<u>Calculating the RIB intensity</u>

Assume the production system is at equilibrium where the production rate in the target is equal to the loss rate. The loss rate is the sum of radioactive decay and release from the target and ion source system. A fraction of the lost atoms will be ionized and extracted from the ion source to form the radioactive ion beam.

The radioactive ion beam intensity is determined using a moving tape collector and a Ge detector to measure the γ-rays from the decay of the beam particles on the tape. The beam is collected on the moveable tape for a known time, t_c. This collection spot is then moved to a point directly in front of the Ge detector, where the γ-rays are detected for a fixed time, t_o. The tape move time, t_m, and any delay time, t_d, between the end of the tape move and the beginning of the observation time must also be known. The energies and relative intensities of the peaks in the γ-ray spectrum are used to identify the isotopes in the beam and the peak areas are used to calculate the beam intensity.

<u>Collection</u>

The number of atoms, N, on the tape is governed by the equation:

$$\frac{dN}{dt} = Y' - \lambda N$$

where λ is the radioactive decay constant and Y' is the yield (or beam intensity) of a particular isotope in atoms/second. Thus at the end of the collection cycle:

$$N(t_c) = \frac{Y'}{\lambda}\left(1 - e^{-\lambda t_c}\right)$$

<u>Move and Decay</u>

During the movement of the tape (and any additional delay), the number of atoms will exponentially decrease:

$$N(t_c + t_m + t_d) = N(t_c)e^{-\lambda(t_m + t_d)} = \frac{Y'}{\lambda}\left(1 - e^{-\lambda t_c}\right)e^{-\lambda(t_m + t_d)}$$

<u>Observation</u>

During observation, the atoms deposited on the tape will continue to decay. The number, **N**, that decayed during time t_o is the number of atoms at the beginning of the observation time minus the number of atoms at the end.

$$\mathbf{N} = N(t_c + t_m + t_d) - N(t_c + t_m + t_d + t_o)$$

$$= N(t_c + t_m + t_d)\left(1 - e^{-\lambda t_o}\right)$$

$$= \frac{Y'}{\lambda}\left(1 - e^{-\lambda t_c}\right)\left(1 - e^{-\lambda t_o}\right)e^{-\lambda(t_m + t_d)}$$

Efficiency correction and normalization

The number of γ-rays of a certain energy that are observed is dependent on the detector efficiency, ε_γ, and the fraction of decays resulting in an emission of a γ-ray of that energy – called the branching ratio, ε_{br}. The detector efficiency, which is energy dependent, will be given and the branching ratios can be found in the Table of Isotopes (on-line or hardcopy).

Thus, the number of γ-rays observed, N_γ, is:

$$N_\gamma = \mathbf{N}\varepsilon_\gamma \varepsilon_{br} = \frac{Y'}{\lambda}\left(1 - e^{-\lambda t_c}\right)\left(1 - e^{-\lambda t_o}\right)e^{-\lambda(t_m + t_d)}\varepsilon_\gamma \varepsilon_{br}$$

and the yield (beam intensity) is:

$$Y' = \frac{\lambda N_\gamma e^{\lambda(t_m + t_d)}}{\left(1 - e^{-\lambda t_c}\right)\left(1 - e^{-\lambda t_o}\right)\varepsilon_\gamma \varepsilon_{br}}.$$

If the collected spectra contains data from n cycles, $N_\gamma = N_\gamma^{tot} / n$.

We usually want to determine the normalized yield, Y, where $Y = Y' / \mathrm{I}$, where I is the beam intensity in μA of the primary production beam. Thus the beam intensity, or yield, in units of ions/second/μA is given by:

$$Y = \frac{\lambda N_\gamma^{tot} e^{\lambda(t_m + t_d)}}{\left(1 - e^{-\lambda t_c}\right)\left(1 - e^{-\lambda t_o}\right)n\varepsilon_\gamma \varepsilon_{br}\mathrm{I}}.$$

Ion Source Efficiency

The ion source efficiency can be obtained by dividing the extracted beam intensity by the production rate, R_{prod}, in the target, if known.

$$\varepsilon_{IS} = \frac{Y}{R_{prod}}.$$

The production rate is dependent on beam energy, beam intensity, cross-section for the specific isotope, target thickness, and any feeding from the radioactive decay of a parent nucleus occurring in the target.