LSC BETA SPECTRA ANALYSIS BY STANDARDIZATION BASED ON SHIFTING AND CALCULATION IN MULTY WINDOWS

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The method describes of analysis of beta-spectra of liquid-scintillation spectrometer implemented on the basis of their standardization by shifting, and multi-window calculations, used for calculations, in particular, in the determination of radiocarbon, is. The coincidence of the spectra at the end point is achieved by their shifting. High-energy windows (sections) of spectra are used for calculations. The average of spectrum calculations results in several windows gives a more reliable solution, while the corresponding standard deviation or uncertainty of the results gives an assessment of the quality of standardization.

Introduction

"Window" calculations are used in the technique of liquid scintillation counting (RSL) from the very beginning, in particular to measure low levels of ^{3}H, ^{14}C and Cherenkov counting. One of the methods of the external standard is used for standardization of spectra. The Quantulus 1220TM spectrometer has an analog-to-digital converter with logarithmic spectrum. The configuration of the spectrometer, which is used for radiocarbon measurements, is realized by choosing a high value of the lower threshold, which cuts off part of the spectrum with low energies. This prevents the effects of interference caused by luminescence and / or tritium.

The impurities present in the LSC samples cause sample quenching and, accordingly, different efficiency of spectrum registration and its shift. Moreover, as we know, the dependence of efficiency on quenching is minimal for high-energy radiation. That is why to ensure the compatibility of the spectra in their analysis, we have proposed an approach, the essence of which is that the calculations use high-energy parts of the spectra, for which the corresponding areas are aligned beyond the upper limit. In practice, we done this by shifting to the coincidence of the upper limit of the spectrum of the sample relative to the calibration and background spectra.

The principle is that for calculations we use several limited parts of the spectra ("windows"), which overlap. Calculations are performed for each relevant window according to its characteristics, and the final result is a average of the results obtained for individual windows. Uncertainty (error) of calculations is obtained as a standard deviation of results calculated on separate window.

Methods

Previously, we had used the beta-spectrometric method of analysis of multicomponent beta-spectra in the case of of presence ^{137}Cs, ^{90}Sr, ^{40}K [3], and later for the isolation of ^{210}Pb on the background of artificial and natural radionuclides [2]. In both cases, to take into account the quenching, we used the shifting of the sample spectrum relative to the calibration spectra.

The current approach for spectrum processing for the Quantulus 1220^{TM} liquid scintillation spectrometer at ^{14}C measurement, using three types of Teflon vials: 7 ml, 3 ml and 0.8 ml, the latter have two varieties. For standardization, we use sets of spectra measured over a long period of time for different levels of quenching of calibration and background samples [1,2], and during processing we introduce a controlled offset of the spectra to match the upper limit. We perform calculations for several high-energy regions of overlapping spectra. The visual coincidence of the end-point of the spectra is achieved by a controlled shift of the spectrum of the sample relative to the calibrated spectra, see Fig.1. We use an automatic scale selection mode for each spectrum for their visual comparison. The joint display of the calibration, sample and background spectra and the selection of the value of the offset of the sample spectrum allows achieving a visually acceptable match of the spectral regions at the end-point.

There is another option for choosing the optimal solution (Fig.2), in this case, the analysis of the results of the calculation of the spectrum for several cases for its shifting (3-5) in the range, for example: from -15 to +15 - in steps of 5 channels, or -10 up to +10 in steps of 2 channels), which corresponds to the shift of the spectrum by the corresponding number of channels to the left or right. The step of the spectral shift is fixed, it can be predefined, as in the previous example, or one that is set experimentally - it corresponds to the minimum offset that can be distinguished, which gives other (different from the previous) results. Next, the optimal solution is chosen from the set of solutions, where the minimum value of the standard deviation indicates the optimality.

Easy View, which we use to calculate the spectra, allows you to select the appropriate calibration and background spectra from the library in one step, as well as set individual parameters for several reading windows, and then save the resulting spectrum reading parameters of each sample in a spreadsheet for future calculations. In the process of processing spectra in Easy View, we apply one-step smoothing for all spectra because after applying several smoothing, the shift of the spectra ceases to be smooth, which makes it difficult to achieve the coincidence of the endpoints of the spectra. To implement the algorithm of standardization and spectrum calculations, you can also use special software products that compare the so-called "pure" spectra: (sample minus background) and (calibration minus background), which allows to achieve a much better match of spectra achievable for spectra of low activity samples.

Results and discussion

The results of the proposed approach were tested by measuring radiocarbon in several samples of the same activity, which were prepared from one benzene sample of different levels of quenching by dilution with background benzene.

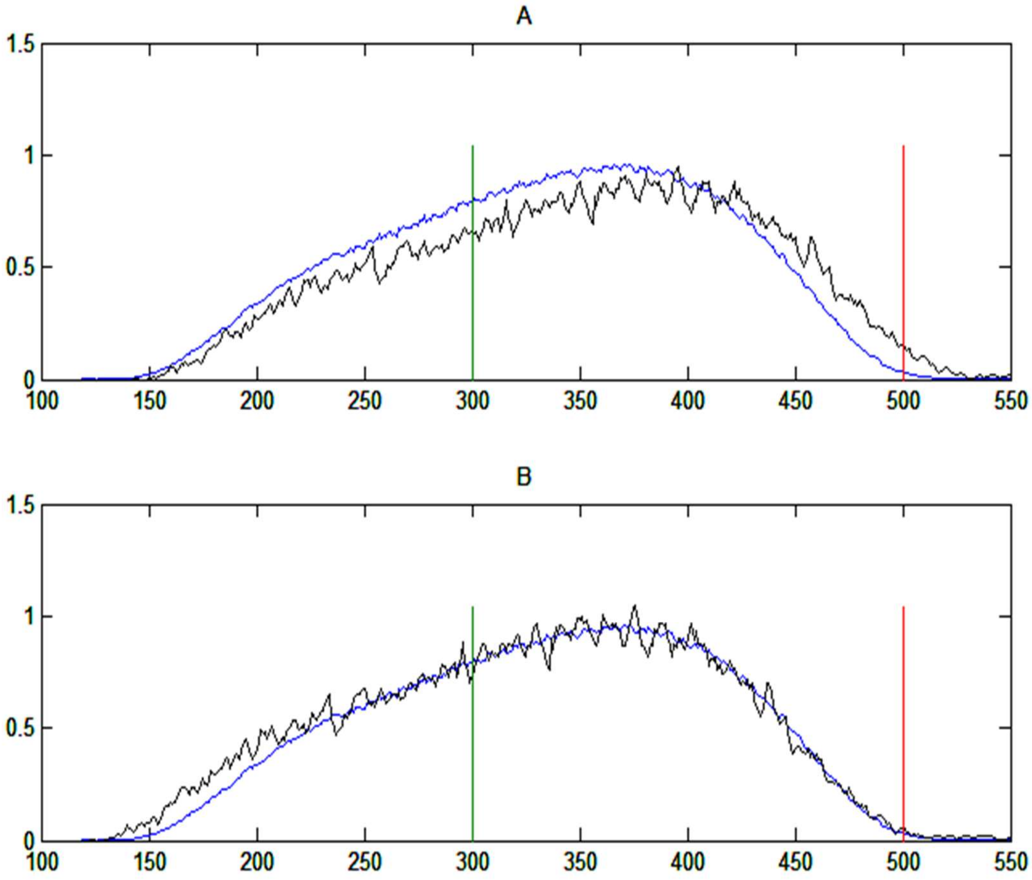

Fig. 1. Normalized spectra of calibration and sample before (A) and after (B) their shifting.

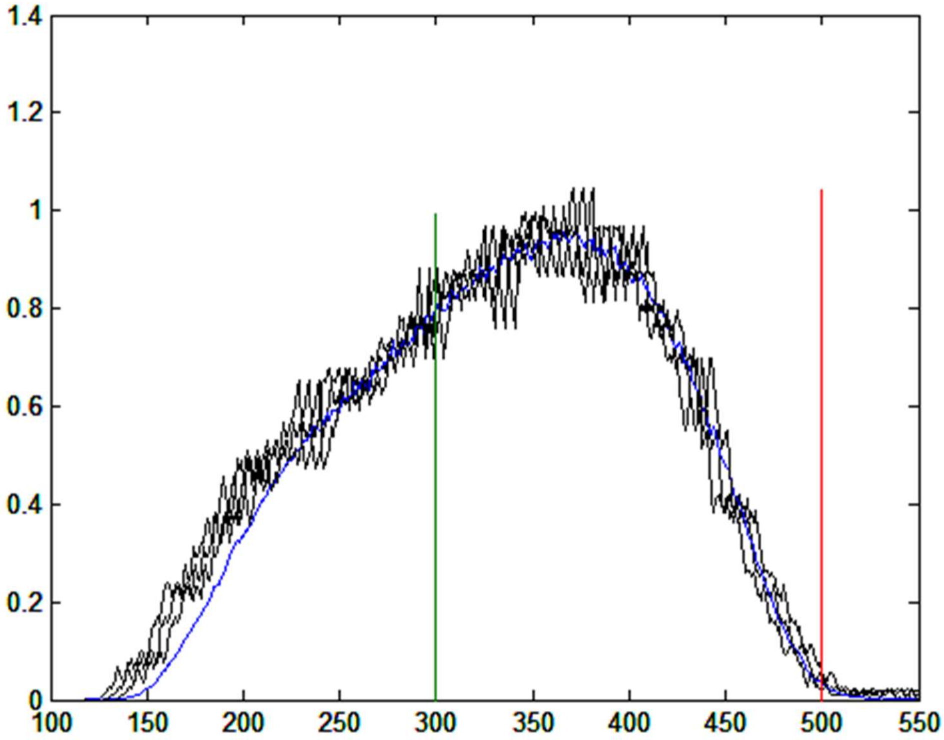

Fig. 2. An example of stepwise offset spectra relative to the calibration spectrum for standardization and subsequent calculations.

Table 1. Example of calculations of the radiocarbon content in the benzene sample (6 windows, 5 variants of the spectrum shift)

LabID	Weight	window	CPM	BG	E, %	Shift	pMC
2448	0,958	250..500	7,653	0,426	64,56%	2500	**93,36**
2448	0,958	200..550	8,96	0,583	73,61%	2500	**94,90**
2448	0,958	200..525	8,927	0,546	73,61%	2500	**94,95**
2448	0,958	200..500	8,892	0,506	73,51%	2500	**95,14**
2448	0,958	200..475	8,804	0,462	72,51%	2500	**95,94**
2448	0,958	200..525	9,006	0,546	73,61%	2550	**95,84**
2448	0,958	200..550	9,037	0,583	73,61%	2550	**95,78**
2448	0,958	200..500	8,967	0,506	73,51%	2550	**95,99**
2448	0,958	200..475	8,855	0,462	72,51%	2550	**96,53**
2448	0,958	250..500	7,76	0,426	64,56%	2550	**94,74**
2448	0,958	200..500	9,036	0,506	73,51%	2600	**96,77**
2448	0,958	200..525	9,081	0,546	73,61%	2600	**96,69**
2448	0,958	250..500	7,866	0,426	64,56%	2600	**96,11**
2448	0,958	200..550	9,112	0,583	73,61%	2600	**96,62**
2448	0,958	200..475	8,896	0,462	72,51%	2600	**97,01**

Continue of Table 1.

LabID	Weight	window	CPM	BG	E, %	Shift	pMC
2448	0,958	200..475	8,926	0,462	72,51%	2650	**97,35**
2448	0,958	200..525	9,15	0,546	73,61%	2650	**97,47**
2448	0,958	200..550	9,181	0,583	73,61%	2650	**97,41**
2448	0,958	250..500	7,973	0,426	64,56%	2650	**97,49**
2448	0,958	200..500	9,1	0,506	73,51%	2650	**97,49**
2448	0,958	200..525	9,213	0,546	73,61%	2700	**98,20**
2448	0,958	200..550	9,244	0,583	73,61%	2700	**98,13**
2448	0,958	250..500	8,07	0,426	64,56%	2700	**98,75**
2448	0,958	200..475	8,946	0,462	72,51%	2700	**97,58**
2448	0,958	200..500	9,155	0,506	73,51%	2700	**98,12**

Table 2. Example of averaging the results of calculations of the radiocarbon content shown in Table 1

Lab ID	Weight	Shift	pMC	SD
2448	0,96	2500	**94,86**	0,94
2448	0,96	2550	**95,78**	0,65
2448	0,96	2600	**96,64**	0,33
2448	0,96	2650	**97,44**	0,06
2448	0,96	2700	**98,15**	0,41

Conclusions

Performing calculations in several windows for shifted spectra allows to obtain the optimal result and, at the same time, and assessing of its uncertainty (stability). Spectrum processing in several windows allows obtaining better (lower) uncertainty for offset spectra even if the results are well compatible even without offset.

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LSC BETA SPECTRA ANALYSIS BY STANDARDIZATION BASED ON SHIFTING AND MULTI-WINDOW COMPUTING

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Radioactivity calculations using spectrum windows were widely used in the LSC technique since the beginning especially for measuring low levels of ^{3}H, ^{14}C and Cherenkov counting. Thus for standardization of spectra were used one of the methods based on external standard.

For a precise standardization of the spectra we use sets of calibration spectra measured under different quenching conditions, count the sample for a long time, we introduce a controlled shifting of sample spectra for processing and we apply multi-window calculation of high energy part of the spectra. Our approach to the processing of the spectra we use both for the old and the new LS spectrometers Quantulus 1220^{TM} when measuring ^{14}C using two types of 7 ml and 0.8 ml Teflon vials. To prove the method we analyzed results given by our approach when measuring samples prepared from the one quenched sample of benzene by various dilutions. We used six high energy windows that partially overlap. Sample spectra were controlled shifted until coincidence of spectra end-point. Visual comparison of spectra was performed using automatic selection of scale for each spectrum. Controlled sample spectra shift and a common visualization of set of spectra: calibration, sample and background allow achieving an acceptable coincidence of spectra end-point. Another way of optimization is to perform set of calculation for each of several shifts of sample spectrum and chose an optimal based on standard deviation.

Spectra processing program *Easy View* enables in one-step loading of calibration and background spectra and choose pre-set of windows and then save the processing parameters of the spectrum of the sample in a spreadsheet format for subsequent calculations. During the processing of all spectra we apply one step smoothing. However, it is not applicable in *Easy View* to make spectra shift by channel after applying several smoothing steps that hinder achievement matches end-points of spectra. The use of specially developed software code which compares net spectra: *sample-background* to *calibration-background* provides a much better coincidence for spectra end-point, which is only attainable that way for low active samples. Performing calculations in multiple windows for shifted spectra allows obtaining optimal result and simultaneous assessing its uncertainty (discrepancy).

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