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THE EFFECTIVE TEMPERATURE FOR DOPPLER BROADENING IN UO_2 LATTICES

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The solid state effect in the Doppler broadening of the ^{238}U neutron resonances in UO_2 lattices has been studied. Its influence on the effective capture resonance integral was investigated for dilution cross sections of 20 to 50 barns, spanning the situation of FBR, HCPWR, CANDU, and LWR reactors.

The resonance integrals for the four strong low-energy resonances below 100eV have been calculated by the NRIM approximation. The study has been performed with a Crystal Lattice Model of solid state effects, the validity of which was tested by different experiments. The lattice vibration frequencies were determined from recent neutron resonance measurements at GELINA. The results are compared with those of the Free Gas approximation.

The solid state effect in UO_2 influences the resonance integrals of individual low-energy resonances by up to 0.2% if compared with the Gas Model result for Lamb's effective temperature T_{eff}^{L}, which provides a best approximation of the resonance cross section in case of weak lattice binding. The larger differences are for higher temperature and larger dilution cross section.

To account for the effect in reactor calculations with actually available codes, not prepared for Doppler calculations with solid state models, adjusted temperature values T_{eff}^{RI} have been derived for the Gas Model, at which the effective integral agrees with the Lattice Model result, see Figure 1. These values depend on the individual resonance, but they depend only slightly on the dilution cross section. The adjusted temperature values preserving the effective capture integral are generally higher than the real temperature and also higher than Lamb's effective temperature. With increasing neutron energy they converge to Lamb's effective temperature.

No simple adjustment of a general parameter in the Gas Model may describe the effect for the whole number of neutron resonances of a nuclide, and Debye temperatures deduced from the results of individual resonances become quite unphysical.

The convergence law of the adjusted temperature values T_{eff}^{RI} derived from the calculations for the individual low-energy resonances has been used to estimate temperatures for neutron resonances at higher energies, see Figure 2.

From these results adjusted temperatures for large energy ranges have been determined conserving the effective capture integral over the energy ranges, see also Figure 3. These values may be used for the Doppler calculation in the respective energy ranges.

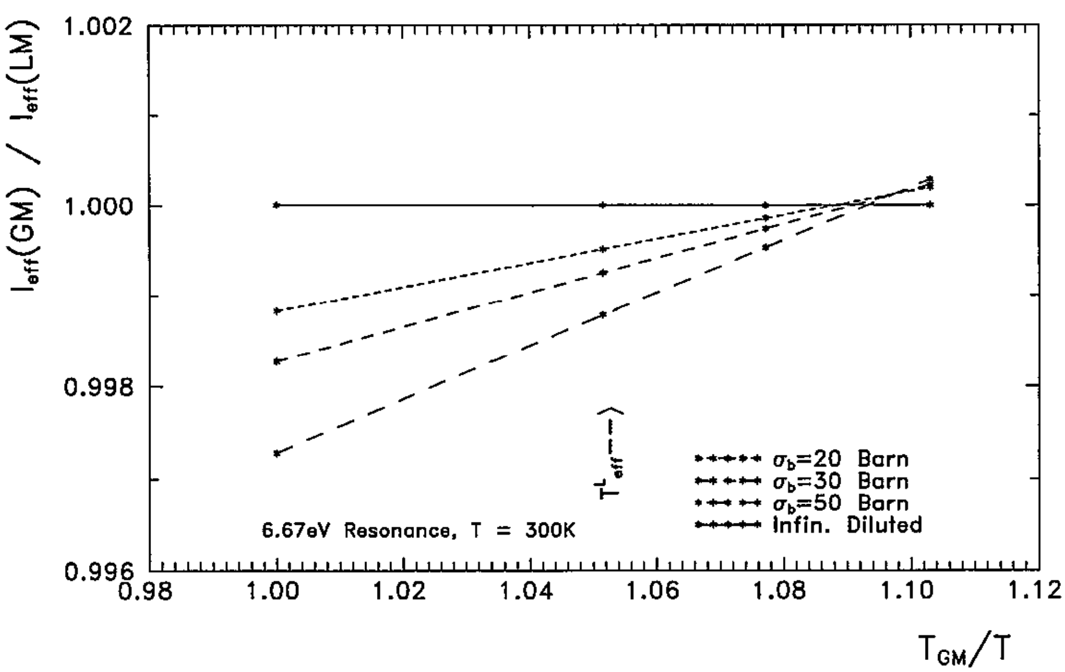
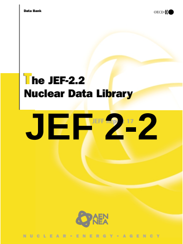


Figure 1:
The effective capture resonance integral for the 6.67eV resonance at 300K, comparison of Gas Model values for different Temperatures T_{GM} with the Crystal Lattice reference calculation.



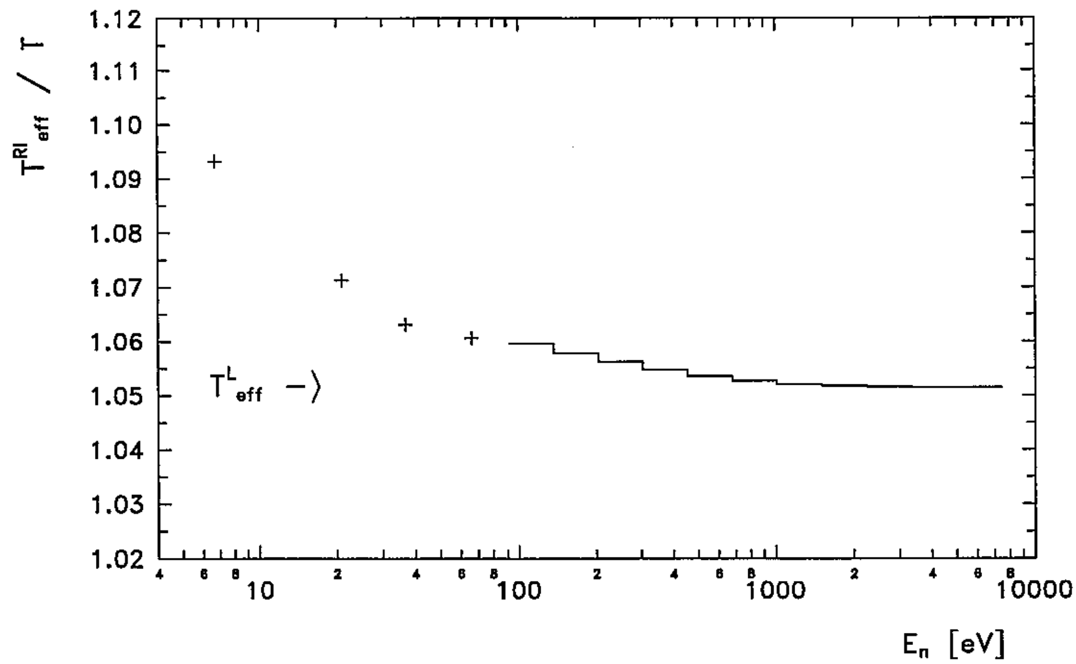


Figure 2:
Adjusted temperatures T_{eff}^{RI} for individual neutron resonances (below 100eV) and extrapolated values (above 100eV, histogram) for T=300K and σ_b=50b.

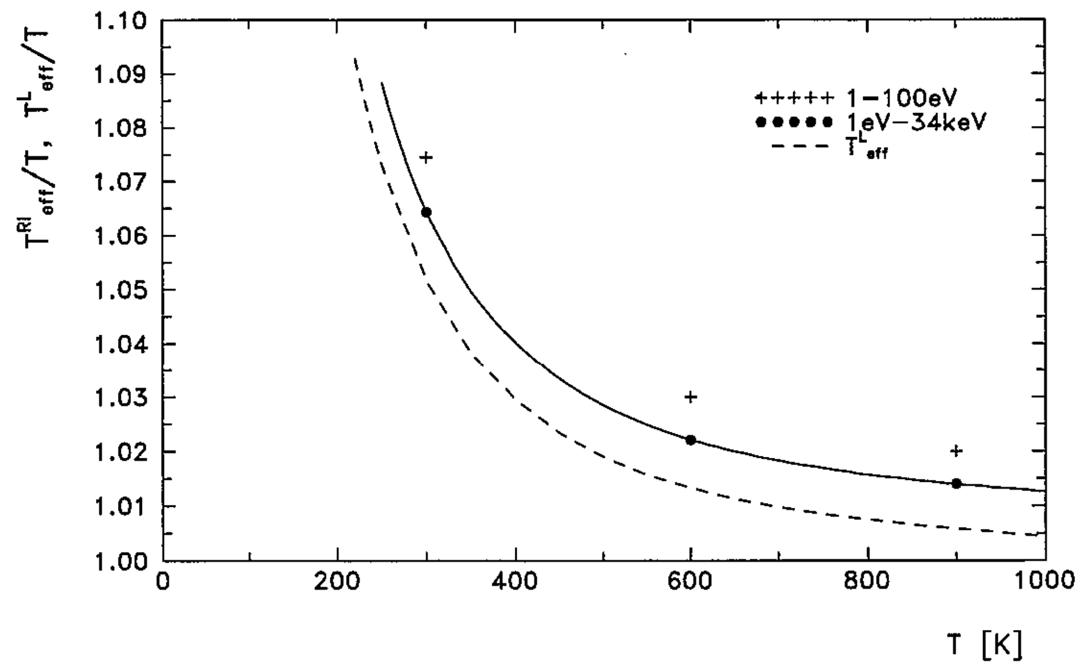


Figure 3:
Ratio T_{eff}^{RI}/T averaged for the whole energy range and for the resonances below 100eV compared to the T_{eff}^{L}/T.