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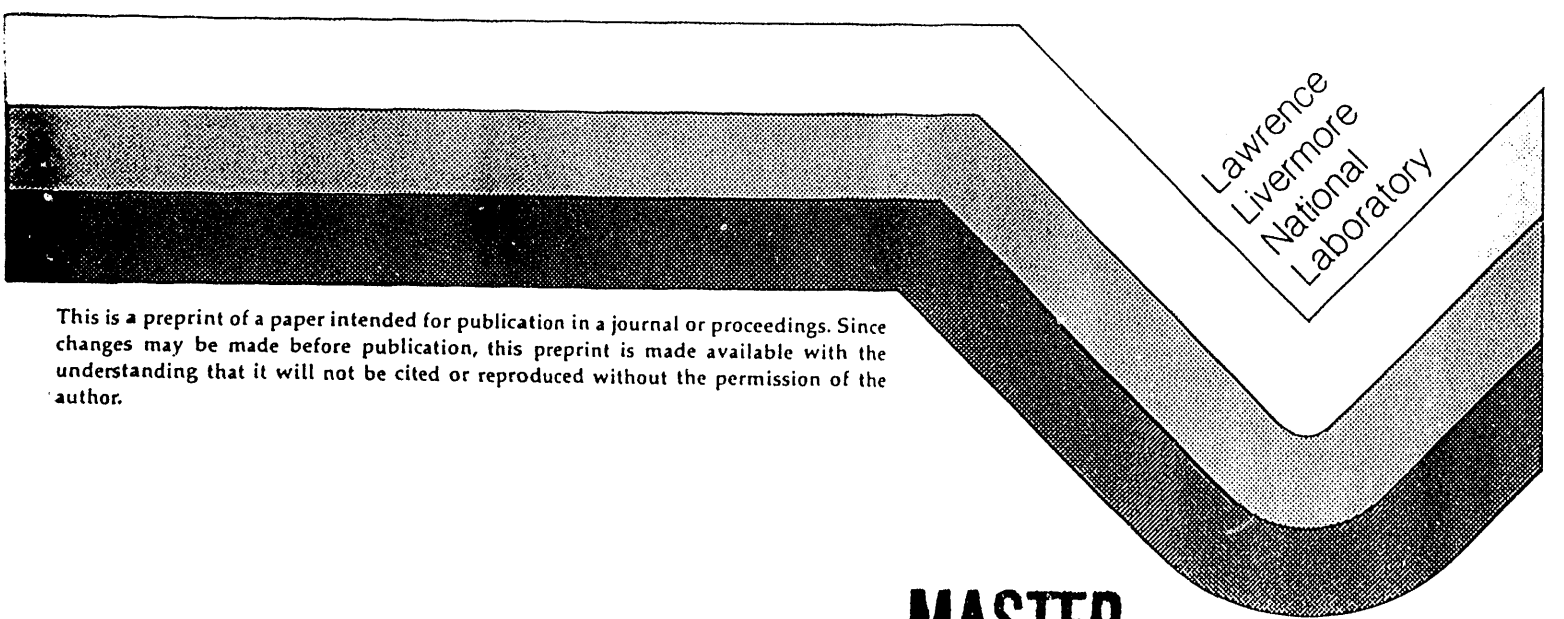

CALCULATED CROSS SECTIONS FOR PRODUCTION AND DESTRUCTION OF SOME LONG-LIVED NUCLIDES OF IMPORTANCE IN FUSION ENERGY APPLICATIONS*

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ABSTRACT

Knowledge of the production and destruction of long-lived species via neutrons, photons, and charged-particles is required in many fusion energy applications, such as reactor first-wall and blanket design, radioactive waste management, etc. Here we describe our calculational results for the production, via the (n,2n) reaction, of the following long-lived species: ^{150}Eu($t_{1/2}$ = 36 y), ^{152}Eu($t_{1/2}$ = 13 y), and ^{192m2}Ir($t_{1/2}$ = 241 y). Some comments on calculations that we've made for destruction reactions of these species are also included.

1. INTRODUCTION

Over the years, we have developed a set of calculational tools[GG92a] that gives us the capability to compute nuclear reaction cross sections, isomer ratios, and particle- and photon-spectra from threshold to 30 MeV, including those for photonuclear processes. We have also calculated complete libraries of excitation functions for neutron-induced reactions on ground-state and isomeric targets for suites of isotopes such as: ^{87}Y-^{89}Y, ^{88}Zr-^{90}Zr, ^{170}Lu-^{179}Lu, ^{187}Ir-^{194}Ir, ^{204}Bi-^{210}Bi . Recently we have been studying the low-energy physics necessary to produce complete sets of cross sections for ^{145}Eu-^{154}Eu and ^{150}Gd-^{156}Gd[GG92b]. Because we have been interested in cross sections for all of the production and for all of the destruction reactions of isomeric states as well as of ground states, including those for neutron-deficient nuclei, we have concentrated on making accurate calculations on unstable targets where no experimental data exist.

The versions of the codes that we use for our calculations: COMNUC, STAPLUS, ECISPLUS, NUSTART, etc. are documented in Ref. GG92a. In the course of carrying out nuclear reaction cross-section calculations of the statistical-model Hauser-Feshbach type, we find it necessary to describe nuclei in the first few MeV above their ground states with discrete levels in order to obtain accurate cross-section and isomer ratio calculations. There appears to be no adequate way in which one can use a level-density expression to represent or substitute for the level structure. The level information should not only consist of those levels that are observed experimentally, but must be supplemented with the level structure theoretically known to be present by model calculations or some other

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means. This is true both for spherical nuclei, where typically tens of levels are found in the first 1 to 4 MeV of nuclear excitation, and for deformed nuclei, where perhaps a thousand levels are present in the first 1.5 MeV. We have found that discrete-level sets are not only important in the description of nuclei at low excitation energies but are also very valuable in the prediction of a number of calculational parameters, particularly for nuclei off the line of stability. Discrete-level information can be used to obtain improvements on global parameterizations of level densities; to predict unknown values of D_{0b}, the average s-wave neutron resonance spacing; to compute correct radiation widths; to deduce absolute E1 and M1 gamma-ray strength functions; and to calculate correct primary capture gamma-ray spectra, especially at the low-energy end. For the calculation of isomer ratios, gamma-ray branchings among the discrete levels are also required.

When gamma-ray branching information is lacking, we use our PC code, NUSTART, to approximate the computation of the multipole branching fractions[LGG90]. For a given set of discrete levels, the general scheme is to calculate the relative strengths of up to 30 of the strongest transitions(up to 20 dipole and 10 E2 transitions) to lower-energy levels for each radiating level, conserving angular momentum and parity. If an M1 or an E2 populates the same final level, their strengths are added. We select the 10 most intense transitions and create the multipole branching fractions by normalizing the total strength to unity. We derive the relative strength for the transitions from transmission coefficients of the form CE1 x $E\gamma^3$, CM1 x $E\gamma^3$, and CE2 x $E\gamma^5$, where $E\gamma$ is the difference between the initial and final level energies. The coefficients CM1 and CE2 are constants in the Weisskopf approximation; the coefficient CE1 may be either constant or energy dependent(as with the giant dipole resonance). These coefficients are equivalent to gamma-ray strength functions; they may be either relative or absolute in magnitude and must be ≥ 0. In general we have found that nuclei that are permanent rotors cannot be treated as just described, but we may modify the decay from their band heads, including K-quantum number restrictions if desired.

2. EUROPIUM CALCULATIONS

We have been developing cross-section libraries containing complete sets of excitation functions for neutron-induced reactions on the isotopes of $^{145\text{-}154}$Eu and $^{150\text{-}156}$Gd [GG92b]. The calculational modeling in this mass region is challenging for a number of reasons. The Eu and Gd isotopes lie close to the N = 82 closed-neutron shell but between the closed-proton shells at Z = 50 and Z = 82, and the deformation of these isotopes changes rapidly. A deformed neutron-potential that works well for the heavier mass isotopes may not be suitable for the lighter, more spherical nuclei. The approach that we are taking is to achieve best agreement between our calculated cross sections for the stable Eu and Gd isotopes and experiment using as consistent a set as possible of all necessary calculational parameters. This set will then be used to predict all required cross sections for the unstable isotopes. Among the experimental data utilized to determine these parameters are:

- β_2 values for some 39 nuclei
- $\Gamma\gamma$ and D_{0b} values for 7 nuclei

- s-wave and p-wave neutron strengths for 7 nuclei
- discrete level information for 16 nuclei
- (n, γ) σ's for ^{151,153}Eu and ^{152,154,155}Gd
- capture γ-ray spectrum for ^{155}Gd
- total (n,2n) σ's on ^{151}Eu and ^{152,154,155}Gd
- (n,2n) σ's to isomers for ^{151,153}Eu
- (p,n) and (p,3n) σ's on ^{151,153}Eu
- photoneutron σ's on ^{151,153}Eu and ^{156}Gd
- averaged total resonance data for ^{151,153}Eu and ^{155}Gd.

We had to determine if all target isotopes could be treated as rotors. The even-even Gd isotopes certainly seem to have a rotor signature. Because the deformation is changing rapidly in this mass region, we needed to find systematics that could predict values of the deformation parameter, β_2, for the light isotopes. We require β_2 values as input to coupled-channel optical model calculations and to our E1 γ-ray strength function modeling[Gar84,GG92a]. The systematics that we used to predict β_2 values was based on the suggested expression, β_2^2 = constant x $E\gamma^{-1}$ x $A^{-5/3}$, where $E\gamma$ is the energy difference in MeV between the ground state and the first member of the ground state rotational band. The value of the constant in this expression was determined by analyzing experimental β_2 values for some 39 nuclei from Nd to Tm; an average value of 42.5+/-3.9 was obtained for even-even nuclei and of 29.6+/-7.9 for all others. More details can be found in Ref. GG92b.

We used the ECISPLUS coupled-channel code to obtain the neutron transmission coefficients and all required total reaction cross sections. Our choice of deformed optical model potentials were those previously deduced for Eu[MY87] and Gd[YA87]. In the case of ^{155}Gd, we needed to invoke the use of a fictitious even-mass, ground-state rotational band[GG92b] following the approach of Ref. Lag+83. The nuclear structures for these isotopes have not been studied well experimentally, especially in the case of Eu. Many levels of the Eu isotopes are completely uncharacterized and gamma-ray branching information among the discrete levels is scant or non-existent. For example, no multipole branching intensities are available for ^{150}Eu. Because of the rapid change in deformation, the Eu and Gd level densities are difficult to model. We found large disagreements between observed numbers of discrete levels and those predicted by Gilbert-Cameron systematics.

^{151,153}Eu(n,xn) Reactions Several neutron reactions on the ground states of stable ^{151,153}Eu have been previously evaluated[You86]. Figure 1 shows how well our calculations for the total (n,2n) reaction on the ground state of ^{151}Eu agreed with the evaluation and with experiment[Fre+80]. We observed similar results for the target isotope ^{153}Eu. For these total (n,2n) cross sections the calculations are sensitive to only two aspects: (1) choice of the neutron optical-model potential and (2) the modeling of the precompound neutron evaporation. They are relatively insensitive to discrete levels and continuum-level densities and to gamma-ray competition, except around reaction thresholds. These calculations do not test the accuracies of computed isomer populations. The latter depend on how well the discrete levels and their multipole branchings are known.

In this work we consider the 36-y, 5^- state of ^{150}Eu to be the ground state and the 0^- state, at 0.042 MeV to be the isomer. We consider the 13-y, 3^- state of ^{152}Eu to be the ground state and the 0^- state and the 8^- state to be isomeric states at 0.046 Mev and 0.148 Mev, respectively. The isotope ^{152}Eu exhibits some band structure, although to what extent is unclear. This collective property should become more evident for heavier, more deformed europium isotopes and less so for the lighter isotopes. Initially, we proceeded to carry out sensitivity calculations by comparing the ^{153}Eu(n,2n) populations of the ground state and two isomeric states using both the existing experimental gamma-ray branchings for the 37 discrete levels that we had adopted for ^{152}Eu and those computed with our NUSTART code. In this way we could determine the upper limit of the error introduced by NUSTART's inability to treat rotational bands properly. For ^{150}Eu, where measured transition probabilities are lacking, the NUSTART computations should better represent the branchings for this less deformed, lighter nucleus. The results of these calculations compared with data[Bli+90, Han+90, IK90, MDR88, Net87] are shown in Fig. 2a for the ^{153}Eu(n,2n) reaction and in Fig. 2b for the ^{151}Eu(n,2n) reaction. In Fig. 2a, the data are squares for the long-lived, 3^- ground state, open circles for the 0^- isomer, and triangles for the 8^- isomer. Note that we have scaled down the experimental data, as well as the calculations, for production of the 8^- isomer by a factor of 10 for a clearer presentation. The solid line shows the calculational results when we used the experimental multipole branches among the levels in ^{152}Eu, while the dashed line shows the results when we used branches from NUSTART. Both sets of branches predict well the cross sections to the long-lived 3^- ground state; but both appear to overpredict the 8^- isomer population. The measurements for the 0^- isomer production span a factor of 5 range in value, but the results obtained using the measured branches seem the better of the two calculations. We ascribe the factor of 2 difference between the calculations for the 0^- isomer primarily to the bands in ^{152}Eu that are not treated properly by NUSTART. In Fig. 2b, the data are squares for the long-lived , 5^- ground state, and open circles for the 0^- isomer. The solid lines now are the calculations using NUSTART branches and appear to be fairly reasonable.

In our most recent calculations for these two reactions, we have made some modifications to both the discrete levels and level densities of the relevant nuclei. In the case of ^{150}Eu, we observed from the spin distribution of our original set of 27 levels up to an excitation energy of 0.589 MeV that there were too few levels of spins mainly in the range of J = 0-3. We supplemented the original levels with about 12 more discrete levels to correct this deficiency and adjusted the level density parameters accordingly. Again, the NUSTART code was implemented to calculate the gamma-ray branching fractions. The resulting cross sections for the population of the 36-y, 5^- ground state and the 0^- isomer are given in Table 1 and do not differ significantly from the original calculations shown in Fig. 2b. In the case of ^{152}Eu, we observed from the spin distribution of our original set of 37 levels up to an excitation of 0.221 MeV that the addition of only about 4 levels was required. However, from the studies of the ^{151}Eu(n,γ)^{152}Eu that we had made at the same time, it appeared that the level density parameter, "a", also needed to be increased by about 5% . Again we used our NUSTART code to calculate all of the gamma-ray branching fractions for this expanded ^{152}Eu level set rather than attempt to supplement the original experimental branchings. However, because of the recognized inadequacies of the

application of the NUSTART code to deformed nuclei, we decided to allow the 8^- isomer population to decay equally to the 13-y, 3^- ground state and the 0^- isomer. The resulting cross sections are given in Table 2. Most recently we have begun to investigate the role of an ad-hoc, trial collective enhancement model[GG92a] for the level densities of deformed odd-odd nuclei such as ^{152}Eu and ^{154}Eu in our (n,γ) cross section calculations. We have not yet studied the impact of this collective enhancement in the (n,2n) cross-section calculations.

3. IRIDIUM CALCULATIONS

As part of our effort to develop a cross-section library containing complete sets of excitation functions for neutron-induced reactions on the isotopes of ^{187}Ir-^{194}Ir, we made a series of preliminary calculations, primarily to identify problems in either the measured cross sections themselves or in the level information for several of the iridium isotopes. The principal problems we encountered in our initial calculations were that most of the existing experimental reaction cross-section data, as well as the discrete-level information are presently incomplete and/or uncertain. The lack of discrete level data for the odd-odd iridium isotopes presented the greatest difficulties. We used the optical-model code SCAT[Ber81]and a neutron potential specifically derived for iridium[Ber78]to compute the neutron transmission coefficients; we added isospin terms to the potential to allow for changes in the mass number.

We described each iridium isotope above the ground state with a preliminary set of about 35 to 70 discrete levels, each having associated gamma-ray decay branching fractions[Mey87]. Above these levels, we employed a level-density expression in which some of the parameters were modified, based on information we extracted from the discrete levels using statistical analyses. Our analyses showed that these preliminary discrete-level sets were incomplete and/or uncertain due to experimental and theoretical structure difficulties. All of the iridium discrete-level sets were missing up to half of the levels that our statistical analyses indicated should be present, especially above 0.5 to 1 MeV, and some of the gamma-ray decay branchings from the levels included were open to question. The level structure of odd-odd iridium nuclei is very complex, and simple models cannot accurately predict all of the levels present. Odd-odd nuclei with somewhat fewer protons than $_{77}$Ir, such as $_{75}$Re and $_{73}$Ta, are symmetric rotors, whereas heavier nuclei, e.g., odd-odd $_{79}$Au, are not symmetric rotors. Models that describe well the $_{75}$Re or $_{79}$Au nuclei fail when used to predict the level structure of $_{77}$Ir. At present, a model such as the Interacting Boson Fermion Fermion(IBFF) model[Par85] is not able to yield complete theoretical sets of levels and is not able to compute E1 transition probabilities. In the case of odd-mass nuclei, we truncated the incomplete sets at about 1 MeV and normalized our level density formulae to these truncated sets. For the odd-odd nuclei, we estimated that the original level sets were missing about 50% of the levels below 0.5 MeV, and truncation was not possible.

^{193}Ir(n,xn) Reactions In our studies, the ^{193g}Ir(n,n')^{193m}Ir($t_{1/2}$ = 10.6 d) reaction was of importance as well. Because of the structure problems just described, our original description of ^{193}Ir, with 68 discrete levels up to an excitation energy of 1.76 MeV, was se-

verely deficient in levels at energies above 1 MeV. We determined that truncating to 37 levels at 1.015 MeV does not greatly affect the calculated isomer production by inelastic scattering and allows a good prediction of the level spacing, D_{ob}, at the neutron separation energy. This is shown in Fig. 3, where our calculations with the original and two truncated level sets are compared with the measurements[Bay+75]. Neither we nor others have successfully reproduced the 7.6-MeV experimental cross-section value.

Additionally, we made improvements in the precompound exciton model in the STAPLUS code; we modified the spin cut-off parameter, σ_p^2, used in the precompound evaporation model in a manner similar to that of Fu[Fu86] and others. It is now a function of the number of particles and holes, N, in the particular exciton configuration ratioed to that at "equilibrium," N_c. The new spin cut-off parameter is also dependent upon the energy, E, in the daughter nucleus by way of the compound limit, $\sigma_c^2(E)$: $\sigma_p^2(N,E) = (N/N_c)\sigma_c^2(E)$. Like Fu, we have the option of choosing for the matrix element, $|M|^2 = 262E^{-1}A^{-3}$. The main effects involve calculated angular distributions and isomer populations because the new model tends to populate lower spin states than the old model. In Fig. 4, we show the differences in the ^{193g}Ir(n,n')^{193m}Ir cross sections due to the use of the original and the newly modified exciton-dependent spin-cutoff parameter. At E_n = 20 MeV, the new σ_p^2 yields only 25% of the value that the original σ_p^2 gave for the inelastic cross section to the isomer. At E_n = 14 MeV, the new modeling gives about 1/3 the value given by the original. At lower incident energies, for example, E_n = 6 MeV, the effect of using one or the other σ_p^2 is only about 5 %. The data are not accurate enough for us to decide quantitatively whether the new modeling of σ_p^2 is an improvement over the original modeling.

For the reaction, ^{193g}Ir(n,2n) producing ^{192}Ir in the ground and two isomeric states, we had observed that when we used an original set of 37 discrete levels for ^{192}Ir and their accompanying gamma-ray branches in our calculation of the cross sections for the reaction ^{193g}Ir(n,2n)$^{192g+m1}$Ir, we were low by a factor of about two compared to the data at $E_n \approx$ 14 MeV. The level set was incomplete with only 37 levels up to 0.532 MeV and the gamma-ray branchings transferred all of the populations of levels with spins greater than or equal to 5 to the m2, 9^+, 241-y isomer. It appeared that about 30 or so levels were missing, especially with spins in the range J = 0-3. When we used a preliminary set of 150 levels, calculated with the IBFF model, we again found it to be significantly deficient in levels in the J = 0-3 range. Since this theoretical set did not include gamma-ray branchings, we computed them with the NUSTART code. The resulting cross sections for $^{192g+m1}$Ir production were only slightly larger than those using the 37-level set.

In an effort to better understand the ^{192}Ir structure, we carried out a preliminary analysis of recent average resonance capture(ARC) data[Ker+91] for 2-keV neutrons incident on ^{191}Ir. We had made similar analyses previously for ^{176}Lu[GGH85] and for some of the actinides. Using our absolute E1, M1, and E2 strength function systematics we calculated the intensities of the primary capture gamma-ray transitions to levels up to about 0.5 MeV in ^{192}Ir. The initial spin distribution produced in ^{192}Ir by the 2-keV neutrons was computed by our version of the COMNUC code and then entered as input into STAPLUS. The uncertainty associated with transitions to all the final states was also calculated from the square root of the variance and found to be about ±12%. By

normalizing these calculations to several of the experimental transitions, we were able to make spin and parity assignments for the levels observed in the data. Our transition-intensity calculations cannot distinguish between level spins of $1^-,2^-$ and $1^+,2^+$. Transitions to 4^+ levels are essentially only E2 in type. The number of J^π states from 0 to 3 that we identified in the data agreed well with initial predictions we made about missing levels. Although our calculations for this analysis were as complete as we could make them, our analysis and interpretation of the data are by no means final. Our principal interest was to compose an intermediate set of ^{192}Ir levels and gamma-ray branches that was as correct as possible for use in our cross-section calculations.

We assembled a third level set for ^{192}Ir in which we took all of the levels that we had characterized from our analysis of the ARC data, levels having spins with J = 0-3, and combined them with the IBFF model levels having J equal to 4 and greater, up to level energies of about 0.5 MeV. This yielded a set of 73 levels, for which we generated gamma-ray branchings using the NUSTART code. As seen in Fig. 5, this ad hoc level set reproduced the experimental data[Bay+75, HMR85] for $^{192g+m1}$Ir production from the ^{193}Ir(n,2n) reaction to within about 10%. Also shown in Fig. 5 are the results when the 37-level and 150-level set for ^{192}Ir were used. The calculated production of the 241-y, 9^+ ^{192m2}Ir state using this 73-level set, along with the calculated production of the g+m1 states and the total (n,2n) cross sections are shown in Fig. 6 and the partial cross sections are tabulated in Table 3. We hope in the future to carry out more detailed calculations near the (n,2n) threshold. Our calculation of the ^{192m2}Ir cross sections at around E_n = 14 Mev appears to be an overestimate, when compared with preliminary measured values of about 0.1 barn[Nag88] but this is understandable from the results shown in Fig. 5. The measured value was obtained assuming a 241-y half-life and may include contributions from the neutron capture on ^{191}Ir.

4. DESTRUCTION CROSS-SECTION CALCULATIONS

In addition to information on the production cross sections for long-lived products, nuclear energy development studies also require knowledge about the subsequent destruction cross sections of these species. As mentioned earlier, we have developed a calculational capability to provide cross sections on unstable and isomeric targets for reactions induced not only by neutrons and charged-particles, but also by photons. Our modification of the STAPLUS code to accept photons in the entrance channel, together with our systematics for absolute gamma-ray strength functions allow us to compute cross sections for (γ,x) and (γ,γ') reactions. We have investigated photonuclear cross sections for ^{151,153}Eu and ^{156}Gd[GG92a], ^{176}Lu[GGH88], ^{210}Bi[GG88], and ^{236}Np and ^{237}Np[GG90]. We have also studied the destruction of the 36-y ^{150}Eu and the 13-y ^{152}Eu by photoexcitation to the short-lived, beta-decaying 0^- isomeric states with half-lives of 13 h and 9 h, respectively. Specifically, we found that incident photons in the 1-6 Mev range convert about 20% of the 36-y ^{150g}Eu, via the (γ,γ') reaction, to the 13-h isomer. Once made, the isomer is not readily destroyed by photons; it is converted back to the ground state by less than 10% . We have obtained similar results for the interconversion of the 13-y ground state of ^{152}Eu and its 9-h isomer via photoexcitation. This il-

lustrates how gamma radiation can play a role in nuclear waste disposal, particularly in nuclei with one or more isomeric states.

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Table 1: Calculated Cross Sections for the $^{151g}Eu(n,2n)^{150g,m}Eu$ Reaction

E_n(MeV)	σ to ^{150g}Eu(barns) (5^-, $t_{1/2}$=36 y)	σ to ^{150m}Eu(barns) (0^-, $t_{1/2}$=13 h)
8.05	0.0012	0.0008
8.25	0.0085	0.0074
8.45	0.0271	0.0275
8.65	0.0615	0.0619
8.9	0.109	0.106
9.1	0.168	0.158
10.1	0.508	0.397
11.1	0.803	0.532
12.1	1.012	0.607
13.1	1.161	0.650
14.1	1.260	0.681
15.1	1.311	0.707
15.3	1.315	0.705
15.5	1.315	0.700
16.1	1.278	0.664
16.9	1.143	0.584
17.9	0.890	0.493
18.9	0.660	0.418
19.9	0.472	0.367

Table 2: Calculated Cross Sections for the $^{153g}Eu(n,2n)^{152g,m}Eu$ Reaction [a]

E_n(MeV)	σ to ^{152g}Eu(barns) (3^-, $t_{1/2}$=13 y)	σ to ^{152m}Eu(barns) (0^-, $t_{1/2}$=9 h)
8.7	0.00136	0.0003
8.9	0.0125	0.0023
9.1	0.0457	0.0078
9.3	0.101	0.0166
9.5	0.171	0.0276
9.7	0.252	0.0402
9.9	0.338	0.0538
10.1	0.426	0.0675
10.9	0.768	0.125
11.9	1.109	0.192
12.9	1.354	0.248
13.9	1.522	0.293
15.0	1.621	0.326
15.8	1.658	0.346
16.0	1.654	0.348
16.2	1.642	0.349
17.0	1.515	0.339
18.0	1.253	0.302
19.0	0.983	0.255
20.0	0.766	0.208

[a] The 8- isomer population was allowed to decay equally to the 13-y, 3- ground state and the 0^- isomer because of recognized inadequacies of the application of the NUSTART code to deformed nuclei; see text for details.

Table 3: Calculated Cross Sections for the $^{193g}Ir(n,2n)^{192g+m1,m2}Ir$ Reaction

E_n(MeV)	σ to $^{192g+m1}$Ir(barns)	σ to ^{192m2}Ir(barns) (9^+, $t_{1/2}$=241 y)
8.1	0.0673	0.00093
10.1	1.471	0.112
12.1	1.810	0.208
13.9	1.841	0.265
15.9	1.659	0.297
17.9	1.103	0.244
19.9	0.732	0.153

Figure 1: Our calculated total ^{151g}Eu(n,2n)^{150}Eu cross sections compared with an ENDF evaluation[You86] and with experiment[Fre+80].

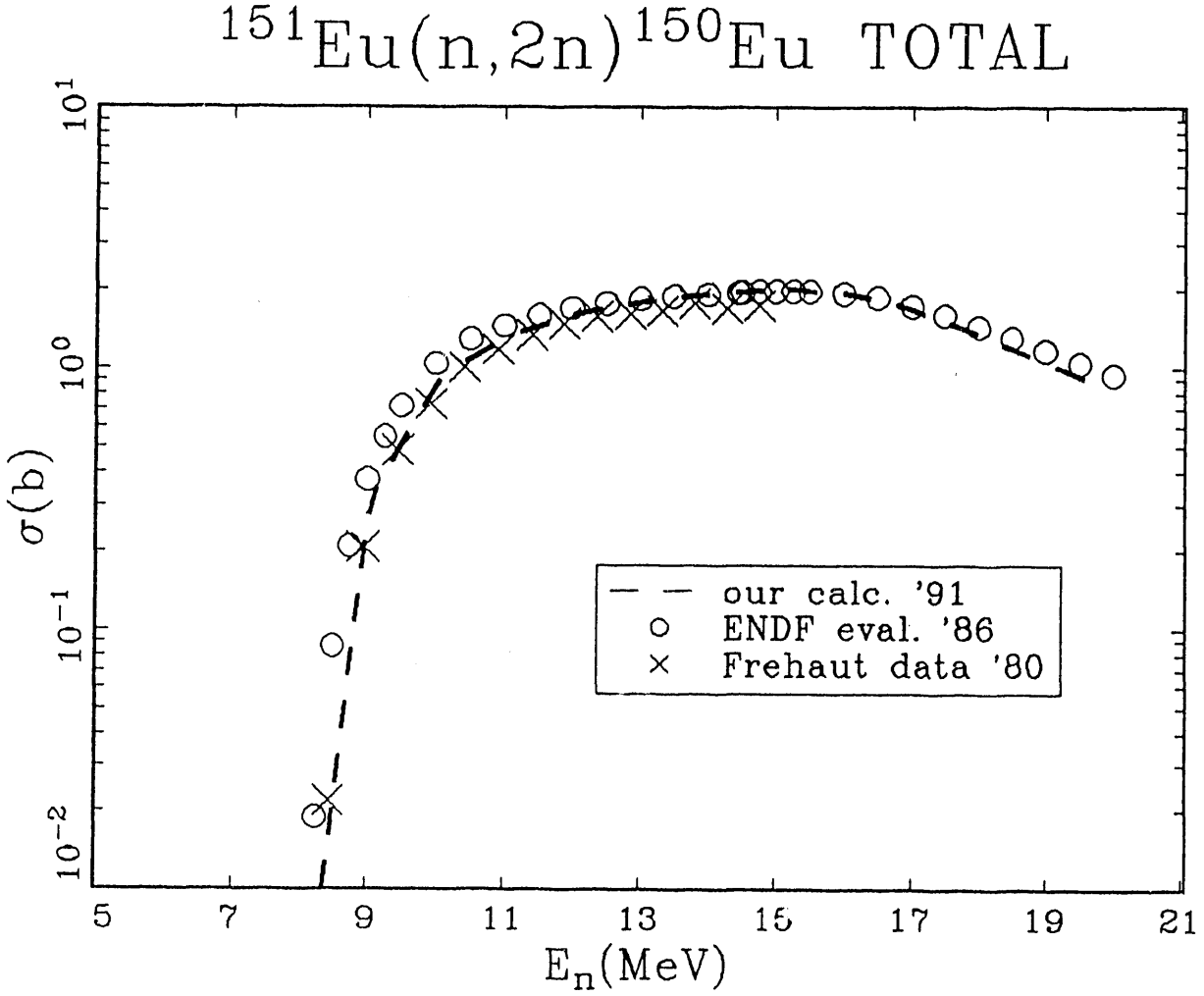


Figure 2: Our calculations compared with data[Bli+90, Han+90, IK90, MDR88, Net87]for **(a)** the reaction ^{153g}Eu(n,2n)^{152}Eu, where the data are squares for the long-lived, 3^- ground state, open circles for the 0^- isomer, and triangles for the 8^- isomer. Note that we have scaled down the experimental data, as well as the calculations, for production of the 8^- isomer by a factor of 10 for a clearer presentation. The solid line shows the calculational results when we used the experimental multipole branches among the levels in ^{152}Eu, while the dashed line shows the results when we used branches from NUSTART. **(b)** the reaction ^{151g}Eu(n,2n)^{150}Eu, where the data are squares for the long-lived , 5^- ground state, and open circles for the 0^- isomer. The solid lines now are the calculations using NUSTART branches.

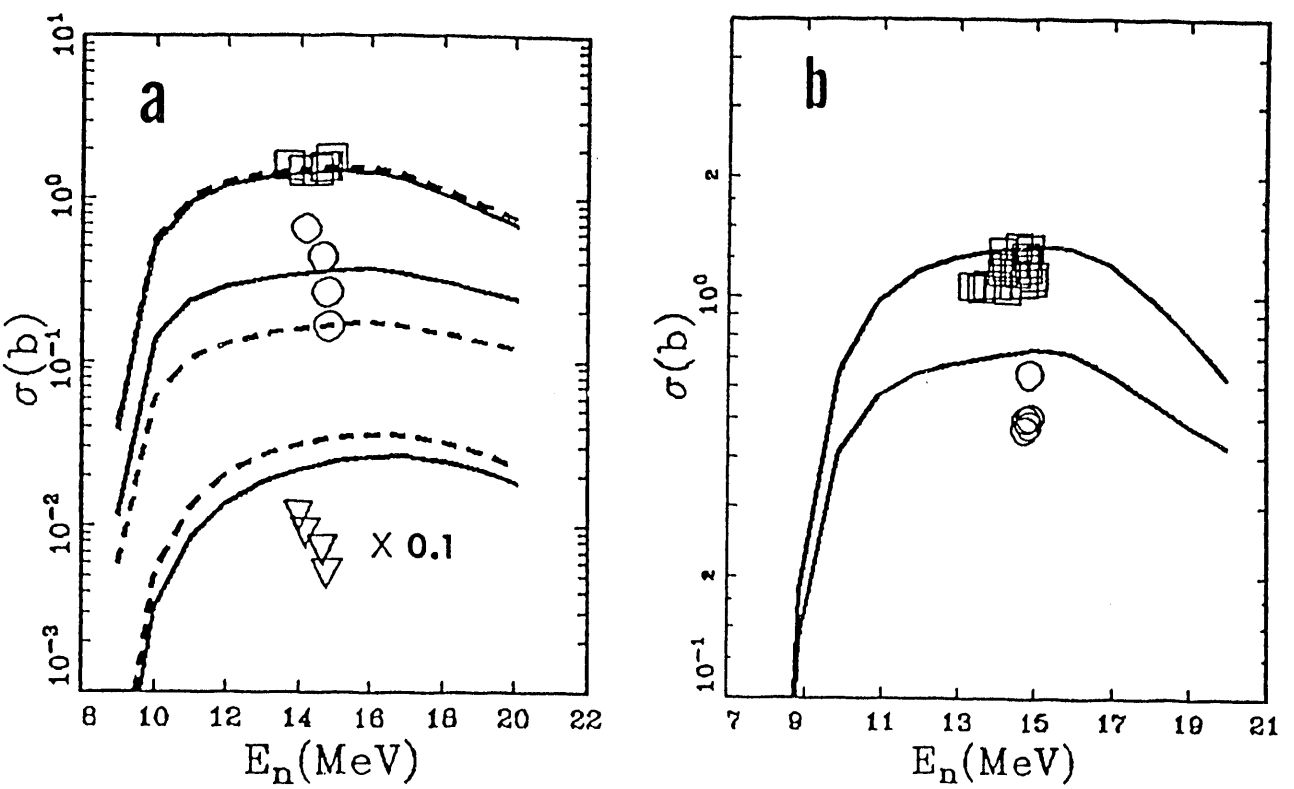


Figure 3: The calculated production of the 10.6-d ^{193m}Ir by the ^{193g}Ir(n,n') reaction, using three sets of discrete levels in ^{193}Ir, compared with a set of measurements indicated by the symbol: • [Bay+75].

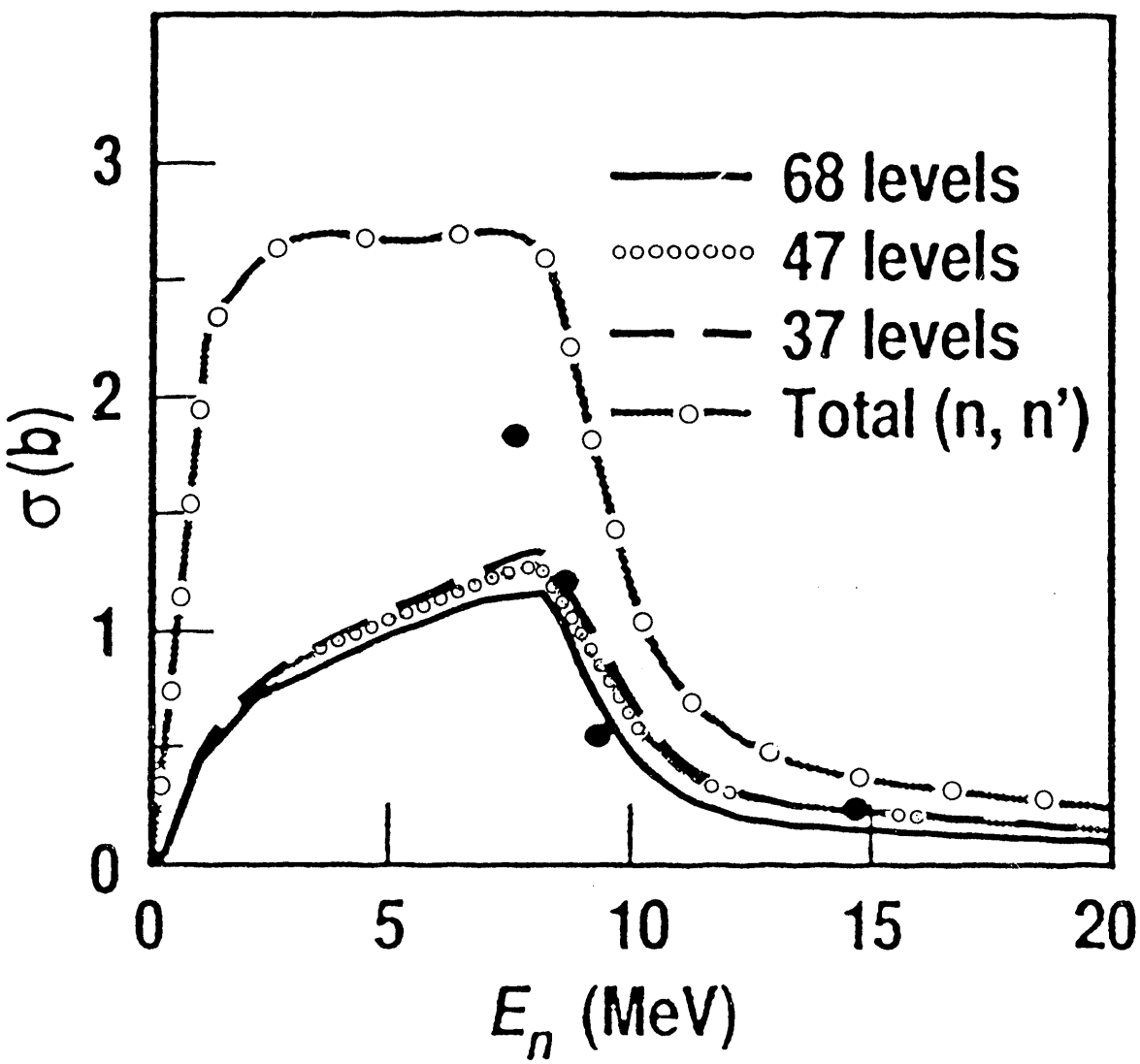


Figure 4: The calculated production of the 10.6-d ^{193m}Ir by the ^{193g}Ir(n,n') reaction, using the original spin cut-off parameter in the precompound modeling and the newly modified exciton-dependent spin cut-off parameter, compared again with the [Bay+75] set of measurements, indicated here with the symbol: ◊ .

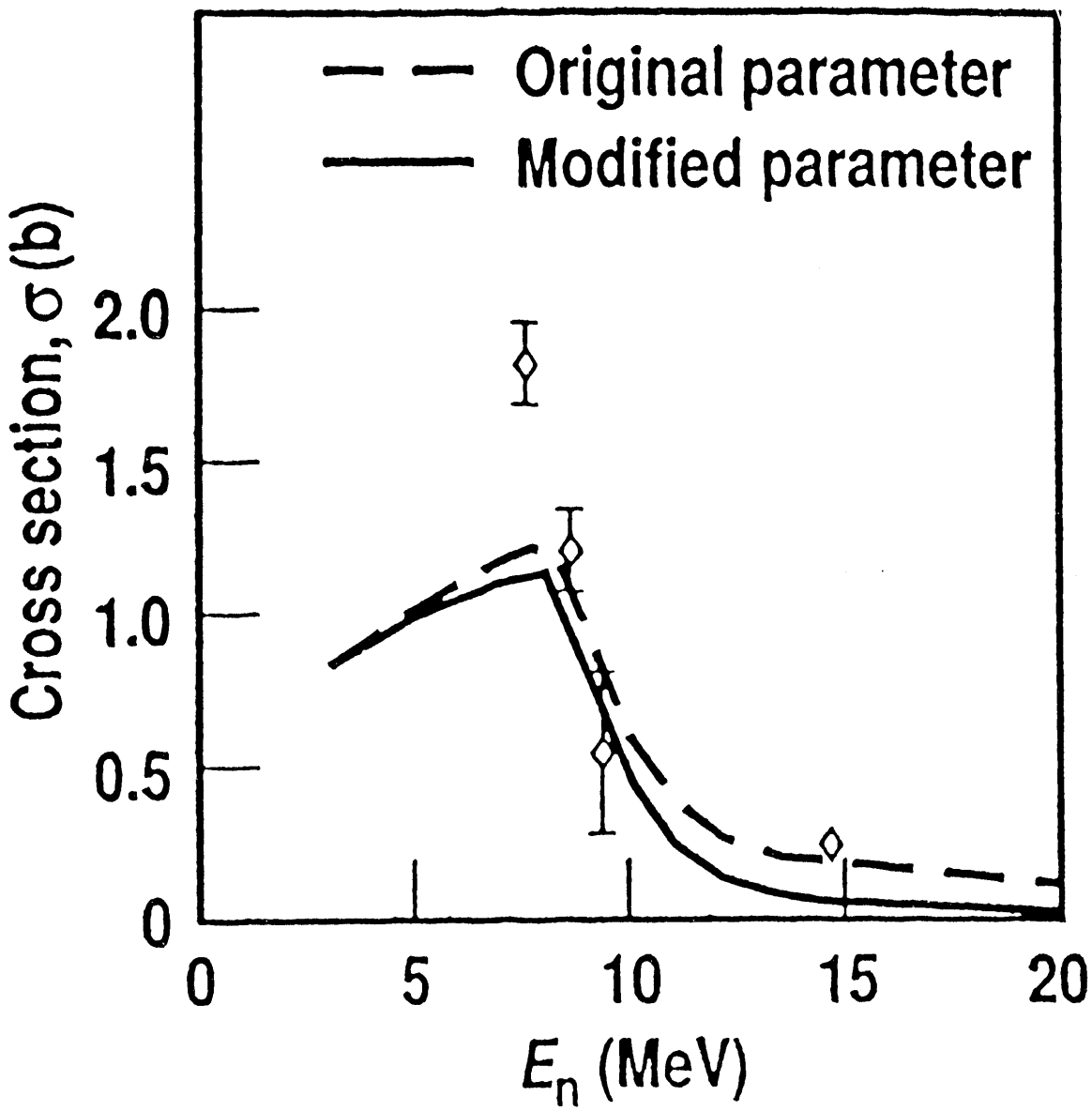


Figure 5: The calculated cross sections for the total ^{193g}Ir(n,2n)^{192}Ir reaction(solid curve) and for the ^{193g}Ir(n,2n) production of the sum of the ^{192}Ir ground state and first isomer(g+m1) using different discrete level sets and associated gamma-ray branchings for ^{192}Ir: 37-level set[Mey87], preliminary theoretical 150-level set with NUSTART-computed gamma-ray branches, and our deduced 73-level set. The calculations for the reaction ^{193g}Ir(n,2n)$^{192g+m1}$Ir are compared with the data of [Bay+75], indicated with the symbol: O, and with the data of [HMR85], indicated with the symbol: □.

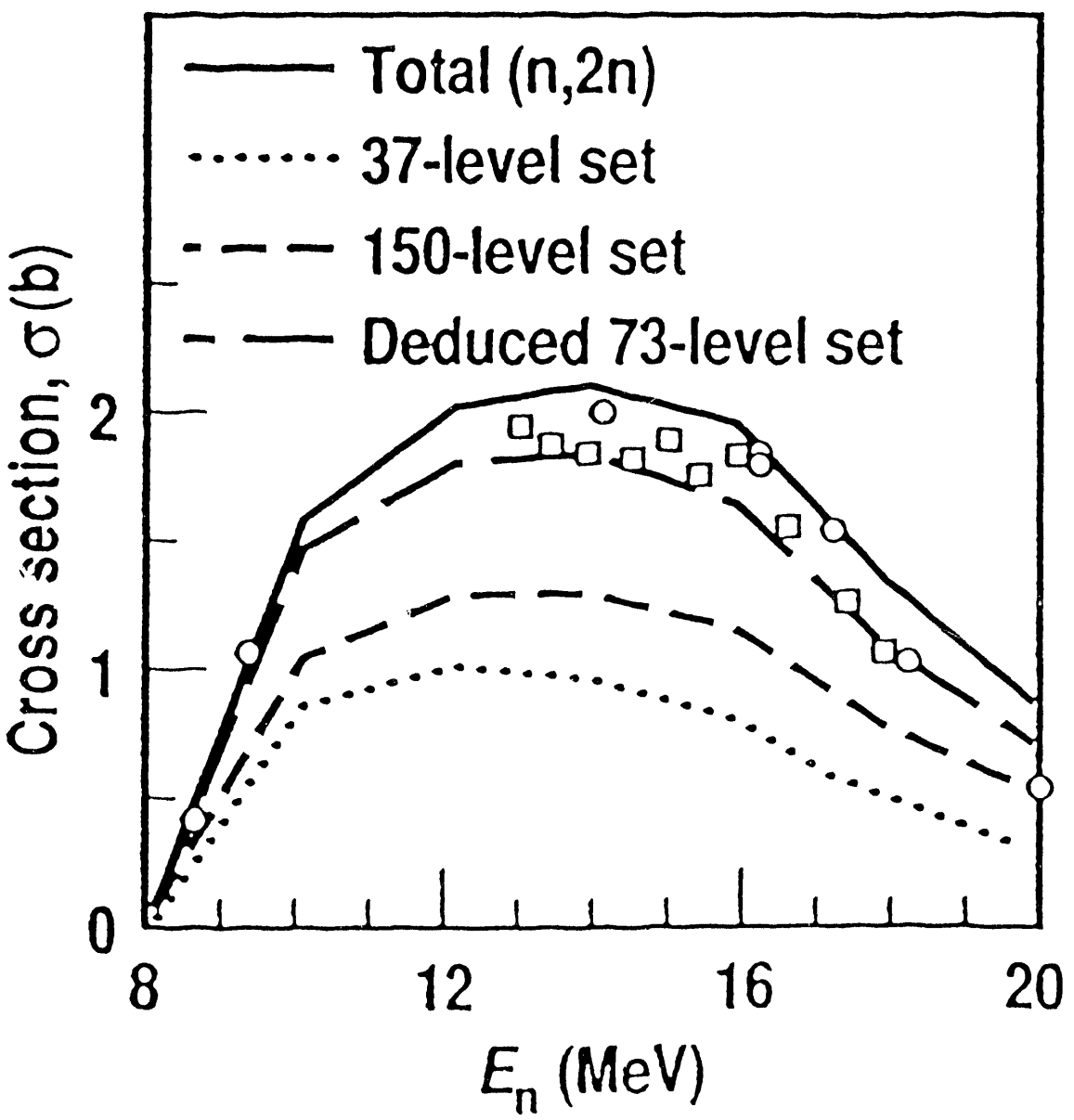
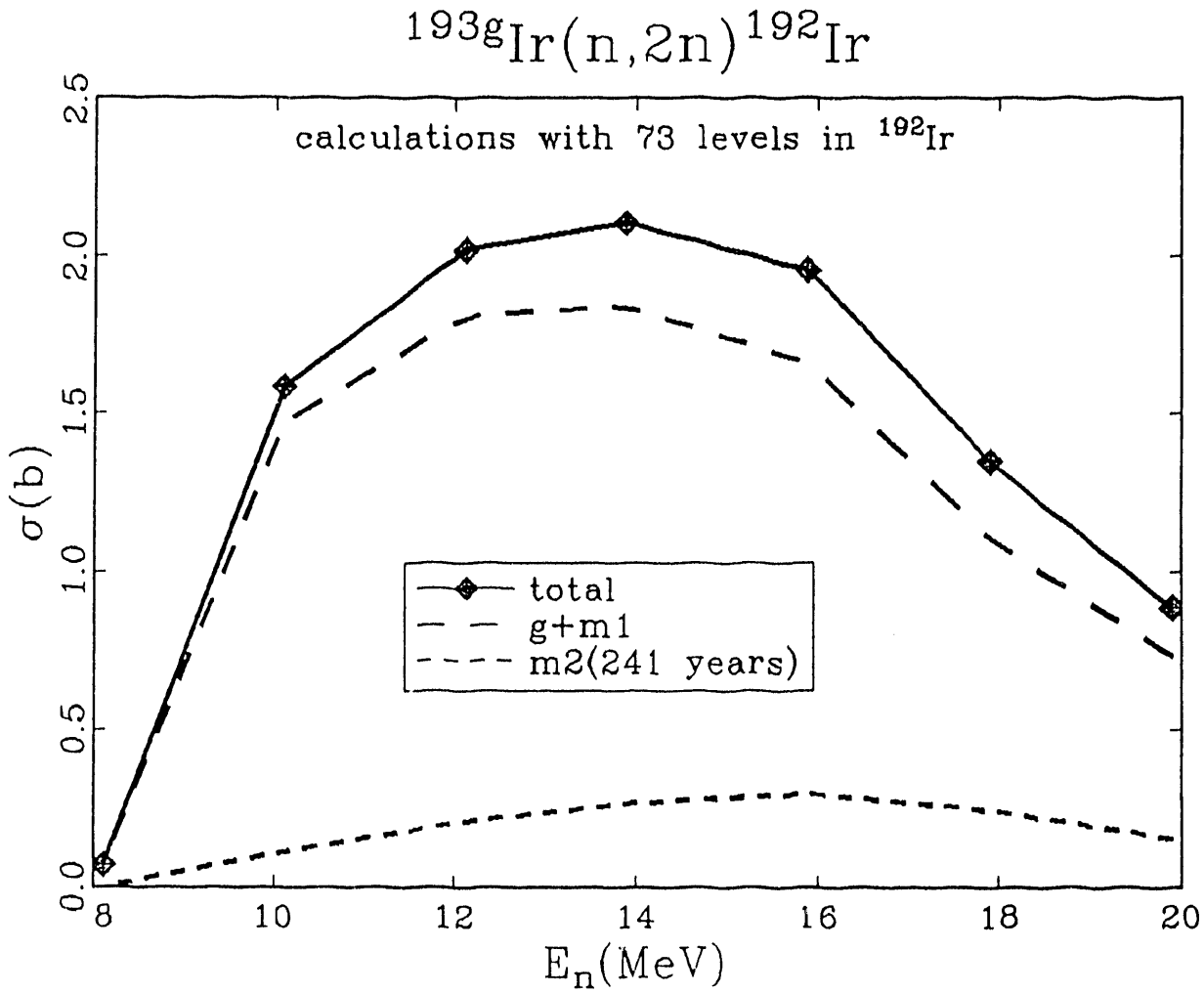


Figure 6: The calculated production of the 241-y, 9+ ^{192m2}Ir state using our deduced 73-level set, along with the calculated production of the g+m1 states and the total (n,2n) cross sections.



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