The $^{10}B(n,\alpha)^{7}Li$ Cross Section

The recommended reference data for $^{10}B(n,\alpha)$ in the 1991 Nuclear Standards File are actually the ENDF/B-VI evaluated cross section data. The main concern expressed in the $^{10}B(n,\alpha)$ summary of that document was the small uncertainties of the evaluated data file [1]. Furthermore, there are indications [2] from an analysis of spectrum integrated cross sections from benchmark fast reactor neutron fields that this cross section should be increased in the energy region above 50 keV relative to the ENDF evaluation.

The $^{10}B(n,\alpha)$ standards have received considerable attention as a result of their relatively poor database and the problems they caused in the ENDF/B-VI standards evaluation process. An interlaboratory collaboration, which later became a subgroup of the Working Party on International Nuclear Data Measurement Activities, of the Nuclear Energy Agency Nuclear Science Committee was formed to provide a mechanism for improving these cross sections. Working groups or task forces such as these have been very successful in the past at resolving data problems. The $^{10}B(n,\alpha)$ subgroup has representatives from the measurement, evaluation and user communities. Its objective is to have several laboratories collaborate on programs to improve the database relevant to an evaluation of the $^{10}B(n,\alpha)$ standard cross sections. There has been an appreciable effort at a number of major laboratories located in the USA and Europe on the $^{10}B(n,\alpha)$ cross section problem since the formation of this subgroup. Work has been done on the branching ratio, the $^{10}B(n,\alpha_1\gamma)$ cross section, the total neutron cross section, the differential cross section for the $^{10}B(n,\alpha)^{7}Li$ reaction, and the $^{10}Be(p,n)$ reaction. These measurements can be effectively utilized in helping to define the $^{10}B(n,\alpha)$ cross sections when used in an R-matrix analysis. Such an analysis can use neutron total, scattering and reaction cross sections for ^{10}B; as well as additional measurements such as angular distributions, polarization and charged-particle studies involving the ^{11}B compound nucleus to define the parameters needed to accurately calculate the $^{10}B(n,\alpha)$ cross sections.

Status of Recent and Ongoing Measurements:

Branching Ratio Measurements

Measurements of the ^{10}B branching ratio, the ratio of the $^{10}B(n,\alpha_0)$ to the $^{10}B(n,\alpha_1)$ cross sections, provide direct information on the ratios of the $^{10}B(n,\alpha)$ cross section standards. Weston and Todd [3] measured the branching ratio from 20 keV to 1000 keV neutron energy at the ORNL LINAC (ORELA) facility. In figure 1, these data are compared with the ENDF/B-VI evaluation. The measurements are 10 % to 30 % low in the 100 keV to 600 keV energy region compared with the ratios calculated from the ENDF/B-VI cross sections. The data agree with ENDF/B-VI at the lowest and highest energies of the experiment. The error bars represent one standard deviation total uncertainties. In view of the large differences observed in ref. [3], new branching ratio measurements are planned at IRMM by Hambsch using a Frisch gridded ionization chamber. Such measurements also offer the possibility of getting information concerning the angular distribution.

$^{10}B(n,\alpha_1\gamma)$ Measurements

In a NIST/ORNL collaboration, measurements [4] were made at the ORELA facility of the shape of the $^{10}B(n,\alpha_1\gamma)$ cross section from 0.3 MeV to 4.0 MeV neutron energy. The cross sections which were obtained, normalized to the ENDF/B-VI evaluation over the region from 0.2 MeV to 1 MeV, agree with the ENDF/B-VI evaluation below 1.5 MeV. However, above 1.5 MeV they differ as much as 40 % from the ENDF/B-VI evaluation. The interest in extending the $^{10}B(n,\alpha_1\gamma)$ standard to higher neutron energies and confirming the results obtained at the ORELA facility led to a NIST/LANL collaborative measurement [5] at the WNR facility at LANL. The data cover the range from 300 keV to 20 MeV. Preliminary results compared with the ORELA data and the ENDF/B-VI evaluation are shown in figure 2. The agreement with the ORELA experiment above 1 MeV confirms the discrepancy with ENDF/B-VI in the energy region above 1.5 MeV. In this figure, the experimental data were normalized to the ENDF/B-VI evaluation for the energy region below 1 MeV to facilitate comparison of the measurements and evaluation.

An additional measurement [6] made by this same collaboration at the ORELA facility extended the cross section to lower energies so that better normalization of shape measurements could be made. The measurement covered the neutron energy range from 10 keV to 1 MeV. The preliminary results normalized to the ENDF/B-VI evaluation over the region from 10 keV to 20 keV are shown in figure 3. These data are lower than the ENDF/B-VI shape by about 5 % in the region above 100 keV. A number of other experiments listed in ref. [5] show a similar result. Using the normalization established from the measurements would require that the Schrack data in figure 2 be reduced by 5 %.

Total Cross Section Work

Many earlier measurements of the ^{10}B total neutron cross section have been affected by the quality of the transmission samples being used and difficulties with backgrounds. Three new measurements have been made of this cross section with special concerns about the quality of the samples and evaluation of backgrounds in an effort to improve the $^{10}B(n,\alpha)$ standards. Brusegan *et al.* [7] have reported preliminary measurements of the ^{10}B total cross section made at the IRMM LINAC (GELINA) facility. Data were presented for the energy region from 80 eV to about 100 keV. The ^{10}B results agree with the ENDF/B-VI evaluation below 10 keV to within half a percent, but are high by up to 7 % in the energy range from 10 keV to 100 keV. Additional data are under analysis which will improve the present results and extend them to higher energies. Also presented in ref. [7] are preliminary measurements made of the ^{10}B total cross section at the IRMM 7 MV Van de Graaff facility by Crametz and Wattecamps [8]. The measurements were made using a white source over the energy region from 1.5 MeV to 18 MeV. The ^{10}B results agree with ENDF/B-VI at the higher energies within the uncertainties. The data are slightly low at the lowest energies compared with ENDF/B-VI. Further work is in progress with monoenergetic neutrons in the energy range from 0.2 MeV to 2 MeV at this facility.

Measurements were also made by Wasson *et al.* [9] at ORELA of the ^{10}B total cross section. The neutron energy region covered by this work extended from 20 keV to 20 MeV. The ^{10}B total cross section measurements agree with the ENDF/B-VI evaluation for neutron energies greater

than about 2 MeV, but are lower by as much as about 4 % between 600 keV and 2 MeV and are greater by as much as about 5 % below 600 keV. A comparison of the three new ^{10}B total cross section measurements is shown in figure 4. There is generally good agreement among these measurements within the uncertainties.

Angular Distribution Measurements

Measurements have been made by Haight of the angular distribution of α particles from the $^{10}B(n,\alpha)$ reaction at the WNR facility at LANL [10]. Data for this experiment were obtained for the energy range from about 1 MeV to 6 MeV. The angular distribution was measured at laboratory angles of 30°, 60°, 90°, and 135° using a thin (3800 Å) ^{10}B film as a target. For this experiment, the α groups are not resolved so the angular distribution includes the contribution from both of the groups. The data from this experiment are now undergoing analysis. Further work has recently been done to reduce the backgrounds for this experiment. This is allowing the experiment to be repeated using only the energy detector so that data can be obtained to lower charged- particle energy. It may even be possible to obtain useful data on the ^{7}Li angular distribution. New measurements are also being made with an ionization chamber containing a ^{10}B deposit.

Charged-Particle Data

Measurements have begun by Massey at Ohio University of the $^{10}Be(p,n)$ reaction [11]. The data that have been obtained are excitation functions at 0° in the laboratory system for proton energies from 1.5 MeV to 4.0 MeV. Full angular distributions are expected in further work. The results of this work will provide data in the region of interest for the R-matrix analysis of the ^{11}B system.

Summary

Though many of the experiments are preliminary, the lower $^{10}B(n,\alpha_1\gamma)$ cross section, the lower branching ratio and the higher total cross section indicate a discrepancy in the hundred keV energy region in one or more of the measurements reported here.

Changes in the evaluated $^{10}B(n,\alpha)$ cross sections resulting from the measurements made since the ENDF/B-VI evaluation will be estimated. The impact on the $^{10}B(n,\alpha)$ standard will be estimated from R-matrix analyses by Gerry Hale, the ENDF/B-VI evaluator for this cross section, using the above mentioned data sets which should be finalized by the middle of 1997 by the subgroup working to improve this cross section.

The ENDF/B-VI evaluation was performed by a comprehensive process which involved R-matrix evaluations for ^{11}B and ^{7}Li which were combined with the results of a simultaneous evaluation. The database for the ^{11}B and ^{7}Li measurements were divided between the two evaluation techniques. It will not be possible to do a complete evaluation in this manner for this

investigation. Instead, the relative change resulting from the recent measurements will be determined by comparing two R-matrix evaluations; one using the entire ^{10}B database used in the ENDF/B-VI evaluation and a second using that database plus the recent measurements. Recently point-wise evaluations of the $^{10}B(n,\alpha)$ cross section and the ^{10}B total cross section were done by Kafala [12] using the neutron database only. The $^{10}B(n,\alpha_1\gamma)$ cross section was not evaluated. These evaluations included the most recent data however they are somewhat limited in that neither R-matrix nor simultaneous evaluation techniques were employed. For the total cross section, the most recent measurements [7-9] have been weighted heavily in this evaluation so the changes compared with ENDF/B-VI are generally consistent with that expected based on figure 4. There are also significant differences compared with the ENDF/B-VI evaluation for the $^{10}B(n,\alpha)$ standard cross section.

New recommendations for the ^{10}B standard cross section are forthcoming.

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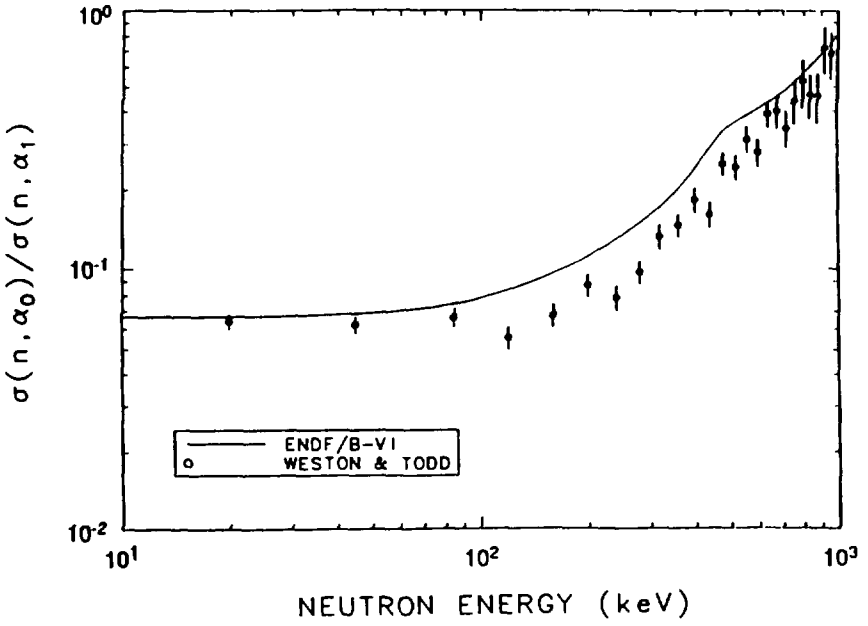

Fig. 1 Measurements of the branching ratio of ^{10}B cross sections by Weston and Todd [3] compared with the ENDF/B-VI evaluation.

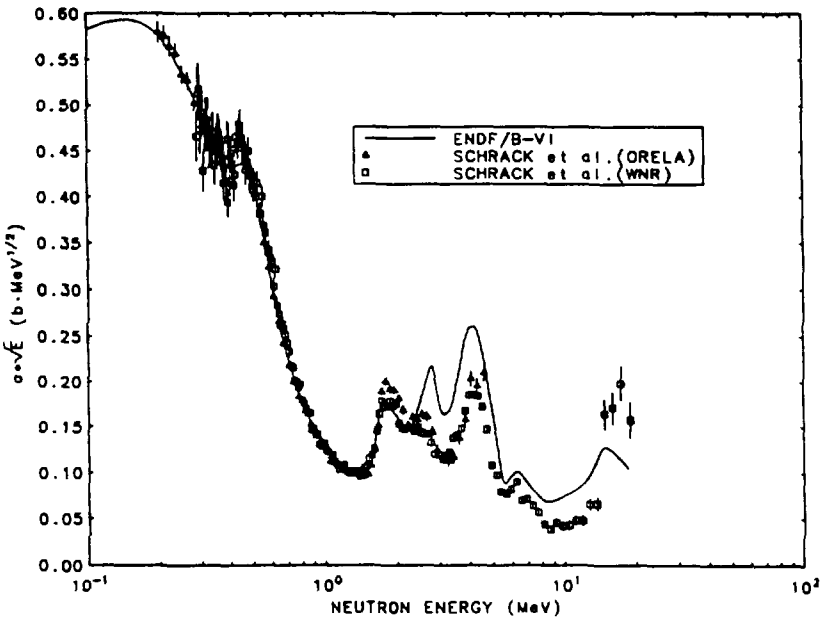

Fig. 2 Comparison of the $^{10}B(n,\alpha_1\gamma)$ cross section measurements of Schrack *et al.*, at ORELA [4] and WNR [5] facilities with the ENDF/B-VI evaluation.

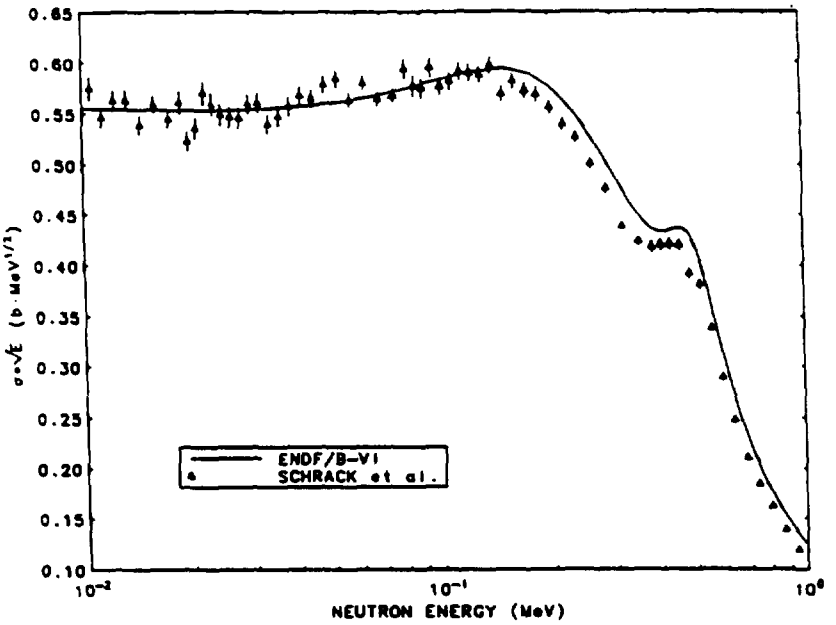

Fig. 3 Measurements of the $^{10}B(n,\alpha_1\gamma)$ cross section by Schrack *et al.* [6] compared with the ENDF/B-VI evaluation.

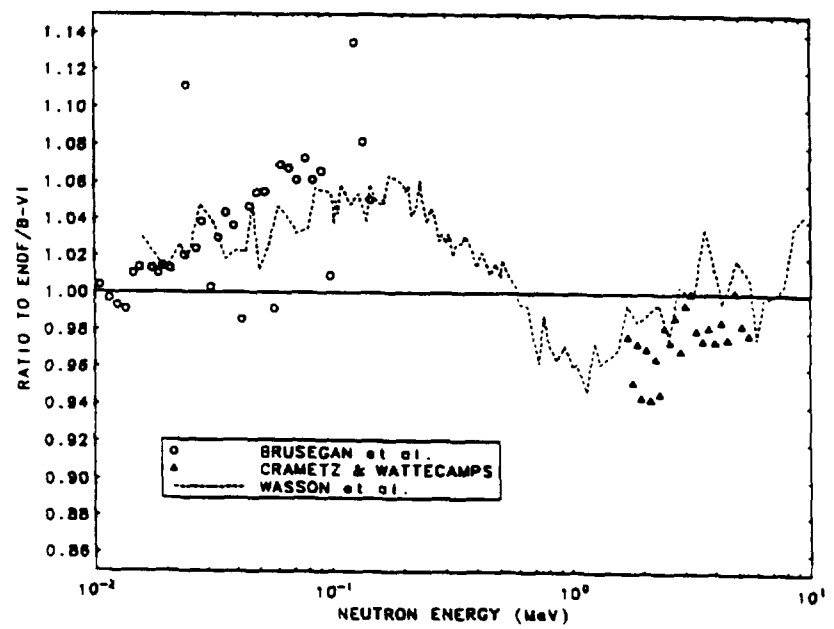

Fig. 4 Comparison of the recent measurements of the ^{10}B total cross section by Brusegan *et al.* [7], Crametz and Wattecamps [8], and Wasson *et al.* [9] with the ENDF/B-VI evaluation.