LIQUID-METAL TARGET DEVELOPMENTS

G. D. Alton and B. Cui [1]

The diffusion process obeys Fick's second law for which the following equation represents diffusion in a one-dimensional target system with production S and loss channels - λC present, as is the case for RIB production:

$$\partial C/\partial t = D\, \partial^2 C/\partial x^2 + S - \lambda C \quad . \qquad (1)$$

In the case of solids, the diffusion coefficient D is related to the frequency of discrete jumps that a particle makes from lattice-point to lattice-point and depends exponentially on the temperature T at which the target is operated (i.e., $D = D_0 exp\,(- H_a/kT)$ where H_a is the activation energy required for the jump to take place. Typical values for this process range between 10^{-12} cm^2/s and 10^{-8} cm^2/s. In contrast, the diffusion coefficient for a particle in a liquid target is weakly dependent on the temperature according to $D \approx \alpha d(8k/\pi M)^{1/2} T^{3/2}$ where α is the coefficient of thermal expansion, d is the diameter and M the mass of the diffusing atom. As noted, the diffusion coefficient is weakly dependent on temperature, i.e., there is no particular gain achieved by heating the material significantly above its melting point. D has typical values of 10^{-5} cm^2/s. As noted, the diffusion coefficients for liquids are several orders of magnitude larger than those for their solid-state counterparts and, therefore, a liquid target is especially attractive for short-lived species; unfortunately, few materials have the vapor pressure characteristics commensurate with its application. This suggests the use of eutectic alloys to reduce the melting points of refractory metals to expedite release of short-lived species. During this reporting period, prototype liquid metal targets were designed for the production and release of ^{58}Cu ($t_{1/2}$ = 3.2s) from liquid Ni and analogously, the production and release of ^{69}As ($t_{1/2}$ = 912s) from liquid Ge. If we assume that D = 3 x 10^{-5} cm^2/s for ^{58}Cu in liquid Ni and 5 x 10^{-5} cm^2/s for ^{69}As in liquid Ge, then optimum target thicknesses, x, for liquid targets that will release 70% of the species within their respective half-lives can be calculated from the expression for the diffusion length given by $x = \pi(Dt_{1/2})^{1/2}$. If we assume that targets for these isotopes have an impermeable boundary at the interface of the receptacle and the liquid, then their optimum thicknesses are 1/2 of the calculated value. The respective values for these two isotopes are x = ~ 154 μm for ^{58}Cu/Ni and x ~ 3350 μm for ^{69}As/Ge. A

schematic drawing of the target arrangement is shown in Fig. 1. The targets are mounted horizontally in thin Re trays with the beam incident at a 13-degree angle with respect to the horizontal direction. The thickness of the liquid material is chosen so that both optimum production and diffusion can occur simultaneously. The liquid target material will be held flat through surface tension forces. Studies of the effect of additives on the flatness of the liquid metals were also made and preliminary studies were conducted of the use of surface tension for wicking the liquid material into the path of the production beams along metallized RVCF.

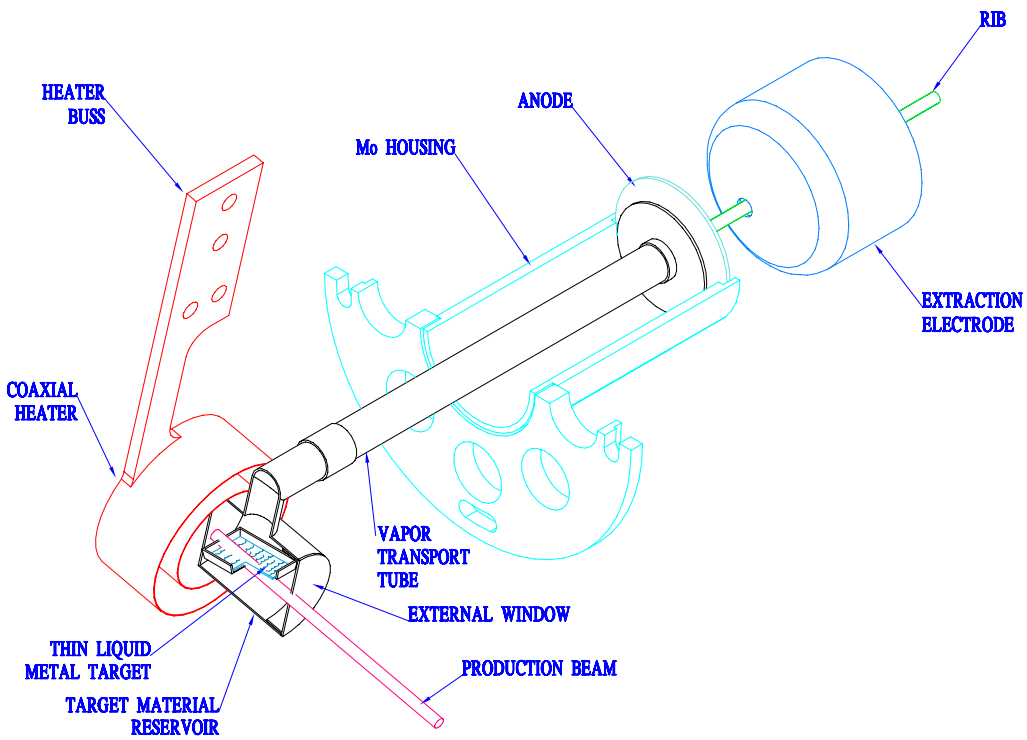

Fig. 1. Liquid-metal target scenario for potential use in generating ^{58}Cu/liquid-Ni or ^{69}As/liquid-Ge.

[1] Visiting scientist from China Institute of Atomic Energy, Beijing, China.