DIMENSIONAL CRITERIA FOR DESIGN OF HIGH EFFICIENCY RELEASE TARGETS FOR RADIOACTIVE ION BEAM GENERATION

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In order to meet the intensity and species requirements for nuclear physics and astrophysics research with radioactive ion beams (RIB)s at present or future ISOL facilities, produced within the bulk of specific target materials by fusion, fission, or spallation reactions between high energy ^{1}H, ^{2}H, ^{3}He, or ^{4}He projectiles and specific target nuclei, refractory material targets must be designed that simultaneously incorporate short diffusion lengths, high permeability, and controllable temperatures necessary to effect fast and efficient diffusion release and effusive transport of the short-lived species of interest to the ion source for RIB generation. In order to generate adequate intensities of short-lived nuclides, the radioactive species must be swiftly released from the target in a time commensurate with the half-life of the species of interest. These criteria connote that target materials must formatted in either low-density, thin layers, small radii fibers, or small diameter spheres with dimensions so chosen to effect optimum release of the species in question. Mathematically, the time dependent form for diffusion in an isotropic medium can be expressed in terms of Fick's second law given by

$$\partial C/\partial t = \text{div } (D \text{ grad } C) \tag{1}$$

where C is the concentration of the diffusing substance and D is the diffusion coefficient. For the release of radioactive isotopes of decay constant λ, the time-dependent diffusion equation, Eq. (1), should be modified to include the rate of production $S(x,y,z,t)$ as well as the rate of loss through decay. Dimensional criteria can be extricated from analytical solutions to the diffusion equation for planar, cylindrical or spherical geometry targets that will release 70% of the radioactive species within their half-lives. These dimensional criteria, expressed in terms of the diffusion lengths for the three geometries, are respectively

$$x = \pi\{D\tau_{1/2}\}^{1/2} \text{ (planar geometry);} \tag{2}$$

$$d_c \cong 4.8\{D\tau_{1/2}\}^{1/2} \text{ (cylindrical);} \tag{3}$$

and

$$d_s = 2\pi\{D\tau_{1/2}\}^{1/2} \text{ (spherical).} \tag{4}$$

These dimensional criteria, in combination with high permeability requirements, are taken as fundamentally important guidelines that must be incorporated in the design of all ISOL targets in order to realize efficient release of RIB species. During this reporting period, these prescriptions have been implemented in the design of highly permeable planar geometry targets that have demonstrated their viability for the efficient on-line release of ^{58}Cu from Ni electroplated onto reticulated vitreous carbon fiber (RVCF) targets, for the efficient release of many fission products from UC_2 chemically deposited onto RVCF, and for the efficient release of ^{58}Cu from liquid metal Ni targets. Analogously, we have procured thin, cylindrical fibrous Al_2O_3, ZrO_2 and HfO_2 target materials and demonstrated their efficiency for the release of ^{17,18}F during many on-line tests at the UNISOR facility and more importantly, during on-line astrophysics experiments. Table 1 provides optimum target thickness information, derived from Eqs. 1-4, for the efficient release of selected candidate RIB species.

Table 1. Optimum target thicknesses for the efficient release of selected RIB species.

Species	$\tau_{1/2}$ (s)	Target Material	Temp. (°C)	D (cm^2/s)	X (μm)	d_r (μm)	d_s (μm)
^{17}F	64.5	Al_2O_3	1400	1×10^{-11}	0.8	1.2	1.6
^{18}F	6588	Al_2O_3	1400	1×10^{-11}	8	12.2	16
^{58}Cu	3.2	Ni	1360	3.2×10^{-9}	3.2	4.9	6.4
^{58}Cu	3.2	Ni$_{liq}$	1360	3×10^{-5}	308	470.3	616
^{69}As	912	Ge$_{liq}$	1150	5×10^{-5}	6708	10250	13416
^{132}Sn	40	U	1135	4×10^{-8}	40	61	80
^{132}Sn	40	Th$_{liq}$	1427	1×10^{-5}	628	960	1256
^{132}Sn	40	Th	1755	4×10^{-6}	400	611	800
^{132}Sn	40	Th$_{liq}$	2000	5×10^{-5}	1404	2145	2808