RIB TARGET DIFFUSION STUDIES

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During this reporting period, considerable efforts have been devoted toward developing methods for simulating diffusion from the three principal target geometries (planar, cylindrical and spherical) that are used for production of RIBs for HRIBF research programs. We have procured codes that are specifically designed to solve the diffusion equation, such as the multiple-component diffusion-code, DICTRA,[1] and developed mathematical tools through the use of Mathematica[2] required to solve the appropriate diffusion equation, analytically. Diffusion release studies have been made of several species including the release of ^{58}Cu from solid and liquid Ni, $^{17,18}F$ from fibrous Al_2O_3, and ^{132}Sn from liquid Thorium and solid UC_2. Mathematically, the diffusion of a radioactive species, with decay constant λ, produced at a rate, S, in an isotropic medium, can be expressed in terms of the time dependent forms of Fick's second equation for the three geometries. These equations are , respectively,

$$\partial C(x,t)/\partial t = D\, \partial^2 C(x,t)/\partial x^2 + S(x,t) - \lambda\, C(x,t) \quad \text{(planar)} \tag{1}$$

$$\partial C(r,t)/\partial t = D[\partial^2 C(r,t)/\partial r^2 + (1/r)\partial C(r,t)/\partial r] + S(r,t) - \lambda\, C(r,t) \quad \text{(cylindrical)} \tag{2}$$

and

$$\partial C(r,t)/\partial t = D[\partial^2 C(r,t)/\partial r^2 + (2/r)\partial C(r,t)/\partial r] + S(r,t) - \lambda\, C(r,t) \quad \text{(spherical)} \tag{3}$$

where C is the concentration of the diffusing substance and D is the diffusion coefficient. In Eq. 1, $\lambda = 0.693/\tau_{1/2}$ where $\tau_{1/2}$ is the half-life of the species; D is assumed to be independent of time t and position x within the target material. For spherical targets, in which diffusion is solely in the radial direction, the diffusion equation takes the same form of Eq. (1) for planar targets by substituting a new variable U = Cr. The rate of production, S, is given by $S = \sigma N I / ZeA$ where σ is the cross section for production of species of interest; N is the concentration of interaction nuclei; I is the primary ion beam intensity; Ze is the charge on, and A the cross-sectional area of, the primary ion beam. The temperature dependence of the diffusion coefficient D for solid-state diffusion processes is given by the Arrhenius relation:

$$D = D_0 \exp(-Q/RT) \tag{4}$$

where Q is the activation energy required for diffusion, R is the gas constant, T is the absolute temperature, and D_0 is called the frequency factor. For diffusion in the liquid-state, the diffusion coefficient is weakly dependent on the operating temperature T according to

$$D = \alpha d\{8k/M\}^{1/2}T^{3/2} \tag{5}$$

where α is the linear coefficient of thermal expansion; d is the diameter of the solvent and M the mass of the solute atom. Examples of the use of these tools are illustrated in Figs. 1 and 2 for F diffusing from fibrous Al_2O_3 and ^{132}Sn diffusing from UC_2.

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[1] DICTRA is a general software package for simulation of DIffusion Controlled TRAnsformations in multi-component systems and is a product of the Royal Institute of Technology, Stockholm, Sweden.

[2] Mathematica is a mathematical software package of Wolfram Research, Inc., Champaign, IL.

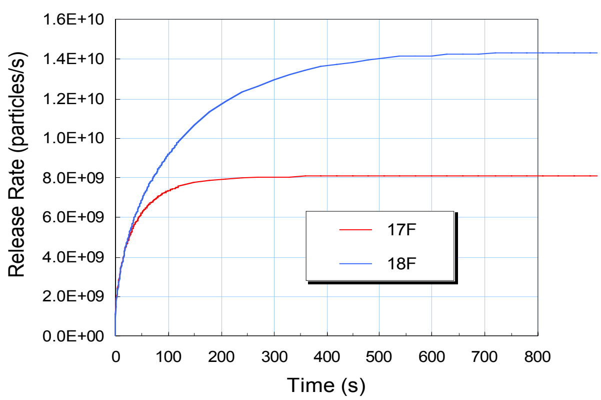

Fig. 1. Simulation of the diffusion release of $^{17,18}F$ from fibrous Al_2O_3.

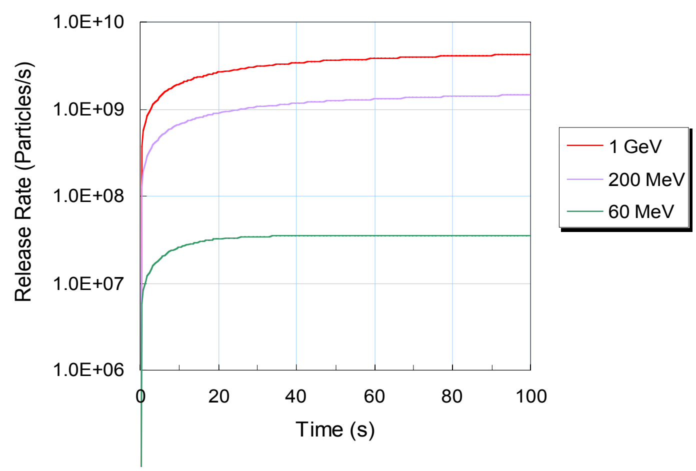

Fig. 2. Simulation of the diffusion release of ^{132}Sn from liquid Th.