A novel system has been simulated with accompanying experimental data that is designed to provide spatial information of elemental concentrations at biologically relevant levels. Using a deuterium-deuterium (DD) neutron generator, two large high-purity germanium (HPGe) detectors operating in tandem, and the associated particle imaging (API) technique, elemental iron concentrations as low as 100 ppm have been resolved in vivo in the liver of a simulated reference man with an equivalent dose to the region of interest of < 5 mSv and an estimated whole body dose of 0.82 mSv. Using the Monte Carlo Neutral Particle (MCNP) transport code, achievable spatial resolutions in the projective and depth dimensions of < 1 cm and < 3 cm are achievable, respectively, for iron-containing voxels on the order of 1,000 ppm Fe – with an overall 225 ps system timing resolution, 6.25 mm² imaging plate pixels, and a Gaussian-distributed DD neutron source spot with a diameter of 2 mm. Additionally, as a departure from Monte Carlo simulations, the underlying concepts of fast neutron inelastic scatter analysis as an initial surrogate to true associated particle neutron elemental imaging (APNEI) were demonstrated using a DD neutron generator, iron-made interrogation targets, a sodium iodide detector, and physical neutron/gamma shielding, which yielded an approximate detection limit for iron of 3.45 kg which was simulated to improve to 0.44 kg upon incorporation of the associated particle collimation methodology. By leveraging the capabilities of modern-day neutron generator and coincident timing technologies with high throughput signal processing discrimination, the applicability of APNEI to disease diagnostics and etiological research is promising.