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Measurement of Alpha-emitting Therapeutic Radiopharmaceutical Ra-223 Dichloride Injection by Different Source-Detector Distances γ-spectrum Method

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Ra-223 dichloride injection is a new type of alpha-emitting therapeutic radiopharmaceutical. To accurately measure the radioactivity of Ra-223 is very important for drug dose control and assessment of various potential contamination events. Gamma spectrometry, with the advantage of simple sample pretreatment and high accuracy, is the first choice for Ra-223 activity measurement. The most important step in the analysis using HPGe is the determination of the number of photons emitted by the source and received by the detector, therefore, the detection efficiency, coincidence effect, and γ-ray emissivity have a great effect on results. The efficiency calibration of the HPGe detector is commonly measured by using the mixed mono-energy γ nuclide solution, however, the price of the mixed mono-energy γ nuclide solution is pretty high. Efficiency calibration also can conduct using the standard sources that emit similar gamma rays with that nuclide to be analyzed.

To accurately analyze Ra-223, the present study determined the efficiency calibration curve of BE5030 for different source-detector distances by using mixed mono-energy γ nuclide solution, Ba-133 simulative standard solution, and Ra-226 simulative standard solution. Multiple γ -rays emitted by Ra-223 and its daughters have been used to measure and analyze the activity of Ra-223 dichloride injection. The experimental results show that (1) when S-D=17 cm, the deviation of the efficiency which is calibrated by 133Ba standard solution (ℰBa-133), and Ra-226 standard solution (ℰBa-133), from the efficiency calibrated by the mixed mono-energy γ nuclide solution (ℰMixed) range from 1% to 5%, but when S-D=0 cm, the maximum deviation reach to 31%. (2) When S-D=17 cm, using the full-energy peak of Ra-223, 351.03 keV, to calculate the activity of Ra-223, the result calculated based on the efficiency calibration curve of 133Ba (RBa-133), the result calculated based on the efficiency calibration curve of Ra-226 (RRa-226) and the result calculated based on the efficiency calibration curve of mixed mono-energy γ nuclide solution (RMixed) have a good agreement, the deviation is less than 3%. Using other full-energy peaks, 269.48KeV and 271.23KeV, the deviation reaches to 5%. When S-D=0 cm, the deviation of the activity between RRa-226 and RMixed is still very small, but the deviation between RBa-133 and RMixed range from 19% to 31%. (3) There is a large deviation between the γ -ray emissivity data of Ra-223 and daughter nuclides, and the maximum deviation can reach 32% compared with ENSDF data. (4) The sample preparation process of Ra-223 solution does not release Rn-219, nor does it break the radioactive equilibrium between Ra-223 and daughter nuclides in the sample. (5) For the BE5030 HPGe detector, the influence of the coincidence effect of 404.83keV, 427.15keV, and 831.98keV on the analysis results are 7.6%, 12.8%, and 9.4%, respectively.

To determine high activity level samples, we advise choosing large source-to-detector distances, and the efficiency calibration can be measured by both Ba-133 simulative standard solution and Ra-226 simulative standard. To determine low activity level samples, we advise choosing small source-to-detector distances, and the efficiency calibration would be better measured by mixed mono-energy γ nuclide solution or Ra-226 simulative standard.

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