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Adjustment and validation of iron-56 data with shielding benchmarks

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Iron is an important structural and shielding material in nuclear reactors. In the recent international Fe-56 nuclear reaction evaluation data, there are still significant differences in the evaluated 56Fe(n,inl) cross-sections. The results of the iron shielding benchmark test showed that the nuclear reaction data for iron still needed further improvement. In order to improve the accuracy of shielding calculation and provide quantitative feedback for nuclear data evaluation, a nuclear data adjustment study based on shielding benchmark experiment was carried out.

In this work, the adjustment of Fe-56(n,el), (n,inl) and (n,γ) reaction cross-sections was carried out based on the IPPE iron sphere shielding benchmark experiment (ALARM-CF-FE-01) and the maximum likelihood function method, and the adjustment coefficients of the cross-sections were calculated, which were used to adjust the Fe-56 cross section data in PENDF format. The microscopic cross-section and covariance data of this adjustment study are from the JEFF-3.3 library, and the neutron leakage spectrum before the test is calculated by the MCNP program. The sensitivity coefficients of the cross-sections were obtained by the direct perturbation method.

The adjustment results showed that the neutron leakage spectrum calculated based the adjusted Fe-56 data was improved in the MeV energy region but no in the keV energy region. The adjusted neutron leakage spectrum obtained by the nuclear data adjustment based on the 3-fold covariance is in better agreement with the experimental data than with the 1-fold covariance. The adjustment factor for (n, inl) cross-section was larger than 1 standard deviation in a certain energy region when 3-fold covariance was used. And the posterior cross section for (n,inl) reaction with the 3-fold covariance used was closer to the corrected Nelson(2004) data. In the energy range of 10 - 15 MeV, the adjusted cross section was closer to the C33b4 revision of Fe-56 data.

The adjusted Fe-56 data was validated with the ASPIS/Fe88 experiment. The 32S(n,p)32P reaction rate calculated with the 3-fold covariance-adjusted Fe-56 data was significantly improved, with the maximum calculation deviation reduced from 31% to 9%. However, the adjusted 27Al(n,α) reaction rates worsened, while the adjusted reaction rate deviations for 115In(n,n')115mIn and 103Rh(n,n')103mRh remained similar to before adjustment but better than C33b4 and INDEN evaluations. The adjusted reaction rate bias for 197Au(n,γ)198Au improved, especially with 3-fold covariance.

In summary, adjustment coefficients for Fe-56 reaction cross-sections were obtained, and the adjusted inelastic scattering cross-section was closer to the C33b4 evaluation in a specific energy range. The neutron leakage spectrum calculation improved partially, and the ASPIS/Fe88 experiment validated the posterior data, highlighting the effectiveness of the 3-fold covariance adjustment in some cases.

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