I. 12. Preparation of Metallic \(^{42}\text{Ca}\) Target for Study by the (p,n) Reaction


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It is of crucial importance to prepare an uniform, thick-enough, and contamination-free target-foil with a sufficient area, for a successful nuclear spectroscopic study by nuclear reactions. In two decades of the last century, a number of nuclear study works by the (p,n) reaction have been carried out at CYRIC\(^{1-5}\), extending over the periodic table from \(^{6}\text{Li}\) to \(^{208}\text{Pb}\), with K = 50 MeV AVF-cyclotron and fast neutron time of flight facilities\(^{6,7}\). In 1998 and 1999 school years, the cyclotron was replaced to K= 110MeV one along with the beam transport system including beam swinger. Related facilities, for example, neutron detector matrix for TOF experiments have been renewed as well in these year\(^{5}\).

Preparation of targets for these works has been, indeed, one of the heavy tasks. Some of them were made of their metallic lump by rolling, though it was not so easy to get such a metallic lump from Fe\(_2\)O\(_3\), NiO, SnO etc\(^{1-3}\). The others, e.g. Cd and Zn foils\(^{4}\), were made by electro-deposition method. As for the target made of metals being unstable for oxidation like Magnesium isotopes\(^{5}\), vacuum deposition by thermal evaporation with deoxidization materials have been applied.

In this report preparation of metallic \(^{42}\text{Ca}\) target, the natural abundance of which is 0.674\%, for study of the (p,n) reaction is given for further development of studies for isospin and spin-isospin excitation in nuclei with the new cyclotron and TOF system.

Preparation of metallic Ca foil

The presently discussed \(^{42}\text{Ca}\) target is classified into the last case mentioned above. Requirements for a target used in the nuclear spectroscopy by the (p,n) reaction at an incident energy ranging 40 ~ 100MeV by the time of flight method are those; (1) Since energy resolution for analyzing neutrons is in the order of several hundred keV, energy loss of protons in the target is less important, thus thicker one of ~10mg/cm\(^2\) in it’s thickness is better for reliable experiments. (2) As well, uniformity of thickness over the irradiated area is less important, since the beam spot size is ~5mm in it’s diameter, however, sufficient area larger than for example 3 x 3 cm\(^2\) is needed to avoid background neutrons from target-frame. (3)
Moreover, contamination of carbon and oxygen yields serious background in a neutron spectrum. Though the Q-values for the (p,n) reactions on $^{12}$C and $^{16}$O are large in negative values (~15MeV) and (p,n) yields by them are small, on the other hand, neutron yields by naturally abundant $^{13}$C and $^{18}$O are quite large with energetic neutrons due to small negative Q-values of the (p,n) reactions on these targets.

Figure 1(a) illustrates the evaporator unit, which is mounted in a bell-jar evacuated with a 1200l/sec oil-diffusion pump. A standard resistance heated tantalum boat with 3-mm deep dimple is used as an evaporation source, the details of which is depicted in Fig. 1(b). The boat is covered with two sheets of 0.1-mm thick tantalum plate. At the center of this plate there is a 1-mm $\phi$ hole through which evaporated gaseous Ca reaches to the catcher plate, while there are two same-size holes in the middle plate in order to homogenize evaporation as shown in Fig 1(b). The latter plate is made of quartz, which is expected to be stable for heat-exposure up to 1200°C. The plate is covered by Cu sheet in order to mask Ca deposit onto the quartz plate except for the interested 30 x 30 mm$^2$ area for the target. This masking makes it easy to remove the target foil from the quartz plate with a thin cutter-knife.

Before mount the enriched $^{42}$CaCO$_3$ carbonate, test runs with less expensive enriched $^{40}$CaCO$_3$ carbonate have been carried out many times. As the deoxidization substrate, powder of Zr metal are used$^9$ since its vapor pressure is two order of magnitudes as low as that of Ca. The present chemical reactions are;

$$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 \uparrow \quad (1)$$

$$2\text{CaO} + \text{Zr} \rightarrow \text{ZrO}_2 + 2\text{Ca} \uparrow \quad (2)$$

Figure 2 depicts vacuum versus time in minute. Initial vacuum is in the order of several $10^{-2}$ torr, then by heating, pressure in bell-jar increases gradually with evaporation of water combined in the form CaCO$_3$·xH$_2$O up to $1 \times 10^{-4}$ torr. After ~1hr evacuation, with heating up there appears a plateau region of several tens minutes, where decomposition of CaCO$_3$ takes place. Further rapid heating up to 1100°C in several minutes makes deoxidization by Zr and evaporation of Ca completely. Note that vapor pressure of Ca at 1100°C is $10^0$ – $10^1$ torr.

**Results and summary**

Metallic Ca foils of several mg/cm$^2$ in their thickness was stripped off the quartz plate successfully. The ratio of weigh of Zr (300mesh) to that of CaCO$_3$ was optimized to 5 : 1 after a number of trials with naturally abundant CaCO$_3$. An amount of 100mg $^{42}$CaCO$_2$ powder, enriched to 99.8% $^{42}$Ca, was used for final goal. As the summary, three pieces of metallic $^{42}$Ca foils, 30 x 30 mm$^2$ in their area and thickness of 1.5, 2.0 and 1.7 mg/cm$^2$, have been obtained from 300mg of $^{42}$CaCO$_2$ powder. These three pieces of foil have been staked into 5.2mg/cm$^2$-thick one target. Figure 4 illustrates a sample neutron excitation energy
spectrum for the $^{42}$Ca(p,n)$^{42}$Sc reaction at $E_p = 50$ MeV taken with the presently prepared $^{42}$Ca target.

With these targets more promising works by the (p,n) reaction with the K=110 MeV cyclotron and TOF facilities are expected.

References

Fig. 1. Schematic representation of the evaporator. The distance between the tantalum boat and quartz plate assembly is optimized to be 25 mm.

Fig. 2. A sketch of three-layer structure of the tantalum boat.

Fig. 3. Pressure in the bell-jar versus time in minutes. Electric power supplied to the electrodes was increased step-wise up to a power by which the temperature of the boat reached to 1200°C.
Fig. 4. Neutron excitation energy spectrum taken for the $^{40}\text{Ca}(p,n)^{40}\text{Sc}$ reaction at $E_p=50\text{MeV}$. 