	10.0 d
5.305	100	Po-210	138.4 d
5.306	7	Cm-245	9.3 x 10 ³ y
5.31	5	Bk-247	1.4 x 10 ³ y
5.315	0.8	Am-242m	152 y
5.321	0.12	Am-243	7.95 x 10 ³ y
5.324	68	U-232	72 y
5.328	0.07	Ac-225	10.0 d
5.337	0.09	Ra-223	11.4 d
5.342	19.0	Cm-246	5.5 x 10 ³ y
5.342	28	Th-228	1.913 y
5.345	2.6	Bk-249	314 d (β-)
5.35	---	Fr-223	22 m
5.350	0.16	Am-243	7.95 x 10 ³ y

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
5.358	0.09	Pu-238	86 y
5.362	80	Cm-245	9.3 x 10 ³ y
5.364	0.15	Ra-223	11.4 d
5.367	~0.01	Ac-225	10.0 d
5.367	1.5	Am-252m	152 y
5.384	18	Bk-249	314 d (β-)
5.386	81	Cm-246	5.5 x 10 ³ y
5.389	1.3	Am-241	458 y
5.398	~0.01	Ac-225	10.0 d
5.409	≤ 1.2	Cm-245	9.3 x 10 ³ y
5.411	1.2	Am-242m	152 y
5.412	69	Bk-249	314 d (β-)
5.424	71	Th-228	1.913 y
5.431	6.7	Bk-249	314 d (β-)
5.432	2.4	Ra-223	11.4 d
5.443	12.7	Am-241	458 y
5.447	5.2	Ra-224	3.64 d
5.447	53.9 %	Bi-214	19.8 m
5.448	0.1	Ac-225	10.0 d
5.456	28	Pu-238	86 y
5.461	≤ 8	Cm-245	9.3 x 10 ³ y
5.486	86	Am-241	458 y
5.486	~100	Rn-222	3.824 d
5.494	~0.02	Ac-225	10.0 d
5.499	72	Pu-238	86 y
5.500	0.9	Ra-223	11.4 d

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
5.508	0.0166	Th-227	18.5 d
5.511	39.2 s	Bi-214	19.8 m
5.513	0.12	Am-241	458 y
5.52	58	Bk-247	1.4 x 10 ³ y
5.531	0.021	Th-227	18.5 d
5.532	≤ 2	Cm-245	9.3 x 10 ³ y
5.538	9	Ra-223	11.4 d
5.545	0.25	Am-241	458 y
5.546	0.07	Ac-225	10.0 d
5.55	7.4 s	Bi-213	46 m (β-)
5.581	0.8	Ac-225	10.0 d
5.584	0.176	Th-227	18.5 d
5.597	1.1 s	Bi-212	60.6 m
5.599	0.170	Th-227	18.5 d
5.605	24	Ra-223	11.4 d
5.610	0.8	Ac-225	10.0 d
5.612	0.216	Th-227	18.5 d
5.617	0.15 s	Bi-212	60.6 m
5.638	4.0	Ac-225	10.0 d
5.639	0.0179	Th-227	18.5 d
5.640	0.15	Cm-243	32 y
5.666	2.06	Th-227	18.5 d
5.666	~55	Cf-251	~800 y
5.673	0.057	Th-227	18.5 d
5.68	37	Bk-247	1.4 x 10 ³ y
5.682	0.2	Cm-243	32 y

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle† Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
5.683	1.0	Ac-225	10.0 d
5.684	94.5	Ra-224	3.64 d
5.686	1.6	Cm-243	32 y
5.691	1.50	Th-227	18.5 d
5.693	0.4	Cf-249	360 y
5.699	3.63	Th-227	18.5 d
5.707	8.20	Th-227	18.5 d
5.712	4.89	Th-227	18.5 d
5.714	53	Ra-223	11.4 d
5.724	2.6	Ac-225	10.0 d
5.726	0.034	Th-227	18.5 d
5.732	9.5	Ac-225	10.0 d
5.742	11.5	Cm-243	32 y
5.745	9	Ra-223	11.4 d
5.747	0.07	Rn-220	55.3 s
5.755	4.4	Cf-249	360 y
5.755	20.3	Th-227	18.5 d
5.761	0.23	Th-227	18.5 d
5.762	1.7 s	Bi-212	60.6 m
5.763	23.3	Cm-244	17.6 y
5.776	0.07	Fr-221	4.8 m
5.784	0.5	Cf-249	360 y
5.786	73	Cm-243	32 y
5.793	29	Ac-225	10.0 d
5.794	0.31	Th-227	18.5 d
5.806	1.27	Th-227	18.5 d

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
5.806	76.7	Cm-244	17.6 y
5.812	84	Cf-249	360 y
5.825	52	Ac-225	10.0 d
5.84	18	Cf-248	350 d
5.846	~45	Cf-251	~800 y
5.848	1.2	Cf-249	360 y
5.856	0.3	Ra-223	11.4 d
5.865	2.42	Th-227	18.5 d
5.870	0.9	Ra-223	11.4 d
5.869	93 s	Bi-213	46 m (β-)
5.879	0.5	Cm-243	32 y
5.889	0.32	Cf-250	13 y
5.905	3.0	Cf-249	360 y
5.907	0.1	Cm-243	32 y
5.908	0.17	Th-227	18.5 d
5.914	0.8	Th-227	18.5 d
5.938	0.2	Fr-221	4.8 m
5.94	0.09	Es-252	~140 d
5.948	3.3	Cf-249	360 y
5.958	3.0	Th-227	18.5 d
5.975	0.28	Cf-252	2.65 y
5.976	23.4	Th-227	18.5 d
5.980	0.5	Fr-221	4.8 m
5.985	(?)	Cf-253	17.6 d (β-)
5.987	17	Cf-250	13 y
5.99	0.07	Es-252	~140 d

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
5.994	6	Cm-243	32 y
5.997	0.08	Cf-249	360 y
6.000	100 s	Po-218	3.05 m
6.007	2.9	Th-227	18.5 d
6.0	---	Rn-221	25 m
6.012	0.9	Cm-243	32 y
6.02	1.1	Es-252	~140 d
6.031	83	Cf-250	13 y
6.037	0.02	Fr-221	4.8 m
6.037	24.5	Th-227	18.5 d
6.051	69.9 s	Bi-212	60.6 m
6.056	0.16	Es-254	276 d
6.061	5	Cm-243	32 y
6.068	1	Cm-243	32 y
6.070	0.2	Fr-221	4.8 m
6.07	0.11	Es-252	~140 d
6.071	26.5	Cm-242	163 d
6.076	15.5	Cf-252	2.65 y
6.079	0.4	Cf-249	360 y
6.09	0.6	Es-252	~140 d
6.090	27.2 s	Bi-212	60.6 m
6.113	0.33	Es-254	276 d
6.115	73.5	Cm-242	163 d
6.119	84.3	Cf-252	2.65 y
6.126	15.3	Fr-221	4.8 m
6.146	1.1	Cf-249	360 y

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
6.157	0.0174	Rn-219	4.0 s
6.19	0.05	Es-254	276 d
6.20	0.05	Es-254	276 d
6.201	1.9	Cf-249	360 y
6.23	0.33	Es-252	~140 d
6.243	1.6	Fr-221	4.8 m
6.26	0.8	Es-252	~140 d
6.27	82	Cf-248	350 d
6.276	0.22	Es-254	276 d
6.278	15.9 §	Bi-211	2.15 m
6.27	100 §	At-219	0.9 m
6.284	0.16	Es-254	276 d
6.288	99.93	Rn-220	55.3 s
6.307	100	Es-255	38.3 d (β-)
6.310	0.054	Rn-219	4.0 s
6.331	0.05	Es-254	276 d
6.340	82.0	Fr-221	4.8 m
6.355	0.74	Es-254	276 d
6.367	2.9	Es-254	276 d
6.392	0.13	Es-254	276 d
6.423	7.5	Rn-219	4.0 s
6.424	1.7	Es-254	276 d
6.436	0.1	Es-253	20.47 d
6.437	93	Es-254	276 d
6.486	0.040	At-217	0.030 s
6.486	0.08	Es-253	20.47 d

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
6.486	0.27	Es-254	276 d
6.493	2.3	Es-252	~140 d
6.504	0.26	Es-253	20.47 d
6.528	0.12	Rn-219	4.0 s
6.547	0.85	Es-253	20.47 d
6.54	100 §	Po-217	<10 s
6.551	11.5	Rn-219	4.0 s
6.559	0.75	Es-253	20.47 d
6.58	13	Es-252	~140 d
6.59	0.05	Fm-255	20.1 h
6.597	6.6	Es-253	20.47 d
6.601	0.7	Es-253	20.47 d
6.622	84.1 §	Bi-211	2.15 m
6.631	0.8	Es-253	20.47 d
6.639	82	Es-252	~140 d
6.640	90	Es-253	20.47 d
6.653	6.4 §	At-218	~2 s
6.695	90 §	At-218	~2 s
6.757	3.6 §	At-218	~2 s
6.777	100	Po-216	0.15 s
6.811	0.12	Fm-255	20.1 h
6.817	81	Rn-219	4.0 s
6.820	0.025	At-217	0.030 s
6.891	0.50	Po-211	0.52 s
6.894	0.014	Po-214	1.62 x 10 ⁻⁴ s
6.895	0.60	Fm-255	20.1 h

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
6.947	0.022	Po-215	1.78 x 10 ⁻³ s
6.954	0.034	Po-215	1.78 x 10 ⁻³ s
6.968	5.3	Fm-255	20.1 h
6.985	0.11	Fm-255	20.1 h
7.027	93.4	Fm-255	20.1 h
7.061	0.9	Fm-254	3.24 h
7.066	99.9	At-217	0.030 s
7.084	0.43	Fm-255	20.1 h
7.106	0.10	Fm-255	20.1 h
7.130	0.09	Fm-255	20.1 h
7.158	14	Fm-254	3.24 h
7.200	85	Fm-254	3.24 h
7.248	0.06	At-216	~3 x 10 ⁻⁴ s
7.325	0.085	At-216	~3 x 10 ⁻⁴ s
7.384	99.9	Po-215	1.78 x 10 ⁻³ s
7.403	0.23	At-216	~3 x 10 ⁻⁴ s
7.448	99	Po-211	0.52 s
7.492	0.5	At-216	~3 x 10 ⁻⁴ s
7.575	<0.5	At-216	~3 x 10 ⁻⁴ s
7.605	<0.5	At-216	~3 x 10 ⁻⁴ s
7.60	0.05	At-215	~ 10 ⁻⁴ s
7.688	99.99	Po-214	1.62 x 10 ⁻⁴ s
7.707	2.1	At-216	~3 x 10 ⁻⁴ s
7.805	97	At-216	~3 x 10 ⁻⁴ s
8.00	99.9	At-215	~ 10 ⁻⁴ s

<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>	<u>Nuclide</u>	<u>t_{1/2}</u>
8.377	100	Po-213	4.2 x 10 ⁻⁶ s
8.785	100	Po-212	3.04 x 10 ⁻⁷ s

†For nuclides marked with § abundances are relative.

APPENDIX II

TABLE OF NUCLIDE VS HALF LIFE, ALPHA-PARTICLE ENERGY AND ALPHA-PARTICLE ABUNDANCE

<u>Nuclide</u>	<u>$t_{1/2}$</u>	<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>
Bi-210	5.01 d	4.654 4.691	58 § 42
Bi-211	2.15 m	6.622 6.278	84.1 § 15.9
Bi-212	60.6 m	6.090 6.051 5.762 5.617 5.597	27.2 § 69.9 1.7 0.15 1.1
Bi-213	46 m (β-)	5.869 5.549	93 § 7.4
Bi-214	19.8 m	5.511 5.447 5.267 5.183 5.022 4.940	39.2 § 53.9 5.8 0.61 0.21 0.25
Po-210	138.4 d	5.305	100
Po-211	0.52 s	7.448 6.891	99 0.50
Po-212	3.04 x 10 ⁻⁷ s	8.785	100
Po-213	4.2 x 10 ⁻⁶ s	8.377	100
Po-214	1.62 x 10 ⁻⁴ s	7.688 6.894	99.99 0.014
Po-215	1.78 x 10 ⁻³ s	7.384 6.954 6.947	99.9 0.034 0.022
Po-216	0.15 s	6.777	100
Po-217	<10 s	6.54	100 §
Po-218	3.05 m	6.000	100 §
At-215	~10 ⁻⁴ s	8.00 7.60	99.9 0.05
At-216	~3 x 10 ⁻⁴ s	7.805 7.707 7.605	97 2.1 <0.5

<u>Nuclide</u>	<u>t_{1/2}</u>	<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>
At-216 (cont)		7.575	<0.5
		7.492	0.5
		7.403	0.23
		7.325	0.085
		7.248	0.06
At-217	0.030 s	7.066	>99.9
		6.820	0.025
		6.486	0.040
At-218	~2 s	6.757	3.6 §
		6.695	90
		6.653	6.4
At-219	0.9 m	6.27	100 §
Rn-219	4.0 s	6.817	81
		6.551	11.5
		6.528	0.12
		6.423	7.5
		6.310	0.054
		6.157	0.0174
Rn-220	55.3 s	6.288	99.93
		5.747	0.07
Rn-221	25 m	6.0	----
Rn-222	3.824 d	5.486	~100
		4.984	0.078
Fr-221	4.8 m	6.340	82.0
		6.243	1.6
		6.126	15.3
		6.070	0.2
		6.037	0.02
		5.980	0.5
		5.938	0.2
		5.776	0.07
Fr-223	22m	5.34	----
Ra-223	11.4 d	5.870	0.9
		5.856	0.3
		5.745	9
		5.714	53
		5.605	24
		5.538	9
		5.500	0.9
		5.432	2.4

<u>Nuclide</u>	<u>t_{1/2}</u>	<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance (%)</u>
Ra-223 (cont)		5.364	0.15
		5.337	0.09
		5.285	0.2
		5.281	0.095
		5.257	0.043
		5.234	0.042
		5.171	0.026
		5.150	0.021
Ra-224	3.64 d	5.684	94.5
		5.447	5.2
Ra-226	1600 y	4.781	94.5
		4.598	5.5
Ac-225	10.0 d	5.825	52
		5.793	29
		5.732	9.5
		5.724	2.6
		5.683	1.0
		5.638	4.0
		5.610	0.8
		5.581	0.8
		5.546	0.07
		5.494	~0.02
		5.448	0.1
		5.398	~0.01
		5.367	~0.01
		5.328	0.07
		5.295	0.1
		5.225	~0.02
Ac-227	21.8 y	4.951	48 s
		4.938	38
		4.897	0.11
		4.870	6.5
		4.853	4.0
		4.819	0.07
		4.793	0.9
		4.782	0.08
		4.766	1.6
		4.735	0.09
		4.712	0.31
		4.591	0.02
		4.586	0.01
		4.442	0.05
Th-227	18.5 d	6.037	24.5
		6.007	2.9
		5.976	23.4

<u>Nuclide</u>	<u>t_{1/2}</u>	<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>
Th-227 (cont)		5.958	3.0
		5.914	0.8
		5.908	0.17
		5.865	2.42
		5.806	1.27
		5.794	0.31
		5.761	0.23
		5.755	20.3
		5.726	0.034
		5.712	4.89
		5.707	8.20
		5.699	3.63
		5.691	1.50
		5.673	0.057
		5.666	2.06
		5.639	0.0179
		5.612	0.216
		5.599	0.170
		5.584	0.176
		5.531	0.021
		5.508	0.0166
Th-228	1.913 y	5.424	71
		5.342	28
		5.211	0.4
		5.176	0.2
		5.140	0.03
Th-229	7340 y	5.054	6.7
		5.034	~0.2
		5.009	~0.1
		4.977	3.4
		4.967	6.0
		4.930	0.25
		4.899	10.7
		4.842	58.2
		4.811	11.4
		4.793	1.0
Th-230	8.0 x 10 ⁴ y	4.756	1.5
		4.683	0.4
		4.684	76
		4.617	24
Th-232	1.41 x 10 ¹⁰ y	4.474	0.12
		4.441	0.03
		4.011	77
		3.952	23
		3.826	0.2

<u>Nuclide</u>	<u>$t_{1/2}$</u>	<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>
Pa-231	3.25×10^4 y	5.051	11
		5.024	~2.5
		5.022	20
		5.005	25.4
		4.977	1.4
		4.967	0.4
		4.943	22.8
		4.926	3.0
		4.845	1.4
		4.787	0.04
		4.729	8.4
		4.705	~1
		4.673	1.5
		4.635	0.1
		4.624	0.1
		4.591	0.015
U-232	72 y	5.324	68
		5.267	32
		5.140	0.32
U-233	1.62×10^5 y	4.821	83.4
		4.778	14.6
		4.749	0.3
		4.722	1.5
		4.697	0.08
		4.660	0.06
		4.501	0.03
U-234	2.47×10^5 y	4.773	72
		4.722	28
		4.60	0.35
U-235	7.1×10^8 y	4.597	4.6
		4.556	3.7
		4.502	1.2
		4.445	0.6
		4.415	4
		4.396	57
		4.366	18
		4.344	1.5
		4.323	3
		4.266	0.6
		4.216	5.7
		4.157	~0.5
U-236	2.39×10^7 y	4.493	74
		4.443	26
		4.333	0.3

<u>Nuclide</u>	<u>$t_{1/2}$</u>	<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>
U-238	4.51×10^9 y	4.195 4.147 4.035	77 23 0.23
Np-237	2.14×10^6 y	4.872 4.870 4.862 4.816 4.802 4.787 4.770 4.765 4.711 4.707 4.698 4.693 4.663 4.658 4.638 4.598 4.594 4.580 4.573 4.514	0.4 0.9 0.2 1.5 1.6 51 19 17 0.13 0.29 0.07 0.18 1.6 0.57 4.6 0.06 0.08 0.02 0.05 ~0.01
Pu-238	86 y	5.499 5.456 5.358	72 28 0.09
Pu-239	2.44×10^4 y	5.157 5.145 5.107	73.3 15.1 11.5
Pu-240	6580 y	5.168 5.123 5.020	76 24 0.09
Pu-241	13.2 y (β^-)	5.051 5.041 4.995 4.971 4.896 4.853 4.798	0.35 s 1.0 0.36 1.1 83 12 1.2
Pu-242	3.79×10^5 y	4.903 4.863	76 24
Am-241	458 y	5.545 5.513	0.25 0.12

<u>Nuclide</u>	<u>t_{1/2}</u>	<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>
Am-241 (cont)		5.486	86
		5.443	12.7
		5.389	1.3
Am-242m	152 y	5.411	1.2
		5.367	1.5
		5.315	0.8
		5.207	89
		5.142	6.1
		5.088	0.3
		5.067	0.2
Am-243	7.95 x 10 ³ y	5.350	0.16
		5.321	0.12
		5.276	87.9
		5.234	10.6
		5.181	1.1
Cm-242	163 d	6.115	73.5
		6.071	26.5
Cm-243	32 y	6.068	1 §
		6.061	5
		6.012	0.9
		5.994	6
		5.907	0.1
		5.879	0.5
		5.786	73
		5.742	11.5
		5.686	1.6
		5.682	0.2
		5.640	0.15
Cm-244	17.6 y	5.806	76.7
		5.763	23.3
Cm-245	9.3 x 10 ³ y	5.532	≤2
		5.461	≤8
		5.409	≤1.2
		5.362	80
		5.306	7
		5.246	2
Cm-246	5.5 x 10 ³ y	5.386	81
		5.342	19.0
Cm-248	4.7 x 10 ⁵ y	5.080	82 §
		5.036	18

<u>Nuclide</u>	<u>t_{1/2}</u>	<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>
Bk-247	1.4 x 10 ³ y	5.68 5.52 5.31	37 58 5
Bk-249	314 d (β-)	5.431 5.412 5.384 5.345 5.109 5.046	6.7 s 69 18 2.6 2.7 0.12
Cf-248	350 d	6.27 5.84	82 18
Cf-249	360 y	6.201 6.146 6.079 5.997 5.948 5.905 5.848 5.812 5.784 5.755 5.693	1.9 1.1 0.4 0.08 3.3 3.0 1.2 84 0.5 4.4 0.4
Cf-250	13 y	6.031 5.987 5.889	83 17 0.32
Cf-251	~800 y	5.846 5.666	~45 ~55
Cf-252	2.65 y	6.119 6.076 5.975	84.3 s 15.5 0.28
Cf-253	17.6 d (β-)	5.985	(?)
Es-252	~140 d	6.639 6.58 6.493 6.26 6.23 6.09 6.07 6.02 5.99 5.94	82 13 2.3 0.8 0.33 0.6 0.11 1.1 0.07 0.09

<u>Nuclide</u>	<u>t_{1/2}</u>	<u>Alpha-Particle Energy</u>	<u>Alpha-Particle[†] Abundance(%)</u>
Es-253	20.47 d	6.640	90
		6.631	0.8
		6.601	0.7
		6.597	6.6
		6.559	0.75
		6.547	0.85
		6.504	0.26
		6.486	0.08
		6.436	0.1
Es-254	276 d	6.486	0.27 §
		6.437	93
		6.424	1.7
		6.392	0.13
		6.367	2.9
		6.355	0.74
		6.331	0.05
		6.284	0.16
		6.276	0.22
		6.20	0.05
		6.19	0.05
		6.113	0.33
		6.056	0.16
Es-255	38.3 d (β-)	6.307	100 §
Fm-254	3.24 h	7.200	85
		7.158	14
		7.061	0.9
Fm-255	20.1 h	7.130	0.09
		7.106	0.10
		7.084	0.43
		7.027	93.4
		6.985	0.11
		6.968	5.3
		6.895	0.60
		6.811	0.12
		6.59	0.05

[†]For nuclides marked with § abundances are relative.

APPENDIX III

RADIOACTIVE SERIES

Np		Np^{237} 2.14×10^6 years				
93						
U		$\downarrow \alpha$	U^{233} 1.62×10^5 years			
92						
Pa		Pa^{233}	$\nearrow \beta$	$\downarrow \alpha$		
91		27.0 days				
Th			Th^{229} 7340 years			
90						
Ac			$\downarrow \alpha$	Ac^{225} 10.0 days		
89						
Ra			Ra^{225} 14.8 days	$\nearrow \beta$	$\downarrow \alpha$	
88						
Fr				Fr^{221} 4.8 minutes		
87						
Rn				$\downarrow \alpha$		
86						
At				At^{217} 0.030 second		
85						
Po				$\downarrow \alpha$	Po^{213} 4.2×10^{-6} second	
84						
Bi				Bi^{213} 46 minutes	$\nearrow \beta$ (97.8 %)	Bi^{209} (stable)
83					$\downarrow \alpha$	
Pb				$\downarrow \alpha$ (2.2 %)	Pb^{209} 3.30 hours	$\nearrow \beta$
82						
Tl				Tl^{209} 2.2 minutes	$\nearrow \beta$	
81						

U 92	U ²³⁸ 4.51 × 10 ⁹ years		U ²³⁴ 2.48 × 10 ⁵ years				
Po 91	α	Pa ²³⁴ 1.17 minutes β Pa ²³⁴ 6.75 hours β	β (99.85%) I.T. (0.15%) α				
Th 90	Th ²³⁴ 24.1 days		Th ²³⁰ 8.0 × 10 ⁴ years				
Ac 89			α				
Ra 88			Ra ²²⁶ 1600 years				
Fr 87			α				
Rn 86			Rn ²²² 3.824 days				
At 85			α	At ²¹⁸ ~2 seconds			
Po 84			Po ²¹⁸ 3.05 minutes β (0.02%) α	Po ²¹⁴ 1.62 × 10 ⁻⁴ second		Po ²¹⁰ 138.4 days	
Bi 83			α (99.98%) 19.8 minutes β	β (99.98%) α 5.01 days		β α	
Pb 82			Pb ²¹⁴ 26.8 minutes α (0.02%) β	Pb ²¹⁰ 21 years β (1.7 × 10 ⁻⁶ %) α		β α 1.3 × 10 ⁻⁴ (stable)	Pb ²⁰⁶
Tl 81				Tl ²¹⁰ 1.3 minutes β		Tl ²⁰⁶ 4.19 minutes β	
Hg 80						Hg ²⁰⁶ 8.5 minutes β	

U	U ²³⁵				
92	7.1 x 10 ⁸ years				
Po		Po ²³¹			
91		3.25 x 10 ⁴			
Th	Th ²³¹		Th ²²⁷		
90	25.5 hours		18.5 days		
Ac		Ac ²²⁷			
89		21.6 years			
Ra			Ra ²²³		
88			11.4 days		
Fr		Fr ²²³			
87		22 minutes			
Rn			Rn ²¹⁹		
86			4.0 seconds		
At		At ²¹⁹		At ²¹⁵	
85		0.9 minutes		~10 ⁻⁴ second	
Po			Po ²¹⁵		Po ²¹¹
84			1.78 x 10 ⁻³ second		0.52 second
Bi		Bi ²¹⁵		Bi ²¹¹	
83		7.4 minutes		2.15 minutes	
Pb			Pb ²¹¹		Pb ²⁰⁷
82			36.1 minutes		(stable)
Tl				Tl ²⁰⁷	
81				4.79 minutes	

Th	Th ²³²		Th ²²⁸		
90	1.41 x 10 ¹⁰ years		1.913 years		
Ac	↓ α	Ac ²²⁸ ↗ β	↓ α		
89		6.13 hours			
Ra	Ra ²²⁸ ↗ β		Ra ²²⁴		
88	6.7 years		3.64 days		
Fr			↓ α		
87					
Rn			Rn ²²⁰		
86			55.3 seconds		
At			↓ α		
85					
Po			Po ²¹⁶		Po ²¹²
84			0.15 second		3.04 x 10 ⁻⁷ second
Bi			↓ α (~100%)	Bi ²¹² ↗ β (64%)	↓ α
83				60.6 minutes	
Pb			Pb ²¹² ↗ β	↓ α (36.0%)	Pb ²⁰⁸
82			10.64 hours		(stable)
Tl				Tl ²⁰⁸ ↗ β	
81				3.10 minutes	

APPENDIX IV

TABLE OF SPECIFIC ACTIVITIES

ALPHA SPECIFIC ACTIVITY OF SOME HEAVY NUCLIDES

<u>Nuclide</u>	<u>$t_{1/2}(y)$</u>	<u>Alpha Activity $\alpha \text{ d sec}^{-1} \mu\text{g}^{-1}$</u>
Ra-226	1600	3.46×10^4
Ac-227	21.8	2.54×10^6
Th-228	1.913	2.90×10^7
Th-229	7340	7.55×10^3
Th-230	8.0×10^4	6.93×10^2
Th-232	1.41×10^{10}	3.93×10^{-3}
Pa-231	3.25×10^4	1.70×10^3
U-232	72	7.69×10^5
U-233	1.62×10^5	3.42×10^2
U-234	2.47×10^5	2.24×10^2
U-235	7.1×10^8	7.80×10^{-2}
U-236	2.39×10^7	2.32×10^0
U-238	4.51×10^9	1.23×10^2
Np-237	2.14×10^6	2.59×10^1
Pu-238	86	6.44×10^6
Pu-239	2.44×10^4	2.27×10^3
Pu-240	6580	8.42×10^3
Pu-241	13.2 (β^-)	4.20×10^6
Pu-242	3.79×10^5	1.46×10^2
Am-241	458	1.21×10^5
Am-243	7.95×10^3	6.97×10^3
Cm-242	0.446	1.24×10^8
Cm-243	32	1.73×10^6
Cm-244	17.6	3.15×10^6

<u>Nuclide</u>	<u>$t_{1/2}(y)$</u>	<u>Alpha Activity $\alpha \text{ d sec}^{-1} \mu\text{g}^{-1}$</u>
Cm-245	9.3×10^3	5.96×10^3
Cm-246	5.5×10^3	1.01×10^4
Cm-247	1.6×10^3	3.46×10^0
Cm-248	4.7×10^5	1.18×10^2
Bk-247	1.4×10^3	3.96×10^4
Bk-259	0.860 (β^-)	1.42×10^3
Cf-248	0.958	5.78×10^7
Cf-249	360 .	1.54×10^5
Cf-250	1.3	4.26×10^6
Cf-251	$\sim 800 \text{ y}$	6.93×10^4
Cf-252	2.65	2.09×10^7

APPENDIX V

RANGE ENERGY CURVE FOR ALPHA PARTICLES IN AIR

APPENDIX VI

DIGITAL FORM OF ALPHA-PARTICLE SPECTRA DATA

2.15 M BISMUTH 211

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 83-BI-211

	0	1	2	3	4	5	6	7	8	9
0	3	7	2	3	0	0	2	2	1	2
10	6	3	5	5	1	0	3	1	6	1
20	2	4	3	2	3	1	6	5	2	4
30	6	2	3	1	3	3	0	5	5	4
40	5	3	6	3	4	5	4	6	5	6
50	5	4	7	5	6	5	9	4	5	7
60	10	5	6	16	21	14	11	19	30	27
70	42	58	95	167	262	419	648	731	571	326
80	156	39	8	1	0	3	2	5	0	3
90	5	1	1	3	2	3	5	4	4	1
100	3	3	1	2	2	2	5	4	5	3
110	6	6	2	3	3	6	5	1	7	8
120	3	6	6	3	2	6	4	4	5	5
130	5	6	5	6	9	6	12	3	11	7
140	9	7	1	4	11	6	14	11	13	10
150	12	9	8	14	6	3	14	13	15	14
160	17	20	18	22	16	22	23	17	22	30
170	24	32	27	28	31	29	39	33	44	50
180	66	62	59	75	90	128	166	209	334	556
190	942	1679	2692	3463	3553	2487	1243	394	77	6
200	3	3	1	1	1	0	0	0	1	0
210	0	0	0	0	0	0	0	0	0	0

60.6 M BISMUTH 212

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 83-BI-212

	0	1	2	3	4	5	6	7	8	9
0	10	11	20	7	15	7	14	14	9	14
10	10	14	14	12	5	23	25	31	31	55
20	85	133	138	146	135	72	35	28	23	25
30	35	24	13	12	22	16	17	11	16	7
40	11	16	18	18	17	11	10	11	14	14
50	16	13	15	13	12	9	11	15	16	17
60	15	12	15	15	15	21	20	15	19	22
70	25	36	40	54	68	109	164	210	231	187
80	119	54	30	19	17	21	17	18	19	19
90	26	10	18	19	16	28	18	26	15	14
100	21	18	14	25	18	19	23	20	21	19
110	23	19	14	16	22	27	28	25	30	20
120	29	29	33	36	29	38	31	37	35	33
130	41	24	38	23	30	42	41	45	43	56
140	63	51	48	48	63	67	64	56	65	80
150	67	78	58	91	112	120	88	114	102	123
160	109	133	178	194	247	325	411	543	774	967
170	1584	2538	4197	6053	7918	8289	6423	3496	1460	539
180	366	389	538	672	1009	1441	2211	2995	3279	2920
190	1734	704	192	33	11	4	5	5	3	6
200	3	6	4	9	6	13	3	2	7	4
210	0	0	0	0	0	0	0	0	0	0

138.4 D POLONIUM 210

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 84-PO-210

	0	1	2	3	4	5	6	7	8	9
0	16	12	14	11	8	15	17	21	7	17
10	13	9	11	11	19	14	14	11	19	17
20	13	15	12	12	12	11	16	13	13	14
30	9	13	24	13	17	12	11	12	8	14
40	9	16	10	9	14	11	12	8	14	12
50	5	5	17	20	12	7	14	11	10	14
60	15	11	6	11	14	14	13	12	16	9
70	18	14	16	9	15	13	9	14	10	15
80	12	15	13	13	12	8	7	14	24	22
90	12	18	8	14	10	13	16	6	14	22
100	14	15	19	10	7	10	13	18	16	15
110	19	12	19	13	16	15	16	23	10	18
120	19	19	24	17	16	17	19	16	16	17
130	19	18	21	15	21	25	28	23	23	14
140	17	25	11	25	16	15	18	22	24	16
150	34	37	20	21	26	25	23	26	32	22
160	26	33	35	26	33	43	35	51	42	46
170	45	49	57	65	62	70	76	89	100	112
180	101	154	164	211	221	245	381	478	623	923
190	1298	2155	3662	7007	13414	23306	34181	40328	34201	19719
200	7775	2049	356	45	11	7	9	6	3	3
210	0	0	0	0	0	0	0	0	0	0

3.04 E-7 S POLONIUM 212

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 84-PO-212

	0	1	2	3	4	5	6	7	8	9
0	3	5	5	4	6	6	4	4	3	9
10	8	7	1	5	3	4	7	6	7	7
20	3	5	5	7	5	6	4	5	3	4
30	5	2	5	6	1	5	4	6	5	6
40	13	4	4	8	10	8	11	5	12	3
50	7	8	7	6	4	7	5	4	8	6
60	12	10	15	11	6	4	9	11	11	12
70	12	9	16	10	19	11	6	10	15	10
80	16	13	12	16	15	17	17	10	10	20
90	16	26	15	18	18	25	32	19	29	24
100	22	36	33	40	35	36	28	51	43	30
110	34	43	42	52	50	71	53	68	58	82
120	85	91	90	105	109	154	156	183	252	327
130	411	583	876	1356	2173	3312	4971	6476	7023	5602
140	3492	1397	350	88	23	16	17	16	17	15
150	18	23	23	19	24	28	31	35	27	34
160	32	32	29	16	24	30	19	20	18	17
170	18	22	27	12	12	11	19	11	12	15
180	9	9	18	15	8	11	9	7	4	9
190	9	7	12	11	8	18	9	4	10	10
200	13	15	7	3	9	5	2	2	9	4
210	0	0	0	0	0	0	0	0	0	0

1.64 E-4 S POLONIUM 214

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 84-PD-214

	0	1	2	3	4	5	6	7	8	9
0	15	19	15	18	15	18	20	20	16	21
10	11	20	25	17	20	23	18	23	21	30
20	27	18	31	26	18	19	19	19	19	22
30	22	25	15	23	29	18	20	24	17	19
40	17	23	25	28	21	26	31	35	29	40
50	29	28	22	35	33	28	27	36	29	34
60	33	31	35	47	30	29	28	42	34	39
70	36	30	41	34	34	36	43	45	36	43
80	45	41	41	48	47	46	48	62	43	56
90	52	51	68	56	64	53	64	61	62	66
100	59	72	69	75	75	91	74	90	98	99
110	104	83	101	98	95	97	104	111	108	119
120	121	140	142	147	153	159	151	190	201	190
130	221	219	211	239	256	287	283	288	300	354
140	372	423	450	504	553	596	586	765	784	891
150	1041	1155	1279	1484	1753	2038	2450	2929	3503	4313
160	5221	6351	7705	9451	10975	12243	13115	13153	11982	9397
170	6686	4084	2005	921	412	263	254	248	240	266
180	252	278	309	279	275	168	101	56	30	23
190	13	10	13	9	6	10	9	9	11	8
200	9	6	11	5	5	10	2	2	3	6
210	0	0	0	0	0	0	0	0	0	0

1.78 E-3 S POLONIUM 215

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 84-PO-215

	0	1	2	3	4	5	6	7	8	9
0	26	28	22	23	26	32	22	24	16	25
10	27	21	22	32	22	25	32	32	35	40
20	33	42	30	18	37	34	31	41	24	31
30	33	32	31	33	25	26	33	28	37	22
40	34	25	39	35	35	38	30	0	31	32
50	38	33	22	53	39	34	31	30	43	40
60	38	39	39	41	35	29	42	41	43	47
70	48	42	38	29	56	43	45	49	43	52
80	42	44	54	56	64	61	45	49	56	55
90	63	56	71	61	64	58	64	69	81	80
100	66	70	79	87	78	100	89	91	89	97
110	121	121	123	120	147	126	158	139	155	135
120	165	167	179	179	188	182	199	223	254	266
130	287	285	300	314	323	369	354	450	469	498
140	604	633	696	758	820	886	1043	1155	1314	1448
150	1611	1730	2082	2380	2827	3238	3871	4723	5673	7246
160	8985	11053	13110	14579	14526	12959	10133	7064	4316	2131
170	1135	701	561	542	572	604	561	653	590	636
180	455	275	195	75	35	33	31	23	20	15
190	9	5	4	2	4	3	3	5	5	4
200	2	2	1	1	1	1	0	1	2	1
210	0	0	0	0	0	0	0	0	0	0

0.15 S POLONIUM 216

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 84-PO-216

	0	1	2	3	4	5	6	7	8	9
0	21	19	16	23	17	13	17	13	14	22
10	18	18	10	23	24	23	16	30	17	30
20	25	18	20	17	19	25	20	24	32	21
30	23	27	23	26	18	26	26	25	22	34
40	27	29	29	40	33	22	34	33	36	39
50	26	33	36	37	29	36	30	48	46	39
60	58	45	38	44	55	29	41	54	53	47
70	42	48	71	43	47	58	70	61	73	76
80	61	64	95	69	81	96	105	99	122	108
90	115	125	125	111	143	154	178	191	176	177
100	239	208	241	251	276	305	329	364	410	425
110	464	585	632	624	751	846	962	1052	1252	1409
120	1605	1945	2338	2863	3474	4277	5367	6734	7968	8716
130	8754	7572	5968	4147	2455	1396	715	543	507	476
140	514	513	565	675	583	427	213	101	50	15
150	4	6	3	4	4	1	0	1	1	1
160	3	1	4	3	1	3	1	3	1	2
170	4	4	2	0	3	5	2	1	2	1
180	1	0	1	4	4	3	2	1	1	0
190	1	1	2	0	0	1	3	2	1	1
200	1	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0

3.05 M POLONIUM 218

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 84-PO-218

	0	1	2	3	4	5	6	7	8	9
0	43	31	48	41	49	36	36	43	44	30
10	42	40	38	47	41	28	44	30	41	44
20	45	56	33	60	52	45	33	54	36	36
30	38	57	64	59	44	54	55	44	58	47
40	67	59	51	69	70	54	64	68	59	61
50	56	58	53	60	51	68	57	64	60	59
60	60	56	75	72	60	62	68	70	79	84
70	81	97	65	72	94	96	90	87	107	93
80	109	112	122	119	132	124	114	117	133	110
90	106	128	119	134	136	152	131	132	150	160
100	163	179	170	180	164	190	219	205	212	235
110	233	228	245	251	258	263	333	325	343	385
120	398	405	407	439	512	537	604	642	673	736
130	812	930	1073	1188	1347	1511	1747	2021	2315	2838
140	3407	4176	5064	6250	8045	9990	12156	15393	18048	19467
150	18519	15751	11024	6553	3194	1507	631	312	226	173
160	202	180	191	199	151	102	61	36	24	14
170	15	12	19	11	18	25	20	16	25	13
180	13	25	15	14	17	21	15	16	9	18
190	18	9	10	10	15	12	5	10	15	13
200	18	14	11	12	22	19	17	14	10	15
210	0	0	0	0	0	0	0	0	0	0

4.0 S RADON 219 AND 2.15 M BISMUTH 211

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 86-RN-219 AND 83-BI-211

	0	1	2	3	4	5	6	7	8	9
0	88	81	85	88	69	89	72	75	74	87
10	80	76	71	77	86	70	88	82	100	76
20	99	89	107	113	102	134	134	131	152	151
30	182	172	194	206	256	238	256	330	296	370
40	416	473	564	653	792	896	1070	1300	1507	1631
50	1739	1664	1474	1122	863	639	435	292	229	193
60	189	206	204	225	257	239	214	172	163	122
70	112	94	97	97	86	95	115	109	120	123
80	106	149	134	139	140	164	178	190	221	232
90	278	328	350	456	559	783	959	1211	1414	1425
100	1397	944	604	394	244	164	152	163	157	156
110	171	157	159	196	146	179	173	178	188	230
120	219	229	235	274	261	289	320	320	358	415
130	455	489	591	611	790	860	1102	1335	1612	2094
140	2347	2671	2419	2052	1597	1200	1004	952	1011	1158
150	1240	1385	1574	1829	2111	2518	2886	3520	4287	5134
160	6241	7229	8283	9121	9173	8193	6797	5095	3327	2068
170	1138	675	566	543	606	577	707	819	883	886
180	734	455	247	168	148	110	120	159	114	142
190	163	160	167	172	179	183	203	216	268	246
200	299	283	298	290	358	345	391	450	514	498
210	565	631	690	788	942	1099	1196	1295	1568	1865
220	2150	2626	3248	4152	5496	7374	9925	12304	14360	13947
230	11788	7965	4674	2332	1009	419	268	194	195	163
240	159	159	131	131	79	59	40	34	25	30
250	26	28	22	23	26	32	22	24	16	25
260	27	21	22	32	22	25	32	32	35	40
270	0	0	0	0	0	0	0	0	0	0

55 S RADOM 220 AND 60.6 M BISMUTH 212

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 86-RN-220 AND 83-BI-212

	0	1	2	3	4	5	6	7	8	9
0	32	33	29	36	32	27	28	37	36	32
10	39	30	56	65	53	56	62	66	65	62
20	51	30	36	23	20	24	27	20	22	31
30	26	30	22	14	40	30	26	27	30	32
40	32	22	20	25	18	23	21	29	25	33
50	43	23	21	40	36	24	25	28	35	29
60	28	29	27	29	27	37	27	33	44	26
70	35	38	41	29	39	41	46	39	42	41
80	55	47	45	50	70	53	60	77	55	79
90	75	92	87	118	141	143	115	163	198	230
100	305	351	389	504	667	841	987	1185	1433	1548
110	1598	1315	953	488	296	222	246	282	360	439
120	512	571	643	663	552	341	177	78	68	59
130	47	65	77	60	68	70	66	79	49	57
140	94	95	72	76	88	97	70	75	111	92
150	111	119	125	135	133	150	145	174	156	171
160	202	205	221	218	251	267	280	325	385	399
170	413	432	497	620	655	779	878	1000	1168	1380
180	1625	1998	2341	3186	4061	5605	7379	9440	10709	10539
190	8625	5851	3502	1829	803	395	285	251	198	216
200	205	213	187	128	71	38	19	16	22	14
210	0	0	0	0	0	0	0	0	0	0

3.823 D RADON 222 AND 138.4 D POLONIUM 210

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 86-RN-222 AND 84-PO-210

	0	1	2	3	4	5	6	7	8	9
0	92	87	88	92	68	60	66	77	72	65
10	49	10066	73	88	10063	67	66	68	73	71
20	74	89	75	64	68	80	65	74	74	86
30	85	89	85	78	86	72	81	92	76	81
40	110	113	93	93	109	87	92	117	99	117
50	101	120	99	110	102	106	112	125	118	133
60	115	122	118	140	122	105	141	153	163	167
70	170	160	192	195	187	195	214	225	211	228
80	264	271	296	286	314	347	388	423	450	499
90	611	713	837	1014	1244	1711	2347	3539	5276	8413
100	13035	19416	26326	30446	28247	18614	8014	2245	454	150
110	112	88	120	97	121	122	108	150	112	122
120	131	115	111	141	132	130	141	136	164	159
130	179	195	214	177	200	207	247	252	269	279
140	281	325	348	378	407	463	498	568	599	698
150	812	941	1102	1344	1605	2061	2697	3441	4419	5944
160	7914	10907	14574	18733	21536	21705	17758	10941	4973	1744
170	454	149	83	74	71	63	69	60	60	49
180	46	49	32	36	33	42	33	50	28	46
190	0	0	0	0	0	0	0	0	0	0

11.43 D RADIUM 223

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 88-RA-223

	0	1	2	3	4	5	6	7	8	9
0	24	17	24	16	18	15	24	13	26	26
10	35	22	39	31	27	26	31	18	41	36
20	22	26	34	25	31	38	21	26	20	32
30	35	38	37	27	34	44	41	57	70	85
40	108	144	242	300	293	271	228	101	49	34
50	26	29	24	40	21	31	40	48	50	44
60	48	58	75	72	91	120	131	138	159	137
70	117	127	148	170	269	327	431	662	890	1133
80	1174	983	604	282	135	76	77	89	95	114
90	118	144	154	204	231	294	413	542	836	1101
100	1659	2281	2760	2855	2343	1356	593	185	74	59
110	80	61	49	76	54	59	62	67	75	94
120	99	133	133	137	145	184	209	230	287	335
130	430	487	634	882	1176	1722	2433	3575	4985	5936
140	6253	4925	2871	1256	586	416	447	613	848	1061
150	1191	1166	820	434	228	130	104	129	104	93
160	80	65	56	52	32	19	29	28	23	29
170	29	26	28	22	21	22	39	28	27	31
180	24	37	35	52	58	58	82	90	80	103
190	112	126	141	107	95	56	25	24	20	17
200	13	19	12	24	12	17	20	16	21	13
210	0	0	0	0	0	0	0	0	0	0

3.64 D RADIUM 224

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 88-RA-224

	0	1	2	3	4	5	6	7	8	9
0	15	26	20	23	16	15	21	20	21	27
10	19	23	27	26	33	21	20	29	17	20
20	19	17	21	16	17	25	17	34	20	26
30	25	16	30	28	26	30	27	25	31	30
40	21	25	37	29	20	17	23	26	32	32
50	24	36	22	24	33	24	37	32	33	36
60	28	47	25	39	43	37	40	54	59	60
70	61	78	82	120	185	200	362	569	810	791
80	759	480	202	84	48	32	27	38	30	38
90	31	38	38	31	37	40	34	35	32	27
100	36	32	43	37	40	31	40	35	36	44
110	38	42	48	44	43	39	42	60	53	44
120	59	60	53	52	57	61	73	79	86	86
130	100	99	84	95	122	127	111	108	134	120
140	138	146	153	176	194	199	212	285	312	340
150	417	511	681	842	1147	1621	2562	4001	6397	9820
160	13950	15718	13241	8312	3503	987	202	72	20	27
170	40	32	27	36	29	27	35	27	42	27
180	37	59	71	53	57	71	68	80	81	80
190	72	49	38	39	27	36	26	32	20	26
200	26	26	25	37	28	32	23	34	33	23
210	0	0	0	0	0	0	0	0	0	0

1600 Y RADIUM 226

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 88-RA-226

	0	1	2	3	4	5	6	7	8	9
0	5	1	1	8	3	6	6	6	9	9
10	3	8	5	6	5	4	4	4	3	5
20	3	3	4	3	4	5	1	6	7	3
30	5	10	2	0	6	4	6	1	2	4
40	5	4	1	5	4	8	3	6	3	2
50	9	5	5	4	1	5	9	7	3	3
60	2	10	4	6	6	3	4	3	9	2
70	2	5	5	5	4	9	6	6	10	9
80	1	9	9	9	7	13	7	9	6	8
90	8	9	6	9	11	5	8	12	3	3
100	6	10	13	9	10	10	16	25	19	21
110	22	37	58	67	97	142	219	247	233	188
120	109	36	13	15	7	9	10	13	10	8
130	10	15	11	16	15	9	8	11	12	16
140	13	16	14	15	23	10	15	14	16	23
150	20	19	22	23	26	39	27	39	18	32
160	53	45	56	54	64	84	87	123	115	168
170	237	285	420	555	871	1292	1924	2721	3712	4082
180	3421	2105	865	274	48	11	3	1	1	4
190	1	3	2	1	1	2	4	0	1	2
200	3	3	6	0	6	2	2	1	2	2
210	0	0	0	0	0	0	0	0	0	0

*****E

1600 Y RADIUM 226 + DAUGHTERS

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 88-RA-226

	0	1	2	3	4	5	6	7	8	9
0	10	4	7	3	0	3	6	5	7	5
10	7	5	2	10	7	7	7	5	7	6
20	4	5	7	4	10	14	3	7	6	7
30	5	8	5	7	9	11	3	9	14	5
40	9	8	7	6	13	17	14	24	17	37
50	33	31	70	112	130	166	166	106	40	18
60	7	12	11	10	11	12	11	9	10	9
70	13	8	12	11	8	10	14	11	5	14
80	13	10	10	15	20	11	13	18	16	16
90	19	15	26	25	26	19	26	16	37	36
100	43	38	48	52	66	66	83	109	116	159
110	245	328	481	730	1078	1629	2388	2792	2472	1325
120	464	72	10	5	7	9	4	9	8	7
130	3	4	5	2	8	8	4	8	6	10
140	3	7	5	6	9	7	5	8	7	7
150	7	7	3	5	8	6	9	12	7	9
160	6	6	12	7	6	6	7	8	7	6
170	12	7	5	7	5	7	10	8	7	10
180	6	12	8	5	9	8	3	8	4	9
190	5	9	7	4	6	12	8	7	11	9
200	7	5	9	10	9	6	6	7	5	12
210	9	5	8	10	6	5	9	15	10	19
220	13	8	13	15	11	7	10	17	15	15
230	11	12	14	16	16	12	15	10	10	6
240	20	16	13	8	20	20	13	22	27	23
250	23	19	28	24	27	23	22	23	35	26
260	38	44	25	33	29	30	35	46	47	48
270	53	43	56	54	58	59	77	74	108	100
280	151	162	180	214	265	359	461	698	1068	1840
290	3366	6027	8946	10121	7506	3257	771	88	19	10
300	9	8	10	15	9	12	8	6	16	10
310	13	9	15	7	14	20	12	7	10	19
320	11	14	21	14	9	14	20	19	21	24
330	25	29	24	23	32	31	30	38	46	66
340	45	76	98	89	136	160	214	236	287	432
350	617	799	1151	1382	1579	1467	1017	524	196	94
360	53	33	26	24	15	12	17	8	10	10
370	6	8	8	8	9	6	8	5	9	4
380	3	2	6	4	2	7	10	3	7	9
390	3	7	10	9	15	6	12	19	14	7
400	5	5	8	2	4	6	4	5	8	6
410	2	8	7	7	5	7	8	8	7	13
420	7	10	12	11	14	13	14	12	12	15
430	16	26	22	20	19	15	13	13	12	18
440	14	20	13	19	11	16	13	14	15	12
450	16	12	14	7	7	9	15	16	9	11
460	13	10	17	10	12	4	5	7	14	14
470	8	6	12	10	9	9	8	14	19	9
480	11	11	13	12	10	14	18	23	18	21
490	19	20	10	25	27	23	17	15	26	25
500	24	23	36	35	36	55	38	44	51	49
510	73	77	96	85	107	125	156	155	196	279
520	329	437	615	729	958	1217	1301	1390	1199	852
530	505	240	117	63	50	50	46	34	28	31
540	26	8	5	3	8	4	5	10	1	6
550	5	3	6	3	2	4	3	4	7	6
560	0	0	0	0	0	0	0	0	0	0

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21.6 Y ACTINIUM 227

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 89-AC-227

	0	1	2	3	4	5	6	7	8	9
0	10	13	17	7	9	10	13	8	8	13
10	13	12	14	14	16	15	13	11	12	14
20	7	6	6	11	12	12	16	12	18	9
30	11	12	8	9	10	12	15	10	15	11
40	14	9	11	10	11	10	5	12	5	16
50	11	16	15	11	12	14	17	5	11	11
60	19	12	8	14	7	20	13	15	10	15
70	17	8	8	11	17	9	15	8	13	9
80	12	5	14	11	9	9	16	11	14	17
90	14	11	14	22	16	16	21	15	16	9
100	11	12	19	25	18	15	23	36	32	29
110	28	27	20	30	28	32	28	29	18	21
120	33	32	48	50	99	101	114	102	63	44
130	45	41	53	61	54	73	75	51	28	17
140	29	31	24	34	30	31	30	23	35	48
150	62	73	96	140	234	255	277	268	223	259
160	323	375	399	316	176	108	68	50	48	62
170	57	74	70	75	96	133	139	196	236	340
180	486	777	1158	1891	2480	2944	2964	2869	2935	2980
190	2647	1662	794	250	66	13	19	13	10	16
200	10	15	12	17	18	14	20	36	23	38
210	0	0	0	0	0	0	0	0	0	0

18.2 D THORIUM 227

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 90-TH-227

	0	1	2	3	4	5	6	7	8	9
0	7	10	6	10	9	7	8	3	15	10
10	11	12	17	7	11	7	4	10	11	9
20	12	8	6	10	5	7	9	11	5	6
30	13	9	8	8	8	2	13	8	8	11
40	3	8	11	9	4	8	11	7	6	13
50	6	9	12	6	15	11	16	6	13	11
60	11	9	8	7	5	13	8	8	9	15
70	15	13	6	12	16	12	23	16	10	13
80	16	14	12	12	16	15	18	12	11	11
90	7	12	12	28	30	20	21	20	16	5
100	14	18	16	14	11	16	21	35	27	37
110	54	70	61	53	61	72	77	116	78	96
120	70	89	55	36	33	31	25	24	28	32
130	32	38	57	52	78	118	175	334	437	534
140	497	398	77	206	241	311	455	757	1051	1377
150	1812	2276	2742	3191	3119	2421	1532	750	365	155
160	142	170	219	310	518	860	1541	2639	4074	5071
170	4717	3243	1392	510	149	53	42	40	42	48
180	82	99	154	179	220	245	285	317	234	94
190	43	22	24	30	17	16	22	24	22	33
200	53	61	90	154	299	431	602	597	409	242
210	103	53	29	34	28	37	40	46	73	57
220	105	174	245	267	250	217	97	62	62	63
230	72	92	131	154	231	340	562	871	1096	1258
240	1403	1891	3027	4682	5661	5232	3429	1617	647	264
250	182	265	363	577	765	840	710	515	413	523
260	838	1397	2481	4143	5455	5869	4629	2558	900	222
270	41	4	2	0	0	0	0	1	0	1
280	2	0	1	1	1	1	2	1	0	1
290	1	0	0	1	2	0	0	1	1	4
300	0	0	0	0	0	0	0	0	0	0

18.2 D THORIUM 227 AND 11.43 D RADIUM 223

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 90-TH-227

	0	1	2	3	4	5	6	7	8	9
0	37	38	51	35	35	46	46	52	52	50
10	59	59	44	43	31	38	27	27	40	32
20	28	40	35	37	50	44	52	42	50	38
30	43	40	36	45	29	47	34	48	44	43
40	40	31	48	34	36	36	50	48	40	36
50	52	58	55	72	84	92	114	214	251	299
60	356	311	229	123	59	57	51	51	47	45
70	45	46	46	51	60	48	61	71	81	99
80	103	139	185	175	197	164	107	124	163	210
90	270	332	514	802	1058	1371	1304	1096	648	329
100	148	83	85	84	99	93	116	136	164	189
110	265	340	487	657	856	1295	1955	2632	3346	3364
120	2774	1696	852	281	122	91	76	74	72	69
130	80	89	101	114	113	148	167	225	333	446
140	496	461	461	357	381	420	579	836	1154	1620
150	2234	3109	4289	5884	7763	9161	8988	6784	4061	1995
160	863	513	653	842	1177	1638	2135	2586	2987	3354
170	3361	3121	1948	1035	470	207	106	77	75	79
180	63	106	112	137	155	175	209	180	195	162
190	92	64	44	43	45	55	47	44	66	83
200	82	108	148	198	254	366	447	529	524	440
210	275	138	82	55	43	41	55	68	40	74
220	79	102	154	179	187	181	142	108	88	97
230	76	105	110	120	170	220	331	461	666	824
240	928	1110	1566	2360	3135	3587	3180	2046	1082	462
250	258	212	229	377	490	581	582	518	411	370
260	532	793	1249	1916	3029	3786	3731	2734	1507	612
270	229	63	49	47	33	29	34	37	42	33
280	35	45	42	36	33	31	32	41	32	29
290	39	41	38	31	40	49	48	48	44	48
300	0	0	0	0	0	0	0	0	0	0

1.913 Y THORIUM 228

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 90-TH-228

	0	1	2	3	4	5	6	7	8	9
0	6	14	21	10	21	14	12	18	22	7
10	6	12	10	16	8	15	13	15	6	14
20	10	14	17	11	14	14	13	10	8	10
30	19	9	14	12	11	15	13	10	15	17
40	12	14	11	11	9	16	13	15	17	20
50	18	10	20	13	27	11	20	13	15	21
60	18	10	20	13	21	16	23	7	13	13
70	18	19	8	11	16	13	19	13	13	17
80	16	14	18	24	14	16	31	33	27	29
90	28	27	25	19	24	26	29	24	30	59
100	77	90	101	75	63	39	32	36	38	52
110	78	102	200	172	137	85	60	38	32	29
120	30	33	29	33	25	15	38	32	32	37
130	35	37	52	47	46	36	47	45	55	71
140	58	80	87	108	133	135	185	210	295	413
150	598	977	1544	2722	4583	7062	9378	9355	6747	3260
160	1160	319	114	88	84	91	102	116	147	132
170	201	228	236	319	437	536	707	1113	1524	2348
180	3915	6803	11634	18605	24572	25435	19228	9665	3382	709
190	136	32	24	38	25	17	12	12	6	6
200	4	4	8	5	6	7	10	10	7	7
210	0	0	0	0	0	0	0	0	0	0

1.913 Y THORIUM 228 + DAUGHTERS

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 90-TH-228

	0	1	2	3	4	5	6	7	8	9
0	55	64	58	63	60	59	59	73	58	63
10	64	62	59	73	84	90	98	66	97	60
20	64	63	52	60	75	92	117	119	160	167
30	146	127	95	88	84	86	78	110	145	189
40	247	259	221	145	106	74	85	88	69	86
50	75	85	79	78	75	70	85	92	92	89
60	81	106	106	113	97	112	117	123	127	135
70	153	181	204	227	304	332	434	560	840	1232
80	1883	3144	5256	8225	11000	11633	9160	4545	1523	429
90	202	195	186	181	194	246	244	289	323	356
100	404	497	587	817	1064	1447	1955	3141	4788	7915
110	13503	21300	29553	32121	25217	13615	4736	1374	929	1207
120	1584	1949	1971	1442	795	333	104	80	71	55
130	67	69	62	67	63	73	64	67	64	67
140	81	72	54	82	62	65	77	71	75	70
150	74	62	78	83	70	86	93	88	92	71
160	97	99	109	100	108	94	127	129	148	165
170	149	186	152	212	235	247	226	254	200	241
180	237	279	327	342	350	396	502	574	702	784
190	994	1239	1611	2088	2874	4028	5898	8832	13181	19504
200	27587	34246	36101	28639	16248	5427	1218	235	98	85
210	87	78	76	72	72	62	71	78	88	82
220	74	97	123	119	119	126	154	145	144	152
230	159	116	105	70	65	45	52	49	74	69
240	56	57	56	66	53	49	44	58	46	48
250	54	54	48	58	51	37	52	62	43	46
260	60	52	55	46	44	55	59	60	56	55
270	62	62	66	72	66	71	60	62	63	56
280	64	66	61	68	73	78	85	78	84	80
290	73	83	75	82	106	105	109	116	122	121
300	131	128	140	131	156	194	214	229	259	285
310	293	330	430	468	611	727	934	1149	1346	1633
320	2062	2556	3250	3743	4385	4685	4437	3314	2068	981
330	606	616	712	827	1107	1194	1378	1681	1788	1776
340	1521	950	422	193	143	123	117	98	121	140
350	131	136	153	152	157	134	167	150	148	156
360	176	152	174	204	206	226	214	237	259	286
370	269	273	303	302	354	365	401	384	420	457
380	554	548	593	595	698	787	821	963	1027	1240
390	1378	1542	1714	2075	2396	2770	3339	4137	5046	6292
400	8108	10768	13978	18359	22907	26360	26628	23385	16296	9688
410	5320	2512	1241	803	580	559	548	517	507	488
420	414	289	141	89	48	48	46	40	54	42
430	40	46	38	59	36	45	43	47	50	39
440	42	44	38	34	42	40	42	37	46	49
450	39	40	51	53	39	38	41	45	48	50
460	49	47	50	47	56	51	48	52	42	48
470	51	46	42	54	41	52	54	51	52	59
480	65	48	61	55	70	54	62	57	63	72
490	62	63	78	72	78	72	68	66	76	86
500	72	77	73	111	99	93	93	104	99	106
510	91	121	105	102	112	133	116	128	155	146
520	150	129	168	157	166	180	185	231	192	216
530	189	212	258	269	267	301	317	353	344	365
540	409	423	431	479	530	539	635	707	740	844
550	922	1011	1119	1228	1415	1627	1773	2014	2231	2625
560	3066	3647	4271	5311	6362	7852	9680	12222	15054	18373
570	20981	22854	22093	19232	14565	9799	5730	3108	1786	1260
580	1098	1092	1127	1226	1340	1392	1324	1083	647	299
590	114	50	26	13	14	7	13	13	7	10
600	9	8	8	5	14	5	5	7	4	4
610	0	0	0	0	0	0	0	0	0	0

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7340 Y THORIUM 229

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 90-TH-229

	0	1	2	3	4	5	6	7	8	9
0	44	34	34	25	31	36	33	28	37	30
10	32	23	28	29	38	36	27	29	18	30
20	45	33	32	31	29	28	32	34	31	33
30	46	37	41	34	50	39	34	46	51	26
40	41	39	45	36	15	29	44	43	39	32
50	42	29	38	33	42	43	46	44	53	46
60	51	49	77	54	84	85	104	73	58	52
70	43	34	50	48	37	51	46	36	54	46
80	57	48	68	51	77	101	130	184	235	254
90	192	153	115	91	104	117	140	179	251	333
100	439	523	574	648	907	1282	1602	1642	1214	889
110	813	988	1365	2024	3397	4888	6833	7201	5628	2959
120	1090	349	210	170	132	137	127	114	144	164
130	204	221	377	556	963	1339	1435	1146	628	279
140	119	51	46	75	94	94	111	88	107	107
150	117	125	141	162	223	287	431	690	994	1066
160	982	779	599	527	340	188	66	57	42	39
170	49	58	62	65	56	65	75	87	97	91
180	104	130	168	204	260	451	687	978	982	766
190	444	170	61	42	33	46	36	50	36	31
200	35	44	32	37	26	28	40	37	24	35
210	0	0	0	0	0	0	0	0	0	0

8.0 E+4 Y THORIUM 230

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 90-TH-230

	0	1	2	3	4	5	6	7	8	9
0	21	19	14	11	19	14	21	10	9	24
10	16	18	17	11	15	12	17	23	15	17
20	9	11	15	17	12	15	10	11	20	20
30	19	10	23	18	16	16	12	17	15	17
40	16	15	14	14	17	19	13	13	22	14
50	13	18	24	16	19	21	18	19	12	17
60	19	10	17	21	20	23	21	15	19	10
70	17	15	15	18	15	20	12	11	23	10
80	23	20	27	18	20	29	11	26	24	21
90	16	19	16	23	19	26	20	26	29	34
100	31	37	39	37	33	26	27	32	31	29
110	38	41	52	77	117	132	132	88	54	44
120	29	34	39	29	34	25	31	33	35	30
130	47	45	51	47	47	52	48	46	62	49
140	58	50	48	70	67	75	94	102	99	101
150	148	145	174	215	276	408	516	769	1252	2137
160	3807	6842	11060	15129	16334	12798	6650	2374	719	345
170	276	303	338	353	449	571	671	899	1223	1895
180	2662	4307	7644	13258	23271	35863	46200	44662	30979	14004
190	4024	676	74	7	3	4	5	4	4	3
200	6	2	1	1	3	1	1	2	0	1
210	0	0	0	0	0	0	0	0	0	0

3.25 E+4 Y PROTACTINIUM 231

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 91-PA-231

	0	1	2	3	4	5	6	7	8	9
0	38	34	38	37	39	30	36	44	30	39
10	42	31	50	21	27	45	33	45	31	33
20	37	28	40	37	41	45	36	42	56	39
30	53	49	37	23	41	40	45	51	61	60
40	55	41	40	31	49	67	93	119	165	172
50	219	188	181	170	157	118	85	87	82	83
60	142	218	334	497	923	1220	1341	1102	752	346
70	196	164	184	342	502	731	956	1100	948	866
80	989	1496	2689	4663	6481	7355	6345	3815	1686	550
90	193	106	93	71	59	49	53	55	48	51
100	47	60	60	77	104	75	79	71	55	43
110	62	59	72	43	60	71	71	82	94	129
120	187	312	583	862	1160	1271	975	660	323	179
130	124	117	98	101	98	97	99	76	110	127
140	124	136	151	185	196	226	301	423	592	1032
150	1573	2378	3522	4241	5042	6670	10065	15236	18586	17622
160	12457	6431	2712	1193	912	913	1111	1289	1567	1788
170	2056	1968	1773	1635	2064	3345	6168	10594	16618	21849
180	22592	18923	14881	14834	18120	20033	17416	11299	5642	2340
190	1521	2140	3615	6074	8596	9465	7924	4752	1916	547
200	91	16	5	8	7	6	5	8	9	6
210	0	0	0	0	0	0	0	0	0	0

3.25 E+4 Y PROTOACTINIUM 231 + DAUGHTERS
ENERGY SCALE 3.0 KEV/CH SOURCE DISTANCE 2 CM
SPECTRUM NO. 91-PA-231

	0	1	2	3	4	5	6	7	8	9
0	27	22	25	30	35	27	33	27	28	37
10	38	67	89	98	119	80	176	99	85	51
20	46	40	41	58	87	159	262	489	700	908
30	787	427	190	90	88	119	152	311	431	621
40	688	583	534	695	1202	2224	3536	4513	4226	2441
50	923	194	64	41	31	24	23	15	19	21
60	20	23	21	27	32	39	43	44	25	26
70	23	23	21	17	32	30	25	38	39	54
80	115	116	206	360	530	761	757	489	216	97
90	42	52	48	52	33	38	58	52	58	69
100	75	79	83	107	100	150	204	253	349	625
110	963	1531	2272	2811	3086	3953	6092	9286	11495	10333
120	5908	2210	666	358	371	503	631	806	907	1096
130	1260	1127	970	974	1436	2550	4322	7380	11427	13768
140	12676	8977	7100	8718	11248	11501	8355	3861	1380	680
150	855	1589	2643	4170	5444	5314	3481	1351	287	35
160	8	7	6	6	6	5	4	4	7	4
170	6	5	8	12	7	5	4	8	5	6
180	9	6	8	4	7	4	13	3	9	7
190	7	7	6	7	6	8	3	4	9	6
200	8	3	9	5	5	6	6	3	9	4
210	4	5	8	7	8	12	13	4	9	10
220	9	10	8	16	11	5	24	11	13	18
230	16	18	17	11	14	11	8	10	7	7
240	10	6	7	6	15	7	14	13	9	13
250	8	8	7	6	7	10	10	14	8	4
260	11	17	6	12	8	7	14	4	14	4
270	10	13	10	13	26	25	31	32	58	79
280	97	102	65	58	16	12	6	12	12	17
290	14	15	19	20	14	18	23	18	26	26
300	40	34	58	65	67	69	52	39	40	55
310	67	90	153	215	264	336	416	319	174	81
320	38	20	16	33	32	23	26	46	78	55
330	85	131	135	210	290	375	535	803	984	887
340	718	394	121	41	27	19	12	11	21	18
350	32	19	32	37	33	49	77	71	132	119
360	147	134	109	100	132	197	245	349	446	610
370	834	1132	1533	1928	2408	2542	2131	1277	551	222
380	141	154	205	336	443	595	709	833	963	943
390	883	555	249	77	29	24	19	15	17	15
400	13	27	34	50	42	54	70	47	43	14
410	18	15	13	14	21	16	11	17	22	20
420	35	39	52	73	110	132	159	148	106	68
430	14	12	14	15	7	19	15	27	16	27
440	41	41	67	47	42	35	28	21	18	26
450	35	33	44	69	88	123	172	216	243	330
460	441	563	782	926	1064	700	376	145	61	39
470	67	86	106	143	190	176	145	129	119	196
480	331	484	723	913	1110	923	507	181	46	17
490	16	10	12	9	10	10	5	9	12	12
500	8	5	11	13	9	10	10	8	9	11
510	11	14	9	10	8	11	9	13	12	11
520	13	12	15	11	13	15	15	12	13	10
530	17	15	15	14	24	17	21	23	22	23
540	27	23	29	27	29	24	28	40	26	36
550	42	52	60	62	93	98	106	134	127	193
560	213	269	284	300	312	287	221	189	138	78
570	55	61	54	55	47	56	60	63	60	43
580	31	25	16	11	20	19	15	18	23	16
590	17	13	17	17	14	18	26	21	28	23
600	29	30	31	39	44	51	69	82	97	98
610	142	187	205	234	220	190	133	74	49	40
620	25	33	22	29	30	26	25	34	23	39
630	28	26	23	31	41	34	37	42	46	37
640	55	51	61	69	50	57	76	102	86	123
650	150	142	190	264	331	381	442	400	337	264
660	202	144	166	168	172	202	219	241	316	308
670	373	453	552	640	799	990	1168	1338	1542	1628
680	1609	1482	1117	810	536	333	229	217	185	219
690	219	241	273	257	215	170	99	50	29	15
700	15	23	15	13	14	21	19	18	19	24
710	27	24	22	36	32	39	31	36	34	37
720	37	53	61	45	62	73	77	57	74	83
730	112	142	138	152	185	195	267	337	397	518
740	684	943	1252	1637	2048	2354	2359	1960	1345	694
750	355	157	126	93	73	71	50	46	45	29
760	20	14	4	5	6	6	5	8	4	4
770	3	7	2	8	5	7	6	6	5	8
780	6	1	5	3	6	7	4	1	5	8
790	8	2	7	4	8	3	4	7	5	5
800	6	8	4	5	5	8	4	3	4	4
810	9	5	8	6	5	7	6	6	3	7
820	4	9	6	10	7	4	7	3	4	8
830	7	14	9	3	15	10	9	6	3	8
840	8	10	6	3	9	14	3	5	5	7
850	6	9	4	9	11	5	13	5	15	7
860	10	9	9	10	6	20	7	14	12	14
870	15	14	14	12	11	8	11	8	13	16
880	14	15	21	19	19	19	19	21	17	23
890	26	24	26	27	31	22	30	17	30	32
900	38	45	32	48	53	48	47	66	51	54
910	60	73	101	87	101	95	106	151	159	153
920	216	213	255	281	352	433	506	559	753	978
930	1157	1541	1761	2142	2450	2441	2131	1650	956	545
940	304	227	192	165	196	171	173	170	174	158
950	103	58	35	13	10	11	3	4	2	3
960	5	1	3	0	0	0	0	0	0	0
970	0	0	0	0	0	0	0	0	0	0

72 Y URANIUM 232

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 92-U-232

	0	1	2	3	4	5	6	7	8	9
0	10	17	14	17	16	11	17	19	21	12
10	19	17	15	13	22	15	10	12	22	11
20	12	15	14	21	10	16	21	19	18	16
30	16	23	12	19	21	21	14	16	16	19
40	15	19	10	28	17	22	13	24	19	18
50	16	20	16	18	23	18	18	18	24	25
60	29	25	32	31	21	26	29	20	18	21
70	27	28	24	30	16	31	19	22	24	30
80	18	18	18	22	24	21	30	30	26	34
90	26	29	25	22	33	26	45	32	27	40
100	36	37	43	51	74	85	118	170	176	164
110	113	72	39	42	40	37	66	57	53	57
120	50	57	65	64	77	65	67	78	79	73
130	85	81	112	102	130	126	145	156	190	207
140	278	320	384	556	839	1324	2225	3979	7294	11466
150	14565	13566	9165	4198	1432	534	376	369	410	491
160	684	768	1176	1703	2577	4522	8156	14293	22701	30227
170	30576	22025	10381	3270	786	186	99	80	42	25
180	9	8	1	2	2	3	7	7	3	5
190	5	3	6	5	4	8	5	15	13	20
200	37	61	92	153	171	193	131	57	21	11
210	0	0	0	0	0	0	0	0	0	0

72 Y URANIUM 232 + DAUGHTERS

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 92-U-232

	0	1	2	3	4	5	6	7	8	9
0	66	41	48	42	55	49	62	51	56	63
10	64	76	89	79	106	152	215	249	267	184
20	99	96	80	91	87	93	99	119	130	124
30	148	156	140	122	134	115	135	122	187	170
40	195	228	253	264	220	240	238	233	255	348
50	379	451	540	739	1059	1703	2760	4848	8844	14090
60	18255	17291	10363	3762	912	500	441	515	567	608
70	860	1082	1506	2013	3101	5111	9167	16518	27941	38242
80	39339	26422	11417	4570	3819	5007	5978	5302	3186	1142
90	315	142	132	146	131	149	150	195	192	197
100	238	298	335	408	499	660	846	1146	1689	2545
110	3954	6209	9632	13619	15834	14328	8506	3234	772	434
120	575	742	985	1032	835	472	178	50	39	49
130	44	39	40	60	52	58	69	66	71	69
140	64	59	50	43	46	42	47	34	35	37
150	41	55	42	39	52	59	62	42	63	65
160	48	48	59	54	61	67	51	76	78	77
170	88	102	135	124	114	139	135	147	158	137
180	158	173	194	194	221	213	285	340	358	452
190	549	633	867	975	1262	1726	2430	3275	4850	7201
200	10455	14101	17857	18359	13768	6524	1822	307	67	61
210	45	45	50	43	38	43	49	46	43	44
220	51	55	65	71	76	77	73	92	89	98
230	89	96	61	51	28	40	42	45	46	42
240	36	48	45	39	39	35	32	39	35	40
250	34	38	27	29	38	42	40	32	32	42
260	46	41	33	31	45	36	34	48	39	39
270	36	41	31	49	45	37	40	39	50	37
280	43	43	49	45	49	52	50	55	42	57
290	64	60	66	49	74	69	69	77	70	70
300	89	92	97	100	96	127	123	148	176	175
310	212	237	240	273	360	387	472	563	643	837
320	1035	1255	1474	1784	1992	2198	2241	1954	1197	667
330	361	334	398	439	535	579	748	790	936	897
340	900	594	303	172	91	111	106	75	98	120
350	110	108	113	95	98	95	67	78	91	82
360	99	103	129	110	127	107	128	123	136	134
370	145	149	157	168	183	194	206	215	219	210
380	239	288	328	325	359	377	436	460	527	533
390	617	688	801	840	1064	1275	1562	1838	2238	2865
400	3717	4656	6032	8089	10489	12318	13286	12263	9136	5550
410	2949	1487	1030	858	767	653	638	605	515	407
420	275	138	86	33	33	31	20	23	23	21
430	22	20	21	22	27	29	26	25	35	32
440	25	29	36	19	28	29	34	27	35	31
450	36	21	33	33	31	31	37	33	30	38
460	26	34	34	34	39	23	27	33	42	28
470	37	48	27	43	28	25	34	34	41	47
480	42	47	51	38	36	40	50	34	45	41
490	42	56	55	52	44	59	41	49	52	60
500	47	65	54	59	72	59	62	67	67	65
510	68	73	61	71	77	72	73	83	81	80
520	98	81	100	109	97	104	104	125	126	133
530	125	122	158	142	161	157	155	176	178	231
540	234	206	234	263	258	275	321	358	345	414
550	438	473	506	620	661	766	848	910	1182	1238
560	1477	1717	2032	2390	3005	3637	4442	5693	7033	8646
570	10073	10957	10705	9221	6808	4119	2382	1567	1302	1164
580	1170	1092	1105	1261	1203	1005	710	379	170	68
590	20	7	4	5	0	4	4	7	5	3
600	0	0	0	0	0	0	0	0	0	0

*****E

1.62 E+5 Y URANIUM 233

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 92-U-233

	0	1	2	3	4	5	6	7	8	9
0	9	13	15	28	7	19	14	23	20	18
10	11	19	14	11	16	14	19	6	16	11
20	9	8	15	15	14	13	12	15	18	12
30	6	17	30	17	15	16	15	22	15	11
40	17	21	15	21	21	10	13	23	19	18
50	10	26	22	18	17	19	17	27	22	31
60	25	15	18	26	20	20	19	15	28	18
70	22	29	36	40	35	45	36	44	33	26
80	14	15	19	10	16	13	20	21	12	17
90	13	22	18	22	23	20	23	24	23	19
100	27	25	24	28	35	19	27	26	40	36
110	34	33	35	26	27	34	36	35	34	41
120	34	29	33	45	37	62	84	68	69	83
130	61	55	73	67	62	70	78	88	118	129
140	153	160	155	156	174	257	367	634	927	1211
150	1193	1111	676	351	236	239	309	392	454	435
160	486	490	665	917	1461	2705	4525	6881	8768	9179
170	7451	4555	2498	1478	1297	1614	2102	3173	5350	9863
180	17697	29668	43077	50511	46816	32576	16187	5707	1392	237
190	72	50	29	26	21	7	8	6	12	11
200	0	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0

2.47 E+5 Y URANIUM 234

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 92-U-234

	0	1	2	3	4	5	6	7	8	9
0	12	5	10	9	6	11	11	7	15	11
10	9	6	6	14	5	7	6	8	12	9
20	8	5	6	5	11	4	14	6	11	6
30	10	6	7	8	10	12	7	12	5	8
40	7	9	13	8	9	7	8	11	7	13
50	8	7	13	5	14	10	10	12	10	6
60	13	12	10	8	5	11	9	10	14	15
70	8	9	20	9	7	17	15	15	5	14
80	7	10	10	11	10	12	11	11	10	10
90	15	14	16	11	10	20	9	13	20	14
100	11	11	19	16	13	6	9	18	9	17
110	16	17	16	13	21	20	20	25	26	42
120	60	83	112	107	98	53	43	23	24	28
130	28	24	30	24	26	36	28	29	39	40
140	44	45	37	38	52	50	66	63	74	61
150	93	115	116	144	184	205	279	360	555	884
160	1661	3181	5412	8738	11693	11906	9038	4595	1731	530
170	276	230	358	417	571	779	1112	1881	3387	6415
180	11615	19643	27398	30775	25468	14839	5811	1475	226	32
190	0	0	0	0	0	1	1	0	0	0
200	0	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0

7.1 E+8 Y URANIUM 235

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 1 CM

SPECTRUM NO. 92-U-235

	0	1	2	3	4	5	6	7	8	9
0	1	2	3	1	3	1	2	5	1	1
10	1	1	4	2	3	1	2	3	0	2
20	1	3	3	1	1	0	0	1	3	0
30	4	2	0	2	3	4	4	3	3	5
40	13	12	13	8	9	12	4	8	7	3
50	3	4	11	6	5	16	21	28	42	46
60	85	126	128	161	140	149	114	84	56	21
70	5	4	5	7	5	4	4	9	9	13
80	8	15	11	9	8	10	11	15	12	7
90	9	12	14	26	31	65	66	85	78	91
100	106	94	90	72	69	63	100	122	171	235
110	32	385	482	498	525	605	560	512	479	639
120	811	993	1302	1494	1569	1446	1346	949	618	325
130	197	108	83	57	47	25	20	16	12	9
140	4	3	5	5	5	1	5	2	4	4
150	2	5	5	8	10	22	13	26	35	40
160	41	36	20	25	5	12	8	6	5	4
170	11	17	43	40	64	84	83	106	110	112
180	84	62	36	29	30	19	37	50	80	84
190	100	122	144	130	87	60	28	10	5	1
200	1	0	0	1	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0

2.14 E+6 Y NEPTUNIUM 237

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 1 CM

SPECTRUM NO. 93-NP-237

	0	1	2	3	4	5	6	7	8	9
0	26	27	41	33	26	26	30	30	41	38
10	26	28	26	26	27	22	37	26	36	34
20	23	28	38	16	29	33	24	26	36	39
30	31	28	34	25	21	29	29	25	33	22
40	42	34	26	39	39	39	37	32	44	32
50	33	36	39	36	44	41	27	41	32	40
60	29	38	40	42	42	61	53	68	66	85
70	82	79	70	74	58	52	63	57	46	55
80	57	64	65	87	90	110	107	167	226	281
90	375	482	520	588	552	459	434	426	439	556
100	589	547	495	362	381	383	574	847	1373	1974
110	3056	4413	5877	7139	7715	7076	5458	3752	2562	2350
120	2814	3374	3920	4004	3227	2330	1340	636	384	387
130	454	604	803	1100	1181	1409	1562	1634	1630	1510
140	1289	928	643	530	502	568	698	866	1079	1639
150	2268	3609	5740	8754	13512	19486	26876	35178	41632	45361
160	45929	45110	45957	49425	54999	55076	48059	34145	19301	9530
170	5268	3925	3594	3318	3336	2982	2414	1631	894	432
180	195	116	128	129	173	256	343	541	841	1292
190	1775	2449	2965	3211	3093	2533	1625	767	291	85
200	13	3	0	1	0	1	0	1	0	0
210	0	0	0	0	0	0	0	0	0	0

86 Y PLUTONIUM 238

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 94-PU-238

	0	1	2	3	4	5	6	7	8	9
0	8	6	10	6	9	10	11	6	10	7
10	9	11	15	13	6	11	15	6	11	8
20	6	10	5	13	8	9	9	9	6	8
30	14	11	10	12	12	9	8	12	10	9
40	9	12	8	9	11	12	12	12	9	13
50	9	9	18	15	16	16	7	12	14	9
60	16	15	13	14	13	9	15	17	19	13
70	16	9	8	11	16	13	12	18	16	5
80	9	12	7	10	20	12	13	11	16	15
90	12	14	9	17	15	14	14	12	13	17
100	19	11	9	14	17	19	16	18	20	18
110	14	11	17	16	22	18	26	16	19	15
120	17	13	25	20	23	17	18	26	20	33
130	21	19	26	30	27	37	32	43	51	53
140	99	99	84	67	41	38	53	40	50	53
150	63	58	70	64	83	105	92	111	114	162
160	148	179	251	246	335	452	566	801	1223	1948
170	3531	6178	9978	14000	15754	13489	7999	3584	1452	1005
180	1124	1571	2278	3723	6491	11834	20336	31060	38099	35874
190	23926	11074	3580	707	82	12	1	1	0	0
200	1	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0

2.44 E+4 Y PLUTONIUM 239

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 94-PU-239

	0	1	2	3	4	5	6	7	8	9
0	8	15	10	12	12	3	3	9	6	2
10	5	12	11	12	19	11	6	7	9	9
20	8	8	6	11	7	14	3	7	11	7
30	3	10	10	11	7	11	9	5	10	8
40	9	8	9	13	15	9	10	7	9	11
50	5	12	9	19	9	8	15	14	7	13
60	14	8	8	10	15	10	11	7	11	10
70	11	9	19	15	6	12	7	19	13	6
80	13	10	12	17	17	11	10	20	16	15
90	8	12	13	10	12	14	13	10	14	12
100	19	15	15	8	15	12	16	15	29	14
110	10	23	18	15	18	14	17	23	22	12
120	27	19	15	18	24	18	31	23	31	23
130	33	33	36	28	35	26	35	27	36	43
140	37	34	37	52	33	55	48	54	54	74
150	77	85	95	75	87	100	113	154	197	244
160	272	424	648	1130	1979	3365	4707	5626	4988	3197
170	1600	772	606	717	967	1460	2315	3984	6567	9862
180	13185	16299	20966	27697	32364	29794	20265	9718	3144	840
190	207	66	24	4	1	0	1	1	0	0
200	1	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0

6580 Y PLUTONIUM 240

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 94-PU-240

	0	1	2	3	4	5	6	7	8	9
0	11	11	8	5	6	7	13	15	13	15
10	13	8	12	11	11	11	14	13	10	16
20	13	13	12	16	7	14	11	10	17	11
30	5	13	8	14	11	13	5	18	13	10
40	21	13	19	7	9	21	18	15	12	13
50	17	17	12	9	12	24	14	13	21	11
60	21	9	10	15	15	10	14	10	17	24
70	16	18	14	17	20	27	8	15	11	25
80	17	22	21	23	15	24	19	22	17	19
90	16	21	21	20	22	23	20	23	17	18
100	13	25	21	33	23	22	18	20	19	16
110	20	23	22	28	21	32	34	27	30	23
120	29	29	24	29	21	33	30	28	47	46
130	42	41	59	49	74	88	99	95	84	72
140	59	46	59	76	74	83	83	100	84	80
150	112	87	123	109	126	133	144	184	211	251
160	284	356	420	600	765	1170	1812	3401	6065	10326
170	14488	16671	13645	8212	3548	1521	905	1060	1353	1819
180	2864	4699	8047	14999	25815	37604	43887	37119	22747	9378
190	2531	460	77	6	1	2	1	0	0	1
200	0	0	0	0	1	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0

13.2 Y PLUTONIUM 241

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 94-PU-241

	0	1	2	3	4	5	6	7	8	9
0	87	82	87	96	90	100	87	88	90	78
10	95	85	81	84	98	65	101	78	71	88
20	90	93	87	86	88	83	92	104	92	87
30	94	96	95	93	90	85	97	97	103	79
40	104	112	106	106	100	117	132	113	114	105
50	113	108	110	117	113	92	119	121	153	148
60	170	220	254	244	319	318	332	293	212	162
70	157	140	151	139	187	210	239	315	362	552
80	718	991	1419	1919	2202	2117	1798	1210	776	640
90	727	954	1365	1910	2891	4537	6632	9477	12489	14248
100	13084	9173	4914	2205	973	587	447	331	351	356
110	349	321	289	258	230	200	192	226	219	250
120	248	266	278	317	378	414	375	293	232	209
130	190	225	221	202	257	246	215	215	254	272
140	337	324	309	300	284	299	366	429	479	507
150	475	426	372	358	357	370	380	399	429	481
160	510	673	779	1096	1411	1984	2717	3983	5530	7438
170	8917	10105	11828	15482	21058	26299	27902	24252	17317	12190
180	10827	13159	17185	22135	27631	35266	44819	54462	61320	67760
190	74976	74952	61382	37160	16493	5841	1904	660	265	118
200	51	39	37	45	39	30	42	25	33	25
210	0	0	0	0	0	0	0	0	0	0

458 Y AMERICIUM 241

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 95-AM-241

	0	1	2	3	4	5	6	7	8	9
0	11	11	8	11	10	10	17	18	11	15
10	13	12	11	12	14	12	13	8	10	17
20	16	13	8	12	15	14	11	16	7	23
30	17	14	13	18	13	20	9	12	19	14
40	20	15	23	14	13	13	17	10	12	21
50	17	18	19	16	19	9	10	27	21	16
60	20	18	19	18	10	20	19	21	23	21
70	17	24	10	25	25	12	17	18	21	23
80	31	21	29	19	18	14	23	15	26	20
90	19	31	31	20	25	34	27	22	27	38
100	22	29	22	29	34	32	36	39	29	37
110	27	35	39	32	31	39	53	38	35	43
120	56	54	49	59	54	57	39	53	46	59
130	70	73	67	95	100	105	106	117	158	240
140	312	548	798	1039	1012	816	504	281	180	201
150	208	250	277	333	391	500	689	1100	1783	3002
160	4821	6777	7560	6698	4327	2368	1381	1207	1530	1962
170	2840	4600	8145	14769	25028	37512	46192	43572	30448	14856
180	5112	1244	276	124	122	144	135	99	75	42
190	48	40	60	84	115	188	196	164	90	48
200	12	3	2	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0

7.95 E+3 Y AMERICIUM 243

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 95-AM-243

	0	1	2	3	4	5	6	7	8	9
0	29	34	20	31	30	29	34	32	34	28
10	41	36	25	26	25	30	20	34	29	38
20	37	36	33	28	40	41	35	36	41	32
30	38	37	40	43	43	28	39	31	29	28
40	43	31	36	46	40	30	41	43	37	34
50	52	37	55	58	57	40	50	63	60	61
60	67	61	59	69	63	87	85	94	104	119
70	116	150	173	217	342	510	882	1269	1610	1575
80	1179	683	401	256	252	239	318	353	445	562
90	745	1126	1729	3060	5364	8879	12053	13338	11073	6903
100	3661	2216	2094	2616	3609	5591	9312	16804	31025	53545
110	80086	95947	86989	57971	27134	8469	1901	338	76	92
120	65	80	81	128	158	229	244	214	153	113
130	77	52	85	121	191	241	265	250	175	61
140	29	14	5	5	8	13	19	40	34	47
150	61	43	21	10	10	11	8	15	11	13
160	16	30	39	61	110	178	267	354	345	261
170	168	85	63	57	98	96	167	272	463	846
180	1502	2011	2292	2067	1174	549	140	47	15	18
190	19	9	14	6	2	11	7	8	9	5
200	12	22	10	14	10	9	3	7	9	4
210	0	0	0	0	0	0	0	0	0	0

163 D CURIUM 242

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 96-CM-242

	0	1	2	3	4	5	6	7	8	9
0	14	20	14	14	15	17	10014	16	15	17
10	22	20	11	14	9	18	16	18	16	18
20	14	27	21	16	19	17	16	23	16	21
30	14	10	18	16	15	15	17	13	19	21
40	22	24	27	28	18	25	24	17	25	30
50	18	21	21	19	18	19	24	24	28	21
60	22	30	35	45	52	64	77	61	49	34
70	35	54	59	75	64	74	74	95	130	197
80	267	261	188	138	98	117	140	158	188	110
90	84	54	27	25	19	30	29	27	28	33
100	31	35	33	35	28	31	38	45	35	33
110	36	36	33	28	39	31	33	28	32	40
120	33	43	33	51	40	43	47	43	52	53
130	43	39	41	46	41	43	49	54	60	51
140	71	74	61	72	79	80	71	102	96	85
150	84	95	82	105	101	106	119	113	116	137
160	143	183	219	239	305	336	415	574	964	1539
170	2866	5049	8230	11307	11781	9561	5556	2487	1067	811
180	988	1422	2386	4114	7631	13971	22919	31130	31964	24659
190	13220	4678	1090	160	20	1	0	0	1	0
200	0	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0

17.6 Y CURIUM 244

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 96-CM-244

	0	1	2	3	4	5	6	7	8	9
0	7	4	10	7	7	12	3	9	4	7
10	8	9	7	4	4	6	7	9	10	6
20	9	9	8	2	12	7	3	6	8	12
30	7	7	5	9	12	7	12	5	8	11
40	10	4	10	12	15	7	9	8	10	8
50	8	12	8	12	7	8	7	6	11	9
60	8	8	9	11	9	14	9	8	8	10
70	8	7	11	8	7	14	6	10	10	14
80	7	9	11	7	15	10	8	9	12	7
90	11	16	16	7	8	14	16	11	8	11
100	12	12	15	12	9	11	18	13	15	17
110	12	14	9	17	17	20	9	17	8	19
120	13	21	16	16	21	20	14	17	21	21
130	16	22	29	31	25	21	31	35	32	31
140	37	39	51	47	46	44	35	51	53	38
150	54	52	71	64	69	76	76	95	125	119
160	111	145	136	205	238	298	382	475	740	1133
170	1881	3334	5692	8023	9039	7598	4598	2178	1023	801
180	1007	1353	2044	3441	6171	11424	18563	26489	29504	23607
190	13375	5080	1209	195	14	1	0	0	0	0
200	0	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0

2.65 Y CALIFORNIUM 252 AND 13 Y CALIFORNIUM 250

ENERGY SCALE 3.0 KEV/CH

SOURCE DISTANCE 2 CM

SPECTRUM NO. 98-CF-252

	0	1	2	3	4	5	6	7	8	9
0	10	5	10	13	9	10	13	5	12	14
10	11	18	12	11	10	8	4	9	11	7
20	10	11	14	9	10	20	13	11	13	11
30	9	14	9	9	14	11	11	11	8	19
40	10	11	16	16	11	24	17	15	13	18
50	14	12	16	18	21	23	15	24	13	22
60	13	15	10	13	16	7	18	14	18	39
70	41	47	65	42	38	24	20	19	17	14
80	13	13	21	19	17	21	28	14	19	15
90	20	27	14	14	23	22	22	12	26	27
100	38	34	22	31	22	29	21	22	30	29
110	33	29	23	38	20	34	35	46	43	41
120	41	35	64	58	69	84	133	115	170	121
130	332	463	583	595	505	345	226	237	243	271
140	292	315	426	612	1047	1679	2445	2759	2532	1531
150	763	295	164	152	201	288	350	525	867	1474
160	2502	1616	4887	5003	3713	2018	1034	734	791	992
170	1330	2008	3283	5687	10055	16669	24058	27487	23314	13661
180	5142	1273	176	14	4	0	1	1	0	1
190	0	1	0	1	0	1	1	1	0	0
200	0	4	3	3	0	2	0	0	1	0
210	0	0	0	0	0	0	0	0	0	0

APPENDIX VII

COMPILATION OF ALPHA-PARTICLE SPECTRA

LIST OF CATALOGUE SPECTRA

<u>Nuclide</u>	<u>Spectrum Number</u>	<u>Nuclide</u>	<u>Spectrum Number</u>
^{211}Bi	83-Bi-211	^{230}Th	90-Th-230
^{212}Bi	83-Bi-212	^{231}Pa	91-Pa-231
^{210}Po	84-Po-210	^{231}Pa + daughters	91-Pa-231
^{212}Po	84-Po-212	^{232}U	92-U-232
^{214}Po	84-Po-214	^{232}U + daughters	92-U-232
^{215}Po	84-Po-215	^{233}U	92-U-233
^{216}Po	84-Po-216	^{234}U	92-U-234
^{218}Po	84-Po-218	^{235}U	92-U-235
^{219}Rn + ^{211}Bi	86-Rn-219 and 83-Bi-211	^{237}Np	93-Np-237
^{220}Rn + ^{212}Bi	86-Rn-220 and 83-Bi-212	^{238}Pu	94-Pu-238
^{222}Rn + ^{210}Po	86-Rn-222 and 84-Po-210	^{239}Pu	94-Pu-239
^{223}Ra	88-Ra-223	^{240}Pu	94-Pu-240
^{224}Ra	88-Ra-224	^{241}Pu	94-Pu-241
^{226}Ra	88-Ra-226	^{241}Am	95-Am-241
^{226}Ra + daughters	88-Ra-226	^{243}Am	95-Am-243
^{227}Ac	89-Ac-227	^{242}Cm	96-Cm-242
^{227}Th	90-Th-227	^{244}Cm	96-Cm-244
^{227}Th + ^{223}Ra	90-Th-227 and 88-Ra-223	^{252}Cf	98-Cf-252
^{228}Th	90-Th-228		
^{228}Th + daughters	90-Th-228		
^{229}Th	90-Th-229

92-U-233