[resonance absorbers]
(Chapter 6.2.6 of *Elements*)

Effective Resonance Width

The resonance width dominates the final-energy resolution in resonance-detector spectrometers and depends on the thickness and the temperature of the absorber material. The transmission probability is

$$T(E) = \exp\left(-n\sigma(E)d\right), \qquad \text{(6-RA-1)}$$

where n is the atomic number density, $\sigma(E)$ is the total cross section at energy E, having a Doppler-broadened Breit-Wigner resonance shape, and *d* is the thickness of the material in the direction of neutron travel. In the illustrative calculations that follow we have assumed a model absorption cross section of the form

$$\sigma(E) = \frac{1}{4}\frac{\sigma_o \Gamma^2}{(E - E_{res})^2 + \Gamma^2/4}, \qquad \text{(6-RA-2)}$$

with peak cross-section $\sigma_o = 4880\,barns$, full-width $\Gamma = 57\ \ meV$, and resonance energy $E_{res} = 4.28\ \ eV$. This is not totally accurate, but representative of the Ta^{181} 4.28-*eV* resonance. Tantalum is monoisotopic, Ta^{181}, with density 16.6 g/cm^3. Weinberg and Wigner (1958) discuss the exact calculation of the Doppler-broadened resonance cross section, which is beyond the scope of the present discussion.

Ignoring scattering in the resonance interaction, the absorption probability for neutrons of energy E is

$$A(E) = \left(1 - T(E)\right). \qquad \text{(6-RA-3)}$$

The standard deviation (resolution) of this function does not exist because the variance integral diverges.

Elements Table 8.4.2, Detectors, gives relevant properties of a few resonance absorbers useful in eV spectrometers: In^{115}, Ta^{181}, Au^{197}, andU^{238}.

Figure 6-RA1 (left) shows the energy variation of the absorption probability of tantalum foils of various thicknesses calculated for the model cross-section. Differences of spectra measured with thin foils and thick foils

$$A_{dif}(E) = w_1 A(E,d_1) - w_2 A(E,d_2) \qquad \text{(6-RA-4)}$$

can be optimized to give both desirable higher counting rates and better energy resolution. The contributions from the wings of the resonance subtract away in the weighted difference between measurements with two absorbers of different thickness, if the weights (w) are in inverse proportion to the thicknesses (*d*),

$$w_1/w_2 = d_2/d_1\ . \qquad \text{(6-RA-5)}$$

then the absorption in the wings diminishes rapidly (see Figure 6-RA1 (right)), and the variance integral converges. Such foil differences leave a cleaner resolution function, suppressing the wings of the Breit-Wigner resonance.

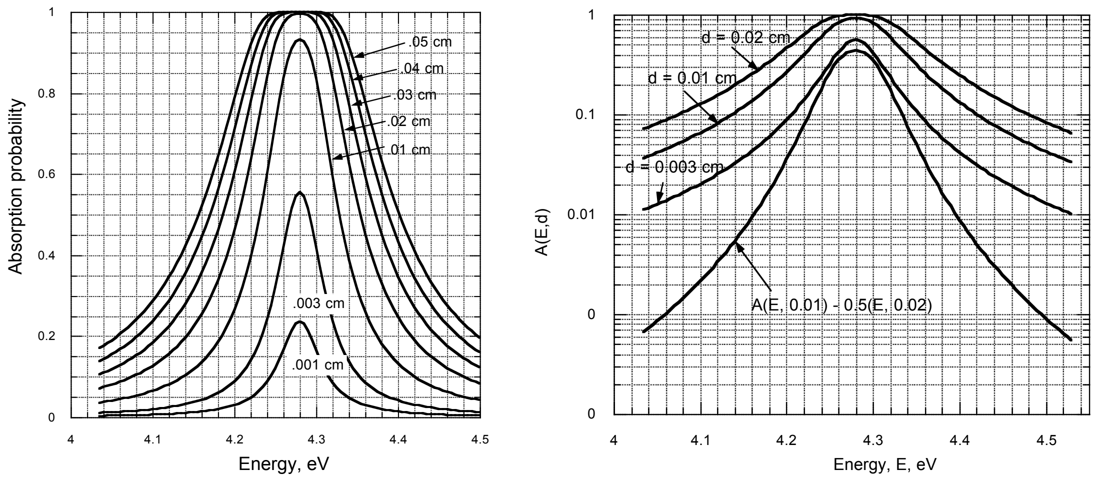

Figure 6-RA-1 (left) The absorption probability of thin foils of Ta[181] *as a function of the energy of incident neutrons. (right) The weighted difference in absorption probabilities* $\left(A\left(E,d=0.01\right)-0.5A\left(E,d=0.02\right)\right)$, *compared to* $A\left(E,d=0.01\right)$, $A\left(E,d=0.02\right)$, *and* $A\left(E,d=0.03\right)$.

In Figure 6-RA (right) , the logarithmic vertical scale emphasizes the more rapid fall-off of the absorption difference function compared to that of the single-thickness functions. The shape of the response for a thickness of about .003 cm is not significantly different from the intrinsic resonance line shape.

In the filter-difference case, the condition (6-RA-5) provides a converging variance integral and a finite standard deviation for the distribution of absorbed neutrons. Although the variance integral and standard deviation of the final-energy distribution do not exist for the single-foil resonance filter case, for purposes of resolution assessment, one may use the Gaussian-equivalent standard deviation of the energy-dependent absorption probability. In either case,

$$\sigma_E^{abs} = \left(FWHM\right)_E^{abs} \Big/ \sqrt{8\ell n 2}\ . \qquad \text{(6-RA-6)}$$

The corresponding standard deviation of the time-of-flight distribution, σ_t^{abs}, resulting from the detector final energy distribution is

$$\sigma_t^{abs} = \left|\frac{\partial t}{\partial E_f}\right| \sigma_E^{abs}\ . \qquad \text{(6-RA-7)}$$

In view of (6.26), (6.29), and (6.30), we can write

$$t = \frac{1}{\mathrm{v}_f}\left(L_i f(\phi) + L_f\right), \qquad \text{(6-RA-8)}$$

so that the standard deviation of the time distribution is

$$\sigma_t^{abs} = \frac{1}{2\,\mathrm{v}_f\, E_f}\left(L_i f(\phi) + L_f\right)\sigma_E^{abs}\ . \qquad \text{(6-RA-9)}$$

Reference

Weinberg, A. M. and E. P. Wigner (1958). *The Physical Theory of Neutron Chain Reactors*. Chicago: The University of Chicago Press, pp. 111-5.