Abstract:

NAA of Ag

Artificial nuclear reactions can be triggered by bombarding target atoms with projectiles. The projectiles can be protons, neutrons or even other nuclides. The resulting compound nucleus can in turn emit nuclides as ejectiles through the nuclear reaction. Neutrons are particularly important projectiles here, since the resulting compound nucleus in the nuclear reaction is just another isotope of the same element. After the nuclear reaction, the product is often radioactive and emits characteristic radiation through radioactive decay. In this way, the elemental and isotopic composition of the samples can be determined. This method is called neutron activation analysis or NAA for short.

Neutrons have no charge, which is why the interaction of neutrons is limited to the atomic nucleus. This allows neutrons to penetrate deeper into matter than charged particles, which makes shielding from neutrons more difficult. Certain elements such as boron have a high affinity for neutrons, which is reflected in the neutron cross-section. As a result, neutrons can be well shielded with these elements. Neutrons are unstable when unbound and decay under emission of a β-particle and an antineutrino. The decay and the fact, that neutrons are not charged makes the storage of them for a longer period of time impossible. To have enough neutrons for a nuclear reaction, you need a neutron source. At the University of Mainz, the TRIGA reactor serves as a neutron source by splitting ^{235}U in a controlled way. Another way to produce neutrons is to obtain them as ejectiles from nuclear reactions. For example, ^{243}Am emits α-particles that start a nuclear reaction with ^{9}Be, emitting neutrons in following reaction $^{9}Be(\alpha,n)^{13}C$. Kinetic energy of neutrons are too high shortly after they are produced, so they must be moderated to thermic energies before they can undergo nuclear reactions. This can be achieved using various materials, such as paraffin, graphite or water.

In the experiment, silver is activated with the help of a mobile neutron source to determine the neutron cross-sections of the two natural silver isotopes ^{107}Ag and ^{109}Ag and the half-life of the two silver isotopes ^{108}Ag and ^{110}Ag. Furthermore, it will be investigated how well cadmium and lead can shield thermic neutrons. For these purposes, silver plates are activated in a neutron source and the β-minus decay is measured in the Geiger-Müller counter.

1. Activation of Ag

The square Ag sheets are irradiated in the neutron source for **exactly** 24, 48, 144, 288 s respectively (stopwatch!). Next measurement only after the activity of the previous measurement has decayed (after approx. 20 min). It is important to keep the experimental conditions consistent: always irradiate and measure the Ag sheets in the same orientation. t = 0 is end of irradiation. Keep transport time to detector constant. The measurement is done in the Geiger counter: 20x15 s, 20x60 s. Evaluation: The half-life of the long-lived component is determined from the longest irradiation, that of the short-lived component from any irradiation. Determine start activities of both components by extrapolation and plot against irradiation duration. Determine saturation activities for both components (for the long-lived component computationally using the experimental data from the activation equation). Determine the ratio of the cross sections

2. Shield measurement

The thin, round Ag sheets are irradiated without a sheath and with Pb and Cd sheaths for 1 min each and measured for 1 min. Keep the pause between end of irradiation and start of measurement constant. The plate must always be irradiated and measured in the same orientation. For measurement, the plate is removed from the shielding(!) and placed on a specimen holder. Evaluation: Determine the transmission coefficients (T_{Pb}, T_{Cd}) and the cross section for cadmium σ_{Cd}.

Note: The effective cross section σ is calculated from:

$$\Phi(x) = \Phi(0) \cdot e^{-n_T \cdot \sigma \cdot x}.$$

Silver activities are used for the relative attenuation of the flux ϕ(x) and ϕ(0):

$$T = \frac{I(With\ Shielding}{I(Without\ Shielding)} = \frac{\Phi(x)}{\Phi(0)}$$

with ρ_{Cd} = 8,65 g/cm^3 = 4,62•10^{22} atoms/cm^3 = n_T; x = 1 mm.