

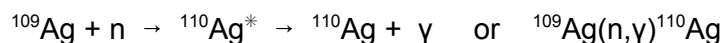
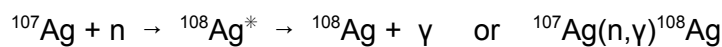
## Neutron Activation of Silver

**Objectives:** This experiment will give you experience with the use of neutron radiation from an isotopic neutron source (Pu-Be) to induce radioactivity in a sample, which you will then monitor to measure the half lives of the  $^{108}\text{Ag}$  and  $^{110}\text{Ag}$  radionuclides produced.

**References:** Ehmann & Vance: pp. 124-127, 140-142.

Nuclear reactions often involve the nuclear capture of particles such as  $\alpha$ , n or p, resulting in a very unstable "compound" nucleus which promptly ( $<10^{-14}$  sec) de-excites by emission of particles or gamma rays. The typical de-excitation energy associated with the absorption of a low-energy neutron is around 7-8 MeV, the nuclear binding energy for such a particle. Since neutrons are electrically neutral, there is no Coulomb barrier to overcome, so neutron absorption can take place readily with neutrons of thermal energies ( $\sim 0.025$  eV). Neutron absorption followed by de-excitation by  $\gamma$  emission will result in a product nucleus with the same Z, but A+1. If this product is radioactive, then one can detect the radiation emitted in its decay.

In this experiment the stable isotopes of silver will be exposed to neutron radiation and activated according to the following:



The  $\beta^-$  radiation emitted during the decay of  $^{108}\text{Ag}$  and  $^{110}\text{Ag}$  will then be monitored. The amount of radioactivity induced by any such neutron activation can be calculated by

$$A_0 = N\phi\sigma S \quad (\text{IV.1})$$

where  $A_0$  is the induced activity, in dps, at the end of the irradiation;

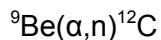
$N$  is the number of target nuclei, and can be calculated from the mass of element in sample ( $m$ ), the abundance of target isotope ( $a$ ), Avogadro's number ( $N_a$ ) and the target element atomic weight ( $AW$ ) according to  $m \cdot a \cdot N_a / AW$ ;

$\phi$  is the neutron flux ( $n/\text{cm}^2\text{-sec}$ ) used to irradiate the sample;

$\sigma$  is the cross section of the neutron absorption reaction, in units of  $\text{cm}^2$ ;

$S$  is called the saturation term and accounts for decay of any induced activity during the irradiation.  $S$  equals  $1 - \exp(-0.693 t_i / t_{1/2})$ , where  $t_i$  is the irradiation time and  $t_{1/2}$  is the half life of the induced radioactivity.

In this experiment, the source of neutrons is a 5 Ci Pu-Be source.  $^{238}\text{Pu}$  emits  $\alpha$  particles which are absorbed by  $^9\text{Be}$ , followed by the prompt emission of a neutron. This reaction can be summarized as



The approximate neutron flux of this source is  $10^5\text{n/cm}^2\text{-sec}$ . The neutrons emitted by this source have an average energy of 4.5 MeV and must be thermalized (slowed down) before significant absorption by the silver isotopes will take place. Slowing down of the neutrons is achieved by use of a moderator, such as water or paraffin, which contains many hydrogen atoms, thus allowing for maximum energy transfer in collisions between neutron and moderator. The large container surrounding the neutron source contains much paraffin for this purpose, as well as other shielding material to protect against the gamma radiation present in this source.

**BEFORE COMING TO LAB:** Calculate the  $^{108}\text{Ag}$  and  $^{110}\text{Ag}$  activity (in dps) to be expected at the end of a 20-minute irradiation of 1 gram of silver in a thermal neutron flux of  $10^4\text{n/cm}^2\text{-sec}$ . The  $(n,\gamma)$  cross section for  $^{108}\text{Ag}$  formation is 36 barns (1 barn =  $10^{-24}\text{cm}^2$ ), while that for  $^{110}\text{Ag}$  production is 87 barns. All other information needed to complete the calculations according to eq. IV.1 is given on your Chart of the Nuclides.

## PROCEDURE

### A. Sample Irradiation and Counting

Weigh one of the silver foils as accurately as possible, then place it by the neutron source as indicated by the instructor. Irradiate the sample for 20 minutes. While the sample is being irradiated, measure the background counting rate during a 5-10 minute period for your G-M counter at the operating voltage. Remove the silver foil from the neutron source, noting the exact time of removal. Transfer it as rapidly as possible to the counter, mount it on a counting disk to simulate the counting geometry of the beta standards as closely as possible and start the count. You should set the time to 30-40 minutes, then read and record the cumulative measured counts every 15 seconds for the first 3 minutes, and every 30 seconds thereafter until the count rate approaches background. Do not stop the counter, just read the accumulated counts while the system is counting. Be sure to correlate counter time with absolute time (i.e., time at the end of the irradiation).

### B. Analysis of Data

Plot the silver foil counting rate (R) versus time on a semi-logarithmic graph. Zero decay time should be at the end of irradiation. Calculate the counting rate (cps) obtained for each 15-second or 30-second period from your data and assign it to the time at the midpoint of the counting interval. Correct for coincidence losses, if appropriate, for the detector used. Resolve your data into decay curves for the two silver radioisotopes and determine the half life of each activity. Calculate the percent error in each measured half life.

Extrapolate the decay curve for each radioisotope to zero decay time to obtain  $R_0$  (correct for background, if necessary). Using your  $\beta$  efficiency vs. energy curve, estimate the counting efficiency for each of these silver activities and convert  $R_0$  values to disintegration rates at zero decay time ( $A_0$ ). From these values of  $A_0$ , use eq. IV.1 to calculate values of the thermal neutron flux to which the foil was exposed and compare. From your  $A_0$  values, calculate the percentage of silver atoms that was converted into each of these radioactive forms.