3.11 Measurement of Neutron Activation Cross-sections for Elements Co, Ni, Y, Nb, Tm and Au between 12 and 20 MeV

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Neutron activation cross-sections for cobalt, nickel, yttrium, niobium, thulium and gold have been measured in the neutron energies from 12 to 20 MeV with the reference cross section of NEA ^{93}Nb(n,2n)^{92m}Nb at Tohoku Dynamitron Facility.

1. INTRODUCTION

Precise cross sections above 12 MeV are still sparse except for the energy of 14 MeV although these are important for the high energy dosimetry, and estimation of damage rates and/or activation level of structural materials tested or used in the proposed high energy accelerator based neutron fields.[1] Such cross sections also provide indispensable information to establish the nuclear model for high energy cross sections.[2] Several activation cross sections for cobalt, nickel, yttrium, niobium, thulium and gold have been measured between 12 and 20 MeV.

2. EXPERIMENTAL

Source neutrons were produced via the T(d,n)^{4}He reaction by bombarding a 2.9-MeV deuteron beam from the Dynamitron accelerator at Tohoku University. Eight packages of high or ultra-high purity metal foils were set around the neutron source at 5 cm from the target in the angular range from 0 to 140 deg. covering the incident neutron energies from 20 down to 12 MeV. Experimental arrangement and technique were almost the same as the previous experiments.[3,4] Neutron flux at each foil was determined from the activation rates of two niobium foils which sandwiched each sample foil in between; the reference cross section for the ^{93}Nb(n,2n)^{92m}Nb reaction was taken from the 1991 NEANDC/INDC standard file.[5]

3. RESULTS

The measured cross sections are described here, and those data are compared with the previous data and cross section file data in Fig. 1 (a) through (h).

3.1. ^{59}Co(n,2n)^{58}Co cross section

This reaction is important for dosimetry application, especially in the high energy neutron field[2]. Also, the evaluated cross section for IRDF-90[6] by IRK group was adopted as the secondary standard[7] by NEA besides the ^{93}Nb(n,2n)^{92m}Nb cross section. However, the above 14 MeV the evaluated data taken from three dosimetry files :JENDL DOSIMETRY FILE (JDF),[8] IRDF-90 and ENDF/B-VI[9] are still not consistent with each other, reflecting the status of experimental data base of this energy region which each evaluation was based upon. The present result shows the cross section curve located between the above dosimetry file's data.

3.2. ^{58}Ni(n,2n)^{57}Ni cross section

This reaction is suitable to apply to the high threshold dosimetry of short term. Previously measured data are deviated tremendously above 15MeV; there are two major data groups with additional minor data sets in between as discussed in Ref.10. The old dosimetry data took the low major group, while the recent evaluations adopted the higher group. Present measurement data do not belong to both two major groups, as indicated by the previous result of our group[4].

3.3. ^{58}Ni(n,np)^{57}Co cross section

Although this reaction is suitable as the high threshold dosimeter with relatively long lasting period (year), the status of the data base of this reaction is rather poor except for the energy region around 14 MeV. The present data show consistency with the previous measurement,[4] also with the ENDF/B-VI evaluation above 15 MeV, whereas not with JENDL-3.[11]

3.4. ^{58}Ni(n,pα)^{54}Mn cross section

This reaction was first observed in the previous experiment.[4] In the present measurement, one possibility of the ^{54}Mn activity due to the impurities in the sample foils in the previous experiment was completely denied because of use of the ultra-high purity nickel foils. Theoretical model calculation[4] by SINCROS-II[12] estimated the appreciable cross section of about 20mb at 20MeV. The present data are almost double of this estimation. This suggest that the proper selection of charged-particle decay channels in the model calculation for the high energy reactions should be made in order to estimate accurately the helium-gas production rates, or activation rate for the medium weight nuclei of the structural materials.

3.5. ^{89}Y(n,2n) ^{89}Y cross section

This reaction is supposed to be included in the update version of JDF because of the large cross section with flat energy dependence above 15 MeV having relatively long life time. Present data support the evaluated data of JENDL-3.

3.6. ^{169}Tm(n,2n)^{168}Tm

This reaction is also supposed to be included in the update version of JDF due to the same reason as the yttrium. The status of the experimental data including the present data is moderately good. The cross-section curve of JENDL Activation File[13] in the figure is slightly lower than the trend of the experimental data between 11 and 16 MeV.

3.7. ^{197}Au(n,2n)^{196}Au

This reaction has been used some time as a reference one in the activation cross section measurement. Up to date, a large number of experimental data have been reported and the status of the data is almost sufficient below 20MeV. The present measurement again support the IRDF-90 evaluation.

3.8. $^{197}Au(n,3n)^{195}Au$

In the high energy dosimetry for the advance neutron sources based on the Li+d reaction1) or spallation reactions, gold is attractive as a single-element dosimeter besides cobalt because of their multiple reactions. This reaction serves as the good dosimeter in the energy range from around 17MeV to 40MeV except for the drawback of the emission of low energy photons which necessitate to use of very thin sample foils. Present data reproduced the previous data of our group,4) and are lower than other previous measurements.

Experimental details and final numerical data for all observed cross sections are in preparation, and will be presented elsewhere. This work was financially supported by JAERI in 1993. The authors are grateful to Messrs. R.Sakamoto, and M. Fujisawa of the Dynamitron Facility.

REFERENCES

1. M. Sugimoto, K. Noda, Y. Kato, H. Ohno and T. Kondo: JAERI-M 92-027 p.58, (1992).
2. S. Iwasaki and N.Odano, to be published in the Proceedings of the International Conference on Nuclear Data for Science and Technology, Gatlinburg, Tenn., USA, May 9-13, 1994.
3. M. Sakuma , S. Iwasaki, H. Shimada, N. Odano, K. Suda, J.R. Dumais and K. Sugiyama: JAERI-M 92-027, p.278 (1992).
4. S. Iwasaki, M. Sakuma, K. Sugiyama and N. Odano: JAERI-M 93-046, p.257, JAERI (1993).
5. H. Vonach: *Nuclear standards for Nuclear Measurements*', NEANDC-311"U", INDC(SEC)-101, NEA/OECD, p80,(1992).
6. N.P. Kocherov and P.K. McLaughlin: IAEA-NDS-141 (1990).
7. H. Vonach: *Nuclear Standards for Nuclear Measurements*', NEANDC-311 "U", INDC(SEC)-101, NEA/OECD (1992), pp.78-79.
8. M. Nakazawa, et al.: "*JENDL Dosimetry File*", JAERI 1325 (1991).
9. D.E. Cullen, et al.: IAEA-NDS-41/R, rev.0 (1982).
10. S. Iwasaki: JAERI-M 93-046, p.211, (1993).
11. K. Shibata , et al.:"*Japanese Evaluated Nuclear Data Library, Version-3 -JENDL-3-*" JAERI 1319, (1990).
12. N. Yamamuro: JAERI-M 90-006, (1990).
13. Y. Nakajima and T.Nakagawa: private communication.

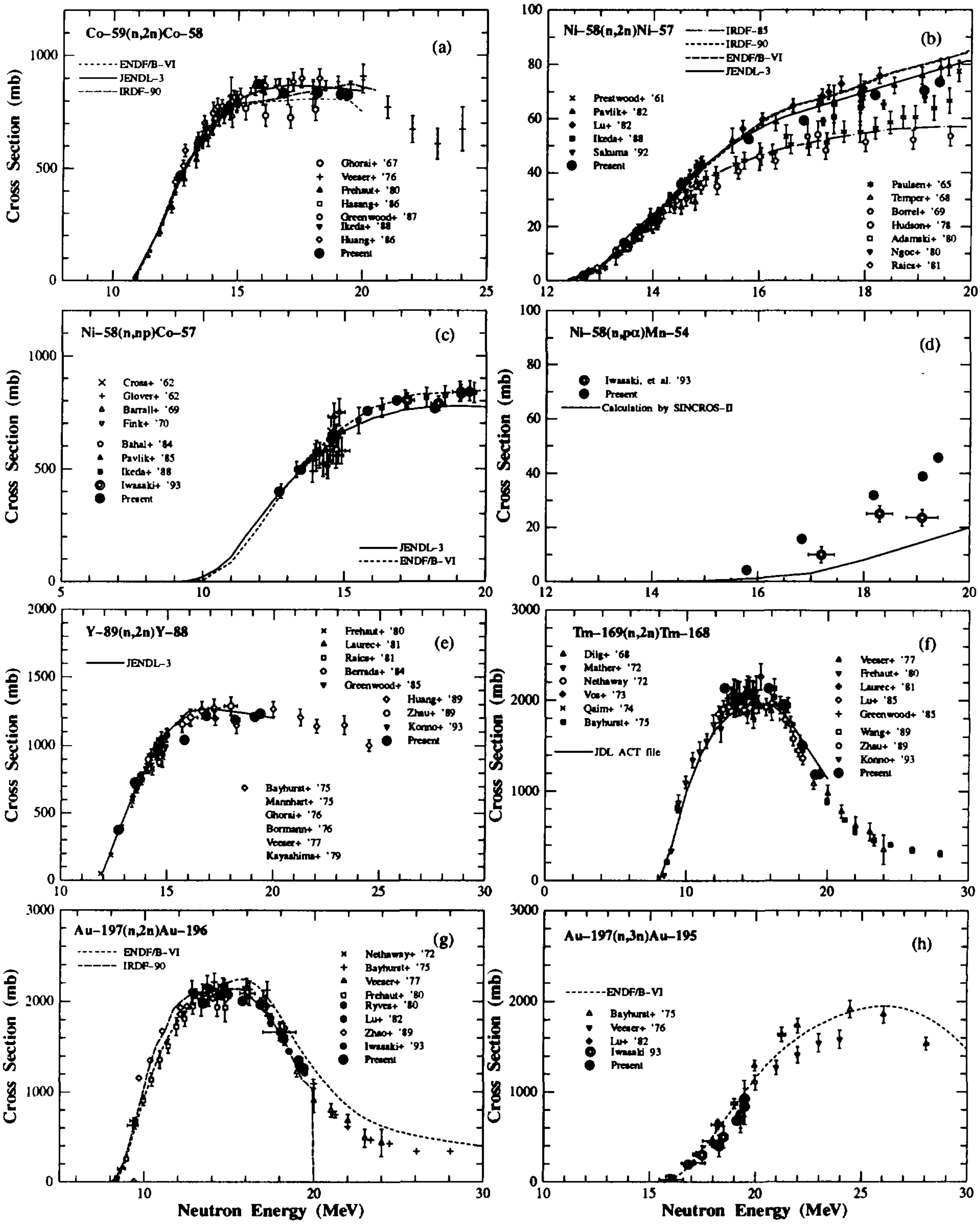

Fig. 1 Comparison of the present experimental data with those of the previous ones and of some evaluated files for the reactions: ^{59}Co(n,2n)^{58}Co (a), ^{58}Ni(n,2n)^{57}Ni (b), ^{58}Ni(n,np)^{57}Co (c), ^{58}Ni(n,pα)^{54}Mn (d), ^{89}Y(n,2n)^{89}Y (e), ^{169}Tm(n,2n)^{168}Tm (f), ^{197}Au(n,2n)^{196}Au (g), and ^{197}Au(n,3n)^{195}Au (h), respectively.