Multiple Beta Spectrum Analysis by Using Gradient Comparison Method

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1. Introduction

Beta spectrum has a wide range of energy distribution by beta-decay with neutrino. When the sample of several mixed radioactive nuclides is measured, it is difficult to divide each nuclide due to the overlapping of spectrums. There have been some studies about beta spectrum analysis. However it is essential to set the liquid scintillation spectrometer channel where the energy of each nuclide is considered. In the present study, therefore, the mathematical approach, which can find intersection of beta spectrums from radioactive nuclides and separate spectrums, is suggested to distinguish beta nuclides without any operation setting overcoming the limit of the conventional beta spectrum analysis.

2. Methods and Results

This research analyzed the data based on the counter graph according to the energy of each nuclide by referring the advanced paper [1]. The nuclides which are used in this analysis are ^{3}H, ^{14}C and ^{45}Ca.

2.1 Preparation of Beta Spectrum Data

This research analyzes the data based on the counter graph according to the energy of each nuclide. Aqueous solutions of ^{3}H-thymidine, ^{14}C-leucine and ^{45}Ca-calcium chloride acid with accurately known disintegration rates are used. The spectrum data of each nuclide is based on advanced paper [1]. This research assumes that the count of sample including several nuclides is equal to the sum of each nuclide's counts. Fig. 1 shows counts of each nuclide per pulse height and Fig. 2 shows count of mixed sample per pulse height.

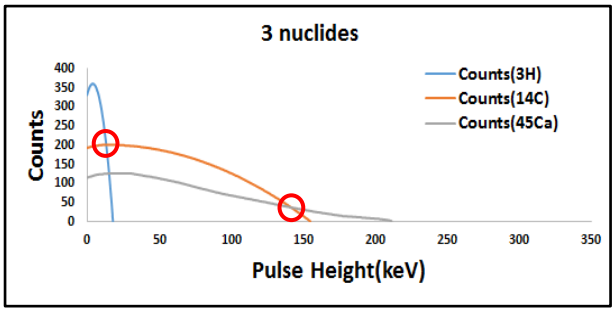

Fig.1. The number of counts of each nuclide per pulse height.

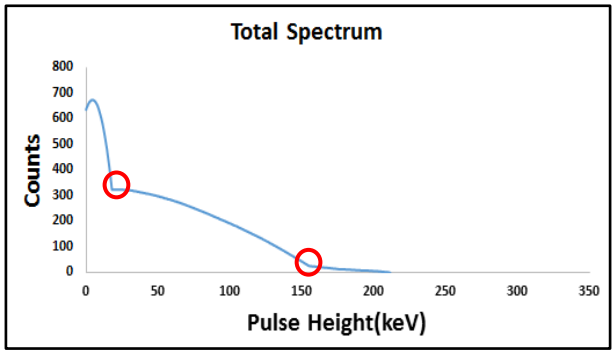

Fig.2. The number of counts of mixed sample per pulse height.

2.2 Finding Peak Intersection

A comparison of the gradient, value variation, is used in order to find intersection of each beta spectrums. As seeing Fig. 1 and Fig. 2, the points where the gradients are dramatically different are almost similar to each nuclide`s end point because gradient of each nuclide is different. Also the shape of each nuclide's spectrum is different. So intersection point can be defined as the point which has the biggest change of gradient. The number of points which is used for getting gradient of spectrum is changed to get more accurate result of finding peak intersection.

2.3 Separating each peak

This research uses two programs which are MATLAB and Excel to plot the graph and find intersections of each peak. The logic which is applicable in all ranges is too complicated, so spectrum is divided into 2 sections to get simple and rapid calculation.

The gradient values are compared with the gradient values of its right point. If gradient difference is big enough (10 times bigger than pervious value in section 1, 2 times bigger than pervious value in section 2), this code catches the values and the values are defined as intersections of each peak. Then program code extrapolates the right end point and intersection point which is the nearest point of right. After this process first peak spectrum is defined and subtracted to total count peak. All of each spectrum peaks are separated by repeating this process.

3. Results

3.1 Multiple Beta Spectrum Analysis

Fig. 3 shows the results about applying the method which is about the number of gradient points change. It can be checked that fluctuation is decreased by the increase of the number of points.

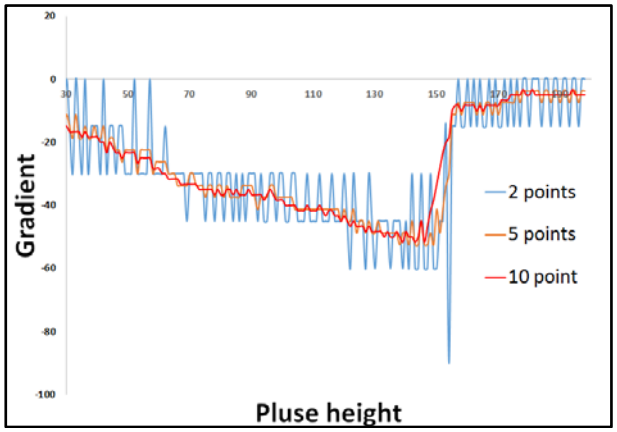

Fig.3. Gradient changes according to the number of points.

Table I is the result of spectrum intersection points by using comparison of gradient. The spectrum intersection points that used in this experiment are 18 and 155. In case of the number of points is 5, 6, 7 and 9, the result is accurate. The fluctuation of data tends to decrease when the number of points used to get a gradient is increased. But if the number of points is over 10, finding intersection of spectrum doesn't work well.

Table I: Spectrum intersection point depending on the number of points

Number of Points	Intersection Point	Number of Points	Intersection Point
2	153, 154, 155	9	18, 155
3	31, 34, 155	10	1, 18
4	3, 4, 155	11	18
5	18, 155	12	18
6	18, 155	13	18
7	18, 155	14	18
9	1, 2, 18	15	18

Fig. 4 shows process of elimination about ^{45}Ca and ^{14}C graph extrapolated. Top part of Fig. 4 is about total count value per pulse height of mixed (^{3}H, ^{14}C and ^{45}Ca) sample. There are two intersection points because spectrum data of 3 nuclides is overlapped. First, spectrum of ^{45}Ca is extrapolated based on intersection point. So spectrum of ^{45}Ca is defined and subtracted from total spectrum of mixed sample by using the spectrum separating process. So spectrum of ^{14}C and ^{3}H remains and can be checked in middle part of Fig. 4. Spectrum of ^{14}C is also defined and subtracted from mixed spectrum by repeating spectrum separating process. Bottom part of Fig. 4 is the result about spectrum separating process which shows the spectrum of ^{3}H. Finally spectrum data of each 3 nuclide is separated.

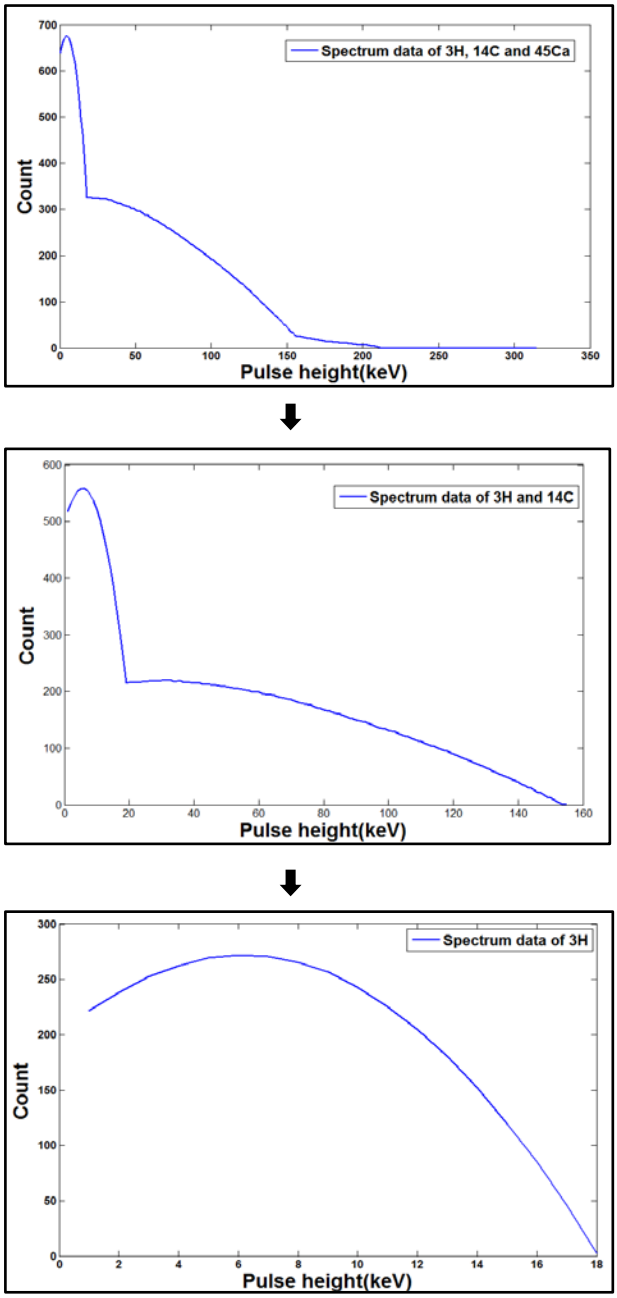

Fig.4. Mixed sample (top), removed ^{45}Ca (middle) and removed ^{14}C and ^{45}Ca (bottom).

Table II shows total counts of each nuclide for reference and calculated value. As seen in the Table I, error which is difference between reference and calculated value is increased by progress of peak separating process because extrapolation is not perfect and error is accumulated. However it is very easy and fast way to distinguish each nuclide's peak spectrums.

Table II: Total counts of reference and calculated value and error

	Counts (^{3}H)	Counts (^{14}C)	Counts (^{45}Ca)
Reference Value	3875	24365	12550
Calculated Value	4921	21659	13897
Error (%)	26.99	11.10	10.73

4. Conclusions

The mathematical process based on the analysis of gradient of spectrum was employed to distinguish the beta nuclides from mixed spectrums. It was understood that the increasing number of points used for getting gradient of spectrum made the fluctuation of the spectrum data reduced while the errors had the tendency of increasing during each process of spectrum separation. It was thought that the method of the gradient comparison could be effectively applied to the analysis on the spectrum of ^{3}H, ^{14}C and ^{45}Ca in spite of the error. In the further study, it was expected that the approach to more precise extrapolation method would be performed considering the reduction of error at the distribution of each spectrum.

REFERENCES

[1] Y.Matsui, M. Takiue, Liquid Scintillation Radioassay of Multi-labeled Beta-emitters, Applied Radiation and Isotopes, Vol. 42, No. 9, p, 841-845, 1991
[2] J.Mantel, The Beta Ray Spectrum and the Average Beta Energy of Several Isotopes of Interest in Medicine and Biology, International Journal of Applied Radiation and Isotopes, Vol 23, p 407-413, 1972