S1-3: Directly realizing the becquerel with quantum thermal sensors

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Abstract: The SI derived unit of radioactivity is the becquerel. A becquerel simply corresponds to one decay per second of a particular nuclide. However, realizing the becquerel is quite complex. Essentially, all methods currently employed operate by detecting the decay products from radioactivity events. Radioactivity produces decay products with a four order of magnitude energy span and multiple particle types. A large suite of measurement methods must be maintained to measure and standardize the vast set of radionuclides of interest to metrology. Unknown impurities, in-grown daughter products, and short half-lives make standardization particularly difficult. Separate absolute and spectrometry techniques must be combined to extract absolute activity and impurity content. Even under the best of circumstances, current methods only indirectly realize the becquerel. NIST and other groups have produced micro-fabricated calorimeters sensitive enough when operated at ultra-low temperatures to detect individual decay events (femtojoules to picojoules). The total absolute activity of radioactive material embedded in the calorimeter is directly measured. At the same time, the calorimeter measures the energy of each decay event with resolving power greater than 1000. This high resolution spectral signature provides the nuclide content. One measurement produces both absolute activity and spectrometry. Several groups have conducted small scale demonstrations. NIST has, together with Los Alamos National Laboratory, measured the energy spectra of alpha particle decay events for the analysis of mixed actinide samples [Anal. Chem. 2015, 87, 3996–4000]. For metrology, we will need to invent robust protocols to embed a wide range radioactive materials into the calorimeter and develop gravimetrically traceable techniques for delivering the radioactive material to the micro-fabricated calorimeters. The goal is a universal metrological method for measurement and standardization of radioactivity that would directly realize the becquerel.