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ADDITIONAL NOTES TO THE FORTHCOMING EVALUATION FOR Ni ISOTOPES

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This note supplements the information given in the "Progress Report on the Activities for the Re-evaluation of Neutron Cross Sections for Ni isotopes", given in FYS-FUS-87-01 or JEF/DOC-156.

1. OTHER RECENT EVALUATIONS

There are various other evaluations of Ni isotopes and of natural Ni.

1.1. U.S. Evaluations

The Ni evaluation for ENDF/B-VI is made at Oak Ridge by Hetrick et al. [1]. The evaluation is nearly finished (status July 1985). The calculations in the high-energy region have been made with the improved TNG code (unified model; pre-equilibrium γ-ray emission; variable bin size) [2]. The data file is not available as yet.

1.2. Japanese evaluations

There exists is fully documented JENDL-2 Ni evaluation for the isotopes and for natural Ni [3]. However, in this evaluation the double-differential cross sections in the continuum are still represented by isotropic evaporation models. Revisions have been applied for JENDL-3PR1 to MTf = 2, 4, 51-91 (MT = 4), MT = 16, 28, 91 (MT = 5). These revisions were made with the ECIS-code (coupled-channels method) and with GNASH (pre-equilibrium effects, also for discrete levels). The ddx data at 14.5 MeV have been improved considerably (comparison with Osaka data) [4]. For JENDL-3 the ddx data will be expressed into MF = 6 [4]. The data file is not available as yet.

1.3. European evaluations

The existing JEF-1 evaluations for natural Ni, ^{58}Ni, ^{62}Ni and ^{64}Ni are based upon Fröhner's resolved-resonance data; at higher energies the data are taken from ENDF/B-IV (natural Ni) and RCN-2.

In the resonance range (upto 0.5 MeV) the more recent partial evaluations of Derrien and Lafond are available on tape. At higher energies there is

the evaluation of Strohmaier et al. [5,6] for σ_t, $\sigma_{el}(\theta)$, activation cross sections, etc. from threshold upto 30 Mev. This evaluation does not contain angular distributions of continuum-emission reactions. Also the format is not ENDF. Some more recent calculations from IRK for ^{58}Ni(n,2n) ^{58}Ni(n,p) and ^{58}Ni(n,np) + ^{58}Ni(n,d) have been published by Pavlik et al. [7].

Very recently, an extension of earlier IRK work on ^{58}Ni and ^{60}Ni was made by Uhl [8] at incident energies from 7 to 40 Mev. This work is of the same or of even better quality as given in Refs. [5-7]. However, it also contains ddx data in the MF6 format of ENDF-VI. Still, it is a partial evaluation, because no data are given at E < 7 MeV. Furthermore, the evaluation does not give the usual quantities, but rather the production cross sections (MT = 5) of the reaction products including light particles and nuclides, i.e. cross sections including all reaction paths. Also the corresponding angle-integrated spectra are given, in a binned representation and in the laboratory system.

2. PRESENT STATUS OF THE EVALUATION

2.1. CC and DWBA calculations (J.M. Akkermans, G.J.M. Janssen, H. Gruppelaar)

The HETEROCLITE coupled-channels code of Lagrange (BRC) has been installed at our CRAY super computer. The calculations with this code are very fast and inexpensive (comparible to DWBA calculations). Comparison between CC and DWBA calculations with the deformed and spherical-model versions of the potential of Guss et al. [9], respectively, give very similar elastic- and inelasticscattering angular distributions at E = 14 MeV. However, the direct component of inelastic scattering has a slightly different absolute value (≈ 10%) if the same β_2-value (= 0.19) is used in the two calculations. The difference between the deformed and spherical potentials is very small: only the imaginary depth has been decreased in the spherical potential. The differences for σ_t and σ_{se} are less than 3% (within the experimental uncertainty). Probably the real depth has to be slightly adjusted.

The DWBA code system DWARF has been extended with an option to obtain the results in the ENDFB-VI format (files MF 3 and 4). Therefore this code is at present more convenient to use. We intend to adjust β_2 until agreement is obtained with the CC or experimental results for direct-inelastic scattering β_2 needs to be increased to about 0.20). A second advantage of using DWARF is that is is quite easy to calculate the direct components of other than the one-phonon states (included in HETEROCLITE), by adopting the β_2-values from proton inelastic scattering work [10]. The new DWENDF module has an option to fit Legendre polynomials with the constraint that no negative cross section values appear on a given angular grid.

A third advantage of using DWBA-type of calculations is that the spherical optical model can be applied in the statistical-model codes, albeit with a renormalization of the compound-formation cross section which has to be decreased by the total direct-inelastic scattering component.

It is noted that near the threshold of inelastic scattering the direct component is small. This allows the use of DWBA. A more complicated situation exists in other vibrational nuclei like ^{102}Ru, ^{104}Ru, ^{106}Pd, ^{108}Pd,

etc. where also near threshold the direct component is quite high (more than 20% of the cross section). This problem is being studied at present (improvement of JEF fission-product file).

2.2. Statistical-model codes (J.M. Akkermans, H. Gruppelaar, Shi Xiangjun, H.A.J. van der Kamp)

Before performing extensive calculations some changes have to be made in the model codes.

GRAPE

The present version of GRAPE employs a continuous level-density formula, constistent with the back-shifted Fermi-gas formula. In multi-particle emission low-lying states are excited which are not very well represented by this formula. It is of course possible to fit the parameters a and Δ such that at low excitation energies a "best" representation is obtained by lowering the continuum cut-off energy E_{cut}. This has been done in the initial calculations. However, it is better to include discrete-levels in the calculatons. There is an option for this in GRAPE, but its use leads (unavoidably) to strange structures in the emission spectra. This is particularly disturbing if it is combined with a non-equidistant grid-size. Perhaps it is mainly the non-equidistant grid-size causing the difficulties. A non-equidistant grid works well for first-particle emission where the initial energy is sharply defined. However, for further decay the initial energy is determiend by an energy grid that may be much broader than the emitted secondary energy. Under these circumstances an "image" of the broad-bin structure is projected over the low-energy side of the spectrum. We feel that these problems should be resolved or at least studied in some detail. An advantage of GRAPE is that it provides a fast calculation of all required data in the new MF6 format.

GNASH-ECN

The GNASH-ECN code is a version of GNASH which has been coupled to GRAPE in such a way that the exciton-model characteristics of GRAPE are inserted

into GNASH in a consistent way, defining a simple unified model. The GNASH-ECN code calculates cross sections, energy spectra and photon-production data, whereas the GRAPE code can be used (at least) for angular distributions. Probably, the emission spectra of GRAPE are superior, because a much finer grid is used (in particular for first-particle emission). Some additional work need to be performed on GNASH-ECN: introduction of precompound γ-ray emission and introduction of recent systematics on γ-ray strength functions. Furthermore, a code for producing data in ENDF format is required. At present work is underway to update the level-scheme information required in GNASH. In the near future a CRAY version of GNASH will be installed.

CERBERO

The GNASH code fails at low energies below 4 to 5 MeV, because of the neglect of width-fluctuations effects. Therefore the code CERBERO is adopted. In addition this code calculates angular distributions for compound-elastic and discrete-inelastic scattering. An output option to store the data in ENDF format is needed.

3. CONCLUSION

There are a number of recent evaluations which are nearly finished. We feel that it is needed to use the available information as much as possible. Steps should be taken to obtain this information and to investigate the use of it for EFF-2. The work for the ECN evaluation is in progress: the optical-model parameters have been selected and both DWBA and CC calculations have been performed. In addition some preliminary statistical-model calculations have been performed. The input for the codes GNASH-ECN, GRAPE and CERBERO is being prepared. Some work is needed to improve the models, but these are minor modifications. Two utilities are required to express the output of the existing codes in the ENDF-VI format.

4. REFERENCES

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