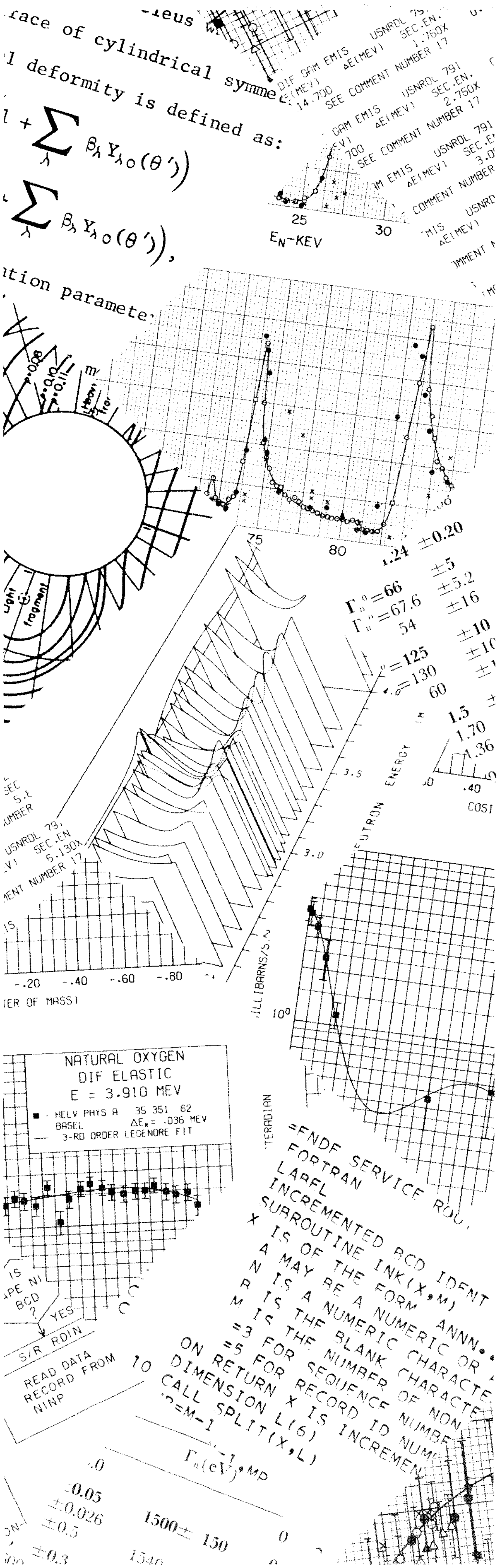

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EVALUATED NEUTRON CROSS SECTIONS FOR THE STABLE ISOTOPES OF XENON

M.R. Bhat
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This report describes an evaluation of the neutron cross section data for the nine stable isotopes of xenon. This evaluation has been presented to the Cross Section Evaluations Working Group for approval and inclusion in the ENDF/B Data File.

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1. INTRODUCTION

This report describes the evaluation of the neutron cross section data for the 9 stable isotopes of xenon. The main purpose of the evaluation is to provide data for these isotopes in connection with their use in the xenon-tag technique described by Henault et al.[1,2] The neutron capture cross section of the xenon isotopes is of main interest for such applications. However, a complete evaluation was done for all the currently available neutron cross section data covering the energy range from 1.0 x 10^{-5} eV to 20 MeV. It is hoped that such an evaluation will be of interest in calculations involving fission product burn-up and also astrophysical applications. All the experimental data available up to Feburary 1972 has been used in this evaluation and was supplemented by nuclear model calculations

2. PROPERTIES OF THE STABLE ISOTOPES OF XENON

2.1 Possible Neutron Induced Reactions

Xenon has nine stable isotopes from mass number 124 to 136. These are given in Table 1 along with their isotopic mass (based on the C12 scale) and their natural abundance. Xenon has a nuclear charge of 54 and the number of neutrons varies from 70 to 82. As will be seen later, the closure of a major shell for the 82 neutrons in ^{136}Xe results in its markedly low capture cross section.

Nuclear reactions that can be initiated by neutrons of energy up to 20 MeV interacting with these isotopes and having an appreciable cross section are given in Table 2 along with their Q values. These were obtained using the mass values of Wapstra and Gove[3] as are the masses given in Table 1.

2.2 Energy Levels of the Xenon Isotopes

It is essential to have a knowledge of the energy levels of the xenon isotopes along with their spins and parities in order to carry out nuclear model calculations. Such data can be obtained from the different studies in nuclear spectroscopy carried out by a variety of techniques. Table 3 summarizes some of the pertinent references along with the year of publication and the type of reactions studied. In addition, the compilations of such data by Lederer et al.[6] and by Horen[7] have been particularly useful. Data on the level energies, spins, and parities obtained from these experiments and used in the present evaluation are shown in Figures 1 - 9. It should be pointed out here that although some of the reaction studies (e.g., the (α,2n)) do populate discrete levels of high spins at high excitation energies, these discrete levels have not been used in nuclear model calculations. They were not included explicitly since it is obvious that at these high excitation energies there is a large continuum of unresolved levels not populated by the particular reaction under consideration. Rather, in such cases, these levels have been replaced with a continuous distribution of levels.

3. NEUTRON CROSS SECTIONS

3.1 Low Energy Cross Sections: Thermal Cross Sections

There have been a number of measurements of the scattering and capture cross sections of xenon or the separated isotopes at thermal neutron energies. Scattering cross sections have been measured by Harris,[22] Crouch et al.,[23] Genin et al.[24] and Krohn and Ringo.[25] Of these, the 4.3±0.02 b from the measurements of Krohn and Ringo was selected as the best value for the scattering cross section of xenon.

Data on the capture cross sections of the individual xenon isotopes at thermal energies are summarized in Table 4. In the last column are given the recommended values for the thermal capture cross sections used in the present evaluations.

For ^{124}Xe, the recommended value is the error-weighted mean of 111± 11 b by Beresesti et al.[26] and 144±11 b as reported by Kondaiah et al.[27] Though the difference between these two values is 3 times the quoted error, the mean of these two values was taken since the experimental technique used seemed to be equally good. Though the measurements of Tobin and Sako,[28] Eastwood and Brown,[29] and Winn[30] are given in Table 4, they were not taken into consideration in recommending the final value, since it was felt that the data of Beresesti et al. and Kondaiah et al. were better.

Again, an error-weighted mean calculation was done on the 2.2± 0.22 b obtained by Bresesti et al.[31] and the 4.27±0.60 b measured by Kondaiah et al.[27] to obtain the recommended 2.4±0.4 b for the thermal capture cross section of ^{126}Xe. The measurement of Winter et al.[32] is considered to be too low to merit consideration.

The problem with ^{128}Xe is that there are measurements of the cross section to the metastable state only. These were done by Kondaiah et al.[27] and Tilbury and Kramer;[33] the mean value of their measurements is 0.36 b. It is noted that the spin sequence of the low-lying levels in ^{127}Xe, viz: $\frac{11}{2}$ -, $\frac{3}{2}$ +, $\frac{1}{2}$ + (the $\frac{5}{2}$ + level is doubtful), is the same as that in ^{129}Xe. Hence, it is assumed that the ratio of the cross sections to the ground and metastable states is the same in $^{128}Xe(n,\gamma)^{129}Xe$ reaction as it is in the $^{126}Xe(n,\gamma)^{127}Xe$ reaction. In the latter case the ratio is known to be 8.82 from Kondaiah's measurements. With this assumption and the mean value of $\sigma^{(m)} = 0.36$ b for ^{128}Xe, the total capture cross section is calculated to be 3.5 b.

There are only two measurements of the thermal capture cross section for ^{129}Xe. The present recommended value of 18 b is slightly lower than the 21±7 b measured by Eastwood and Brown.[29] This lower value was arrived at by noting that their measurements were made in a reactor spectrum with contributions to the capture from epithermal neutrons; hence, their quoted value was decreased by about half their quoted error.

In the case of ^{130}Xe there are two measurements of the capture cross section to the metastable state only and none for the total capture cross section. Hence, a method similar to that used to arrive at the capture cross section of ^{128}Xe was adopted. It is noted that in ^{131}Xe the ground state has a spin of $\frac{3}{2}$ with a metastable state of $\frac{11}{2}$ - and the same is true of ^{133}Xe. Hence, it is assumed that the ratio of the cross sections to the metastable and ground states is the same in these two nuclei. By taking a value of 13.83 for this ratio from the measurements of Kondaiah,[27] and taking the mean value of $\sigma^{(m)} = 0.417$ b for ^{130}Xe, the total cross section is calculated to be 6.2 b. The measurements of Tilbury and Kramer[33] for ^{132}Xe have not been taken into consideration as their $\sigma^{(m)}/\sigma^{(g)}$ ratio is at variance from the trend shown by the data of Eastwood and Brown[29] and by Kondaiah.

In the case of ^{131}Xe the recommendedation is 90 b for the thermal cross section; this value is lower than the measurements of MacNamara and

Thode[34] and Eastwood and Brown.[29] Their quoted value was lowered since their measurements were made in a reactor spectrum with consequent epithermal neutron contributions and 90 b was chosen so that the absorption cross section of natural xenon could come to 24.5 b.[35]

The thermal capture cross section of ^{132}Xe is assigned a value of 0.45 from Kondaiah's[27] measurements.

For ^{134}Xe the mean of the data of Eastwood and Brown[29] and Kondaiah[27] is calculated to be 0.250 b.

Similarly for ^{136}Xe the error-weighted mean of the measurements of Bresesti[26] and Kondaiah[27] is calculated to be 0.16 b.

For the thermal absorption cross section of natural xenon, the present recommended value of 24.5 b compares well with the value of 25.1±1.0 b measured by Krohn and Ringo.[25]

3.2 Epithermal Cross Sections

In this subsection measurements of the resonance parameters of the xenon isotopes and the values of the absorption resonance integrals are discussed.

These measurements are due to Mann et al.[36] and Ribon.[37] These workers used samples of different enrichment in the various isotopes and could assign some resonances to specific isotopes. Ribon's measurements are the most extensive and the resonance parameters used in this evaluation are based on his measurements and isotopic assignments. Since the radiative widths of a few of the lowest resonances can be estimated reliably, the mean of their widths was assigned to the rest of the resonances in each isotope. In general, the gamma width is about 100 meV which is in agreement with the systematics of gamma widths in this mass region. Ribon's data was analysed by shape analysis and he obtained a value of 5.8±0.4 fm for the effective scattering radius. This agrees with other measurements[25] and is taken as the effective scattering radius in this evaluation.

The resonance parameters used in this evaluation are given in Tables 5 - 12 for the xenon isotopes 124 - 134. No resonances have been assigned to the closed neutron shell isotope ^{136}Xe.

From Table 5 it is noted that the neutron width of the 5.16 eV resonance of ^{124}Xe is 18.4 meV which is much larger than the 7.6±0.8 meV value measured by Mann et al.[36] There are good reasons for assigning such a large value of the neutron width. ^{124}Xe has a large thermal capture cross section of 128 barns, and also a large resonance capture integral of 3600±500 b as measured by Bresesti et al.[31] For the capture integral, Eastwood and Brown[29] measured 2690 b in the core and 2100 b in the reflector for their experiment. The value quoted by Bresesti may be high but the fact seems to be that the resonance integral for ^{124}Xe is of the order of 2500 b. In order to satisfy both these conditions the neutron width of the 5.16 eV resonance was increased to give a thermal capture cross section of 128 b. It may be that there are very low energy resonances in ^{124}Xe which could account for both these experimental facts. Unfortunately, the measurements of Mann et al. went only as low as 1 eV. Hence, there is need for further low energy measurements on ^{124}Xe to try to locate these low energy resonances. With the neutron width of 18.4 meV for the 5.16 eV resonance and .266 eV for the 251.6 eV resonance, a calculation of the capture cross section, by pointwise integration, produces an absorption integral of 2482 b. This is lower than Bresesti's value and lies in between the two measurements of Eastwood and Brown. It is thought that Bresesti's value is definitely on the high side.

The measured resonance absorption integral of ^{126}Xe is 38.0±3.8 b and from the resonance parameters in this evaluation a value of only 12.7 b is calculated. It may be that this experimental value by Bresesti is too high; or it may be that there are low energy resonances in ^{126}Xe as yet unassigned. Instead of postulating new resonances to account for the resonance integral, the difference is duly noted and should be resolved by future measurements.

For the other xenon isotopes, all the resonances identified by Ribon have been included.

Using the parameters for each isotope, the 2200m/sec thermal capture cross section was calculated, and the difference between this value and the recommended value in Table 4 was added as a 1/v background in File 3 of the ENDF/B evaluation.

3.3 High Energy Cross Sections: Total Cross Section

The total cross section of natural xenon has been measured by Vaughn et al.(38) from 0.1 - 6.25 MeV and from 12 - 20 MeV. This data is useful in deciding on a set of optical model parameters for the nuclear model calculations. The optical model parameters used were those of Wilmore and Hodgson(39) with $r_o = 1.26$. These parameters are shown in Table 13. With these parameters, the total cross section of a nucleus having the mass of natural xenon was calculated using the code ABACUS-2.(49) The results are shown in Figs. 10 and 11 along with the experimental data. There is a reasonable agreement between the calculated values and the experimental data though there is a large discrepancy at about 1.0 MeV. However, it was decided to adopt these parameters for the model calculations since they have given good agreement with more extensive experimental data in this mass region in the case of other nuclei.(40) For each of the xenon isotopes, the total cross sections in the MeV region were calculated using ABACUS-2.

3.4 High Energy Cross Sections: Capture Cross Sections

Since there are no extensive data on the capture cross sections of the individual xenon isotopes, nuclear model calculations were primarily used. These calculations were done using the code CØMMNUC by C. Dunford.[41] The data on the excited states of the xenon isotopes used in these calculations have been referred to earlier and are shown in Figures 1 - 9.

The other input data required by this program is $2\pi \Gamma_\gamma/\langle D\rangle$ where Γ_γ and $\langle D\rangle$ are the capture width and level spacing respectively, and are usually determined from the resonance data. The mean spacing $\langle D\rangle$ is known with some reliability for ^{129}Xe and ^{131}Xe from the data of Ribon.[37] As for the other isotopes, since the number of assigned resonances is small it was decided to estimate $\langle D\rangle$ from nuclear model calculations. The procedure for these calculations is described by Benzi[42] who has also given estimated capture widths which are found to be of the order of 100 meV in agreement with experimental data. The parameters $2\pi \Gamma_\gamma/\langle D\rangle$ used in the nuclear model calculations as well as the neutron binding energies are given in Table 14.

Since there is no experimental data on the capture cross section of these isotopes around 14.5 MeV, an estimate of the contribution of direct capture to the capture cross section could not be made. Therefore, this has been omitted in the evaluation.

It is interesting to note that ^{136}Xe with a closed neutron shell has a low capture cross section and the calculated value of 1.8 mb at 1 MeV is in reasonable agreement with a value of 1 mb as measured by Hughes et al.[43] However, it is desirable to have more capture measurements on the individual xenon isotopes to check and correct the model calculations. The integral measurements on the capture cross sections of some of the xenon isotopes by Harker[44] should be available soon, and the present evaluation will be modified to agree with his measurements.

3.5 Inelastic and Differential Elastic Scattering

These were calculated using CØMMNUC and ABACUS-2. The calculated cross sections for total elastic scattering were fitted to a number of Legendre polynomials using the code CHAD[45] to obtain the corresponding coefficients of a Legendre fit.

3.6 (N, Particle) Reactions

The data on the (n, particle) reaction cross sections by Kondaiah et al.[46] is summarised in Table 15. The Q values of these reactions are given in Table 2. Since the experimental data are available for only one energy (14.4 MeV), the general shape of the reaction was calculated using the code FASCRØ[47] based on a statistical model of nuclear reactions. The calculated values were then normalized to the experimental values at 14.4 MeV. The difference between the calculated and the experimental values was from 20 - 30%. For some of the xenon isotopes (e.g., ^{130}Xe or ^{132}Xe), where the only available experimental data corresponds to transitions to the metastable state, it was decided to use the calculated values. The same is true of the cross sections for other (n, particle) reactions where there were no experimental data available. The experimental (n, particle) cross sections, when available, were used to normalize the calculated cross sections.

3.7 Energy Distribution of the Secondary Neutrons

Energy distributions of secondary neutrons originating from (n,2n), (n,3n), and inelastic scattering to the continuum of levels were also calculated. These energy distributions are expressed as normalized probability distributions. This distribution has been specified as an evaporation spectrum of the type

$$f(E \rightarrow E') = \frac{E'}{I} e^{-E'/\theta}$$

where I is the normalization constant. The nuclear temperature θ was calculated as a function of neutron energy using the nuclear level density formulation of Gilbert and Cameron.[48]

4. EVALUATED CROSS SECTIONS

In this report we have also reproduced curves of the evaluated cross sections for ^{124}Xe in Figures 12-30 as being typical of the xenon isotopes. Data for the other xenon isotopes show similar behavior. These curves indicate general trends of the cross sections and were plotted from the evaluated data files using a CALCØMP plotter. In these plots the squares do not indicate experimental points. They are the data points given in the data files and connected by straight lines.

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TABLE 1

Properties of the Stable Xenon Isotopes

Isotope	Fractional Abundance	Isotopic Mass
Xe-124	0.00096	123.90612
Xe-126	0.00090	125.90428
Xe-128	0.01920	127.90353
Xe-129	0.26440	128.90478
Xe-130	0.04080	129.90351
Xe-131	0.21180	130.90508
Xe-132	0.26890	131.90416
Xe-134	0.10440	133.90540
Xe-136	0.08870	135.90722

TABLE 2

Nuclear Reactions and Their Q Values

Isotope	Q-Values (MeV)							
	(n,γ)	(n,2n)	(n,3n)	(n,p)	(n,d)	(n,t)	(n,He^3)	(n,α)
Xe-124	7.7643	-10.230	-18.530	0.6865	-4.5554	-8.160	- 4.002	6.788
Xe-126	7.2249	-10.090	-17.860	-0.4685	-5.3504	-8.689	- 5.511	5.643
Xe-128	6.9057	- 9.614	-16.839	-1.3424	-5.9432	-8.825	- 6.656	4.814
Xe-129	9.2549[a]	- 6.905	-16.520	0.5915	-6.0234	-6.591	- 7.265	7.018
Xe-130	6.6056	- 9.258	-16.1634	-2.2097	-6.4414	-9.0237	- 7.752	4.055
Xe-131	8.9363[b]	- 6.6056	-15.864	-0.1884	-6.5904	-6.789	- 8.271	6.221
Xe-132	6.4535	- 8.9361	-15.5416	-2.7975	-6.8998	-9.269	- 8.793	3.372
Xe-134	6.4518	- 8.535	-14.988	-3.3646	-7.3254	-9.303	- 9.790	2.715
Xe-136	3.8613	- 7.992	-14.443	-6.2206	-7.7114	-9.330	-10.712	2.128

[a]See Reference 4.

[b]See Reference 5.

TABLE 3

References for the Energy Level Data of the Xe Isotopes

Isotope	References	Reaction
Xe-124	Ref. 8. I. Bergstrom, et al., 1969	Te(α,2n)
Xe-126	Ref. 8. I. Bergstrom, et al., 1969	Te(α,2n)
	Ref. 9. M. G. Betigeri, et al., 1967	Te(^{3}He,3nγ)
Xe-128	Ref. 8. I. Bergstrom, et al., 1969	Te(α,2n)
	Ref. 10. G. M. Julian, et al., 1967	Decay of ^{128}I and ^{128}Cs
	Ref. 9. M. G. Betigeri, et al., 1967	Te(^{3}He,3nγ)
Xe-129	Ref. 11. I. Rezanka, et al., 1970	Te(α,3n)
	Ref. 12. G. Graeffe, et al., 1967	Decay of ^{129}Cs
Xe-130	Ref. 13. S. M. Qaim, 1970	Decay of ^{130}I
	Ref. 8. I. Bergstrom, et al., 1969	Te(α,2n)
	Ref. 14. T. E. Fessler, et al., 1968	Decay of ^{130}I and ^{130}Cs
	Ref. 9. M. G. Betigeri, et al., 1967	Te(^{3}He,3nγ)
	Ref. 15. C. Kellershohn	Decay of ^{130}I
Xe-131	Ref. 16. A. Kerek, et al., 1971	^{130}Te(α,2nγ), (α,3nγ)
	Ref. 12. G. Graeffe, et al.	Decay of ^{131}I
Xe-132	Ref. 16. A. Kerek, et al., 1971	^{130}Te(α,2nγ), (α,3nγ)
	Ref. 13. S. M. Qaim, 1970	Decay of ^{132}Cs
	Ref. 17. J. H. Hamilton, et al., 1970	Decay of ^{132}I
	Ref. 8. I. Bergstrom	Te(α,2n)
Xe-134	Ref. 18. E. Takekoshi, et al., 1969	Decay of ^{134}I
	Ref. 19. W. G. Winn, et al., 1969	Decay of ^{134}I
Xe-136	Ref. 20. L. C. Carraz, et al., 1971	Decay of ^{136}I
	Ref. 21. P. A. Moore, et al., 1970	(p,p') on ^{136}Xe

TABLE 4

Experimental Data on Thermal Capture Cross Sections and Resonance Integrals

Isotope	MacNamara & Thode '50	Tobin & Sako '58	Eastwood & Brown '63	Bresesti '64	Winter et al., '65	Tilbury & Kramer '67	Winn '68	Kondaiah et al., '68	This Evaluation
Xe-124		74.4 b	94±10 b	111±11 b R.I = 3600±500 b			σ^m = 18 ±4 b	144 ±11 b σ^m = 23.6 ±2.5 b	128 ±15
Xe-126			≈ 2 b	2.2±0.22 b R.I = 38.0±3.8 b	0.7±0.4 b		σ^m = 0.23±0.07 b	4.27 ±0.60 b σ^m = 0.435±0.14 b	2.4±0.4
Xe-128	< 5 b		< 8 b			σ^m = 0.43±0.10 b		σ^m = 0.29 ±0.12 b	3.5
Xe-129	45±15 b		21^{+7}_{-6} b						18 ±7
Xe-130	< 5 b		< 26 b			σ^m = 0.34±0.08 b		σ^m = 0.495±0.17 b	6.2
Xe-131	120±15 b		130^{+11}_{-5} b						90
Xe-132			σ^m = 0.022± .002 b σ^g = 0.250±0.025 b			σ^m = 0.53±0.10 b σ^g = 0.05±0.02 b		σ^m = 0.030± .005 b σ^g = 0.415± .045 b	0.45
Xe-134	< 5 b		0.228±0.020 b					0.265± .020 b σ^m = 0.003± .0003 b	0.250
Xe-136	< 5 b		< 1 b	0.281±0.028 b				0.130± .015 b	0.16

TABLE 5

Resolved Resonance Parameters for Xe-124

E_R	J	Γ	Γ_n	Γ_γ
5.16000+ 0	5.00000- 1	1.18415- 1	1.84149- 2	1.00000- 1
2.51600+ 2	5.00000- 1	3.66000- 1	2.66000- 1	1.00000- 1

TABLE 6

Resolved Resonance Parameters for Xe-126

E_R	J	Γ	Γ_n	Γ_γ
4.59640+ 2	5.00000- 1	1.01300- 1	1.30000- 3	1.00000- 1

TABLE 7

Resolved Resonance Parameters for Xe-128

E_R	J	Γ	Γ_n	Γ_γ
2.37690+ 2	5.00000- 1	4.20000- 1	3.20000- 1	1.00000- 1
3.70780+ 2	5.00000- 1	1.45600- 1	4.56000- 2	1.00000- 1
5.54540+ 2	5.00000- 1	2.51000- 1	1.51000- 1	1.00000- 1
7.16040+ 2	5.00000- 1	3.69500+ 0	3.59500+ 0	1.00000- 1
1.36500+ 3	5.00000- 1	2.67000- 1	1.67000- 1	1.00000- 1
1.40840+ 3	5.00000- 1	2.64000- 1	1.64000- 1	1.00000- 1
1.60990+ 3	5.00000- 1	4.91000- 1	3.91000- 1	1.00000- 1
2.75580+ 3	5.00000- 1	1.09000+ 0	9.90000- 1	1.00000- 1
3.44130+ 3	5.00000- 1	2.47000+ 0	2.37000+ 0	1.00000- 1

TABLE 8

Resolved Resonance Parameters for Xe-129

E_R	J	Γ	Γ_n	Γ_γ
9.44000+ 0	1.00000+ 0	1.20000- 1	6.00000- 3	1.14000- 1
9.05300+ 1	5.00000- 1	1.39800- 1	4.80000- 3	1.35000- 1
9.23000+ 1	1.00000+ 0	2.02300- 1	8.33000- 2	1.19000- 1
1.25840+ 2	0.00000+ 0	4.13000- 1	3.22000- 1	9.10000- 2
1.62810+ 2	1.00000+ 0	2.00700- 1	6.67000- 2	1.34000- 1
1.85680+ 2	1.00000+ 0	2.14700- 1	7.67000- 2	1.38000- 1
2.28140+ 2	1.00000+ 0	1.66900- 1	4.49000- 2	1.22000- 1
2.44480+ 2	5.00000- 1	1.54200- 1	3.22000- 2	1.22000- 1
3.41520+ 2	5.00000- 1	1.27400- 1	5.40000- 3	1.22000- 1
3.74740+ 2	1.00000+ 0	2.14700- 1	9.27000- 2	1.22000- 1
3.79290+ 2	5.00000- 1	1.27700- 1	5.70000- 3	1.22000- 1
4.32230+ 2	1.00000+ 0	2.72000- 1	1.50000- 1	1.22000- 1
4.62610+ 2	1.00000+ 0	3.24700- 1	2.02700- 1	1.22000- 1
5.08620+ 2	0.00000+ 0	2.60400- 1	1.38400- 1	1.22000- 1
5.80820+ 2	1.00000+ 0	6.41300- 1	5.19300- 1	1.22000- 1
5.85030+ 2	0.00000+ 0	8.56000- 1	7.34000- 1	1.22000- 1
6.05070+ 2	1.00000+ 0	1.97300- 1	7.53000- 2	1.22000- 1
6.36800+ 2	1.00000+ 0	4.87300- 1	3.65300- 1	1.22000- 1
7.59910+ 2	5.00000- 1	1.39800- 1	1.78000- 2	1.22000- 1
7.77310+ 2	5.00000- 1	1.46000- 1	2.40000- 2	1.22000- 1
7.98870+ 2	1.00000+ 0	4.74700- 1	3.52700- 1	1.22000- 1
8.85100+ 2	5.00000- 1	1.53400- 1	3.14000- 2	1.22000- 1
9.08630+ 2	0.00000+ 0	1.34600+ 0	1.22400+ 0	1.22000- 1
9.20170+ 2	5.00000- 1	1.44000- 1	2.20000- 2	1.22000- 1
9.33140+ 2	1.00000+ 0	2.28000- 1	1.06000- 1	1.22000- 1
9.66760+ 2	5.00000- 1	1.61000- 1	3.90000- 2	1.22000- 1
1.02890+ 3	5.00000- 1	1.62000- 1	4.00000- 2	1.22000- 1
1.05350+ 3	1.00000+ 0	3.37300- 1	2.15300- 1	1.22000- 1
1.13610+ 3	5.00000- 1	2.85000- 1	1.63000- 1	1.22000- 1
1.18600+ 3	1.00000+ 0	7.39300- 1	6.17300- 1	1.22000- 1
1.19900+ 3	1.00000+ 0	3.70000- 1	2.48000- 1	1.22000- 1
1.23420+ 3	5.00000- 1	2.28000- 1	1.06000- 1	1.22000- 1
1.29610+ 3	0.00000+ 0	4.78000- 1	3.56000- 1	1.22000- 1
1.35530+ 3	1.00000+ 0	4.87300- 1	3.65300- 1	1.22000- 1
1.41370+ 3	5.00000- 1	2.32000- 1	1.10000- 1	1.22000- 1
1.48960+ 3	5.00000- 1	2.51000- 1	1.29000- 1	1.22000- 1
1.50520+ 3	0.00000+ 0	6.82000- 1	5.60000- 1	1.22000- 1
1.62280+ 3	5.00000- 1	2.83000- 1	1.61000- 1	1.22000- 1
1.65100+ 3	5.00000- 1	3.26000- 1	2.04000- 1	1.22000- 1
1.66440+ 3	5.00000- 1	4.82000- 1	3.60000- 1	1.22000- 1
1.71480+ 3	1.00000+ 0	2.00000- 1	7.80000- 2	1.22000- 1
1.73420+ 3	1.00000+ 0	3.51300- 1	2.29300- 1	1.22000- 1
1.78660+ 3	5.00000- 1	3.41000- 1	2.19000- 1	1.22000- 1
1.81420+ 3	1.00000+ 0	6.89300- 1	5.67300- 1	1.22000- 1

TABLE 8 (Continued)

Resolved Resonance Parameters for Xe-129

E_R	J	Γ	Γ_n	Γ_γ
1.90730+ 3	0.00000+ 0	1.03000+ 0	9.08000- 1	1.22000- 1
1.92140+ 3	1.00000+ 0	4.77300- 1	3.55300- 1	1.22000- 1
2.01380+ 3	1.00000+ 0	4.70000- 1	3.48000- 1	1.22000- 1
2.03780+ 3	1.00000+ 0	5.25300- 1	4.03300- 1	1.22000- 1
2.09070+ 3	1.00000+ 0	7.39300- 1	6.17300- 1	1.22000- 1
2.27450+ 3	5.00000- 1	5.04000- 1	3.82000- 1	1.22000- 1
2.30590+ 3	5.00000- 1	3.94000- 1	2.72000- 1	1.22000- 1
2.34640+ 3	5.00000- 1	4.55000- 1	3.33000- 1	1.22000- 1
2.41080+ 3	5.00000- 1	2.81000- 1	1.59000- 1	1.22000- 1
2.43760+ 3	5.00000- 1	5.34000- 1	4.12000- 1	1.22000- 1
2.46830+ 3	1.00000+ 0	5.58000- 1	4.36000- 1	1.22000- 1
2.56590+ 3	1.00000+ 0	3.70200+ 0	3.58000+ 0	1.22000- 1
2.63990+ 3	5.00000- 1	8.97000- 1	7.75000- 1	1.22000- 1
2.93270+ 3	0.00000+ 0	1.03000+ 0	9.08000- 1	1.22000- 1
2.99600+ 3	5.00000- 1	3.30000- 1	2.08000- 1	1.22000- 1
3.08960+ 3	1.00000+ 0	7.92000- 1	6.70000- 1	1.22000- 1
3.21470+ 3	1.00000+ 0	1.40530+ 0	1.28330+ 0	1.22000- 1
3.29870+ 3	0.00000+ 0	1.22600+ 0	1.10400+ 0	1.22000- 1
3.32040+ 3	1.00000+ 0	4.06700- 1	2.84700- 1	1.22000- 1
3.46800+ 3	0.00000+ 0	4.21200+ 0	4.09000+ 0	1.22000- 1
3.63110+ 3	1.00000+ 0	9.95300- 1	8.73300- 1	1.22000- 1
3.81850+ 3	0.00000+ 0	6.29200+ 0	6.17000+ 0	1.22000- 1
4.00260+ 3	5.00000- 1	1.10500+ 0	9.83000- 1	1.22000- 1
4.02230+ 3	1.00000+ 0	1.41200+ 0	1.29000+ 0	1.22000- 1
4.08230+ 3	5.00000- 1	1.59200+ 0	1.47000+ 0	1.22000- 1

TABLE 9

Resolved Resonance Parameters for Xe-130

E_R	J	Γ	Γ_n	Γ_γ
1.48410+ 3	5.00000- 1	2.42000+ 0	2.33000+ 0	9.00000- 2
2.43150+ 3	5.00000- 1	2.20000+ 0	2.11000+ 0	9.00000- 2
2.57750+ 3	5.00000- 1	6.17000- 1	5.27000- 1	9.00000- 2
2.61490+ 3	5.00000- 1	5.20000- 1	4.30000- 1	9.00000- 2
2.64560+ 3	5.00000- 1	1.76500+ 0	1.67500+ 0	9.00000- 2
2.98040+ 3	5.00000- 1	2.45400+ 0	2.36400+ 0	9.00000- 2
3.00320+ 3	5.00000- 1	2.24400+ 0	2.15400+ 0	9.00000- 2
3.25730+ 3	5.00000- 1	1.34000+ 0	1.25000+ 0	9.00000- 2
3.56390+ 3	5.00000- 1	4.74400+ 0	4.65400+ 0	9.00000- 2

TABLE 10

Resolved Resonance Parameters for Xe-131

E_R	J	Γ	Γ_n	Γ_γ
1.44000+ 1	2.00000+ 0	3.09000- 1	2.16000- 1	9.30000- 2
4.60000+ 1	2.00000+ 0	1.24900- 1	1.09000- 2	1.14000- 1
7.56000+ 1	2.00000+ 0	1.33400- 1	1.04000- 2	1.23000- 1
1.14930+ 2	2.00000+ 0	1.20600- 1	6.60000- 3	1.14000- 1
1.73570+ 2	1.00000+ 0	1.46900- 1	7.90000- 3	1.39000- 1
2.09470+ 2	2.00000+ 0	1.34600- 1	1.76000- 2	1.17000- 1
2.83490+ 2	1.00000+ 0	1.86100- 1	6.91000- 2	1.17000- 1
3.02490+ 2	1.50000+ 0	1.19300- 1	2.30000- 3	1.17000- 1
3.62600+ 2	1.50000+ 0	1.18200- 1	1.20000- 3	1.17000- 1
4.26840+ 2	1.00000+ 0	1.76300- 1	5.93000- 2	1.17000- 1
4.50380+ 2	2.00000+ 0	2.81800- 1	1.64800- 1	1.17000- 1
4.95080+ 2	1.50000+ 0	1.19700- 1	2.70000- 3	1.17000- 1
5.57590+ 2	2.00000+ 0	1.37800- 1	2.08000- 2	1.17000- 1
6.51350+ 2	1.50000+ 0	1.23800- 1	6.80000- 3	1.17000- 1
7.23200+ 2	1.00000+ 0	2.10300- 1	9.33000- 2	1.17000- 1
7.36070+ 2	2.00000+ 0	1.98600- 1	8.16000- 2	1.17000- 1
8.55210+ 2	2.00000+ 0	1.36800- 1	1.98000- 2	1.17000- 1
9.76310+ 2	1.00000+ 0	2.16300- 1	9.93000- 2	1.17000- 1
9.81160+ 2	1.50000+ 0	1.23810- 1	6.81000- 3	1.17000- 1
9.92980+ 2	1.50000+ 0	1.32500- 1	1.55000- 2	1.17000- 1
1.03440+ 3	1.50000+ 0	1.42000- 1	2.50000- 2	1.17000- 1
1.05350+ 3	1.00000+ 0	2.31000- 1	1.14000- 1	1.17000- 1
1.06820+ 3	1.00000+ 0	2.09000- 1	9.20000- 2	1.17000- 1
1.30280+ 3	2.00000+ 0	1.77000- 1	6.00000- 2	1.17000- 1
1.33420+ 3	1.50000+ 0	1.32000- 1	1.50000- 2	1.17000- 1
1.51050+ 3	1.50000+ 0	1.87500- 1	7.05000- 2	1.17000- 1
1.58660+ 3	1.50000+ 0	1.44000- 1	2.70000- 2	1.17000- 1
1.65560+ 3	2.00000+ 0	2.21000- 1	1.04000- 1	1.17000- 1
1.74320+ 3	1.50000+ 0	1.84000- 1	6.70000- 2	1.17000- 1
1.84460+ 3	1.50000+ 0	1.79000- 1	6.20000- 2	1.17000- 1
1.87110+ 3	2.00000+ 0	3.96200- 1	2.79200- 1	1.17000- 1
1.95720+ 3	1.50000+ 0	1.87000- 1	7.00000- 2	1.17000- 1
1.98250+ 3	2.00000+ 0	1.98600- 1	8.16000- 2	1.17000- 1
1.99450+ 3	1.50000+ 0	1.92000- 1	7.50000- 2	1.17000- 1
2.08270+ 3	1.50000+ 0	1.92000- 1	7.50000- 2	1.17000- 1
2.14940+ 3	2.00000+ 0	3.53800- 1	2.36800- 1	1.17000- 1
2.35590+ 3	2.00000+ 0	2.61800- 1	1.44800- 1	1.17000- 1
2.55330+ 3	1.00000+ 0	5.30300- 1	4.13300- 1	1.17000- 1
3.10160+ 3	1.50000+ 0	3.29000- 1	2.12000- 1	1.17000- 1
3.94530+ 3	1.00000+ 0	1.59700+ 0	1.48000+ 0	1.17000- 1

TABLE 11

Resolved Resonance Parameters for Xe-132

E_R	J	Γ	Γ_n	Γ_γ
6.43300+ 2	5.00000- 1	1.35000+ 0	1.25000+ 0	1.00000- 1
3.03070+ 3	5.00000- 1	4.20000- 1	3.20000- 1	1.00000- 1
3.85390+ 3	5.00000- 1	7.20000- 1	6.20000- 1	1.00000- 1

TABLE 12

Resolved Resonance Parameters for Xe-134

E_R	J	Γ	Γ_n	Γ_γ
1.00060+ 3	5.00000- 1	1.09500- 1	9.50000- 3	1.00000- 1

Table 13: <u>Optical Model Parameters</u>

$$V(r) = Uf(r) + iWg(r)$$

$$f(r) = \left[1 + \exp(r-R)/a_U\right]^{-1}$$

$$g(r) = 4\exp\left\{(r-R)/a_W\right\}\left[1 + \exp(r-R)/a_W\right]^{-2}$$

$$r_o = 1.26\text{fm} \quad a_U = 0.66\text{fm} \quad a_W = 0.48\text{fm}$$

$$R = r_o A^{1/3}\text{fm}$$

$$U = 47.01 - 0.267E - 0.00118E^2 \text{ MeV}$$

$$W = 9.52 - 0.053E \text{ MeV}$$

Spin orbit term = 0.

TABLE 14

Parameters Used in keV Capture Calculations

Isotope	Bn(MeV)	$2\pi \frac{\Gamma_\gamma}{\langle D \rangle}$
Xe-124	7.7643	7.208E-03
Xe-126	7.2249	3.696E-03
Xe-128	6.9057	2.413E-03
Xe-129	9.2549	2.036E-02
Xe-130	6.6056	1.762E-03
Xe-131	8.9363	1.257E-02
Xe-132	6.4535	8.601E-04
Xe-134	6.4518	3.821E-04
Xe-136	3.8613	1.816E-05

TABLE 15

Neutron Activation Cross Sections at 14.4 MeV for Xe Isotopes

Isotope	$\sigma(n,2n)$ (mb)	$\sigma(n,p)$ (mb)
Xe-124	1130±110	
Xe-126	1355±165 σ^m 700±200	
Xe-128	1530±170 σ^m 840± 65	
Xe-130	σ^m 1435±130	6.7±0.8
Xe-131		5.3±0.6
Xe-132	σ^m 775± 65	2.5±0.3
Xe-134	2360±240 σ^m 665± 80	2.2±0.5
Xe-136	1700±100 σ^m 750± 50	

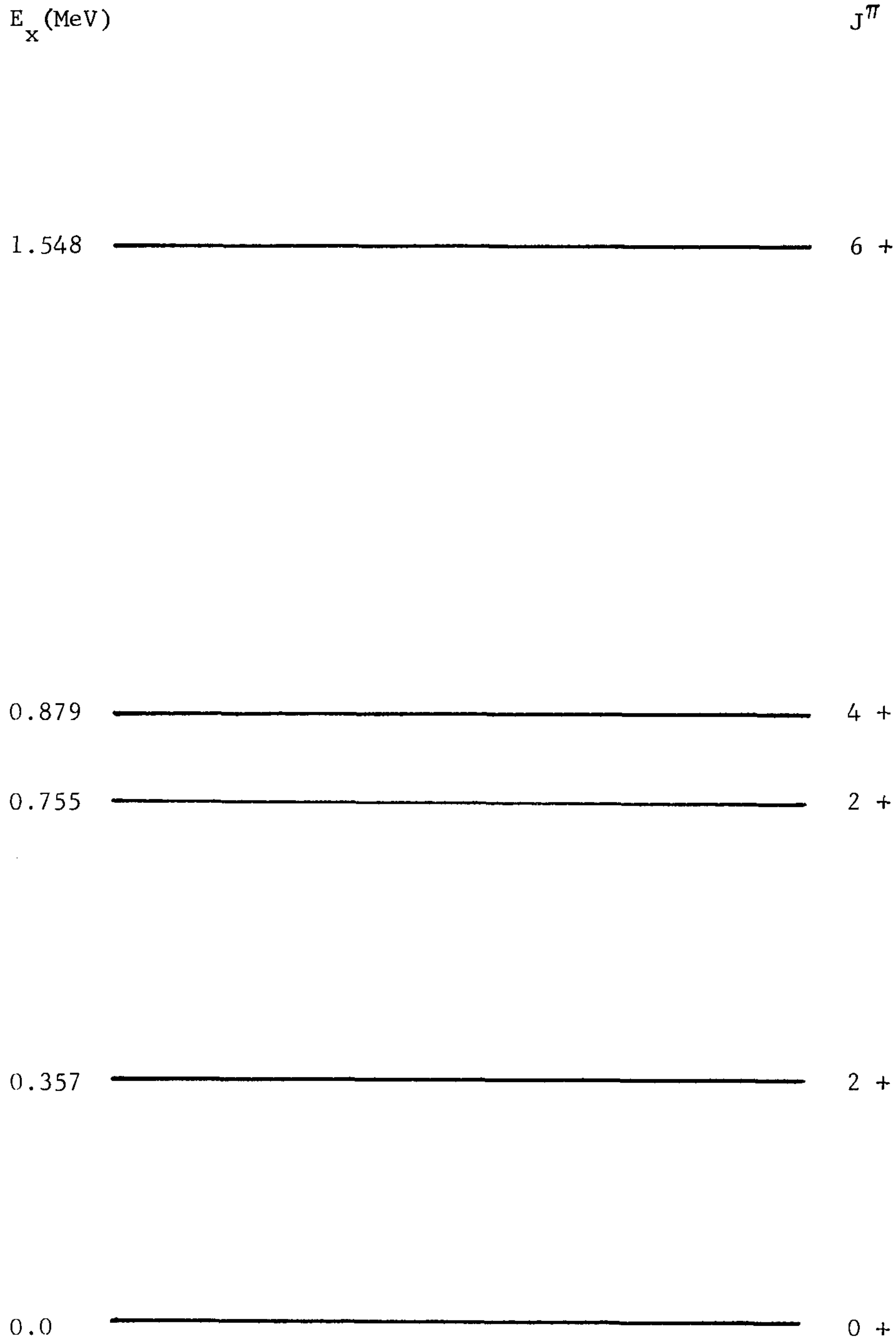

Figure 1 - Energy Levels of Xe-124

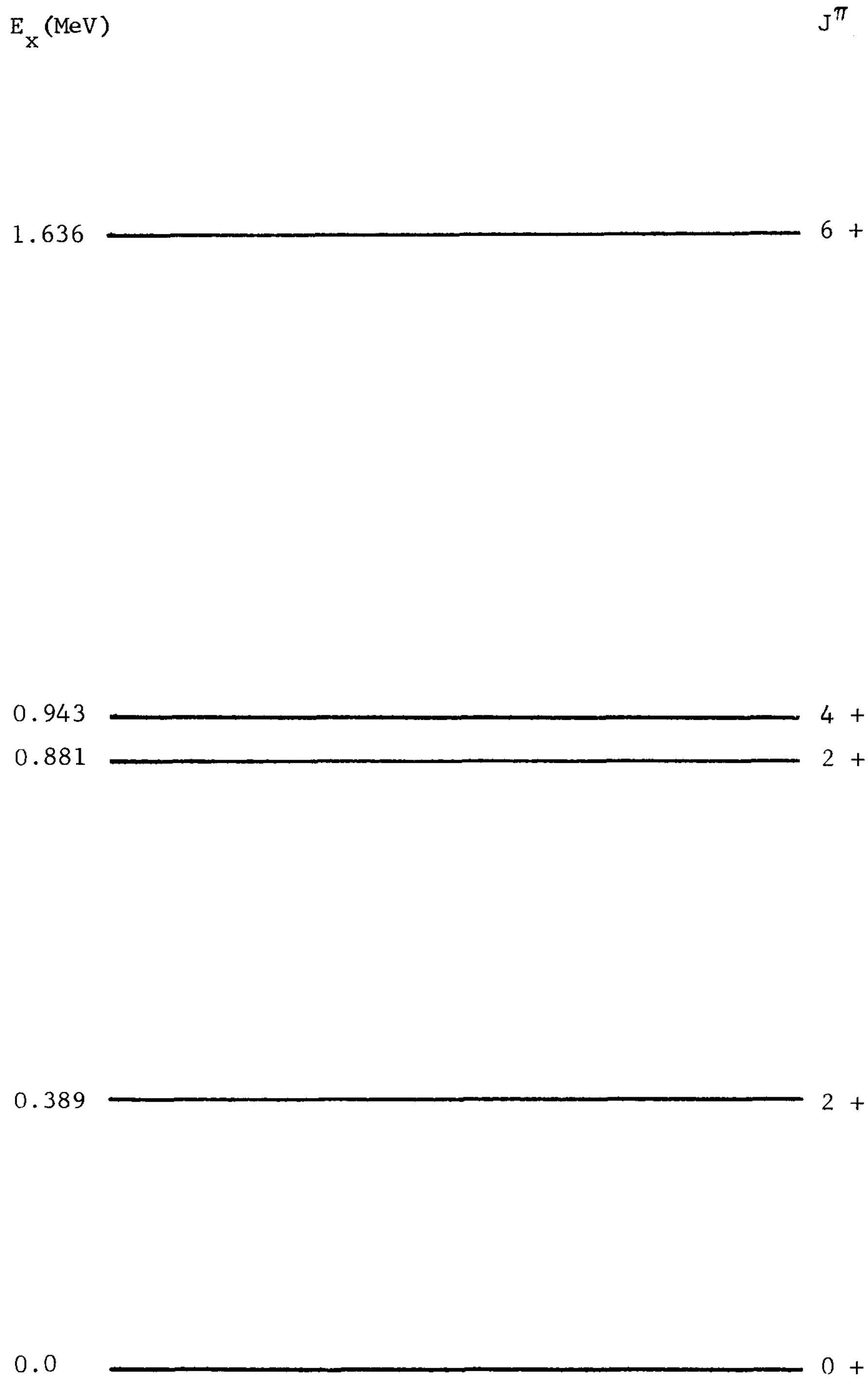

Figure 2 - Energy Levels of Xe-126

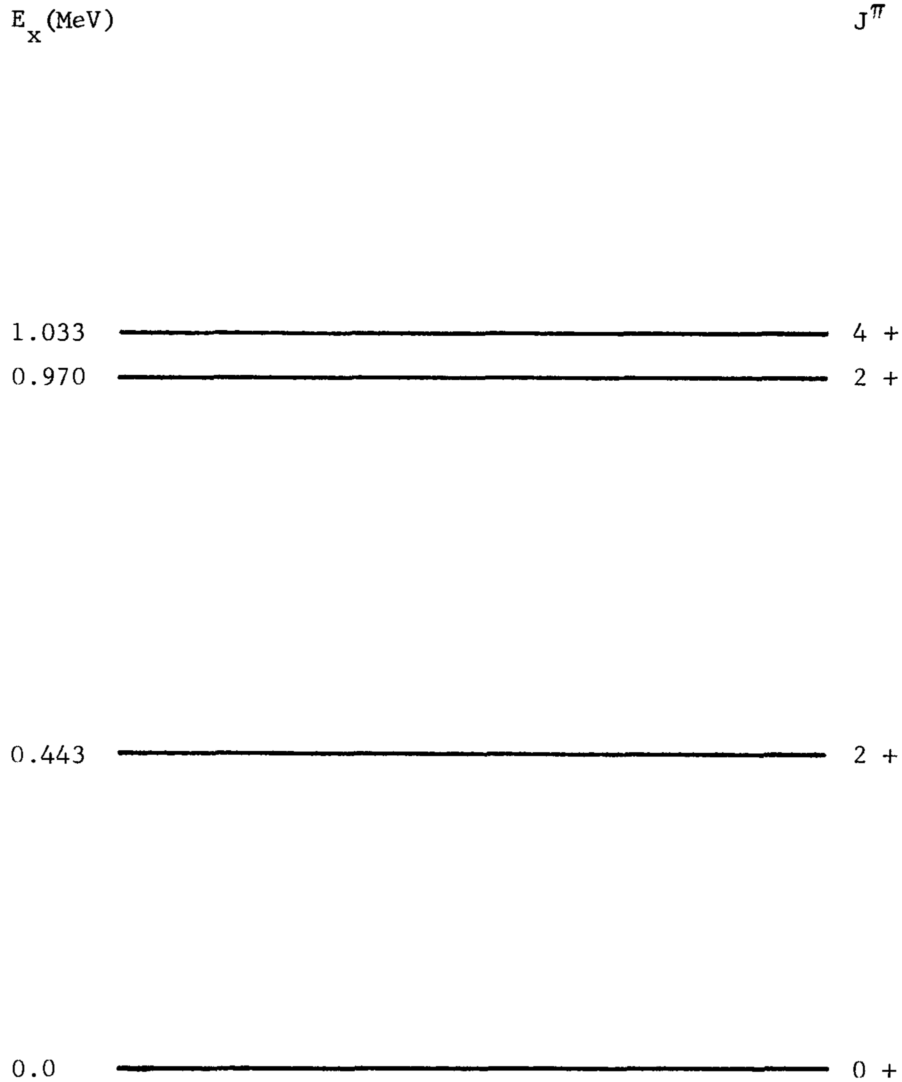

Figure 3 - Energy Levels of Xe-128

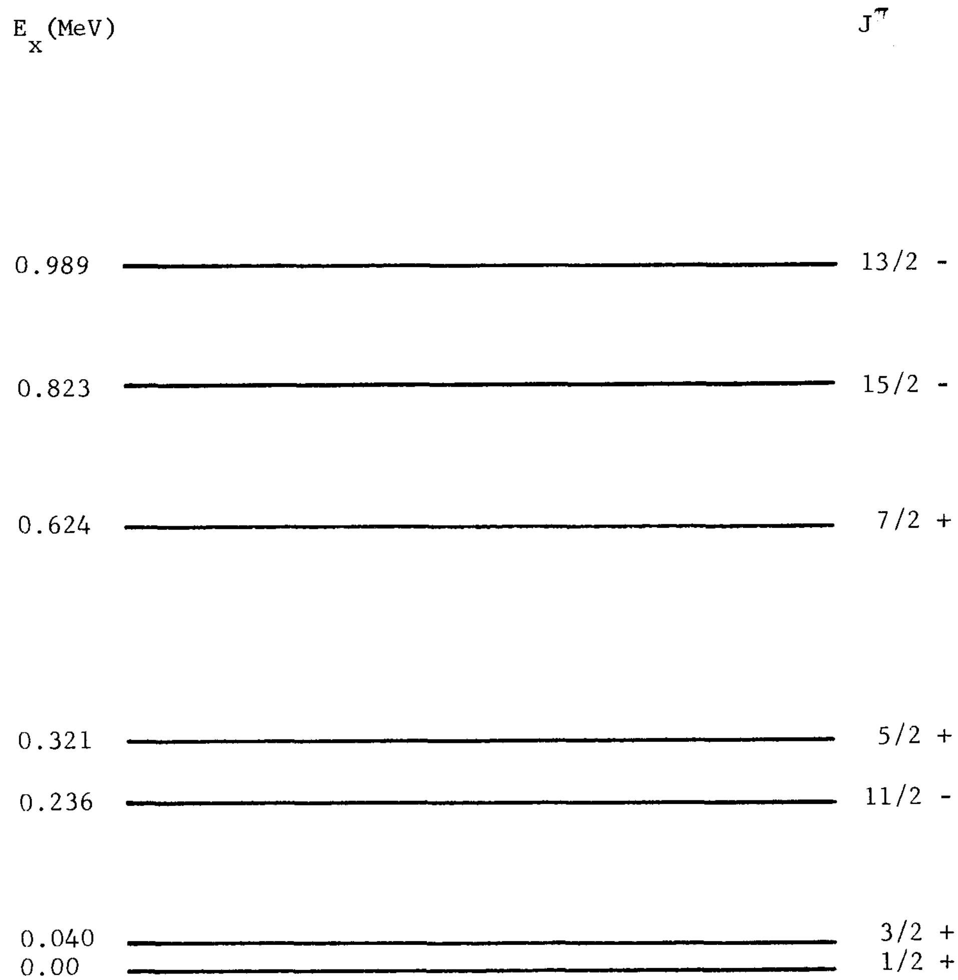

Figure 4 - Energy Levels of Xe-129

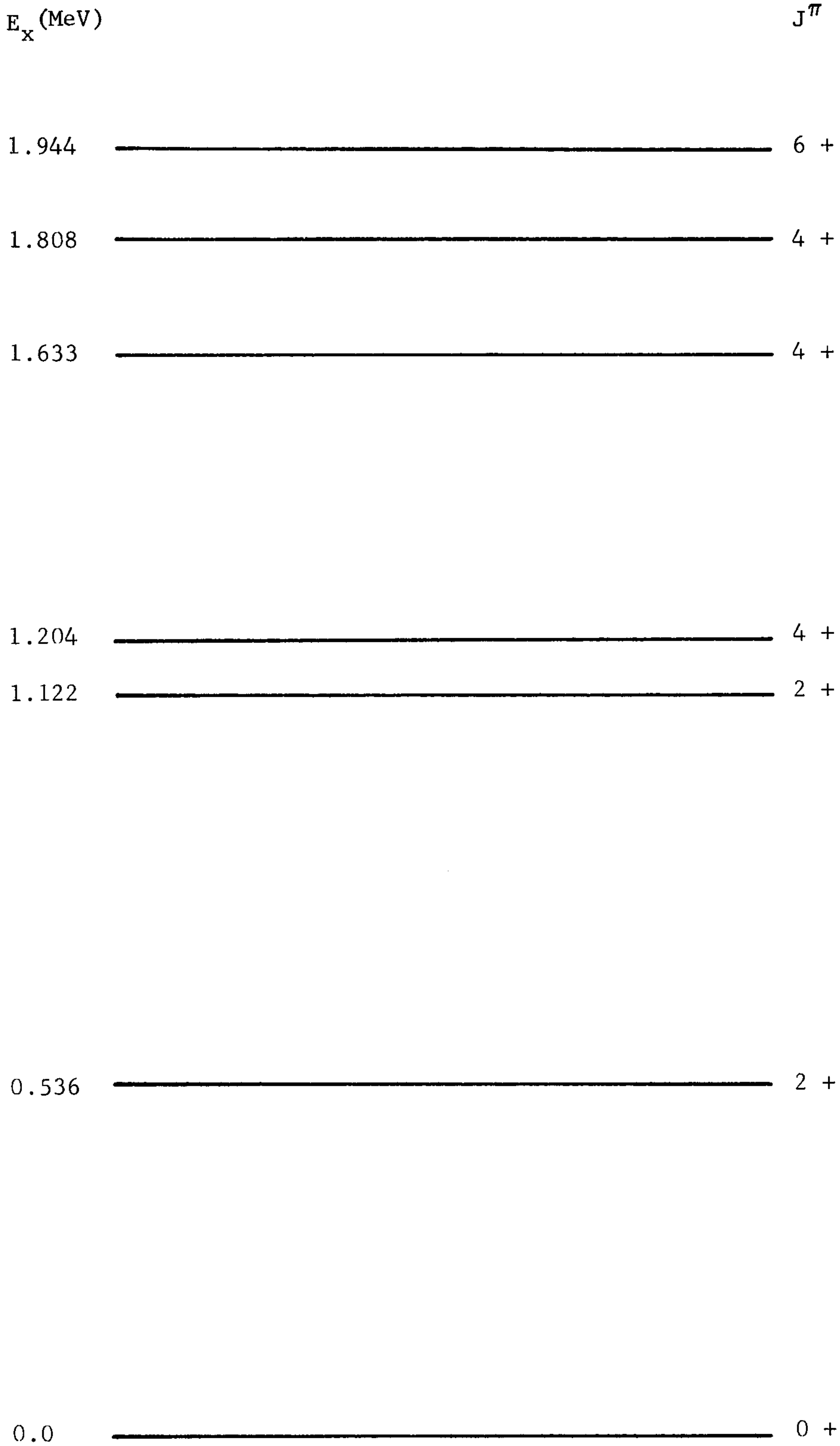

Figure 5 - Energy Levels of Xe-130

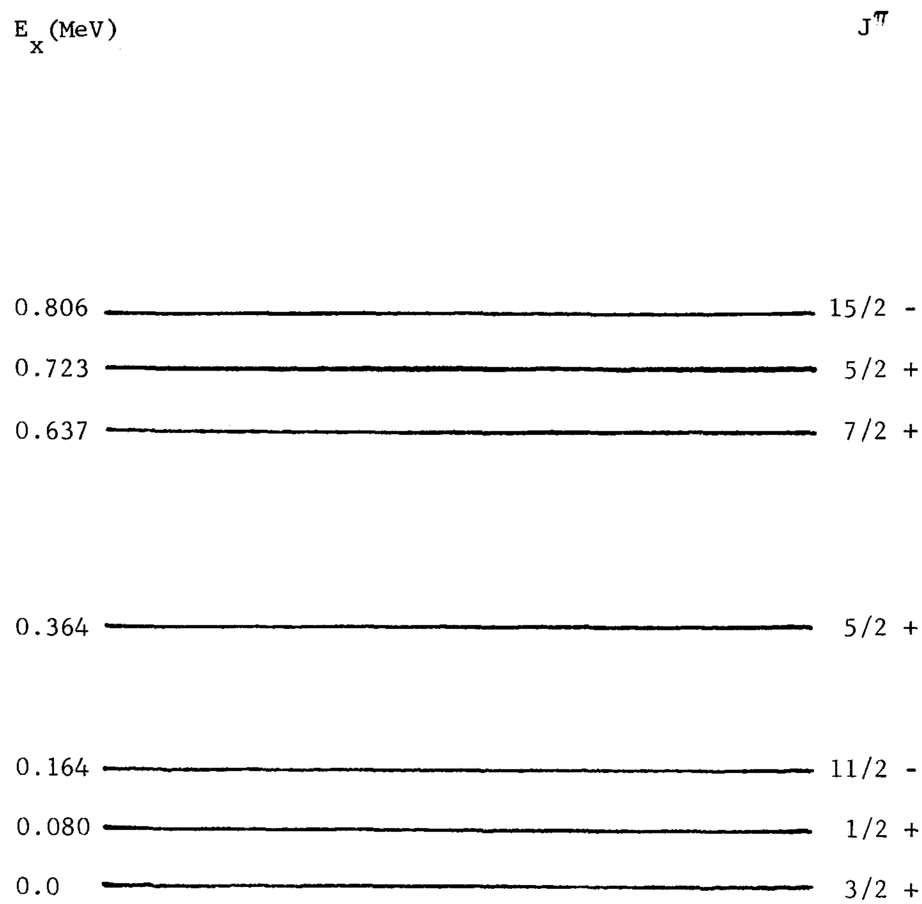

Figure 6 - Energy Levels of Xe-131

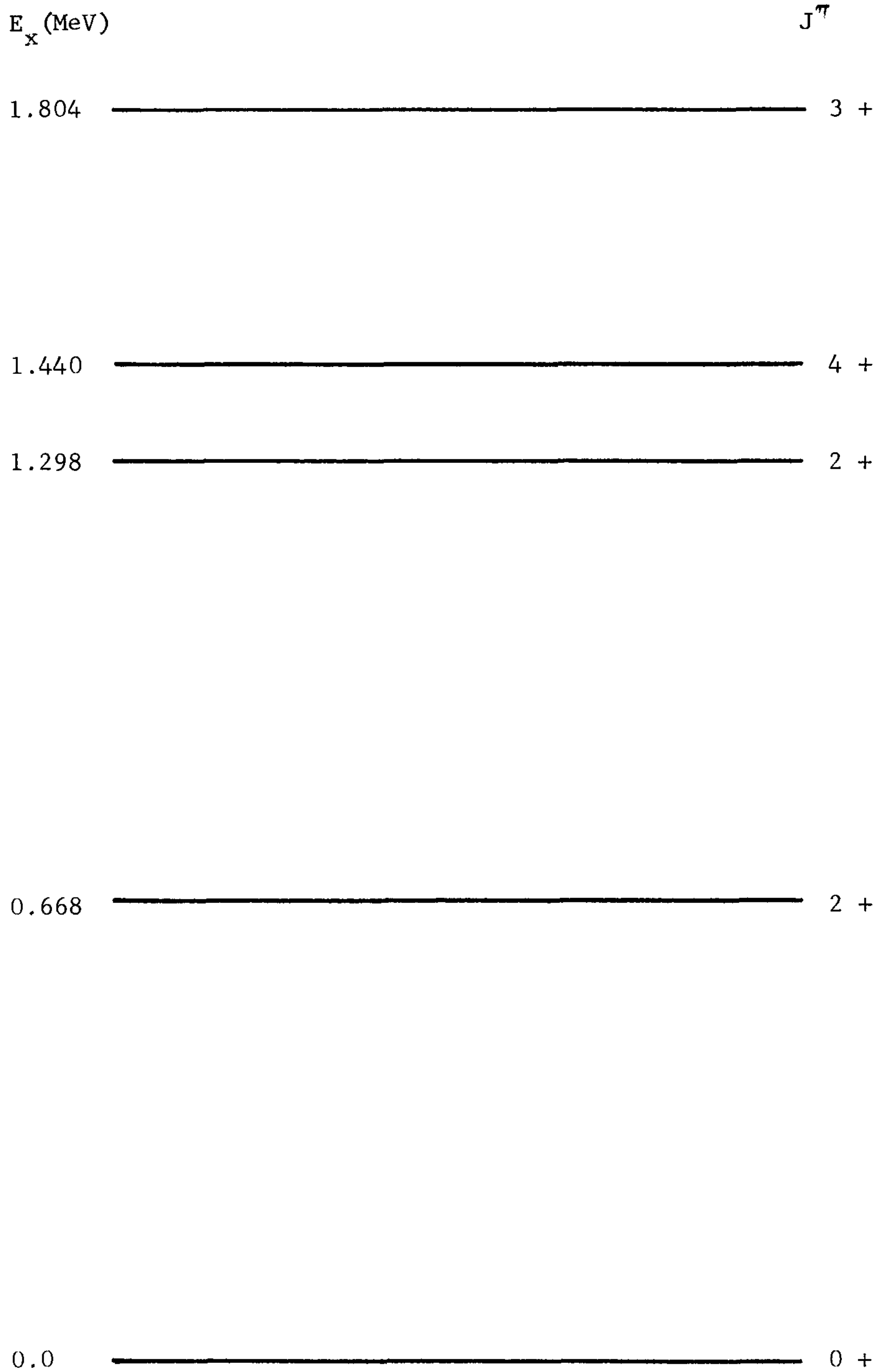

Figure 7 - Energy Levels of Xe-132

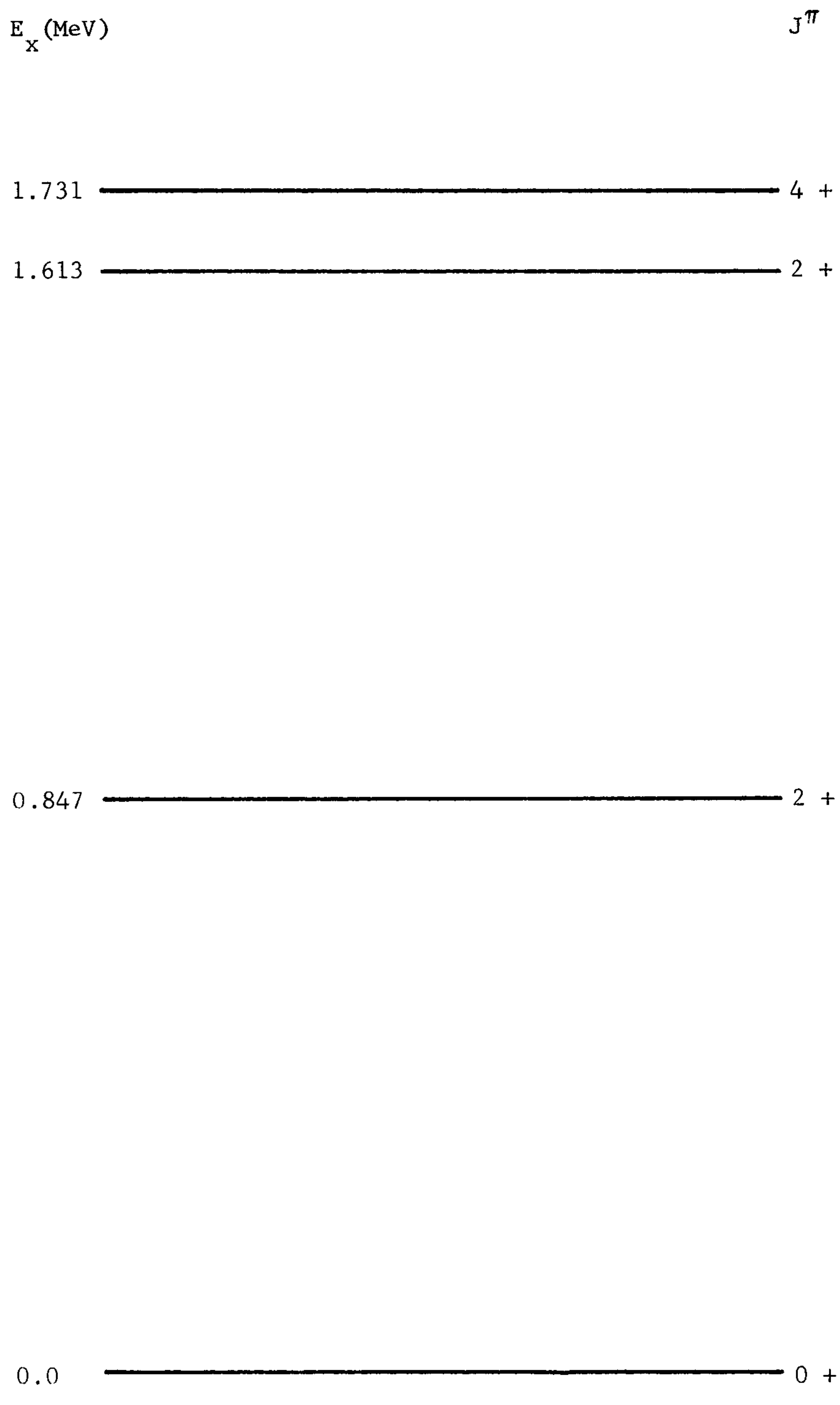

Figure 8 - Energy Levels of Xe-134

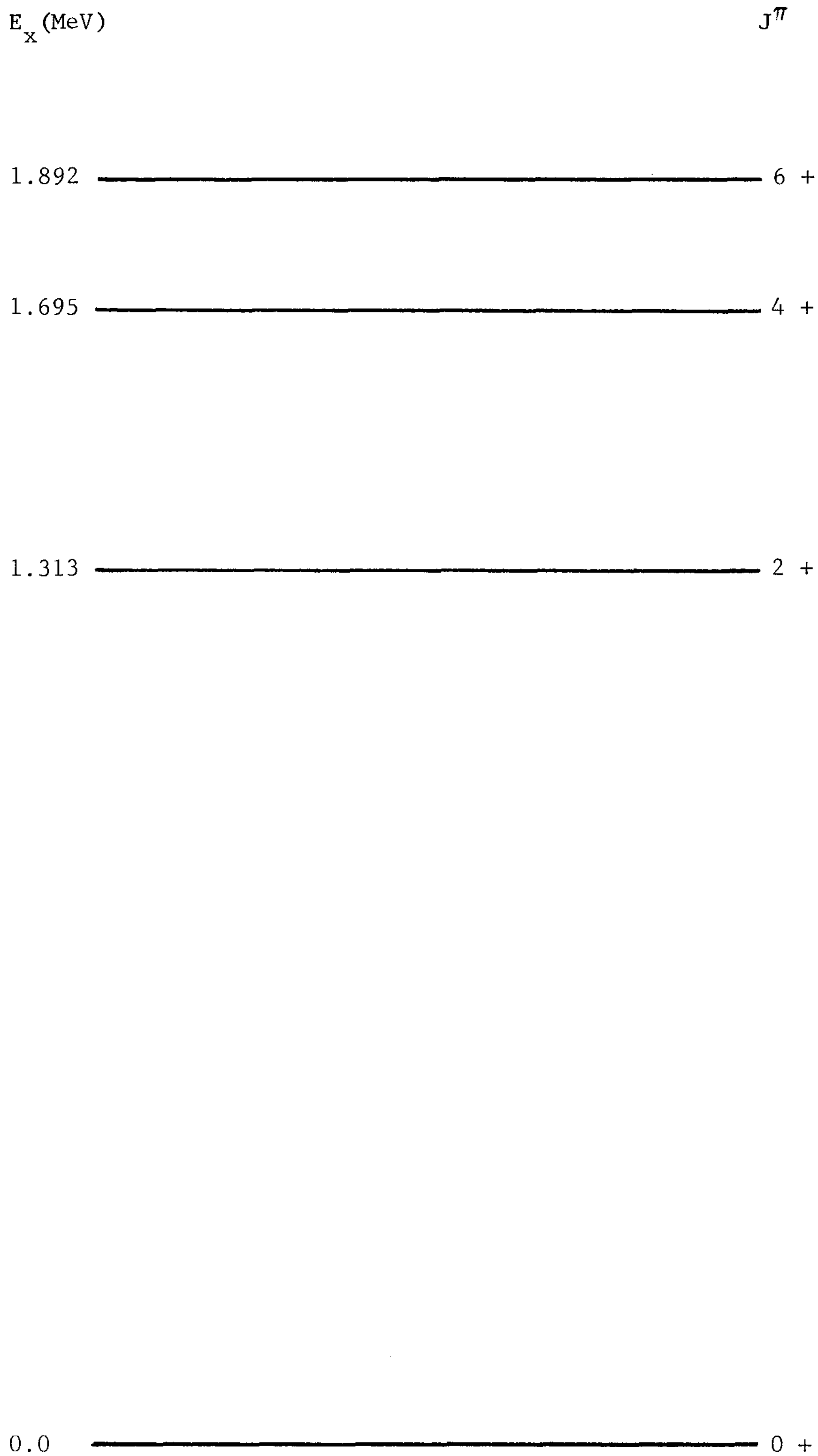

Figure 9 - Energy Levels of Xe-136

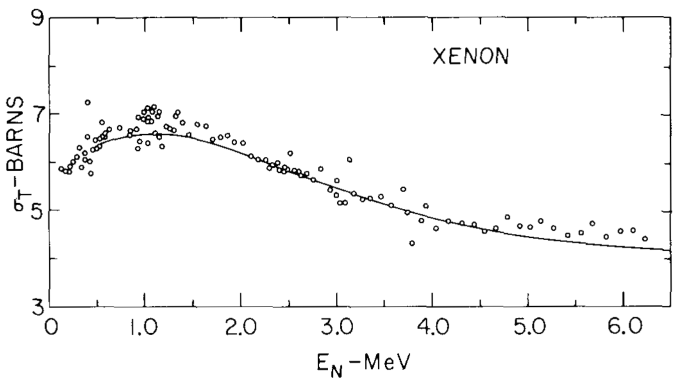

Figure 10 - Optical Model Calculations
Compared with Total Cross Section Data

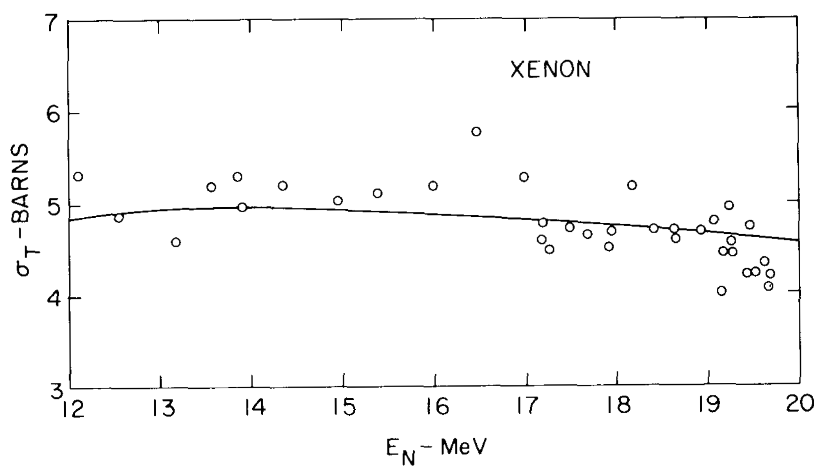

Figure 11 - Optical Model Calculations
Compared with Total Cross Section Data

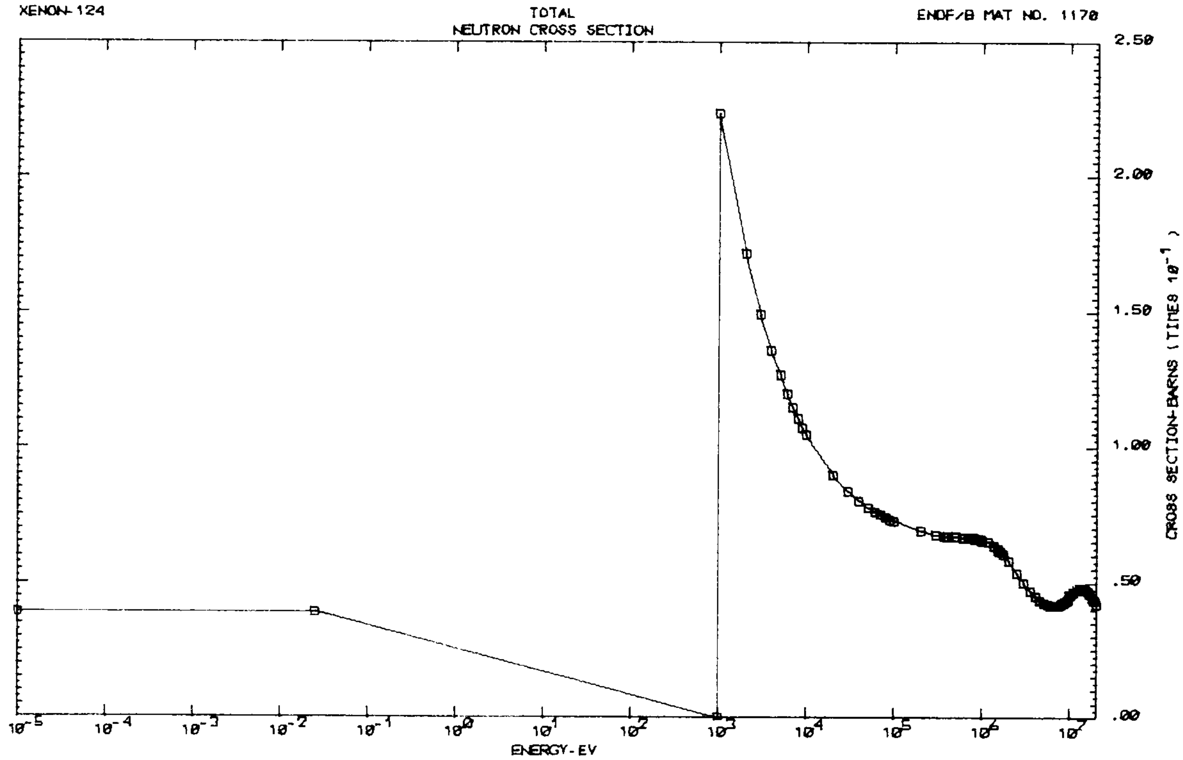

Figure 12

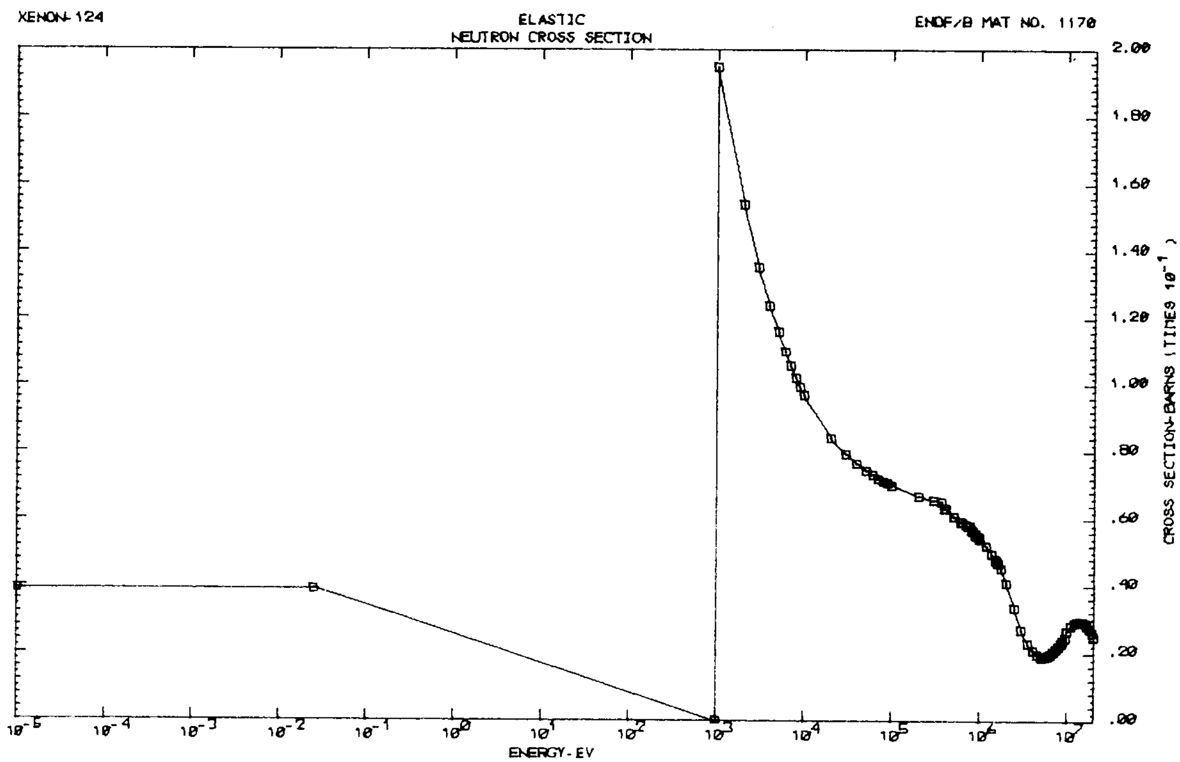

Figure 13

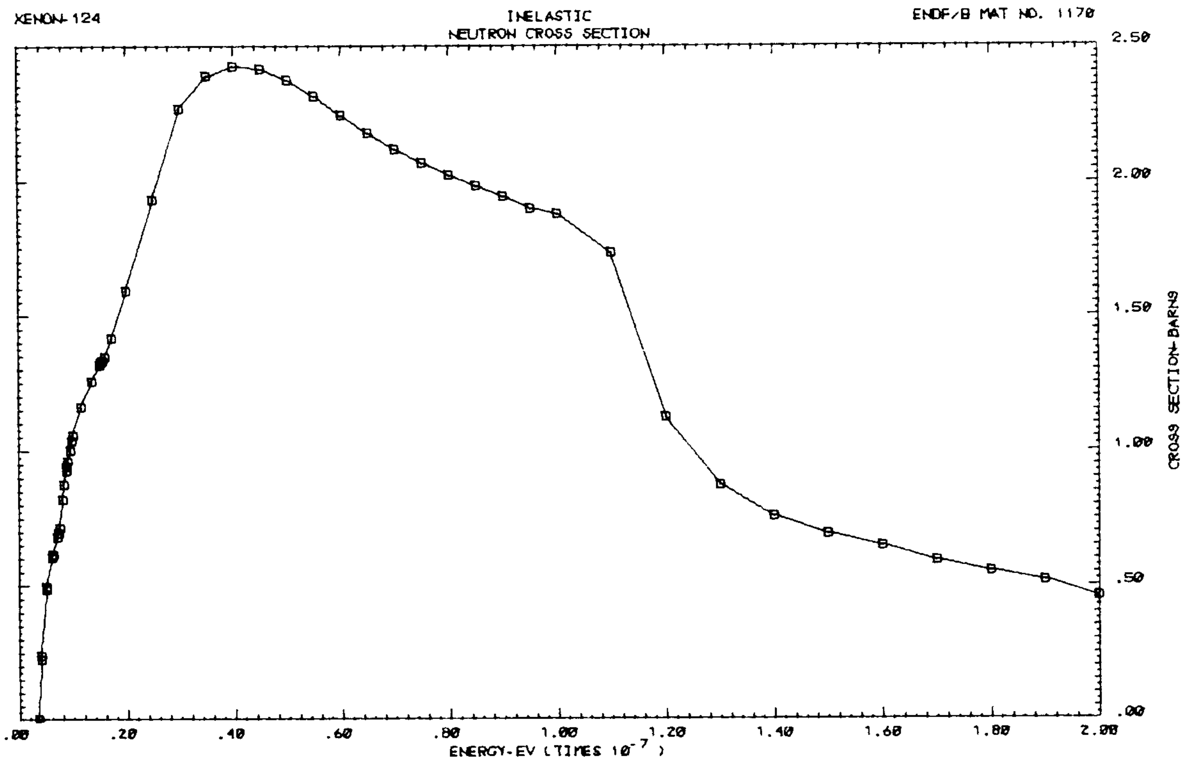

Figure 14

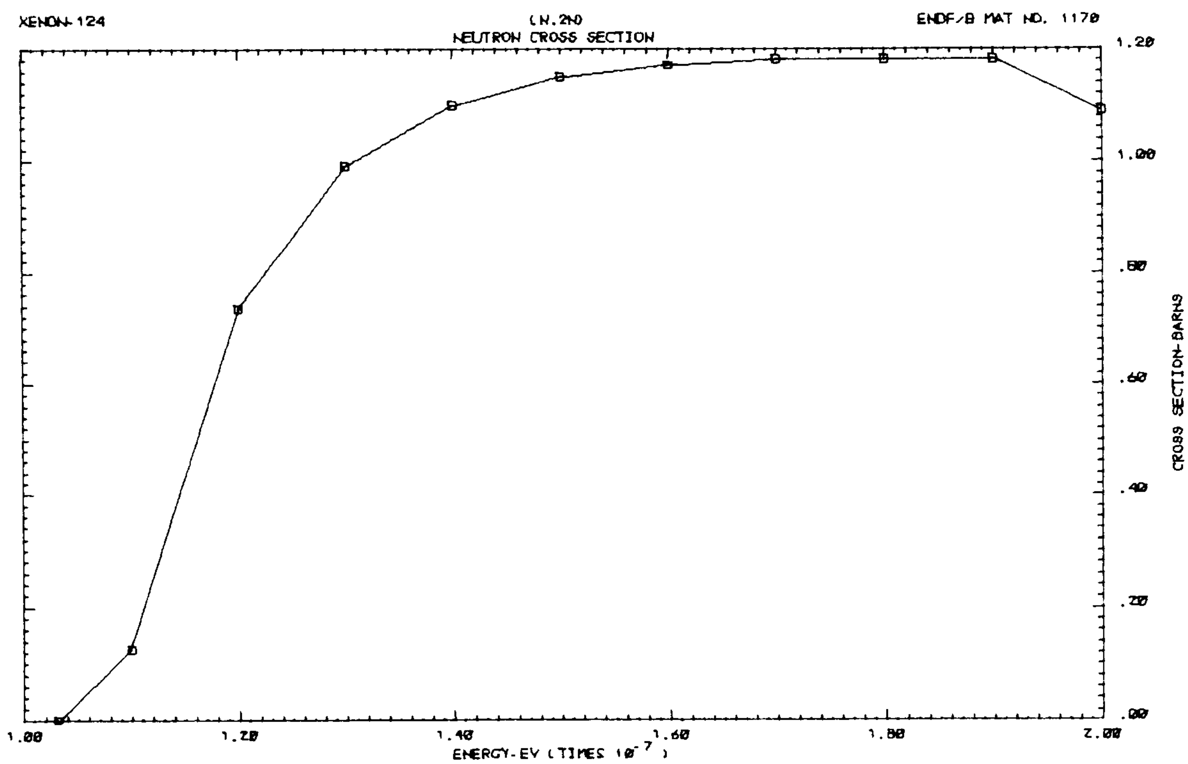

Figure 15

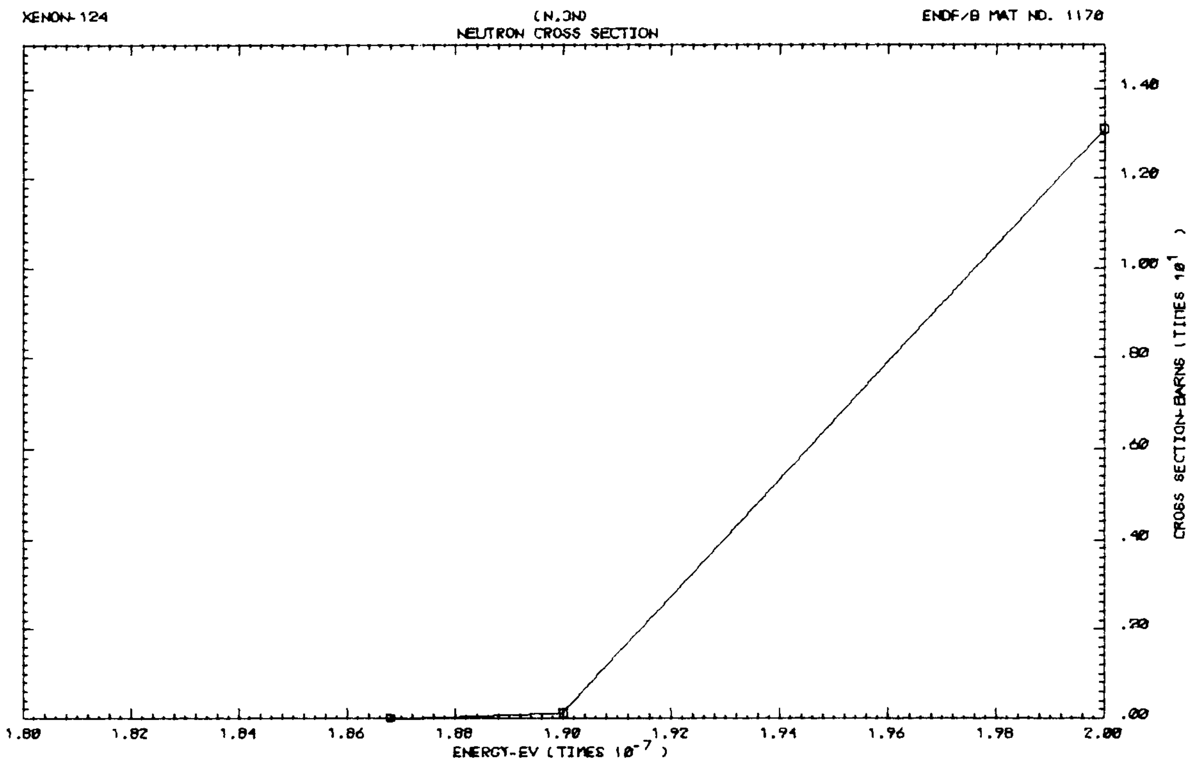

Figure 16

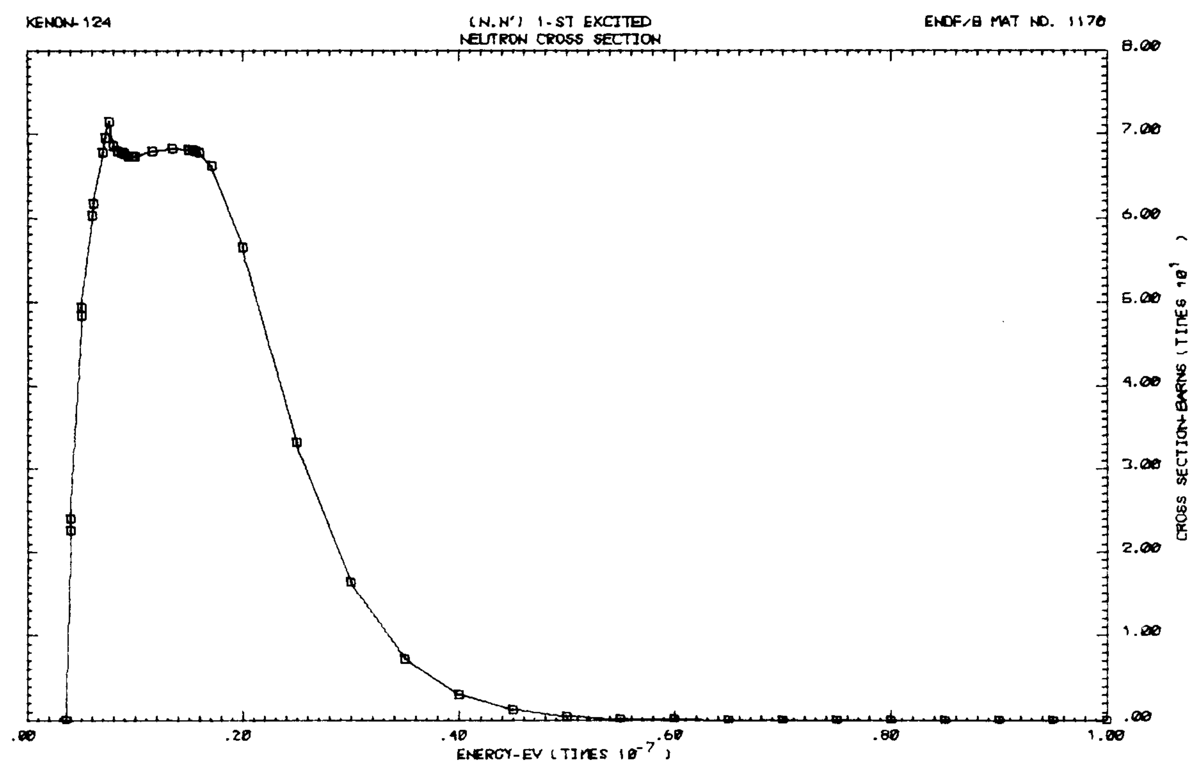

Figure 17

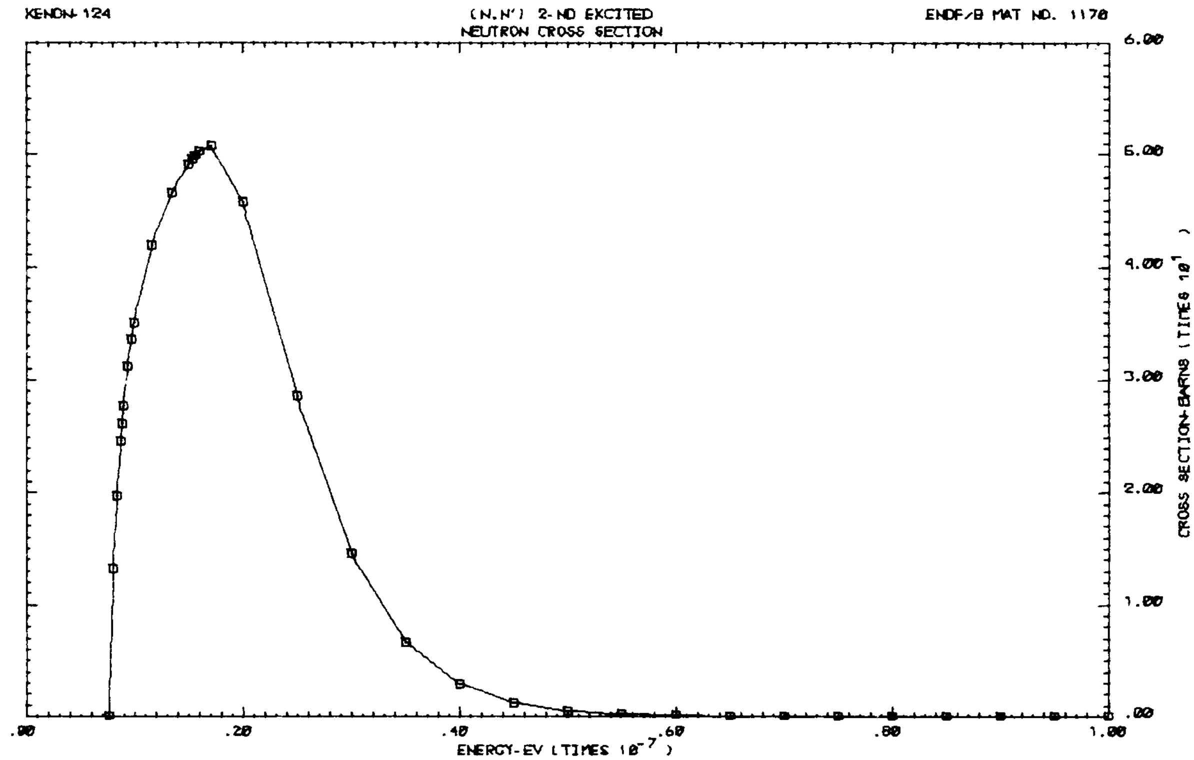

Figure 18

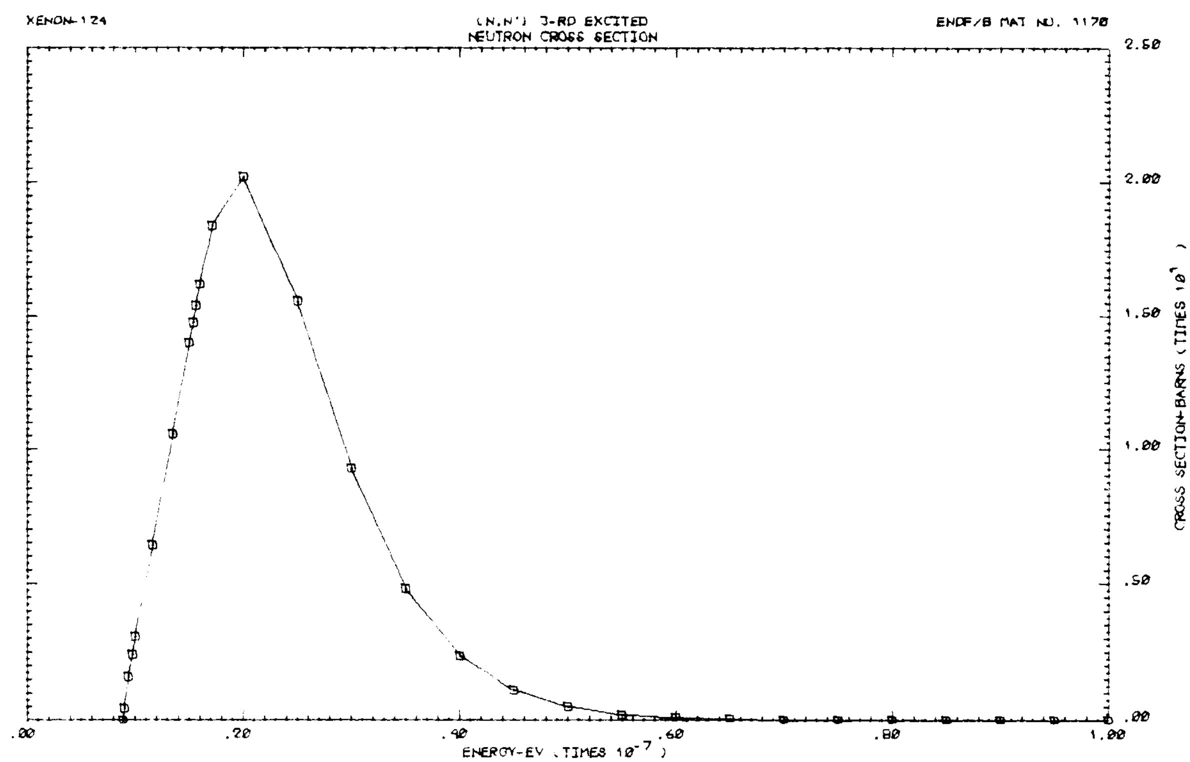

Figure 19

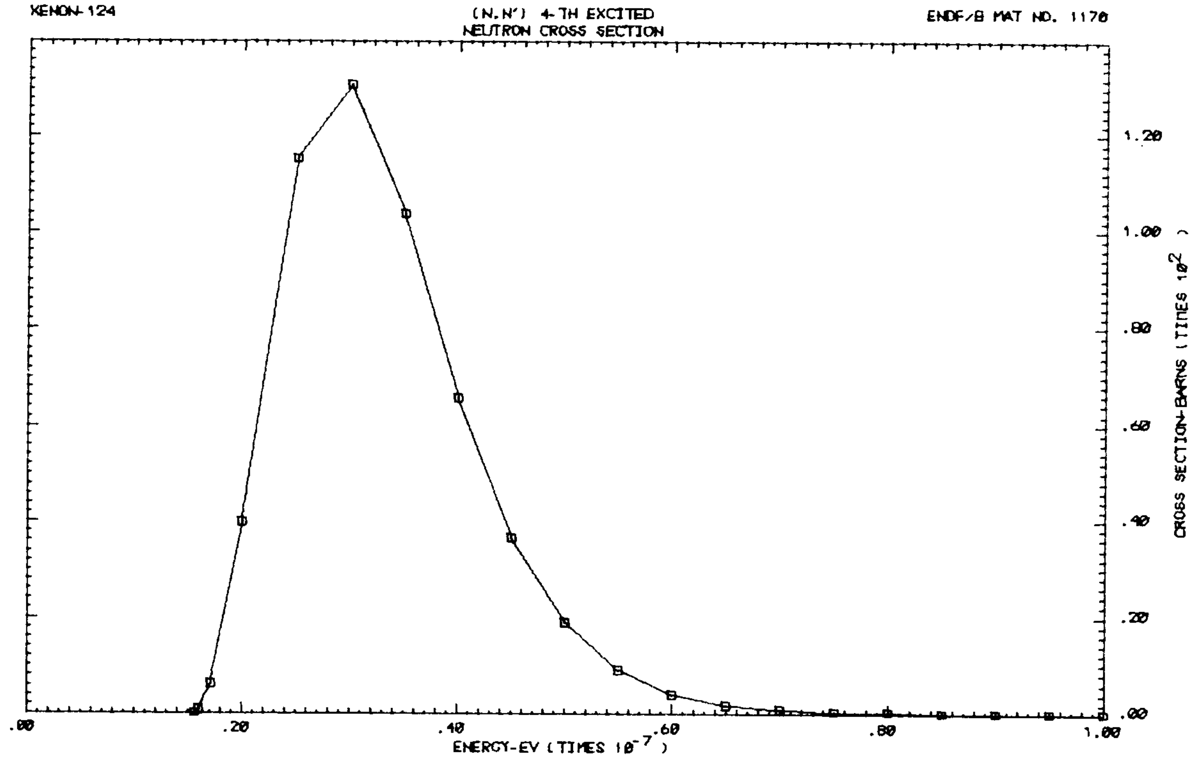

Figure 20

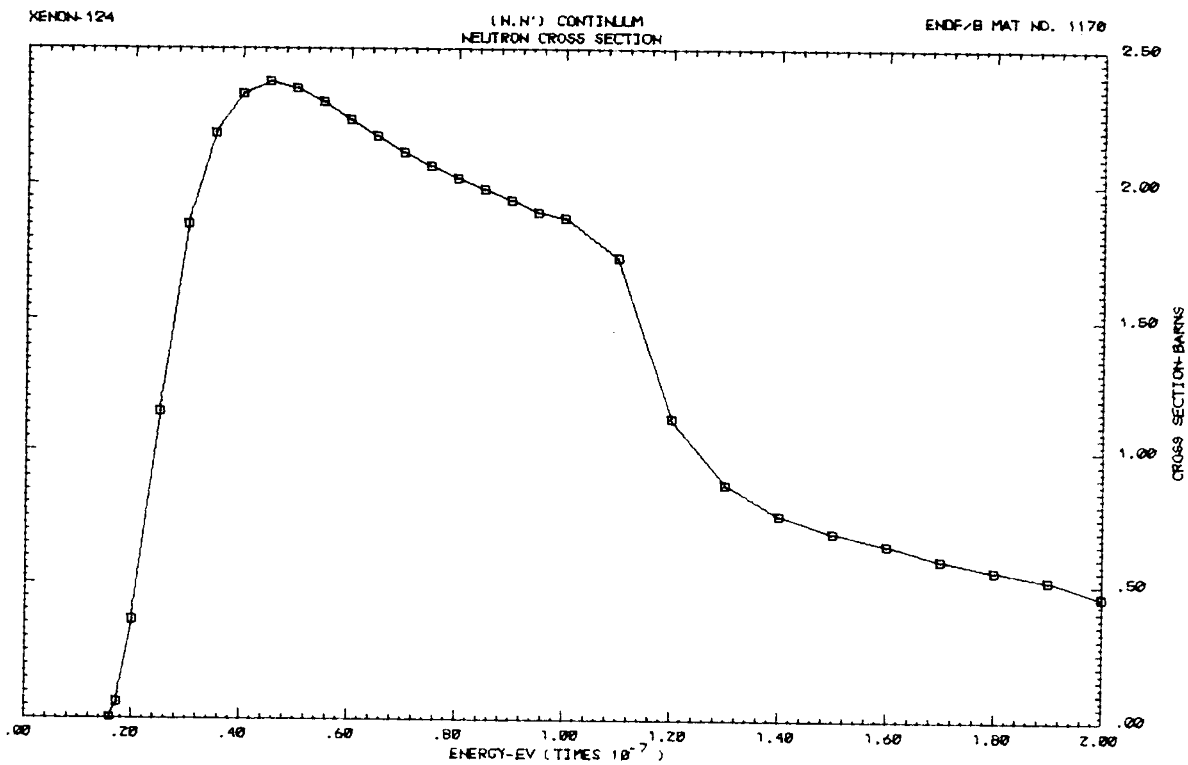

Figure 21

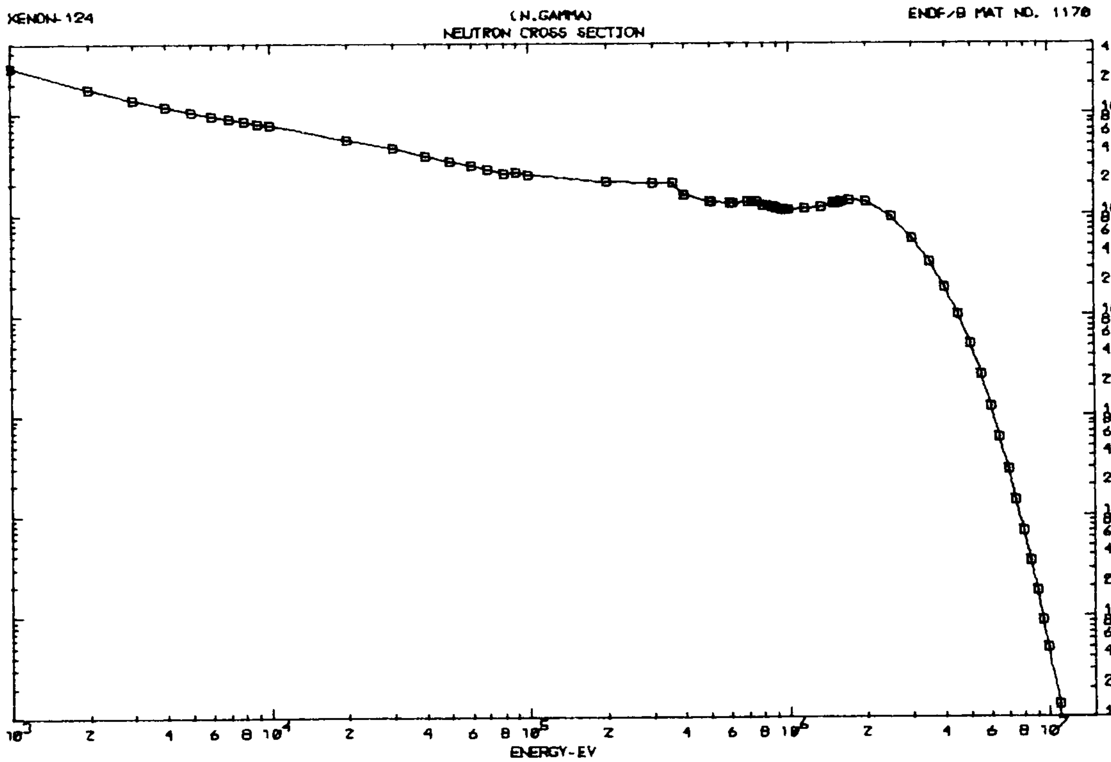

Figure 22

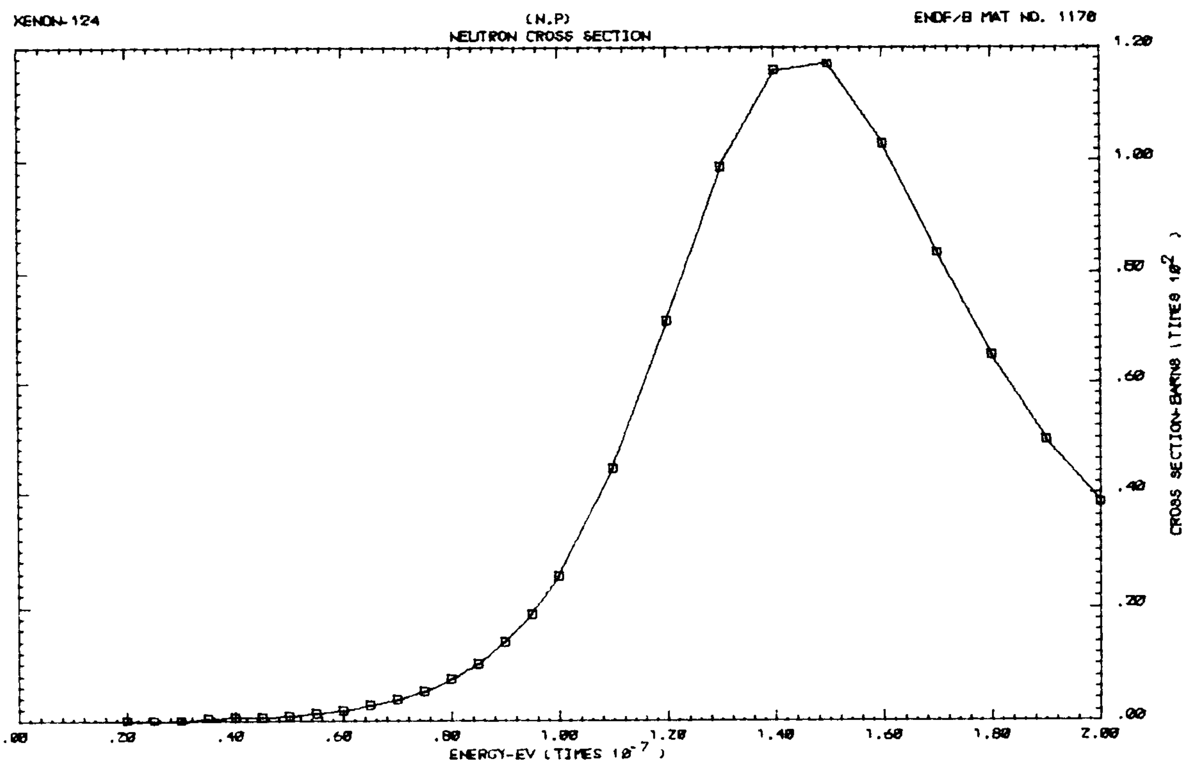

Figure 23

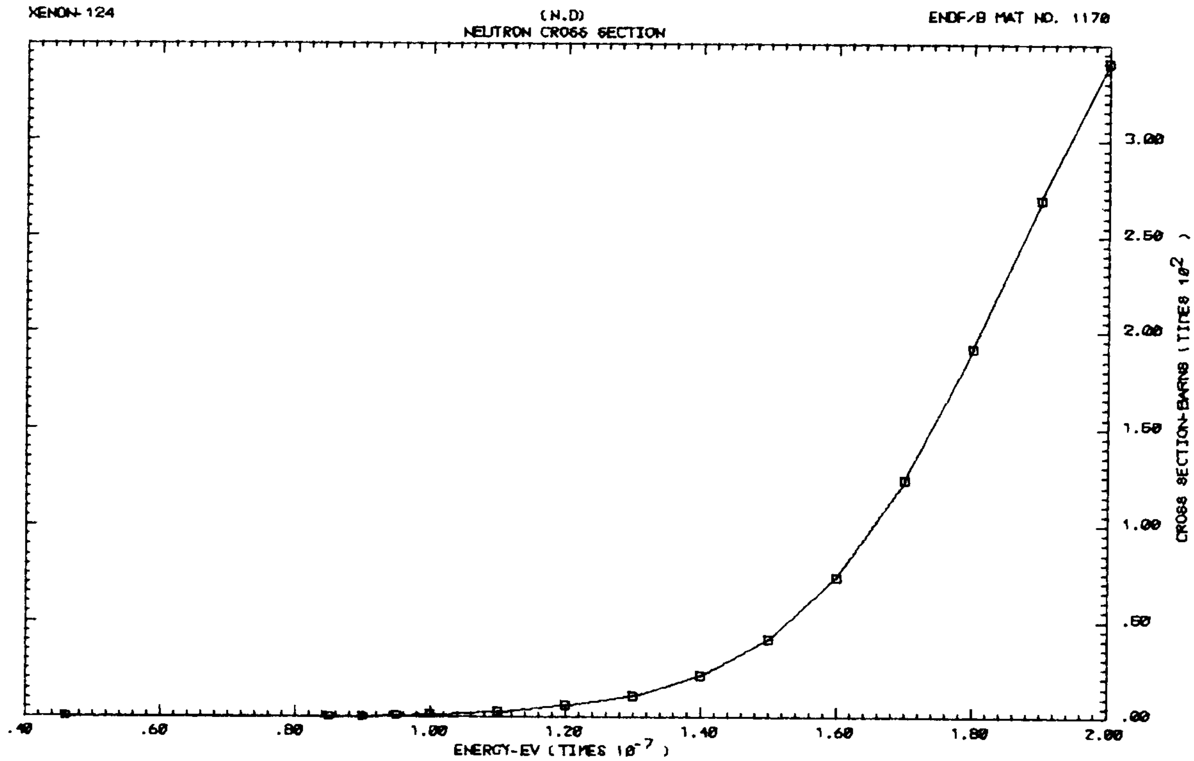

Figure 24

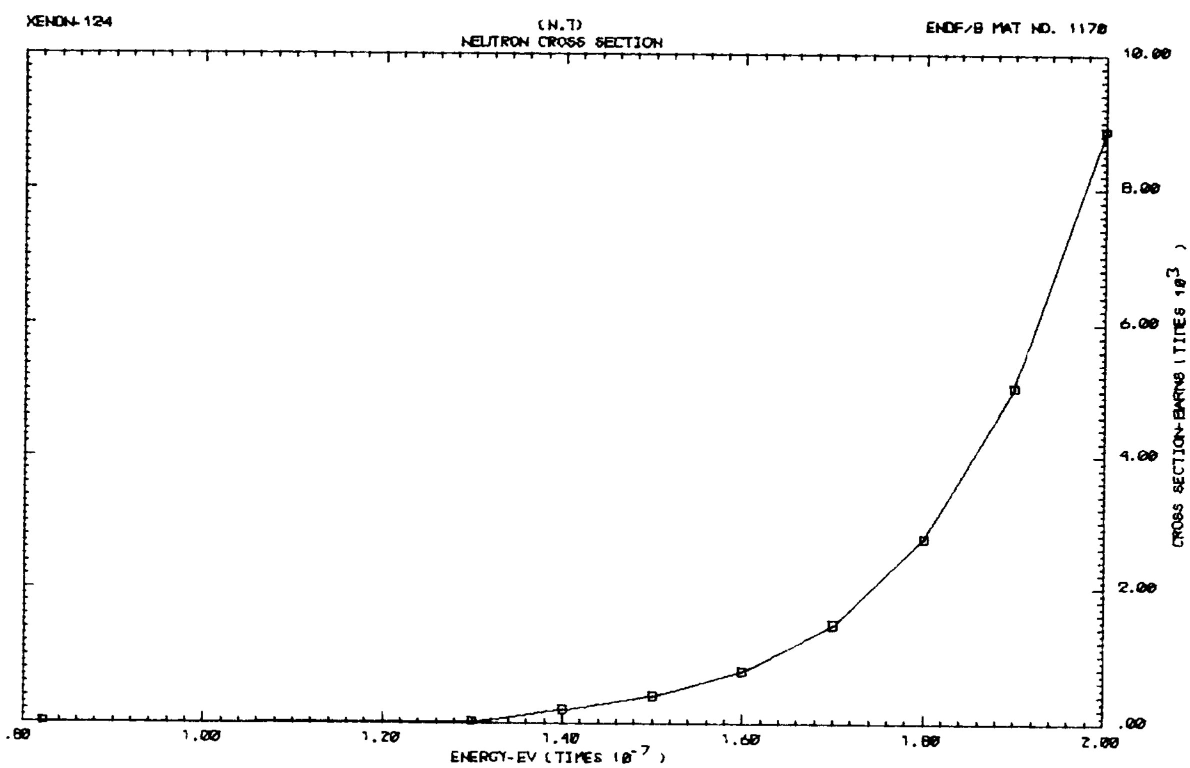

Figure 25

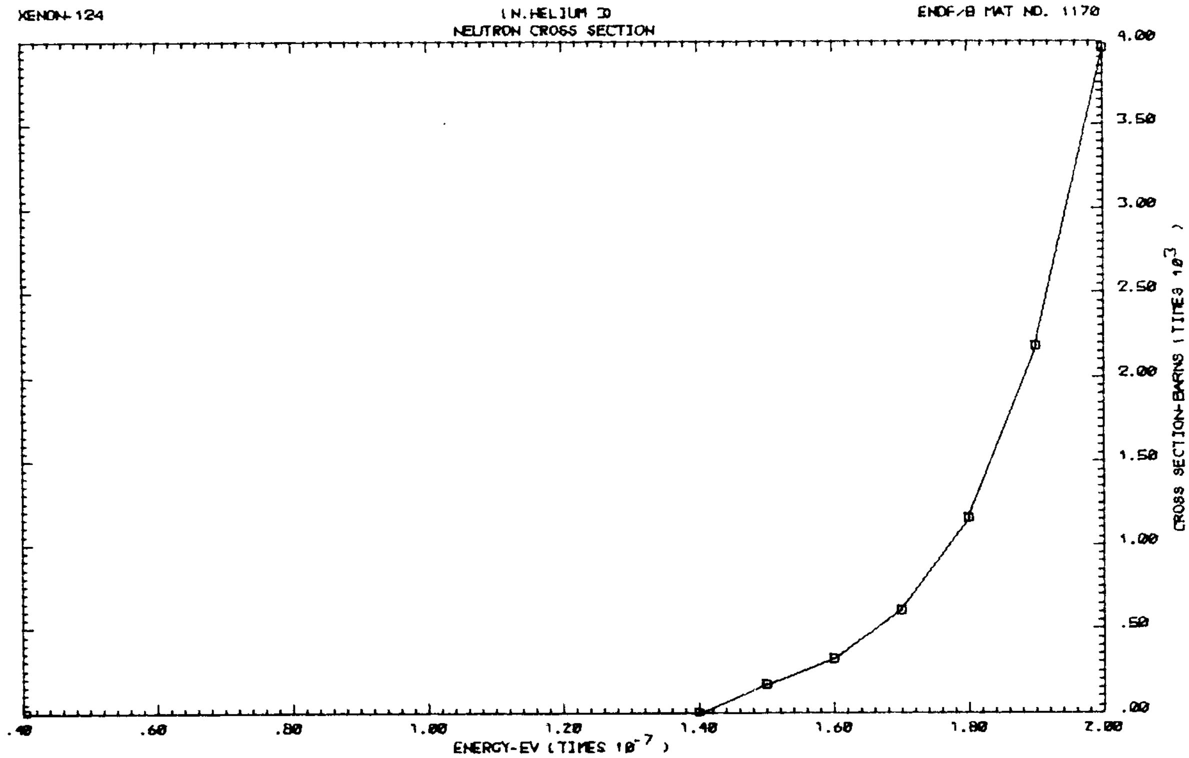

Figure 26

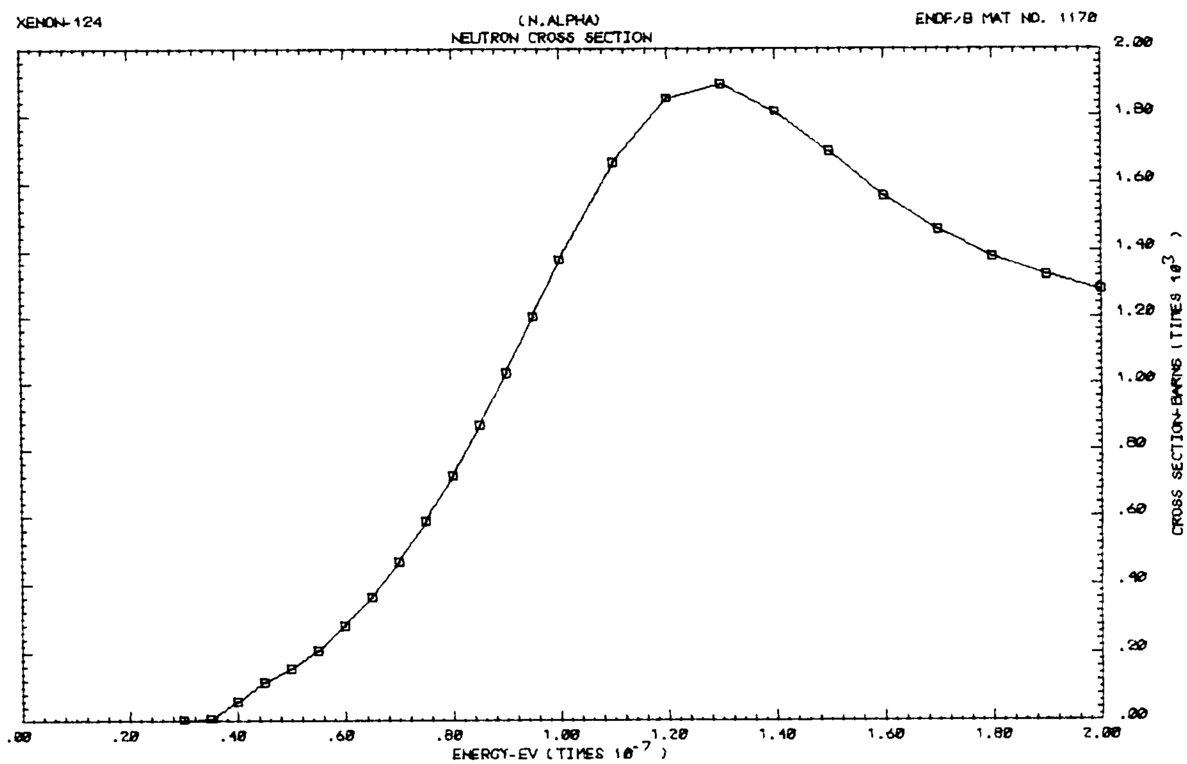

Figure 27

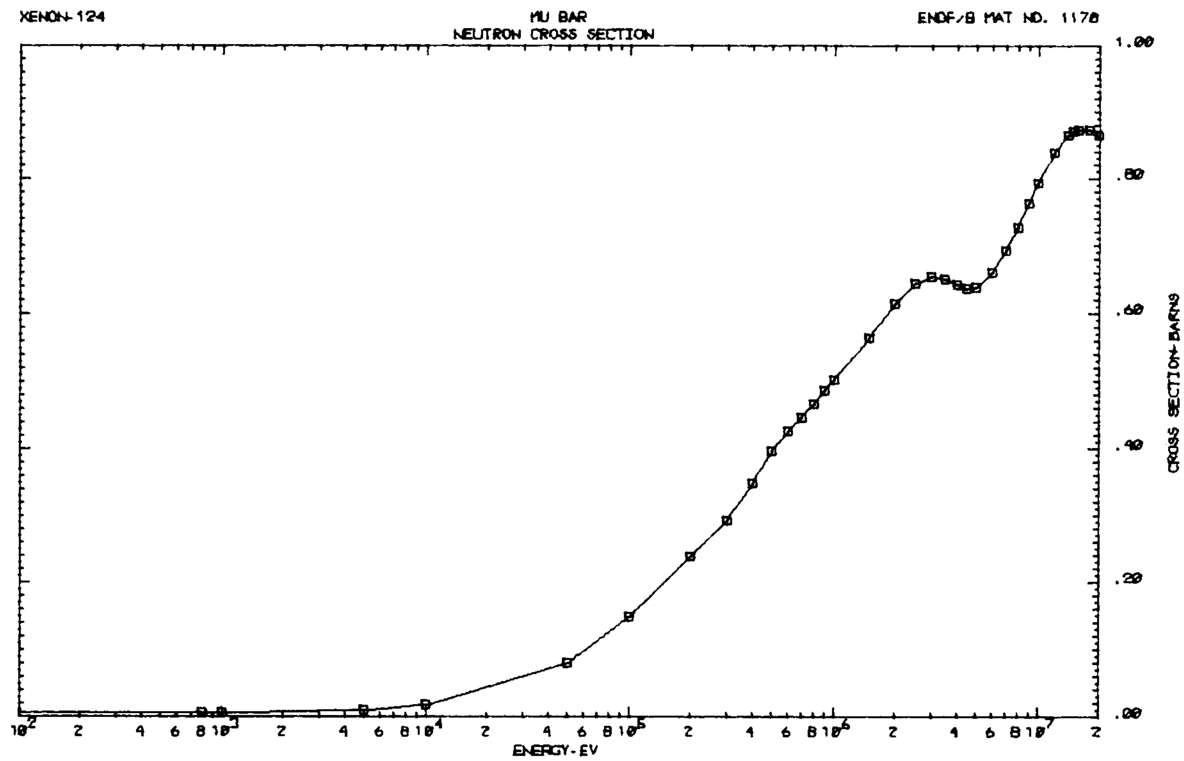

Figure 28

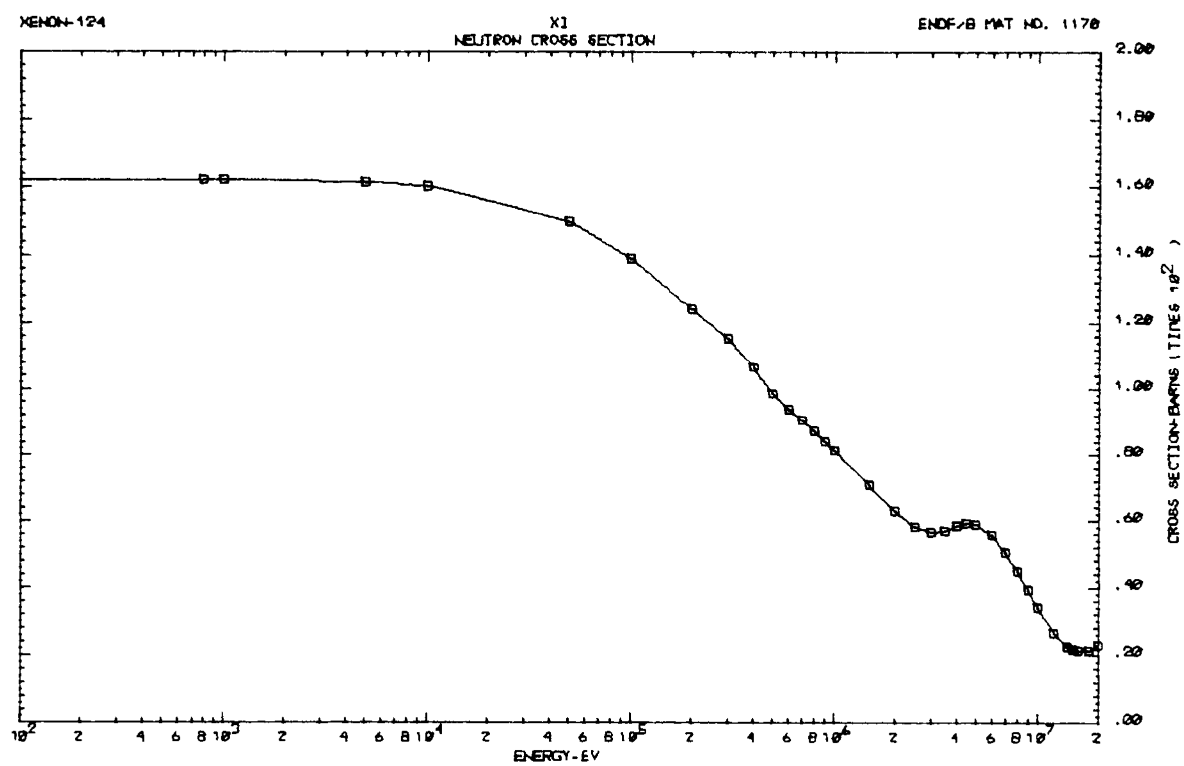

Figure 29

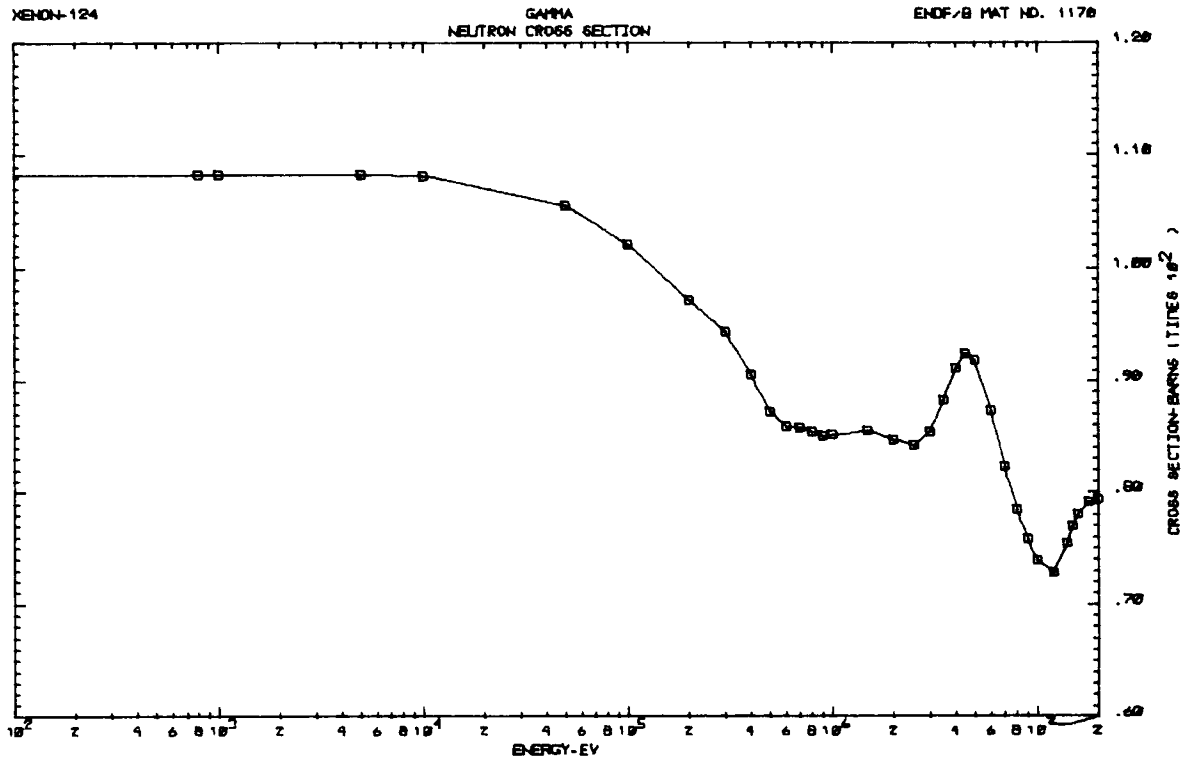
XENON-124
GAMMA
NEUTRON CROSS SECTION
ENDF/B MAT NO. 1170
1.20
1.10
1.00
.90
.80
.70
.60
CROSS SECTION-BARNS (TIMES 10^{2})
ENERGY-EV

Figure 30