Cross-sections of $Au^{197}(n,\gamma)Au^{198}$ and $Cu^{63}(n,\gamma)Cu^{64}$ induced by Cf-252 neutrons

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Introduction

Analytical work, employing nuclear techniques, is normally carried out through (n,γ) reaction because of the availability of neutrons either from reactors or laboratory sources such as Sb-Be, Am-Be, Ra-Be, Po-Be, Cf-252, etc. The laboratory neutron sources are though portable and adaptable to a particular experimental arrangement, suffer from the disadvantage of 3low neutron yield (except Cf-252) typically in the range 10^5 to $10^{7n}/cm^2$-s, which has, however, no comparison with the neutron flux from a reactor. Even if one tries to increase the yield to a level of 10^8 n/cm^2-s, the size of the source would become awkwardly large. Neutrons from Cf-252 after passing through graphite and paraffin medium were used to induce (n,γ) reaction. At any irrradiation site neutrons of different energies are available. The energies of the neutrons may vary from keV to MeV range. The fluence of these thermal and low energy neutrons were estimated to be around 10^8n/sec almost at the site of irradiation. In the literature, normally the cross-section values are quoted either for thermal neutrons or at different known neutron energies. In this set up since the neutrons available are monoenergetic, it was thought appropiate to initiate a program to measure cross-sections of a few nuclear reactions which have practical applications. Earlier studies on cross-section measurement of the reaction $Au^{197}(n,\gamma)Au^{198}$ and $Cu^{63}(n,\gamma)Cu^{64}$ has been carried out using different sources, monitors and techniques.

Experiment

For this work. Cf-252 source in the Department of Chemistry, University of Pune was used. Manganese dioxide was chosen as the monitor for flux measurement. An experimental setup with the Cf-252 is shown in figure 1.

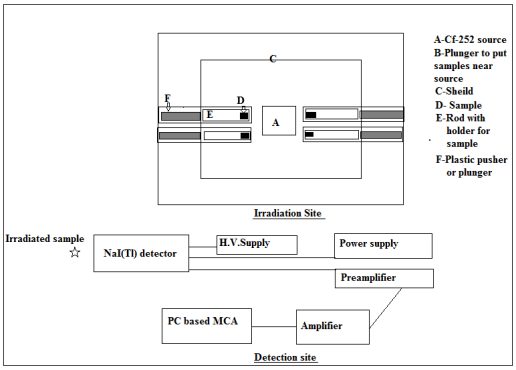

Fig. 1 Experimental set up

For measuring the cross-section of $Au^{197}(n,\gamma)$ Au^{198} reaction the sample was a 99.99% pure gold wire weighing 0.241g. This gold wire was cut into small pieces. These gold wire pieces alongwith 0.1g of manganese dioxide were packed in a polyethylene bag separately and placed near the source (within 5cm). This sample was irradiated for two days to induce the reactions:

$$Au^{197}(n,\gamma)Au^{198},$$

With $t_{1/2}$=2.69 days, Eγ=0.412 MeV (95%)

and $Mn^{55}(n,\gamma)Mn^{56}$,

For which $t_{1/2}$=2.57h , Eγ=0.847 MeV(99%)

The abundance of Au^{197} in natural gold is 100%. Other reactions which are also induced with the manganese dioxide did not interfere with the gold activity. A cooling time of 10 minutes was given to transfer the sample from the irradiation site to the detection site. The induced gamma-ray activity was measured with a 3"X3"NaI(Tl) scintillator detector coupled to a 4096 channel analyser/PC based MCA. The activity was

measured for ten hours and the area under the photopeaks at 0.84 MeV of Mn^{56} and 0.412 MeV of Au^{198} were separately measured.

For measuring the cross-section of copper, pure 99.99% copper in the form of foil was used for this experiment. This foil was chemically cleaned and cut into small pieces. These pieces weighing about 4.79g were packed in a polyethylene bag alongwith 2g of manganese dioxide powder separately. This sample was fixed in a lidded groove at the end of the sample holder rod which was pushed near the Cf-252 source using a pusher or plunger and irradiated for fifteen hours to induce the reactions

$$Cu^{63}(n,\gamma)Cu^{64}$$

With $t_{1/2}$=12.8h , Eγ = 0.511 MeV(38%)

and $Mn^{55}(n,\gamma)Mn^{56}$,

For which $t_{1/2}$=2.57h, Eγ=0.847 MeV(99%)

The abundance of Cu^{63} in natural copper is 69.9%. Other reactions which are also induced however emitted gamma-rays which did not interfere with 0.511 MeV(Cu^{63}) and 0.84 MeV(Mn^{56}) gamma-rays. However a cooling time of 30 minutes was given to transfer the sample from the irradiation site to the detection site. The activity of Cu^{64} was measured by keeping the sample near the NaI(Tl) scintillator detector coupled to a 4096 channel analyser/PC based MCA.

Results and Analysis

The activity obtained was used in the following relation to obtain the values of the cross-sections[2].

$$\sigma = \frac{A\lambda N_m \varepsilon_m f_{sm} f_{dm} \sigma_m \left(1 - e^{-\lambda m T}\right)\left(e^{-\lambda m t a} - e^{-\lambda m t b}\right)}{A_m \lambda_m N \varepsilon f_s f_d \left(1 - e^{-\lambda T}\right)\left(e^{-\lambda t a} - e^{-\lambda t b}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where A, λ,N,ε, fs, fd, σ, T, ta and tb denote the activity, decay constant, number of target nuclei, self absorption coefficient, decay ratio, cross-section, time of irradiation, time of cooling and time of (counting+cooling) respectively, m subscript denotes the monitor (here manganese). Such four measurements were made for the cross-sections.

The value of cross-section for the nuclear reaction $Au^{197}(n,\gamma)Au^{198}$ was found to be 99 $\pm$ 5 barns. Using this reaction, amount of gold in a piece of jewellery was estimated. After irradiation with Cf-252 neutrons and repeating the above mentioned procedure the amount of gold in the jewellery was estimated and found to be 0.19918g which indicated that the jewellery was made from 20 carat gold. The activities obtained for copper and manganese sample from $Cu^{63}(n,\gamma)Cu^{64}$ and $Mn^{55}(n,\gamma)Mn^{56}$ was put in relation (1). And the cross-section value obtained was equal to 4.1$\pm$0.45 barns. From this cross-section value, percentage of copper in an unknown sample was estimated and found to be 20.7%.

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