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#07-7 Low-resolution gamma spectroscopy to estimate the concentration of uranium ores and the radioactive disequilibrium with two energy bands

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The estimation of uranium content in ore samples by high resolution gamma-ray spectroscopy requires long measurement times and expensive high-purity germanium (HPGe) detectors. In this work, we present the possibility to measure uranium by low-resolution gamma-ray spectrometry with an easy-to-operate and cost effective NaI(Tl) detector. This method is based on the analysis of two energy bands of the NaI gamma spectrum, which allows estimating a possible "U/Rn"imbalance between the top (238U and its daughters up to 230Th) and the bottom (226Ra, 222Rn and their daughters) of the 238U decay chain, due to differential leaching in roll-front deposits. In case of secular equilibrium, more than 95 % of gamma rays emitted by uranium ores come from 214Pb and 214Bi isotopes, which are in the back-end of 238U chain. Consequently, a disequilibrium in the chain might produce an overestimation of the uranium concentration if U/Rn < 1, or an underestimation if U/Rn > 1 (activity ratios). Therefore, the estimation of the disequilibrium between the beginning and the end of the chain represents a key objective in uranium mining exploration and exploitation. The disequilibrium is estimated with a count ratio between a low-energy band of the NaI(Tl) gamma spectrum around 100 keV that includes a significant signal coming from the top of the chain (92-keV gamma rays of 234Th and 235U and uranium X-rays), and a higher energy band around 609 keV, characteristic of the back end of the chain (gamma ray of 214Bi). Finally, the uranium concentration is derived from this U/Rn disequilibrium (activity ratio) and from the "Rn"activity of the back-end chain. This last is directly obtained by conventional gamma-ray spectroscopy with the 609 keV peak of 214Bi. The MCNP model of the NaI(Tl) detector has been validated using experimental data measured with a representative ore sample, with known uranium concentration and U/Rn disequilibrium. Then a linear relationship has been established by numerical simulation between the ratio of the two energy bands and the disequilibrium. More than 800 simulations have been performed to establish gamma corrections according to the density of the ore, filling height of the sample, and uranium concentration itself (gamma self-absorption in the sample), resulting in a total relative uncertainty smaller than 30 % on the uranium concentration. Experimental results obtained with a series of 38 ore samples provided by ORANO Mining, with acquisition times ranging from a few dozen seconds to a few minutes (depending on uranium concentration, which ranges from 100 ppm to 10000 ppm) show a very good agreement with ICP-MS analyses performed on real samples. For these samples, the gain in measurement time is between a factor 20 and 50 with respect to HPGe measurements.

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