Study of X-ray emitting radionuclides for dosimetry in reactors

Topic: Engineering sciences / Metrology

Short description

The LNHB (Laboratoire National Henri Becquerel) is the French metrology laboratory in the field of ionizing radiation. One of the tasks of the laboratory is the measurement of radionuclides activity (in becquerels) and the determination of radionuclides decay data. The measurement of the activity of X-ray emitting radionuclides, in the energy range below 100 keV, presents several difficulties that limit the accuracy of the result. These include the calibration of the detector efficiency and, in general, the large uncertainties associated with X-ray emission intensities. In addition, the effects of self-attenuation of X-rays in standard sources or samples lead to important corrections that must be controlled.
Among the important applications of the measurement of X-ray emitters, the dosimetry in reactor, which allows to determine the neutron fluence received during an irradiation and to characterize the spectrum, is based on the analysis of the activity of irradiated dosimeters. These dosimeters are made of pure metals or alloys of perfectly known composition, some of which are subject to activation or fission reactions under the effect of neutrons. For example, the reactions ^{93}Nb(n,n')^{93m}Nb and ^{103}Rh(n,n')^{103m}Rh are of primary importance for reactor dosimetry and are particularly interesting for characterizing neutron fluxes around 1 MeV.

The task of the postdoc will consist in:

- Exploiting the results of the efficiency calibration of a high purity germanium (HPGe) detector using a cryogenic electrical substitution radiometer and transfer photodiodes. This will be used to measure the absolute X-ray emission intensities of radionuclides used as standard for the calibration of detectors (^{133}Ba, ^{152}Eu, etc.);
- Improve the knowledge of photon emission intensities following the decay of ^{93m}Nb, ^{103}Pd and ^{103m}Rh;
- Critically analyzing published data on these radionuclides and to contribute to the evaluation and publication of their decay schemes.

Contract duration: 1 year (possible renewal 1 time)

Desired starting date: 01/03/2023

Location: Laboratoire National Henri Becquerel - CEA Saclay- 911914 GIF-SUR-YVETTE Cedex http://www.lnhb.fr/

Candidate profile: The candidate must have a PhD in physics with knowledge in nuclear instrumentationand/or atomic physics. He/she must have a solid knowledge of radiation-matter interactions and an interest in laboratory experiments. He/she should demonstrate good critical thinking skills and be able to analyze the results in details.

Application: Please send a curriculum vitae and a motivation letter to:

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Description of the subject (long version):

The measurement of the activity of X-ray emitting radionuclides in the energy range below 100 keV encounters several difficulties that limit the accuracy of the results. These include the difficulty in calibrating the efficiency of detectors and, in general, in the large uncertainties associated with X-ray emission intensities. In addition, the effects of self-attenuation of X-rays in standard sources or samples lead to important corrections that must be controlled.

Among the important applications of the measurement of X-ray emitters, the dosimetry in reactor, which allows to determine the neutron fluence received during an irradiation and to characterize the spectrum, is based on the analysis of the activity of irradiated dosimeters. These dosimeters are made of pure metals or alloys of perfectly known composition, some of which are subject to activation or fission reactions under the effect of neutrons. For example, the reactions ^{93}Nb(n,n')^{93m}Nb and ^{103}Rh(n,n')^{103m}Rh are of primary importance for reactor dosimetry and are particularly interesting for characterizing neutron fluxes around 1 MeV.

The data used for the experimental calibration of X-ray spectrometers in the energy range below 100 keV correspond to the emission intensities of the XKα and XKβ lines of radionuclides used as standards. These data are fully correlated, as they are calculated from the same basis for the fluorescence yields, and it appeared that they are partially inconsistent, including for the Kβ/Kα ratios of the same radionuclide. A detailed analysis of the atomic parameters used to calculate the emission intensities and the evaluation of new values, based on a critical analysis of the most recent publications, is necessary.

For the calibration of X-ray spectrometers, an innovative approach consists in being free from radioactive standards by using monochromatic photon beam whose energy and intensity are well characterized. This is being achieved with an electrically substituted cryogenic radiometer that has allowed the "absolute" calibration of photodiodes, which in turn are used as a transfer detector to calibrate a spectrometer based on a high-purity germanium detector (HPGe). With a efficiency calibration obtained independently from the tabulated X-ray emissions, it will be possible to measure the X-ray emission intensities in a completely independent way and thus to provide valuable information for all analyses relying on spectrometry in the energy range below 40 keV. This will in particular be applied to the measurement of X-rays emitted in the decay of europium-152, which has two branches, towards samarium-152 and gadolinium-152, thus emitting two series of X-ray lines. It appears that the X-ray emission intensities of the two branches are inconsistent. New measurements are thus necessary to remove this ambiguity. The measurements consist in using radioactive sources of known activity and to measure the of photon emission intensities by X-ray spectrometry. Relative uncertainties of the order of 1 % are expected, which requires a strict metrological approach.

For the measurement of the activity of dosimeters used in the reactor, it is also necessary to improve knowledge of the intensities of low-energy X-ray and gamma emissions from niobium-93m and rhodium-103m. The measurement of the second radionuclide is delicate, because its radioactive period is less than 1 hour. A specific approach is thus necessary, using palladium-103 whose decay at the metastable level of rhodium-103m: the two decay schemes of ^{103}Pd and ^{103m}Rh are thus directly linked. Moreover, there is an inconsistency between the intensity of the gamma emission at 40 keV and the K Xray emissions around 20 keV, common to these two radionuclides (the X emission corresponding to the internal conversion of the transition at 40 keV for 103mRh). A new evaluation of these two decay schemes will be based on the analysis of recent experimental data (including those obtained in this study) and on the use of codes for the calculation of internal conversion coefficients. This work will lead to "recommended values" and will allow updating the "Table of radionuclides" distributed by the Laboratoire National Henri Becquerel (http://www.lnhb.fr/donnees-nucleaires/donnees-nucleaires-tableau/).

Several of these studies may lead to publication.