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ENDF/B-V NEUTRON CROSS SECTION EVALUATION FOR THE KRYPTON ISOTOPES

A. PRINCE

January 1979

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NATIONAL NUCLEAR DATA CENTER
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

national nuclear data center

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ABSTRACT

This report describes the evaluation of the neutron cross-section data for the six stable isotopes of Kr from 10^{-5} eV to 20 MeV. These evaluations incorporate all the new data on these isotopes including those on the resonance parameters, level schemes of the various isotopes and residual nuclei and reaction data. Evaluation procedures adopted to assess experimental data and the nuclear model calculations used are described.

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1.0 INTRODUCTION

Because of the importance of krypton as a tag material for detecting and locating fuel failure in the FFTF,[1] the decision was made to upgrade the evaluation for the six stable isotopes for inclusion in ENDF/B-V. The major differences between the ENDF/B-IV [1] evaluation and the new one are related to the recent experimental resonance parameter data of Block et al.[2] New data on the level schemes of the various isotopes and residual nuclei resulting from neutron interactions also prompted a more detailed treatment of the various reaction cross sections. The evaluation covers all significant possible neutron-induced reactions from 10^{-5} eV to 20.0 MeV.

The isotopes and their corresponding MAT numbers are given below for ENDF/B-V.

Isotope	MAT
^{78}Kr	1330
^{80}Kr	1331
^{82}Kr	1332
^{83}Kr	1333
^{84}Kr	1334
^{86}Kr	1336

2.0 RESONANCE REGION

^{78}Kr MAT (10^{-5} eV to 865.0 eV)

The recent experimental data of Block et al.,[2] were used for calculating the cross section and resonances integral in this energy region. Block et al., concluded the ^{78}Kr and ^{80}Kr form a doublet around E = 106.0 eV, an assumption that was made in ENDF/IV. In addition, since neither Block[2] nor Mann and Watson[3] could definitely assign the 640-eV level to any particular isotope, although they designated the possibilities to be ^{78}Kr, ^{80}Kr,[1,3] and a doublet in ^{82}Kr,[2] this resonance was used in both ^{78}Kr and ^{80}Kr.

A negative resonance at E_R = -120.6 eV produced a thermal capture cross section

$$\sigma(0.0253 \text{ eV}) = 4.85 \text{ b}$$

which compares favorably with the experimental

$$\sigma(0.0253 \text{ eV}) = 4.71 \pm 0.68 \text{ b.}^{4,5}$$

There are no experimental data for the absorption resonance integral for ^{78}Kr. The calculated value, based on the resonance parameters given in Table 1, is $I_{ab}(E_{cutoff} = 0.5 \text{ eV}) = 23.67$ b. Block et al., estimated that $I_{ab} = 20.0 \pm 1.0$ b between 20.0 and 1200.0 eV. Both these values are about five times as large as the value quoted in Ref. 6, the reason being that in Ref. 6 only the 640.0-eV resonance was used.

Figures 1 to 3 shows the calculated values of the total, scattering, and capture cross sections, in the resonance region, based on the single-level Breit-Wigner formalism. The potential scattering cross section was estimated to be 7.00 b on the basis of several measurements ranging from 6.2±0.1 b[7] to 7.61±0.04 b[8] (also see Refs. 6 and 9) for Kr(Nat).

^{80}Kr MAT 1331 (10^{-5} eV to 1.0 keV)

Use of the resonance parameters shown in Table 1, where a bound level is located E = -118.0 eV, yielded a thermal capture cross section $\sigma_{n\gamma}$ = 11.74 b, which may be compared with the range of values given in Table 2.

The resonance integral calculated by using the parameters in Table 1 produced a value of I_γ(0.5-eV cutoff) = 68.6 b, which, although somewhat higher than those recommended in Refs. 2, 6, and 10, is preferred since the most recent quoted value[2] is based on data in the region 20.0 to 1200.0 eV which clearly underestimate the evaluated value that goes from 0.05 eV to the MeV range.

The potential scattering cross section is taken to be the same as that of ^{78}Kr.

The total, elastic, and capture cross sections in the resonance regions are shown in Figures 4 to 6.

^{82}Kr MAT 1332 (10^{-5} eV to 100.0 eV)

Only one resonance at an energy of ~ 40 eV has been firmly established for ^{82}Kr.[2,6] Block et al.,[2] have concluded that there is a doublet belonging to ^{82}Kr around 640.0 eV, but, since they give no neutron width (Γ_n), this resonance has been ignored.

The radiation width $\Gamma_{\gamma r}$ was determined by the method proposed by Malecky et al.,[11] in which it is assumed that the main contribution to $\Gamma_{\gamma r}$ is due to the electric dipole radiation; from a semi-empirical analysis it may be estimated as

$$\Gamma_{\gamma r} = 10.5\ U/A\ (a^{-1/2})(1.0 - 0.01\ I^2)\ \text{eV} \qquad (1)$$

where

A = mass of nucleus,
U = effective energy of excitation ($U = E_B - \Delta$),
E_B = binding energy of compound nucleus,
Δ = δ(N) and δ(p) the pairing energies,
I = spin of target nucleus, and
a = single-particle state density parameter near the Fermi surface.

The relation between a and A is based on the analysis of Cook et al.,[12] where

$a/A = 0.00917S + 0.142$, and
$S = S(N) + S(Z)$ shell correction parameter.

A value of $\Gamma_{\gamma r}$ = 236 mV was calculated from Eq. (1) for ^{82}Kr.

In addition to the reported resonance at 39.8 eV, it was necessary to assume a bound level at -42.83 eV (Table 1) to yield a thermal capture cross section $\sigma_{n\gamma}$ = 30.17 b. The experimental value leading to the metastable state in ^{83}Kr of $\sigma_{n\gamma}{}^m$ = 20.0±3.5 b has been reported in Ref. 4. The value calculated here is barely within the recommended value of

$\sigma_{n\gamma}^{(m+g)}$ = 45±15 b.[6] A value $\sigma_{n\gamma}$ = 25.0 b has been estimated by Iijima.[13]

As with ^{78}Kr and ^{80}Kr, the potential scattering cross section was chosen to be σ_{pot} = 7.0 b.

The resonance integral calculated from the data in Table 1 is I_γ = 183.56 b (E_{cutoff} = 0.5 eV). The recommended value calculated from a single resonance at 39.8 eV has been given as 200±40 b.[6] A calculated I_γ = 190.0 b where 13.7 b is due to the unresolved region was reported in Ref. 13.

The total, elastic, and capture cross sections for the resonance region are displayed in Figures 7 through 9.

<u>^{83}Kr MAT 1333</u> (10^{-5} to 520.625 eV)

The resonance parameters given in Ref. 3 yielded a thermal capture cross section of the only 16 b, which is much too small compared with the various recommended values 200±30 b[6] and 205 b.[13]

Calculating the radiation width by Eq. (1) yielded $\Gamma_{\gamma r}$ = 233.0 mV; assuming a bound level at -3.9 eV gives a thermal capture cross section $\sigma_{n\gamma}$ = 207.67 b.

The calculated resonance integral is I_γ = 188.65 b, which is lower than the value I_γ = 230±30 b quoted in Ref. 6 but higher than the value I_γ = 170.2 b in Ref. 13.

As earlier, the potential scattering cross section is the same as that of Kr(Nat), namely 7.0 b.

Figures 10 through 12 show the total, elastic, and capture cross section from 1.0 eV to 1.0 keV.

<u>^{84}Kr MAT 1334</u> (10^{-5} to 2.0 keV)

An unassigned resonance reported by Mann and Watson[3] was assumed to be due to ^{84}Kr at an energy of 1625.0 eV, with a neutron width Γ_n = 2.84.0 mV and Γ_γ = 226.0 mV (Eq. 1). This resonance along with the other two low-lying resonances at 519.0 and 580.0 eV yielded a thermal capture cross section $\sigma_{n\gamma}$(0.0253 eV) = 0.0864 b. Kondaiah et al.,[4] reported an experimental value of 0.09±0.013 b for the 4.4-h ^{85}Kr and a value of 0.042±0.004 b for the 10.74-y ^{85}Kr. A recommended value of $\sigma_{n\gamma}$ = 0.130±0.014 b ^{85}Kr$^{(m+g)}$ is given in Ref. 6, and $\sigma_{n\gamma}$ = 0.16 b is reported in Ref. 14.

The calculated resonance integral of magnitude 3.27 b is in good agreement with the calculated value of 2.7±0.7 b reported in Ref. 6, and in excellent agreement with I_γ = 3.54 given in Ref. 14.

The total, elastic, and capture cross sections are given in Figures 13 to 15.

^{86}Kr MAT 1336 (10^{-5} eV to 13 keV)

Since no resonance parameters have been experimentally verified for ^{86}Kr, it was necessary to make certain assumptions. From Mann et al.,[3] there is an unassigned resonance at an energy of ~ 2700 eV. Since the thermal capture cross section and resonance integral for ^{86}Kr have been estimated to be very small (see following references) this resonance was taken to be due to this isotope.

On the basis of an estimated s-wave strength function, $s_o = 0.5\chi10^{-4}$, and assuming $\Gamma_\gamma/\Gamma_n << 1$, the resonance parameters given in Table 1 were derived. These parameters produced a thermal capture cross section equal to 0.0635 b, which is not too far from the value 0.06±0.02 b[6] and is consistent with the estimate of 0.062 b.[14] Again, a potential scattering radius of 7.0 was used.

The resonance integral was calculated to be 0.122 b, which may be compared with the calculated value of 0.03±0.03 b[3], and 0.07 quoted in Ref. 14 (also see Ref. 13).

The resonance region cross sections are shown in Figures 16 to 18.

Kr(Nat) Data

The total cross sections for the Kr isotopes calculated by using the resonance parameters in Table 1 were weighted by the respective isotopic abundance (see Table 3) and combined to produce the Kr(Nat) data. These results are compared with experimental data in Figures 19 and 20.

3.0 CONTINUUM REGION CROSS SECTION

The cross sections (total, elastic, inelastic capture, n-proton, and n-^{4}He) in the keV to 20-MeV region were calculated by using the code CERBERO-2.[16] The sources for the various optical model potentials employed are given in Table 4. No experimental data are available for the total cross sections for the Kr isotopes, but data do exist for Kr(Nat).

The O.M. calculations for the various isotopes were weighted by their abundance (see Table 3) and combined to give a calculated σ_T for Kr(Nat). The experimental data are compared with these results in Figure 21.

The n,γ, n,n', n,p, and n-^{4}He reaction calculations were carried out in the Hauser-Feshbach formalism with width fluctuation correction and with the Q values given in Table 5. The level schemes used in these calculations are given in Table 6 (these levels were taken from Ref. 22 unless otherwise stated). The calculations were then modified to take into account other threshold reaction cross section (n,2n, n,3n, n,d, n,t) which were calculated for ENDF/IV (see Ref. 1).

Figures 22 through 67 show some of the more important reaction cross sections, up to 20.0 MeV.

4.0 ANGULAR DISTRIBUTION OF SECONDARY NEUTRONS

The angular distribution of the elastically scattered neutrons was interpreted in terms of a Legendre polynomial fit using CHAD[26] for File 4.

For the inelastically scattered neutrons and the n,2n reactions, the distribution was assumed to be isotropic.

5.0 ENERGY DISTRIBUTION OF SECONDARY NEUTRONS

The energy distributions of neutrons due to the n,2n, n,3n, and continuum inelastic scattering were expressed in terms of a normalized probability distribution having an evaporation spectrum given by

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

where I = normalization constant, and θ = nuclear temperature. The energy dependence of θ was formulated according to Gilbert and Cameron.[27]

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Table 1
Adopted Resonance Parameters

Isotope	E_R (eV)	Γ_T (mV)	Γ_n (mV)	Γ_γ (mV)	Ref.
^{78}Kr	-120.6*	936.0	706.0	230.0	-
	108.4	279.0	49.0	230.0	2
	450.9	460.0	230.0	230.0	2
	640.0	1730.0	1500.0	230.0	2
^{80}Kr	-118.0*	1460.0	1230.0	230.0	-
	89.2	234.0	4.0	230.0	2
	106.0	670.0	440.0	230.0	2
	927.0	2530.0	2300.0	230.0	2
^{82}Kr	-42.83	496.0	260.0	236.0	1
	39.80	324.3	88.3	236.0	1
^{83}Kr	- 3.9	245.44	12.44	233.0	1
	27.9	300.0	67.0	233.0	1
	233.0	523.0	290.0	233.0	1
^{84}Kr	519.0	571.0	345.0	226.0	1
	580.0	313.0	87.0	226.0	1
	1625.0	2410.0	2184.0	226.0	1
^{86}Kr	2730.0	3568.0	3400.0	168.0	1

*See text.

Table 2
Experimental and Recommended Thermal Capture Cross Sections for ^{80}Kr

$\sigma_{n\gamma}$ (b)	Reference
14.0±1.5	BNL 325, Vol. 1 (3rd ed.), 1973.
11.3±0.4	G. Bondley and W.H. Johnson, NSE 47, 151 (1972).
15.6±2.8	I.R. Barabanov et al., JETP Lett. 15, 456 (1972).
11.5±0.6	N.E. Holden and F.W. Walker, G.E. Chart of Nuclides (11th ed.), 1972.
11.5±0.5	N.E. Holden (BNL), Private Communication, 1978.
12.6	F.W. Walker et al., G.E. Chart of Nuclides (12th ed.), 1977.
11.74	This work.

Table 3
Natural Abundance and Mass of Krypton Isotopes

Isotope	% Abundance	Mass (amu)	S_n (MeV)*
78	0.35	77.920401	8.368
80	2.25	79.916376	7.850
82	11.60	81.913482	7.467
83	11.50	82.914131	10.518
84	57.00	83.911506	7.111
86	17.30	85.910616	5.511

*S_n = Binding energy of last neutron in compound nucleus.

Table 4
Optical Model Potential

Reaction	Reference
n,n	Wilmore and Hodgson[17]
n,p	Becchetti and Greenlees[18]
n,α	Makowska[19]

Table 5
Q Values for Nuclear Reactions

Reaction	^{78}Kr -Q (MeV)	^{80}Kr -Q (MeV)	^{82}Kr -Q (MeV)	^{83}Kr -Q (MeV)	^{84}Kr -Q (MeV)	^{86}Kr -Q (MeV)	ENDF MT
(n,p)	-0.089	1.228	2.306	0.187	3.920	6.520	103
(n,^{3}He)	5.752	7.730	9.695	10.461	11.707	14.202	106
(n,n'd)	17.129	17.581	17.884	15.151	18.067	18.669	
(n,n'^{4}He)	4.358	5.066	5.990	6.479	7.101	7.511	22
(n,^{4}He,n')	4.358	5.066	5.990	6.479	7.101	7.511	22
(n,p,^{4}He)	4.931	7.252	5.990	7.942	12.322	14.308	
(n,2n)	11.981	11.525	10.980	7.467	10.518	9.860	16
(n,d)	5.974	6.886	7.766	7.548	8.480	9.655	104
(n,^{4}He)	-3.665	0.969	-1.111	-1.526	-1.168	-1.384	107
(n,n't)	19.942	19.610	19.468	19.052	19.410	19.194	
(n,p,n')	8.199	9.111	9.907	9.773	10.705	11.880	28
(n,^{4}He,p)	4.931	7.252	9.475	7.942	12.322	14.208	
(n,3n)	21.14	19.893	18.839	18.450	17.985	16.971	71
(n,t)	10.87	11.322	11.585	8.892	11.808	12.410	105
(n,n'p)	8.199	9.111	9.907	9.773	10.705	11.880	28
(n,n'^{3}He)	16.913	18.226	19.590	17.162	20.978	22.753	
(n,2p)	6.052	8.470	10.711	8.907	13.500	17.111	
(n,d,n')	17.129	17.581	17.884	15.151	18.067	18.669	

Table 6(a)

Energy Levels for Hauser-Feshbach Calculations: ^{78}Kr

Residual Nucleus: ^{79}Kr		^{78}Kr		^{78}Br		^{75}Sc	
$\sigma_{n\gamma}$		$\sigma_{nn'}$		σ_{np}		$\sigma_{n\alpha}$	
E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}
0.000	$1/2^-$	0.000	0^+	0.000	1^+	0.000	$5/2^+$
0.300	$7/2^+$	0.455	2^+	0.032	2^-	0.110	$3/2^+$
0.147	$5/2^-$	1.119	4^+	0.180	4^+	0.285	$1/2^-$
0.183	$3/2^-$	1.978	6^+			0.420	$5/2^+$
0.291	$5/2_-$					0.610	$3/2^-$
0.384	$3/2^-$					0.750	$7/2^-$
0.402	$5/2^-$					0.860	$5/2^-$
0.450	$7/2^-$					0.903	$3/2^-$
0.534	$1/2^+$					1.030	$7/2^-$
0.660	$5/2^-$						
0.689	$5/2^-$						
0.695	$3/2^+$						
0.720	$7/2^-$						
0.810	$3/2^-$						
1.038	$7/2^-$						
1.912	$1/2^+$						
2.060	$3/2^+$						
2.768	$7/2^+$						

Table 6(b)

Energy Levels for Hauser-Feshbach Calculations: ^{80}Kr

Residual Nucleus: ^{81}Kr		^{80}Kr		^{80}Br		^{77}Sc	
$\sigma_{n\gamma}$		$\sigma_{nn'}$		σ_{np}		$\sigma_{n\alpha}$	
E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}
0.000	$7/2^+$	0.000	0^+	0.000	1^+	0.000	$1/2^-$
0.190	$1/2^-$	0.616	2^+	0.037	2^-	0.162	$7/2^+$
0.457	$3/2^-$	1.252	2^+	0.085	5^-	0.175	$9/2^+$
0.549	$1/2^+$	1.320	0^+	0.256	2^+	0.239	$3/2^-$
0.608	$5/2^-$	1.436	4^+	0.271	2^-	0.250	$5/2^-$
0.636	$7/2^-$	2.390	6^+	0.281	3^-	0.440	$5/2^-$
0.701	$3/2^+$	3.400	8^+	0.314	1^+	0.521	$3/2^-$
0.919	$3/2^-$			0.366	1^-	0.680	$5/2^+$
1.025	$3/2^+$			0.381	3^-	0.818	$1/2^-$
1.108	$1/2^+$			0.468	1^+	0.912	$3/2^+$
1.280	$3/2^+$			0.684	2^-	0.956	$1/2^+$
1.677	$5/2^+$			0.722	1^+	1.006	$3/2^-$
1.803	$3/2^+$			0.760	1^+	1.126	$1/2^+$
				0.835	1^-	1.412	$1/2^-$
				1.139	1^+	1.623	$1/2^-$
				1.200	2^-	1.819	$1/2^-$
				1.410	3^+	2.393	$3/2^-$
				1.700	2^-		
				1.880	2^-		

Table 6(c)

Energy Levels for Hauser-Feshbach Calculations: ^{82}Kr

^{83}Kr		Residual Nucleus: ^{82}Kr		^{82}Br		^{79}Sc	
$\sigma_{n\gamma}$		$\sigma_{nn'}$		σ_{np}		$\sigma_{n\alpha}$	
E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}
0.000	$9/2^+$	0.000	0^+	0.000	5^-	0.000	$7/2^+$
0.009	$7/2^+$	0.777	2^+	0.046	2^-	0.096	$1/2^-$
0.042	$1/2^-$	1.475	2^+	0.078	1^+	0.130	$9/2^+$
0.562	$5/2^-$	1.820	4^+			0.365	$5/2^-$
0.571	$3/2^-$	2.094	3^+			0.526	$1/2^-$
0.690	$3/2^+$	2.172	0^+			0.620	$3/2^+$
0.798	$7/2^-$	2.427	3^+			0.720	$3/2^+$
		2.648	4^-			0.974	$1/2^-$
		2.828	5^-			1.160	$1/2^+$
		2.920	6^+			1.490	$1/2^+$
						1.670	$3/2^+$
						2.040	$1/2^-$
						2.280	$3/2^-$
						2.590	$3/2^+$
						2.960	$1/2^+$
						3.280	$1/2^+$
						3.440	$3/2^+$

Table 6(d)

Energy Levels for Hauser-Feshbach Calculations: ^{83}Kr

^{84}Kr		Residual Nucleus: ^{83}Kr		^{83}Br		^{80}Sc	
$\sigma_{n\gamma}$		$\sigma_{nn'}$ *		σ_{np}		$\sigma_{n\alpha}$	
E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}
0.000	0^+	0.000	$9/2^+$	0.000	$3/2^-$	0.000	0^+
0.882	2^+	0.009	$7/2^+$	0.357	$5/2^-$	0.686	2^+
1.834	0^+	0.042	$1/2^-$	0.988	$1/2^-$	1.449	2^+
1.900	2^+	0.562	$5/2^-$	1.030	$3/2^-$	1.479	0^+
2.086	4^+	0.571	$3/2^-$	1.700	$1/2^-$	1.960	2^+
2.337	4^+	0.690	$5/2^-$	2.050	$3/2^-$	2.310	2^+
2.705	3^-	0.798	$7/2^-$	2.450	$7/2^+$	2.514	2^+
2.775	2^+			2.646	$7/2^+$	2.814	2^+
3.048	4^+			2.738	$1/2^+$	3.126	2^+
3.225	1^-			2.946	$7/2^-$	3.248	2^+
3.477	1^-			3.09	$1/2^-$	3.350	1^+
3.570	3^-					3.390	2^+
3.650	5^-					4.063	0^+
3.721	3^-						

*Reference 24.

Table 6(e)

Energy Levels for Hauser-Feshbach Calculations: ^{84}Kr

Residual Nucleus: ^{85}Kr		^{84}Kr		^{84}Br		^{81}Sc	
$\sigma_{n\gamma}$		$\sigma_{nn'}$*		σ_{np}		$\sigma_{n\alpha}$	
E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}
0.000	$9/2^{+}$	0.000	0^{+}	0.000	2^{-}	0.000	$1/2^{-}$
0.305	$1/2^{-}$	0.822	2^{+}	0.408	1^{-}	0.103	$7/2^{+}$
1.050	$3/2^{-}$	1.834	0^{+}	0.557	6^{-}	0.294	$9/2^{+}$
1.230	$5/2^{-}$	1.900	2^{+}	0.873	2^{-}	0.468	$1/2^{-}$
1.767	$3/2^{+}$	2.086	4^{+}	0.979	3^{-}	0.625	$5/2^{-}$
2.108	$1/2^{-}$	2.337	4^{+}	1.196	4^{-}	1.053	$3/2^{+}$
2.166	$1/2^{+}$	2.705	3^{-}			1.232	$1/2^{+}$
2.237	$7/2^{+}$	2.775	2^{+}			1.303	$3/2^{+}$
2.418	$5/2^{-}$	3.048	4^{+}			1.406	$1/2^{-}$
3.380	$7/2^{-}$	3.225	1^{-}			1.725	$3/2^{+}$
		3.477	1^{-}			1.828	$5/2^{+}$
		3.570	3^{-}			2.174	$3/2^{+}$
		3.650	5^{-}			2.550	$5/2^{+}$
		3.721	3^{-}			2.680	$1/2^{+}$
						3.070	$3/2^{+}$
						3.310	$5/2^{+}$
						3.490	$3/2^{+}$
						3.570	$1/2^{+}$
						3.670	$3/2^{+}$
						3.720	$5/2^{+}$

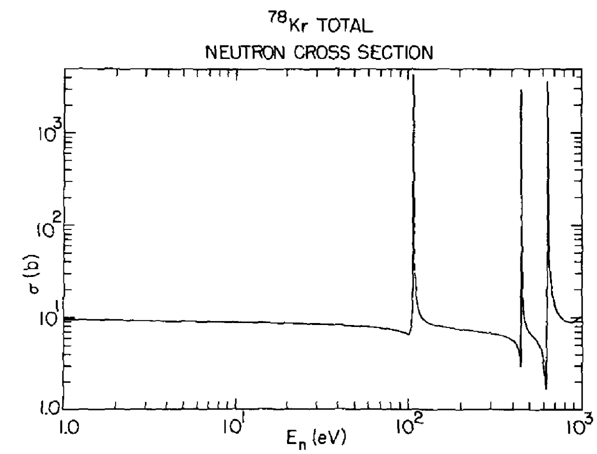
*Reference 23.

Table 6(f)

Energy Levels for Hauser-Feshbach Calculations: ^{86}Kr

Residual Nucleus: ^{87}Kr		^{86}Kr		^{86}Br		^{83}Sc	
$\sigma_{n\gamma}$		$\sigma_{nn'}$*		σ_{np}		$\sigma_{n\alpha}$	
E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}	E (MeV)	I^{π}
0.000	$5/2^{+}$	0.000	0^{+}	0.000	2^{-}	0.000	$9/2^{+}$
0.529	$1/2^{+}$	1.563	2^{+}	0.196	1^{-}	0.220	$1/2^{-}$
1.468	$3/2^{+}$	2.248	4^{+}	0.268	4^{-}	1.050	$3/2^{-}$
1.873	$5/2^{+}$	2.355	2^{+}	0.390	2^{-}	1.230	$5/2^{-}$
1.996	$3/2^{+}$	2.733	0^{+}	0.862	1^{-}	1.767	$3/2^{+}$
2.080	$5/2^{+}$	3.109	3^{-}	1.210	1^{-}	2.108	$1/2^{-}$
2.112	$3/2^{+}$	3.542	0^{+}	2.232	1^{+}	2.166	$1/2^{+}$
2.250	$9/2^{-}$	3.832	0^{+}	2.392	1^{+}	2.237	$7/2^{+}$
2.277	$1/2^{+}$	3.959	4^{+}	2.772	1^{+}	2.418	$5/2^{-}$
2.515	$7/2^{+}$	4.111	2^{+}			3.380	$7/2^{-}$
2.775	$3/2^{+}$	4.194	2^{+}				
2.825	$3/2^{+}$	4.298	3^{-}				
3.015	$5/2^{+}$	4.668	4^{+}				
3.223	$3/2^{+}$	4.826	2^{+}				
3.237	$5/2^{+}$	4.948	2^{+}				

*References 23 and 25.



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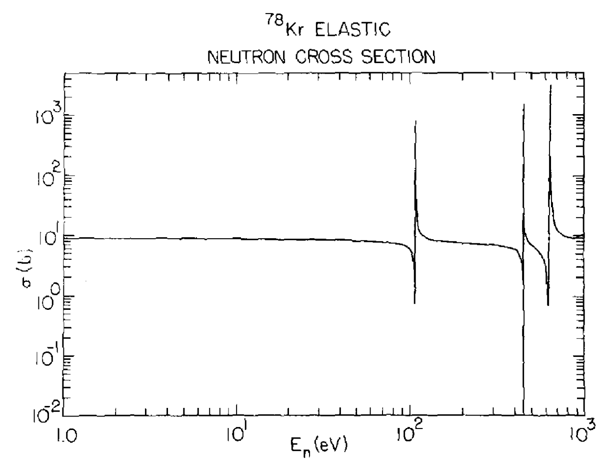

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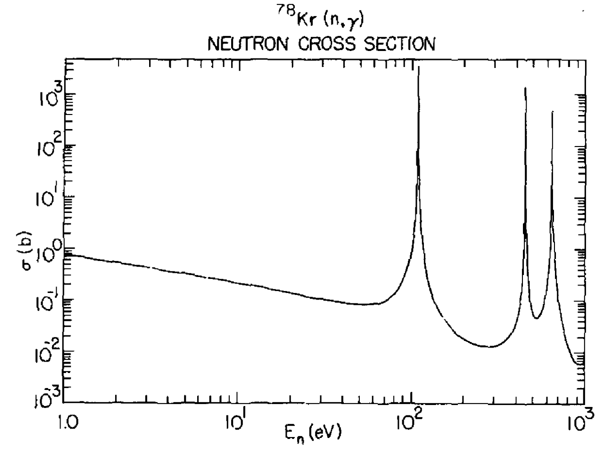

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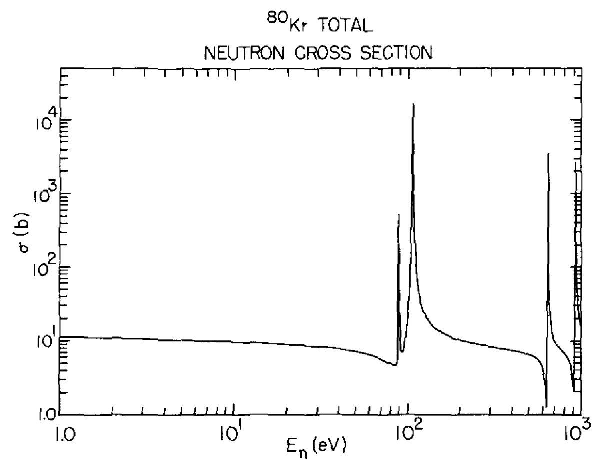

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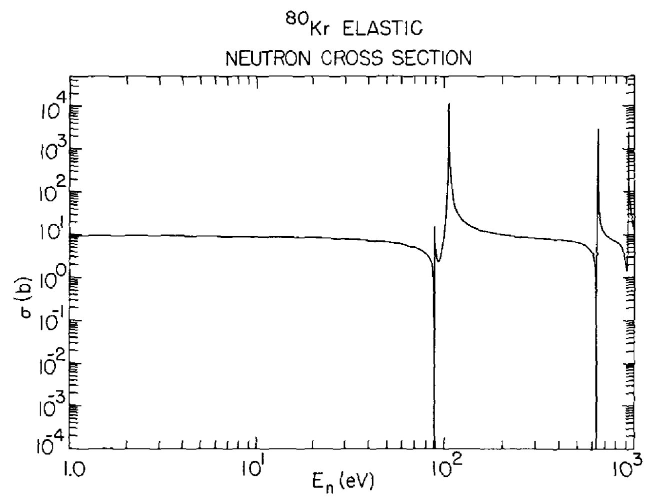

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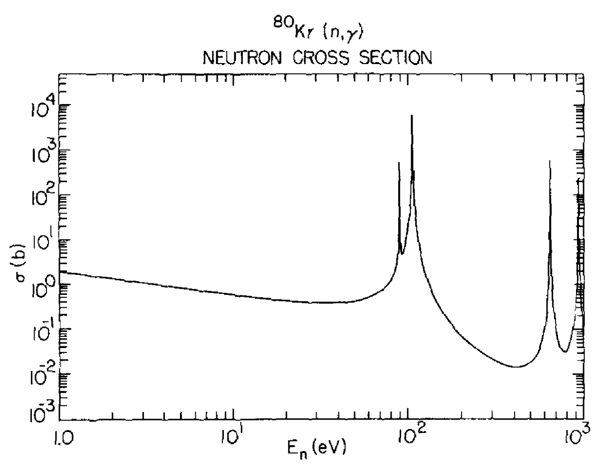

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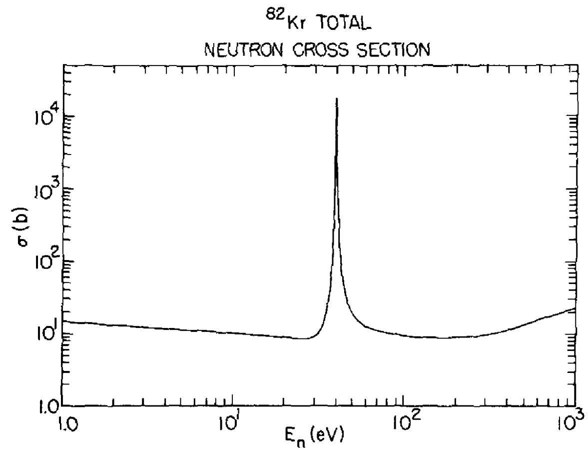

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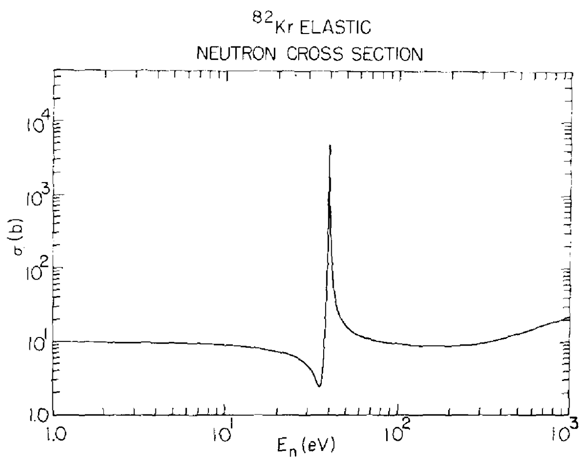

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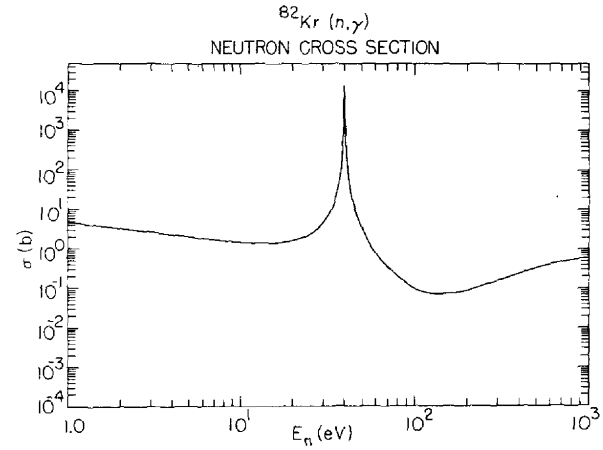

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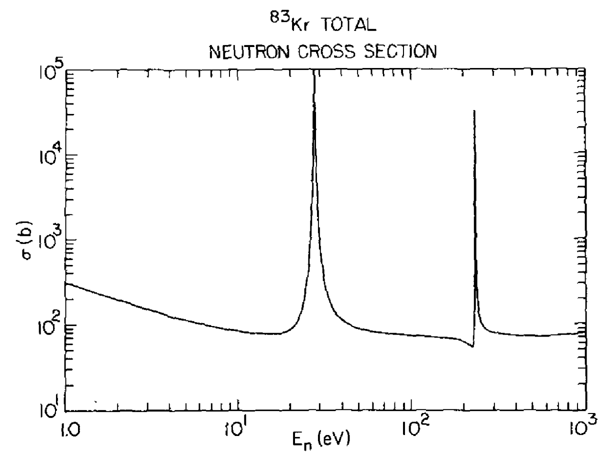

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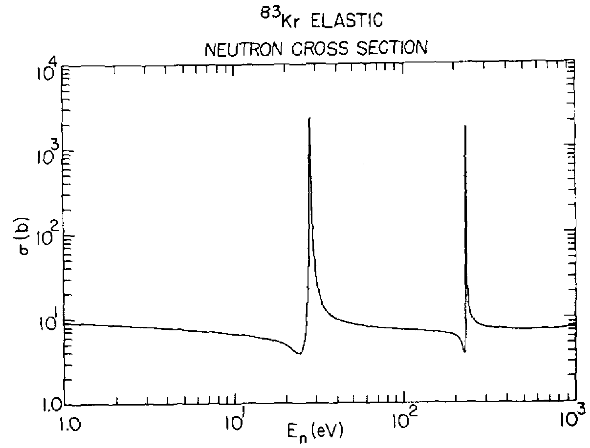

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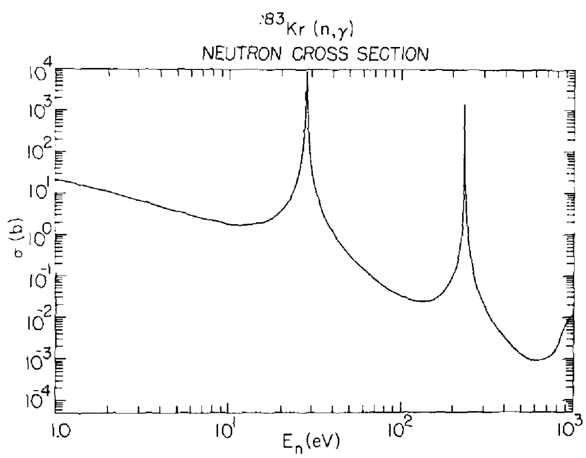

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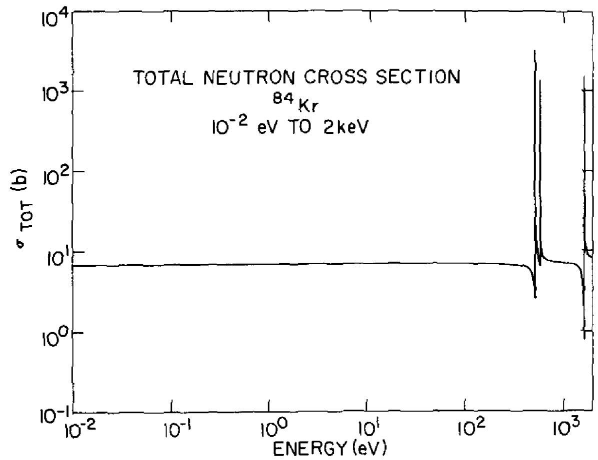

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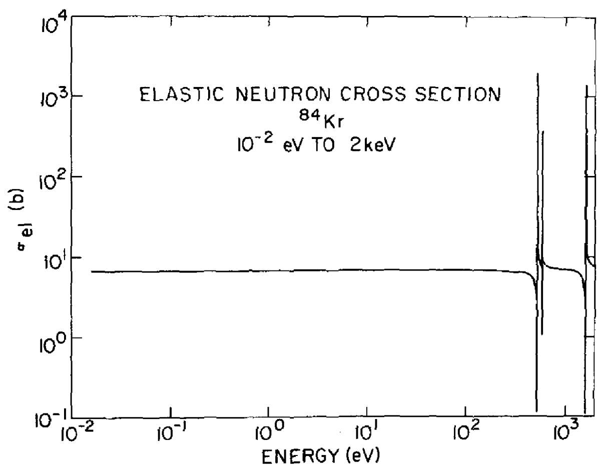

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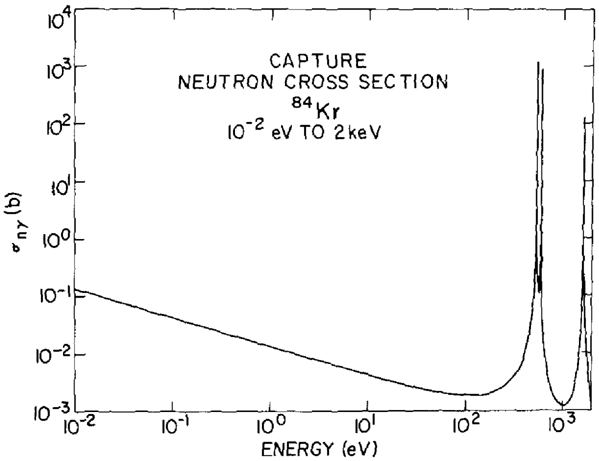

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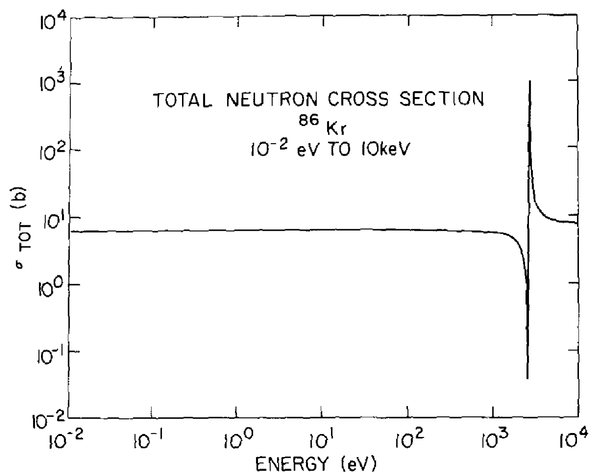

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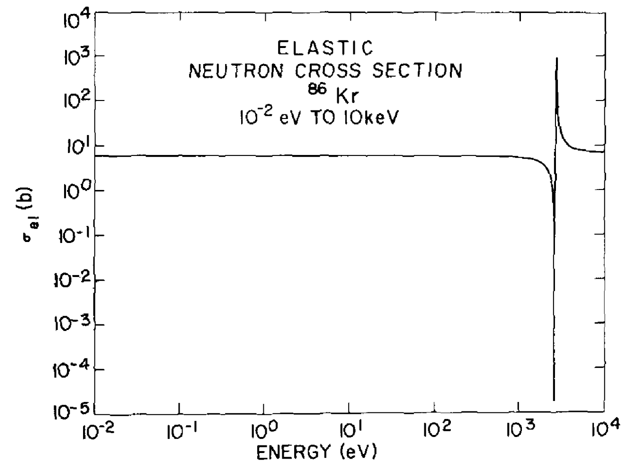

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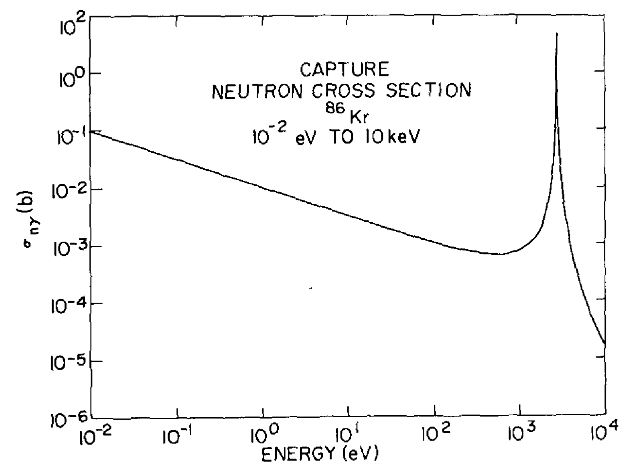

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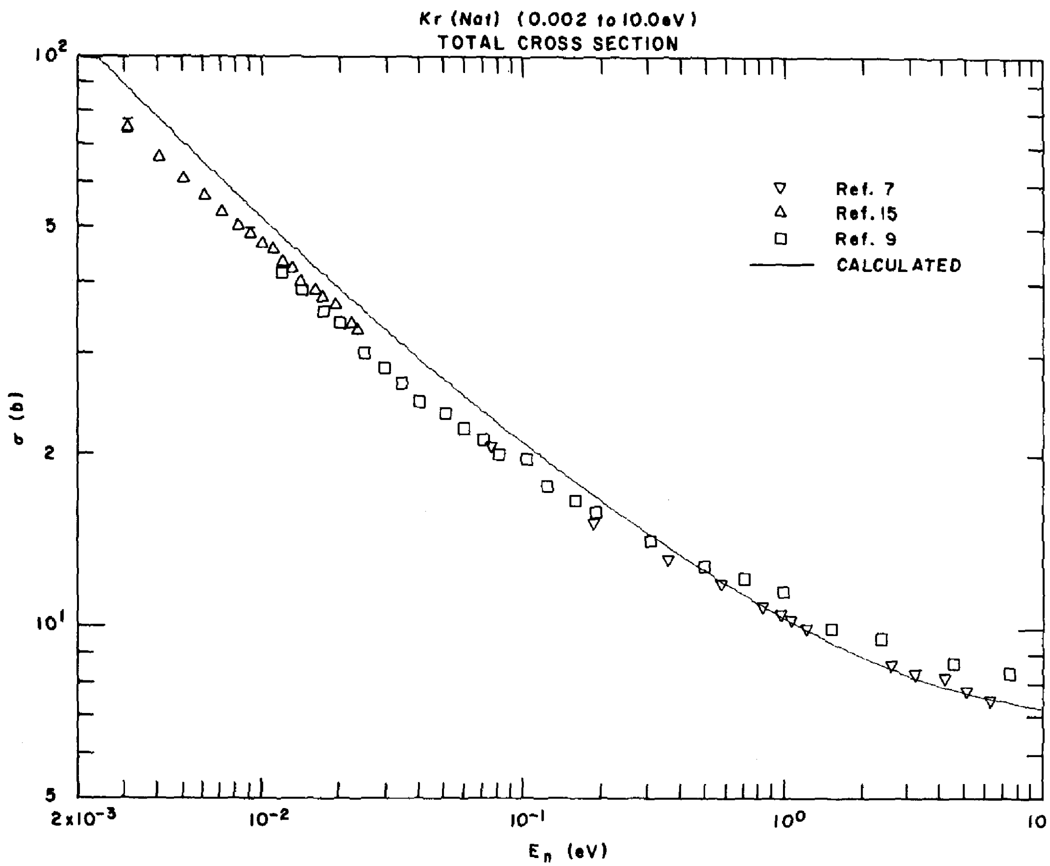

Kr (Nat) (0.002 to 10.0eV)
TOTAL CROSS SECTION
Ref. 7
Ref. 15
Ref. 9
CALCULATED
σ (b)
E_n (eV)
10²
5
2
10¹
5
2x10⁻³
10⁻²
10⁻¹
10⁰
10¹

Figure 19.

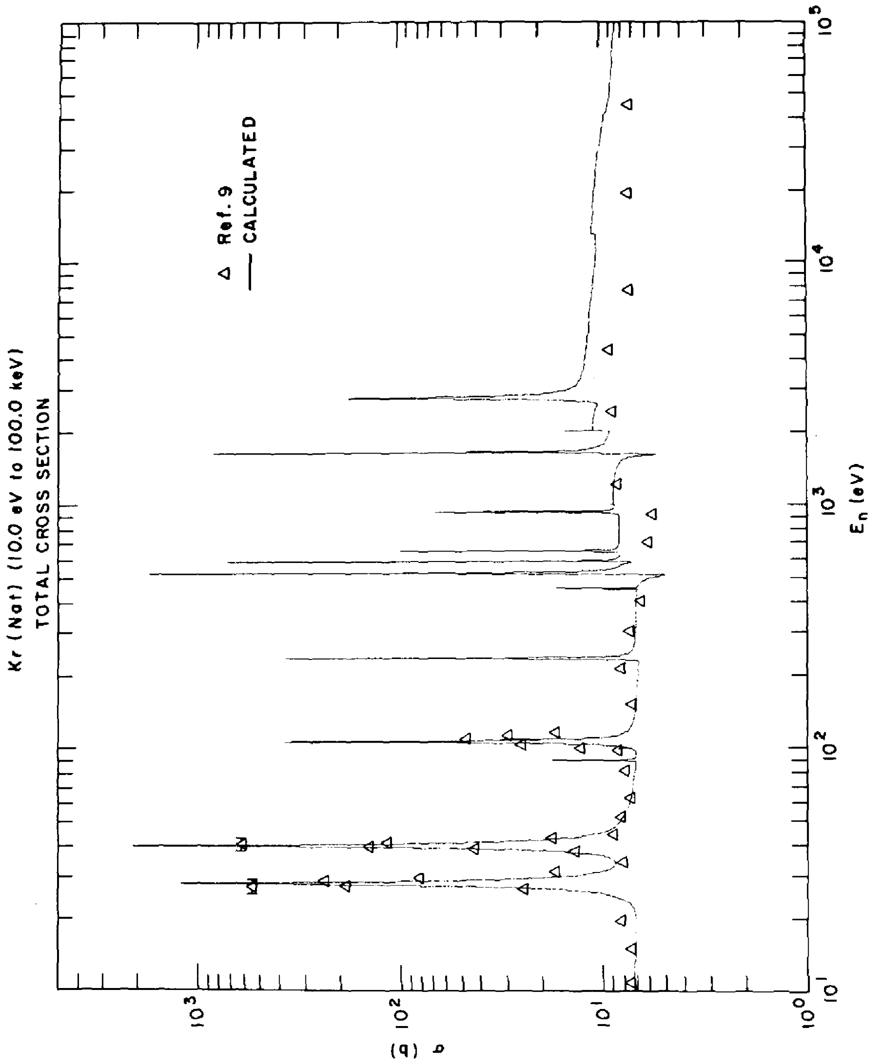
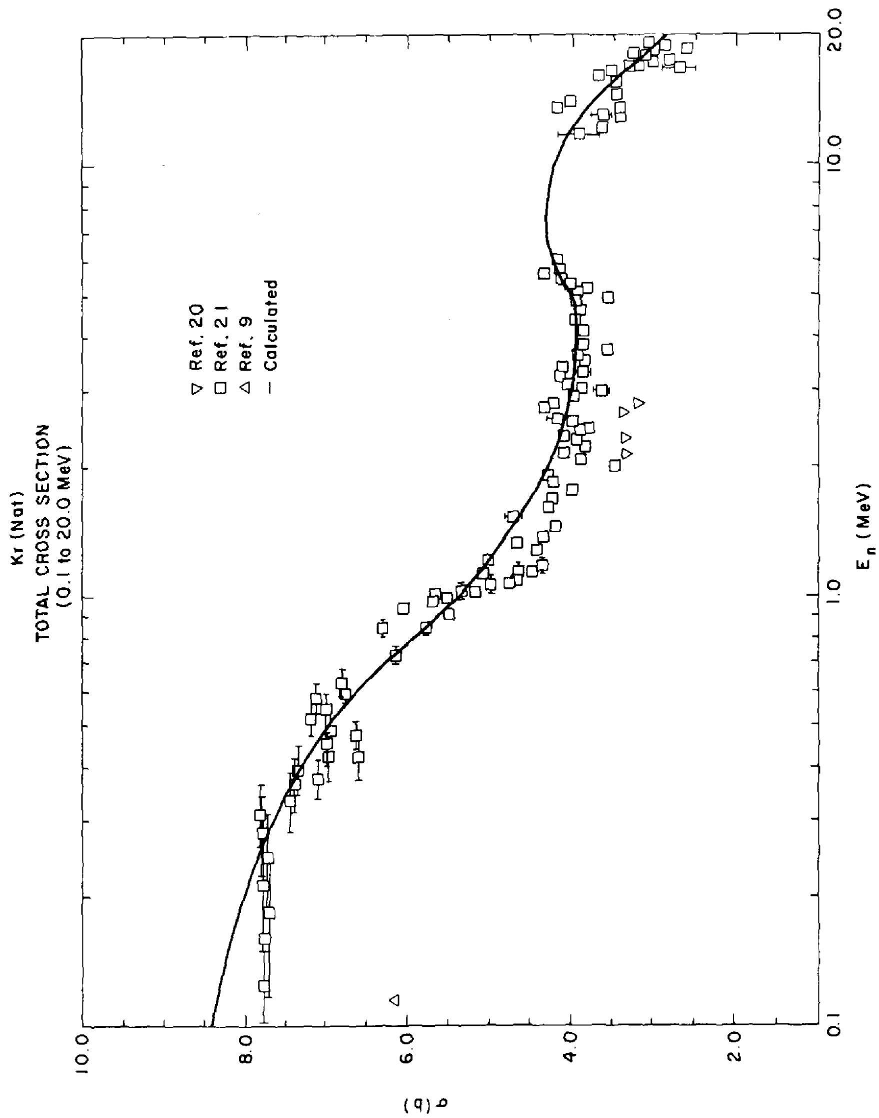
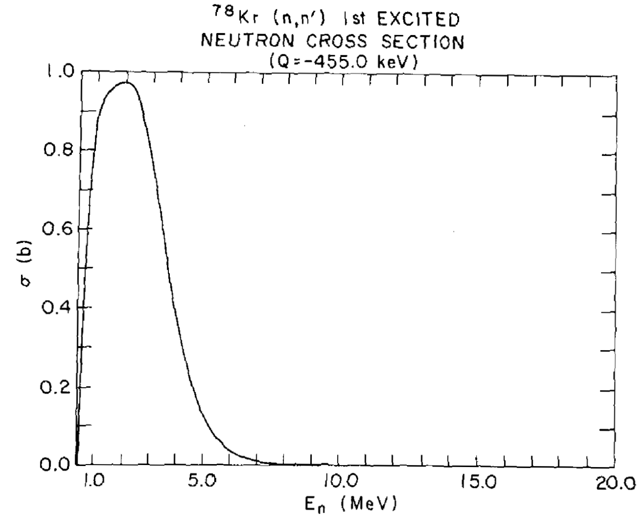

Kr (Nat) (10.0 eV to 100.0 keV)
TOTAL CROSS SECTION
Δ Ref. 9
— CALCULATED
σ (b)
E_n (eV)
10^0
10^1
10^2
10^3
10^4
10^5

Figure 20.



Kr (Nat)
TOTAL CROSS SECTION
(0.1 to 20.0 MeV)
▽ Ref. 20
□ Ref. 21
△ Ref. 9
— Calculated
σ (b)
E_n (MeV)

Figure 21.



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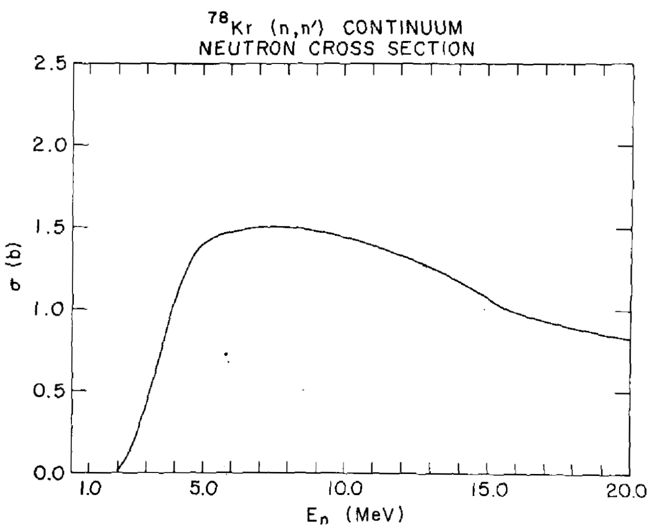

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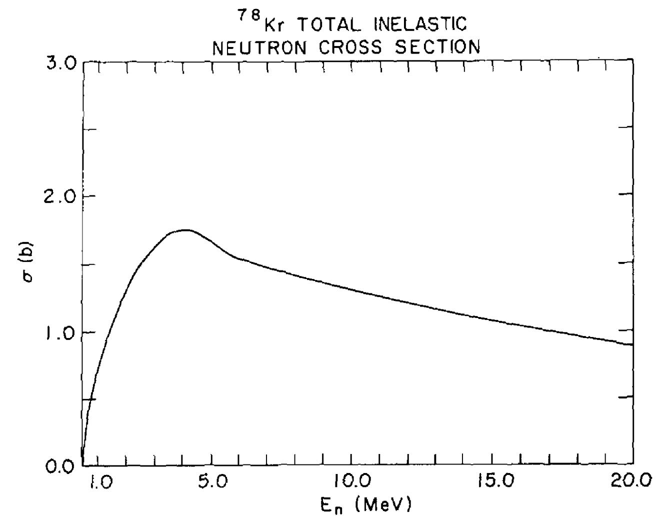

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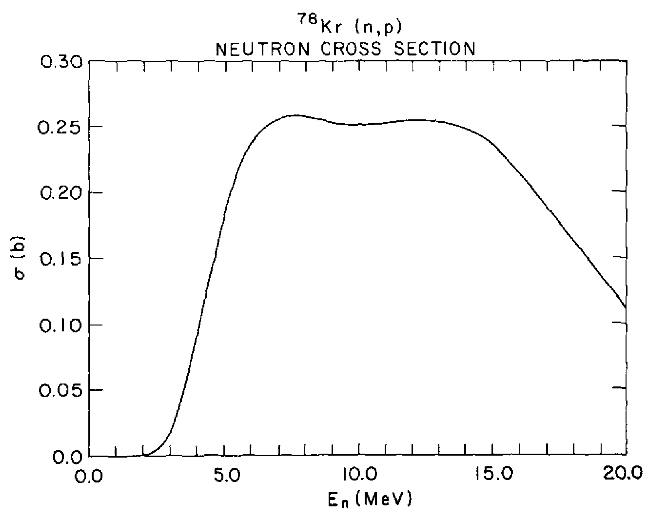

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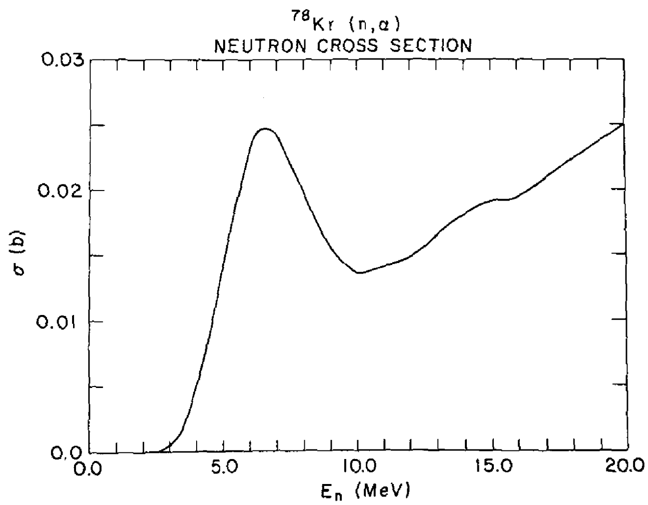

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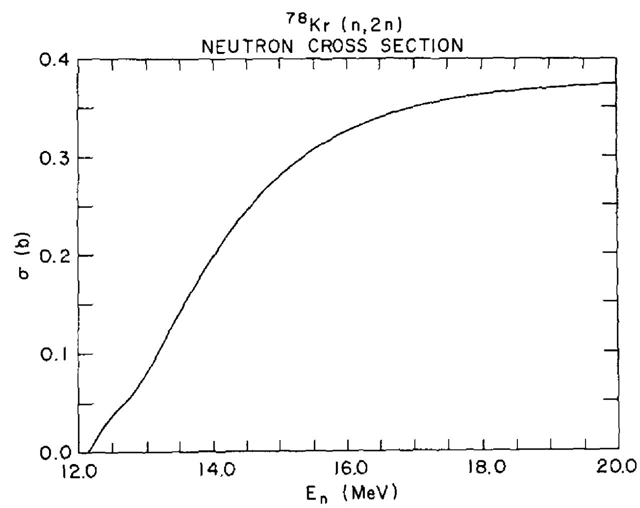

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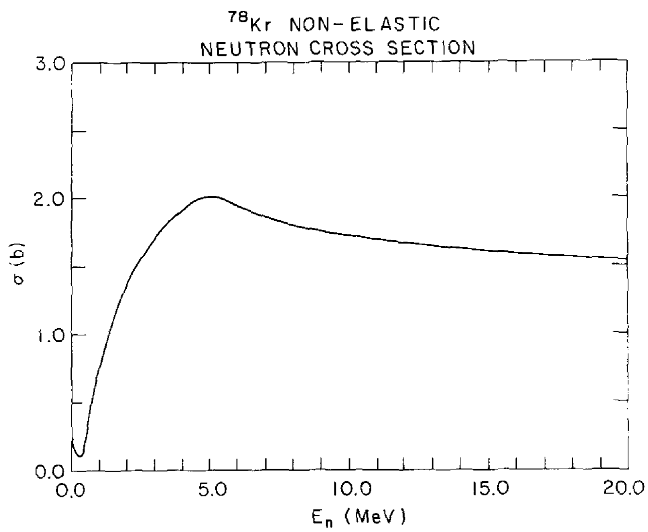

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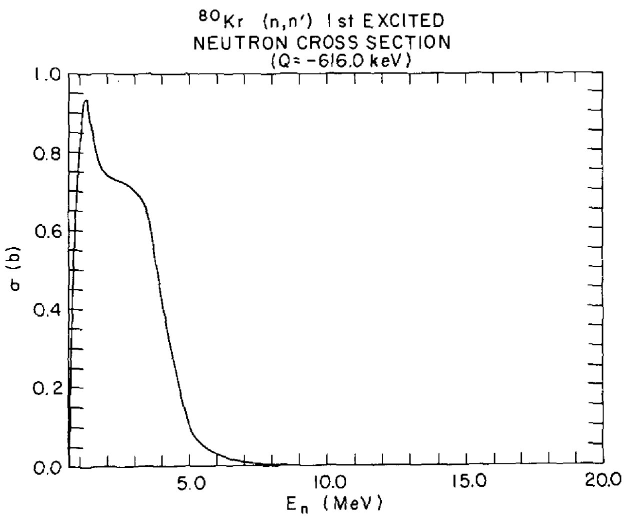

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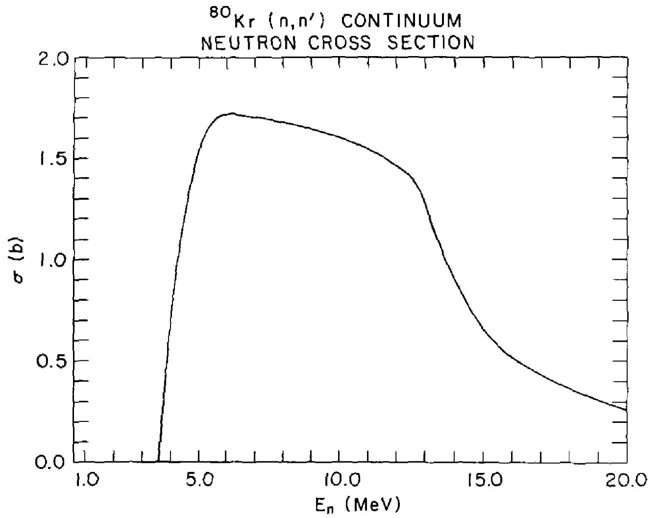

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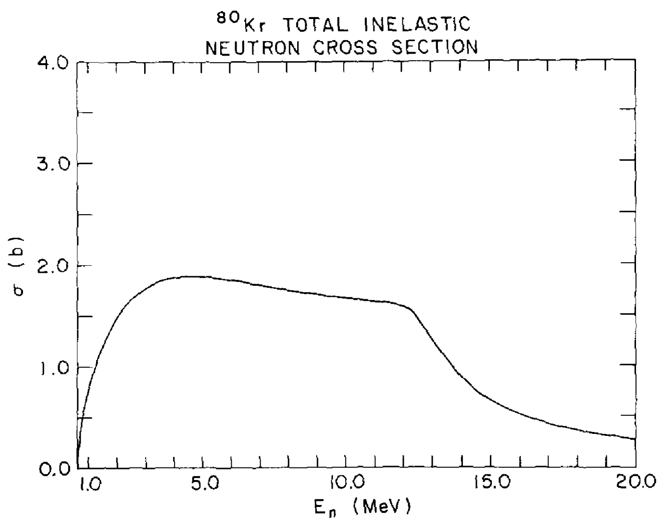

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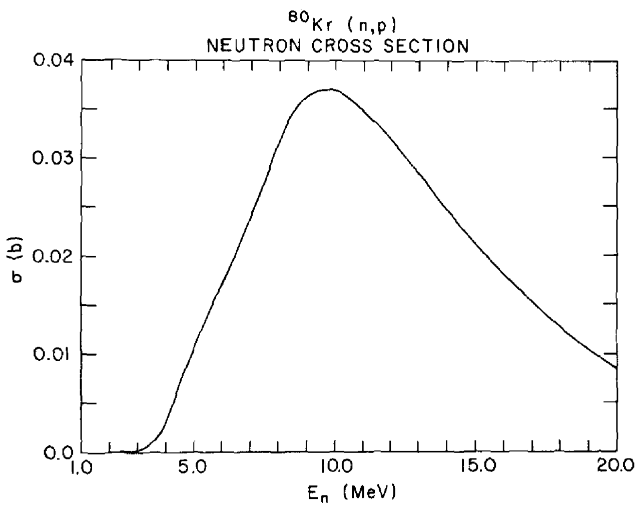

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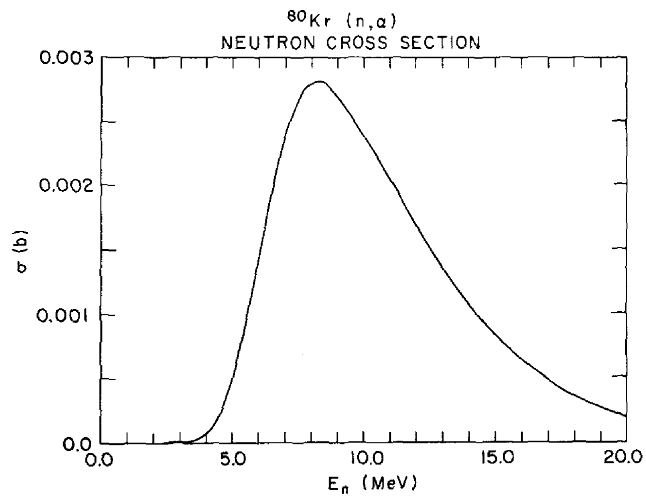

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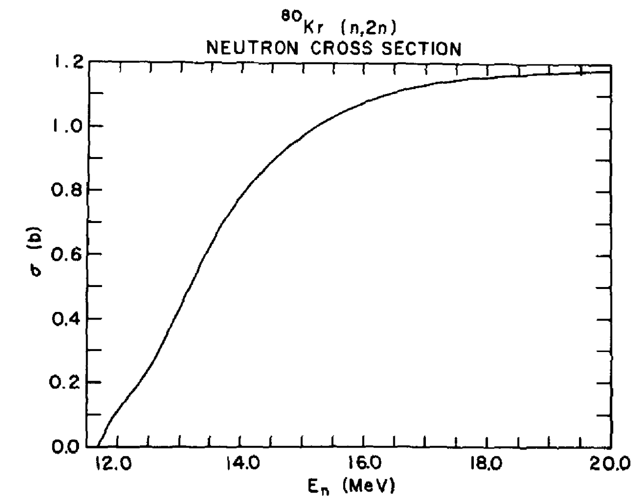

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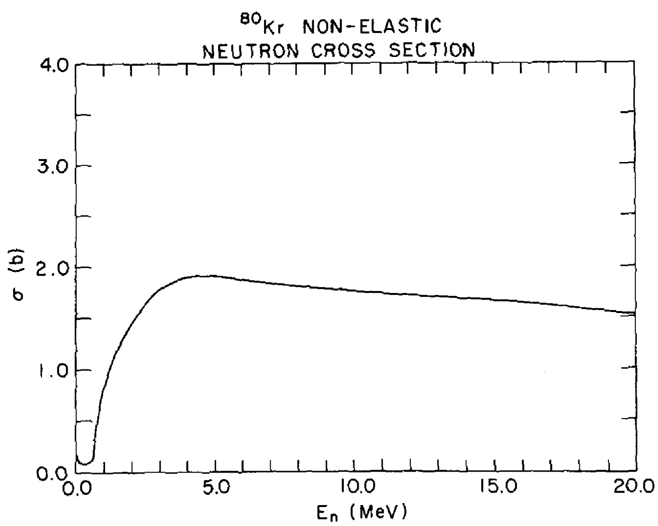

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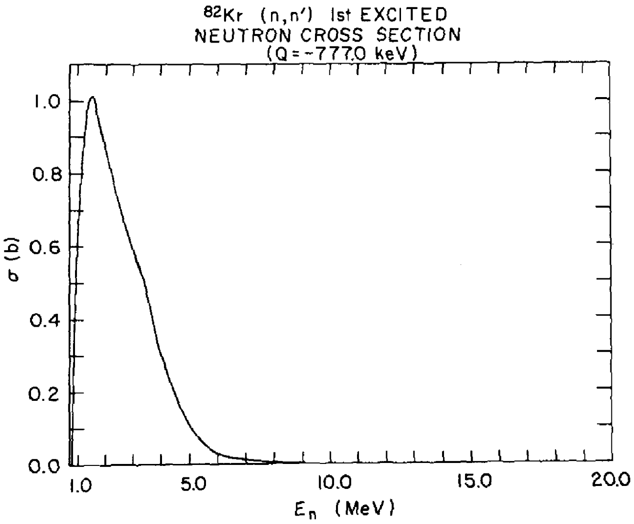

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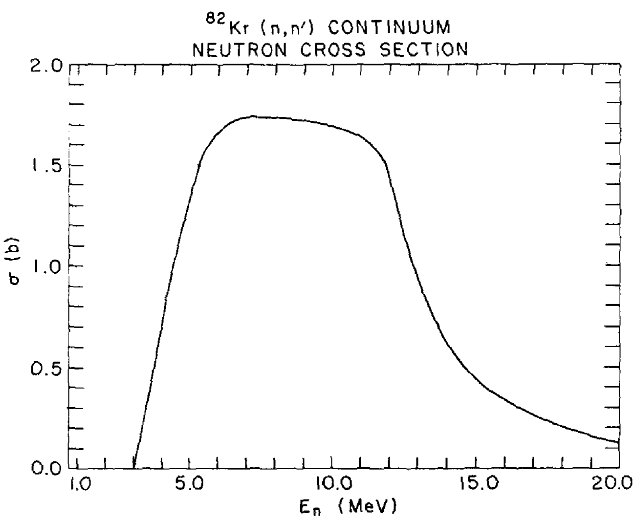

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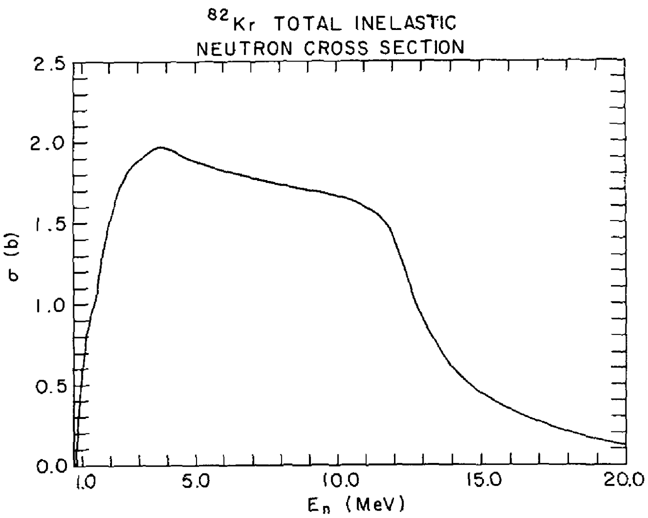

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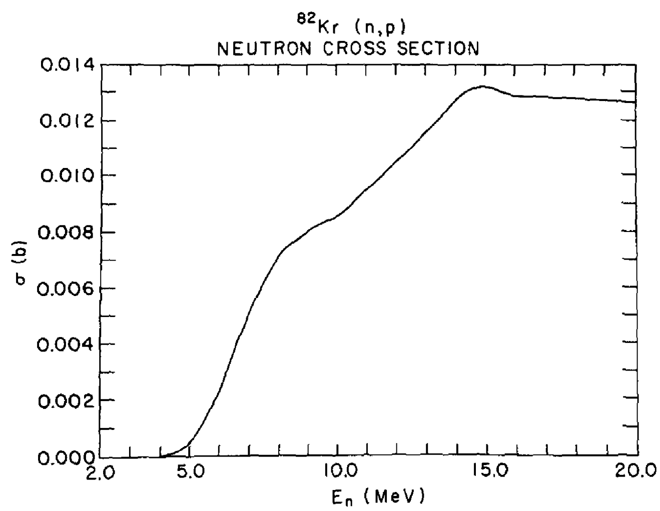

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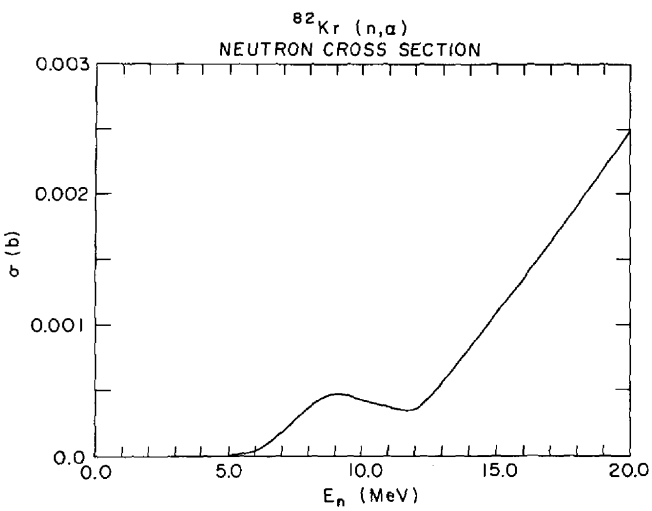

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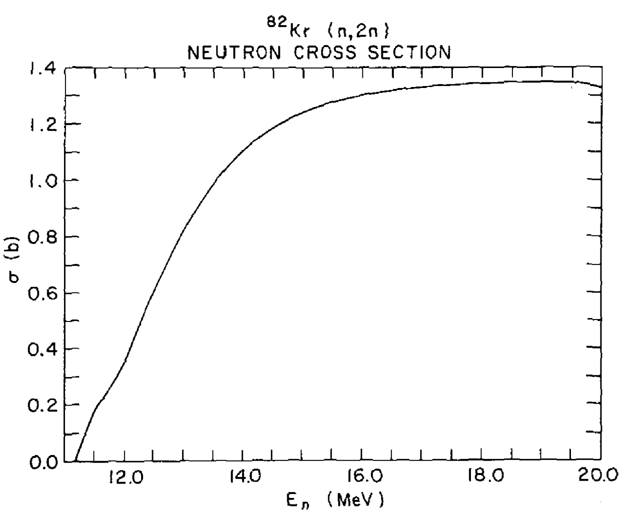

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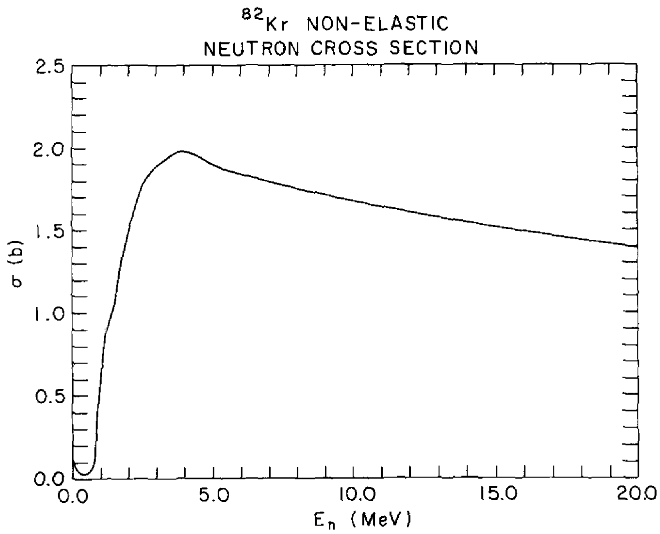

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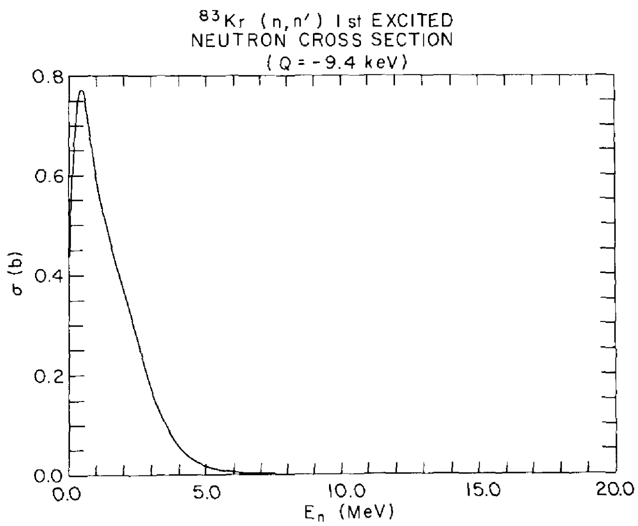

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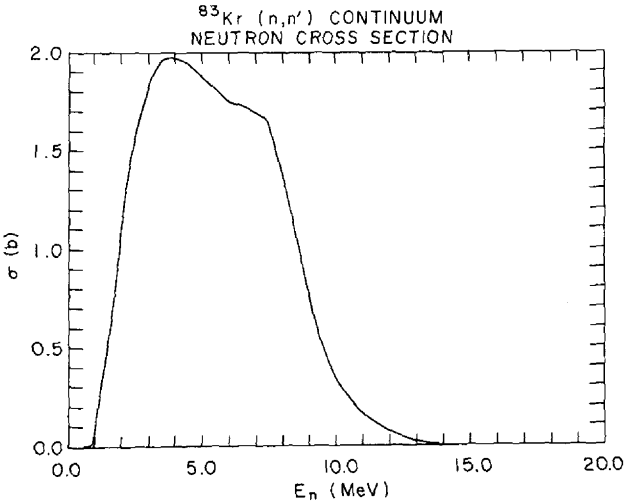

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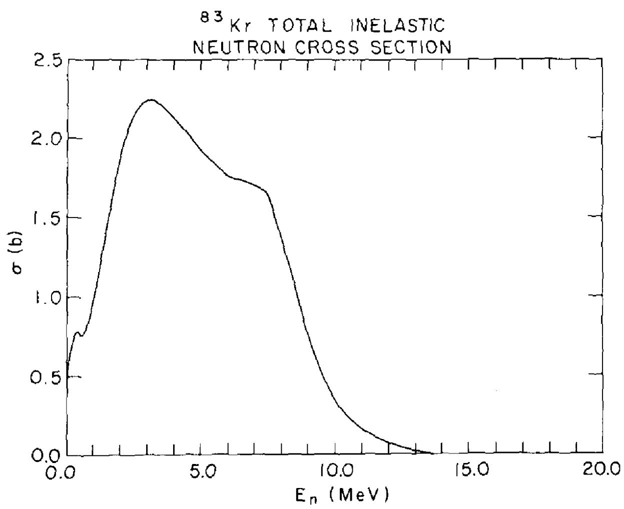

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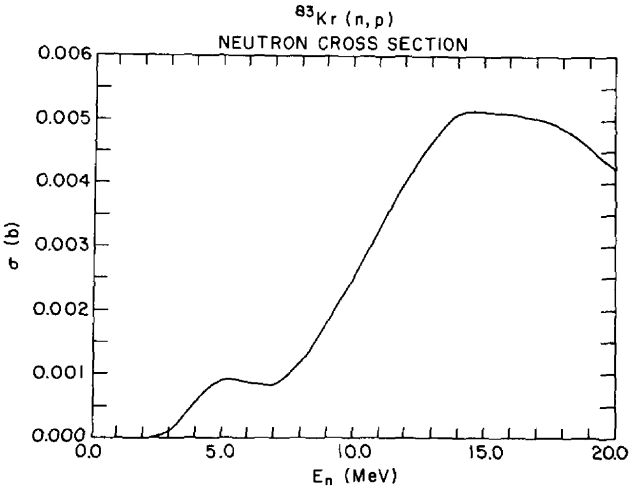

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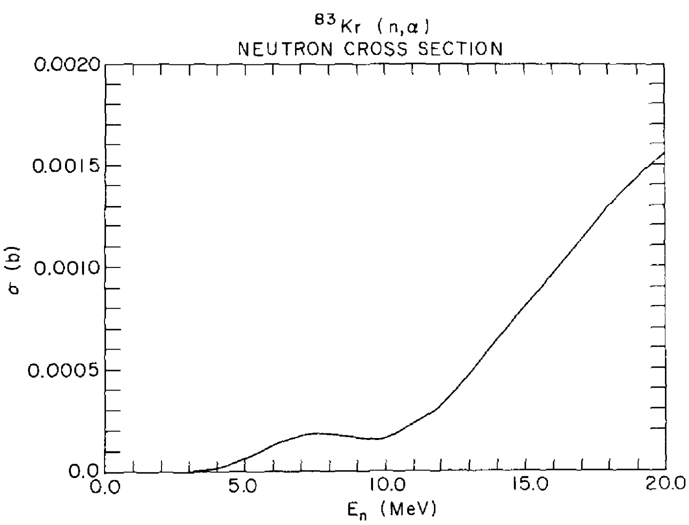

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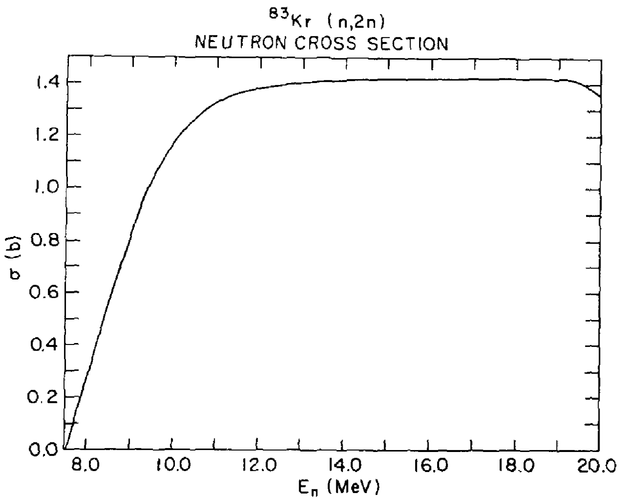

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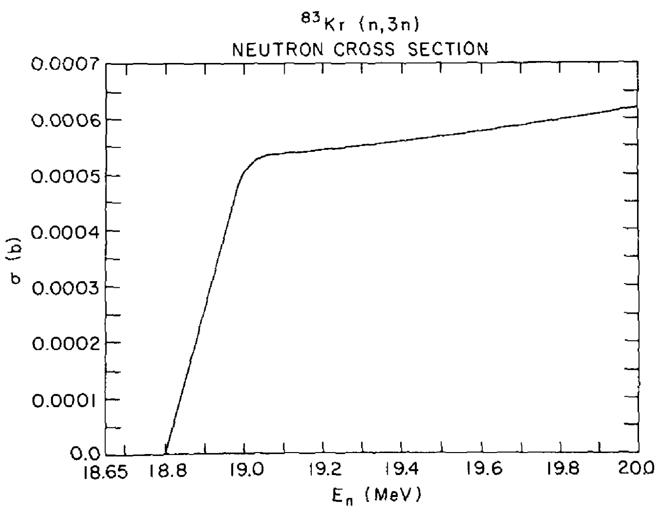

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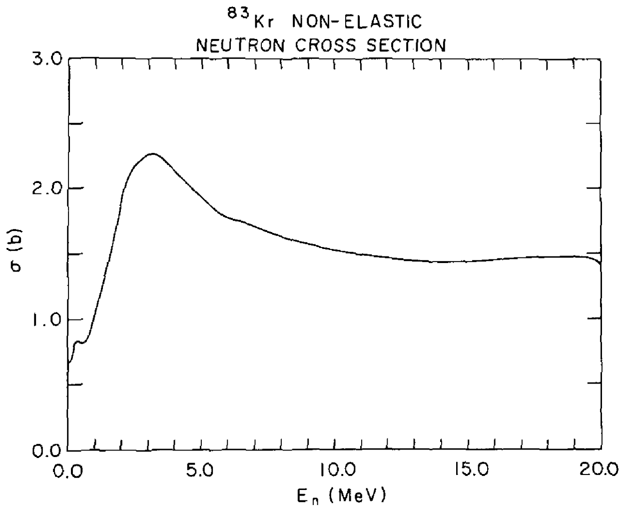

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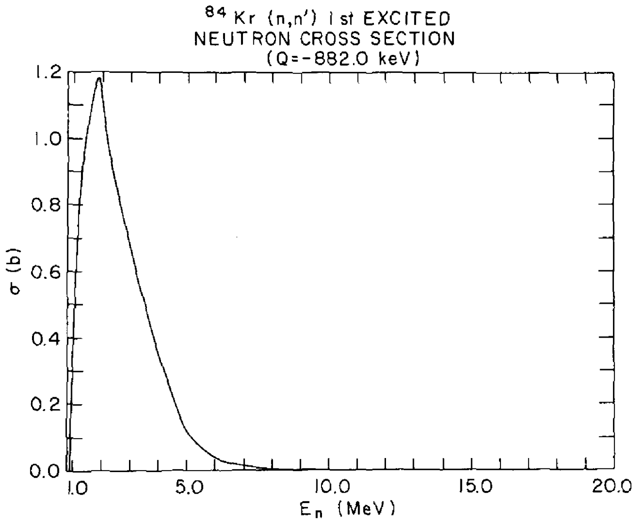

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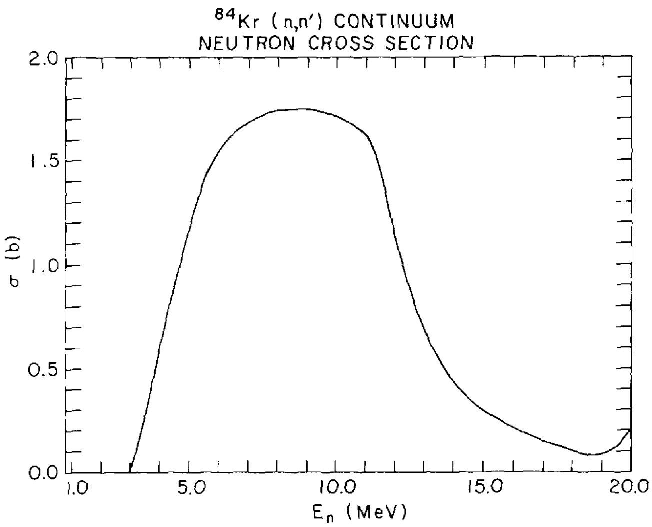

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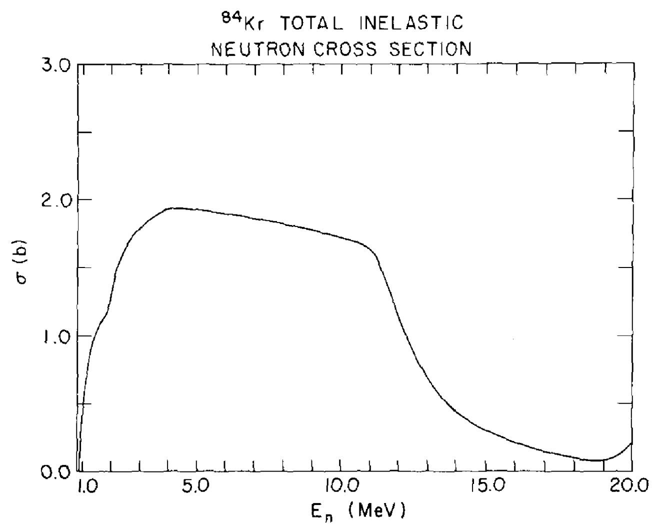

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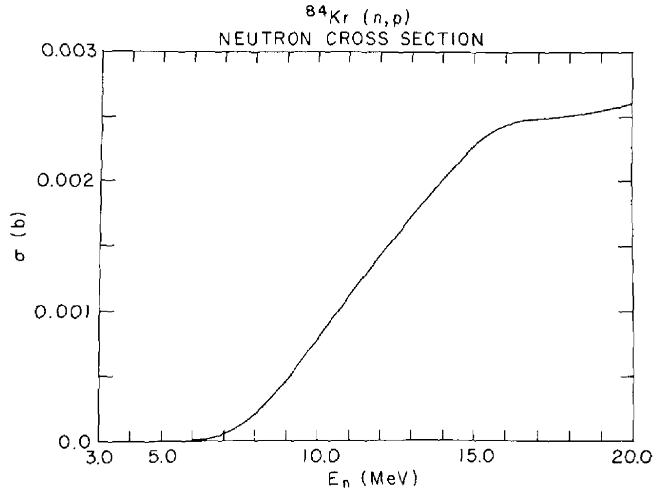

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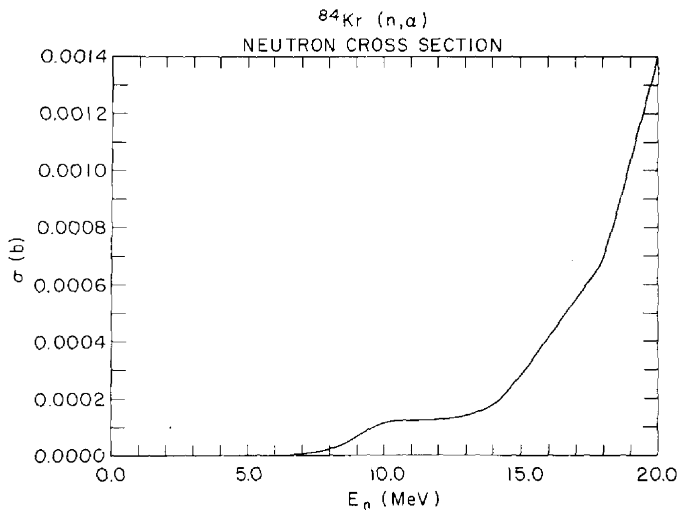

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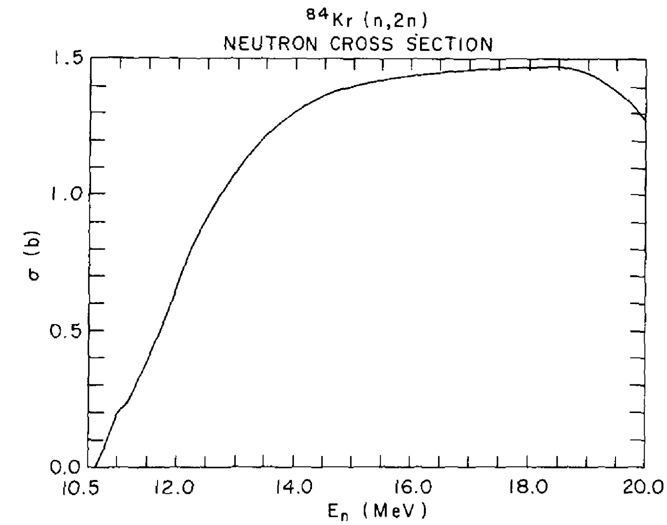

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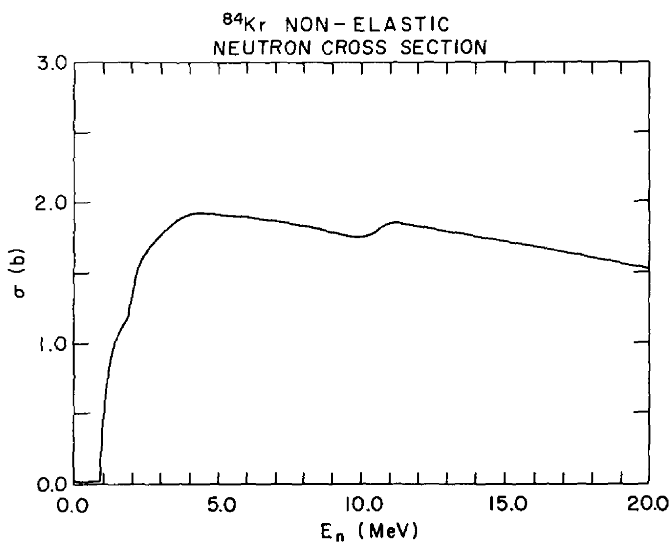

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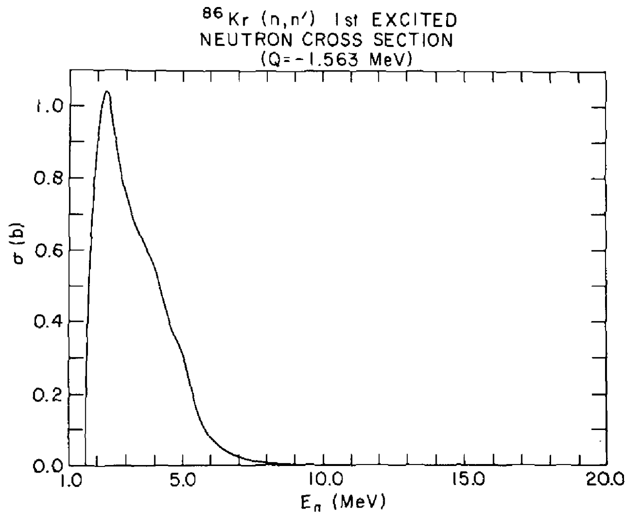

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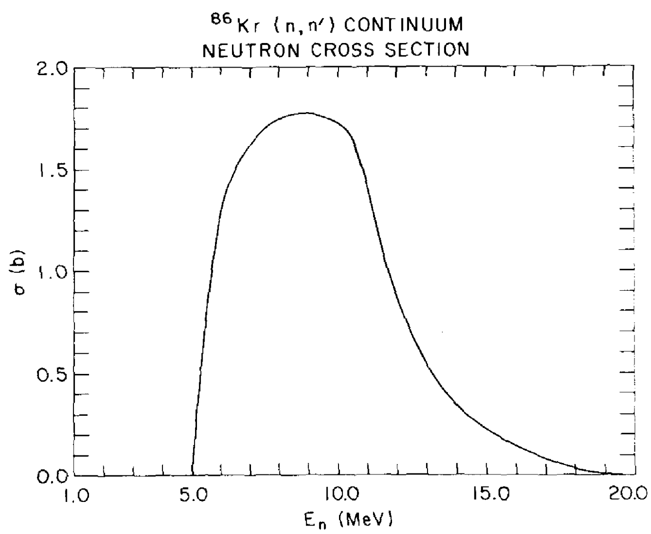

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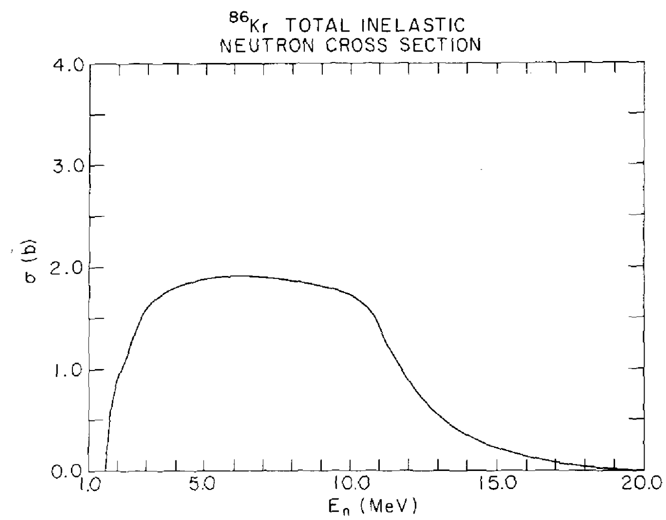


Figure 60.

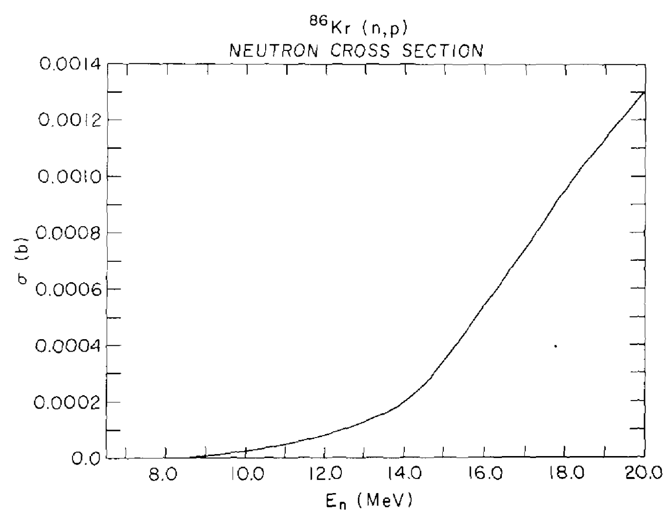


Figure 61.

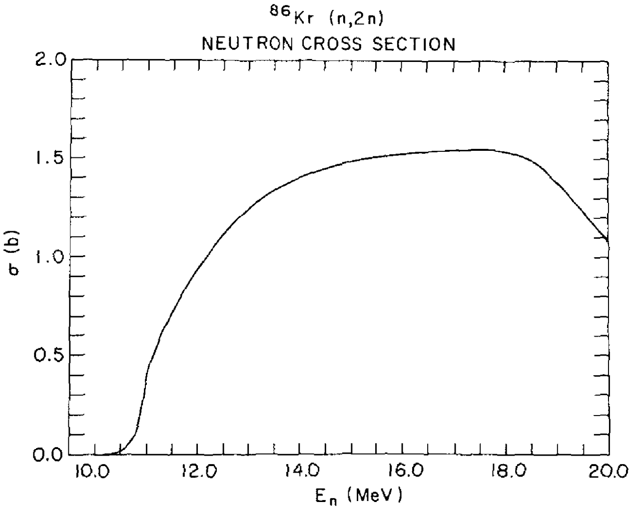


Figure 62.

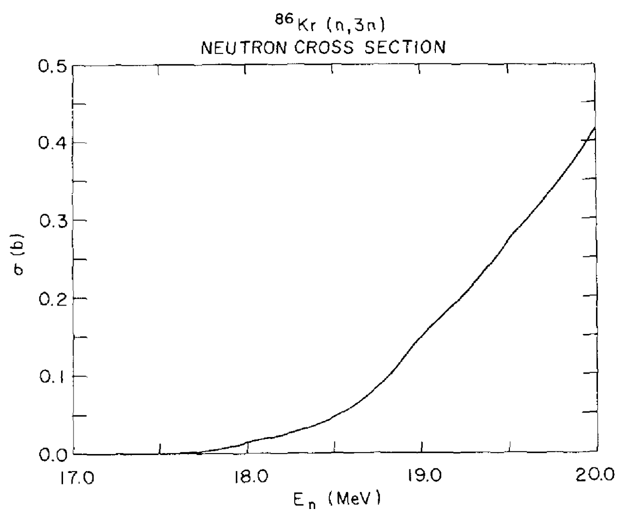
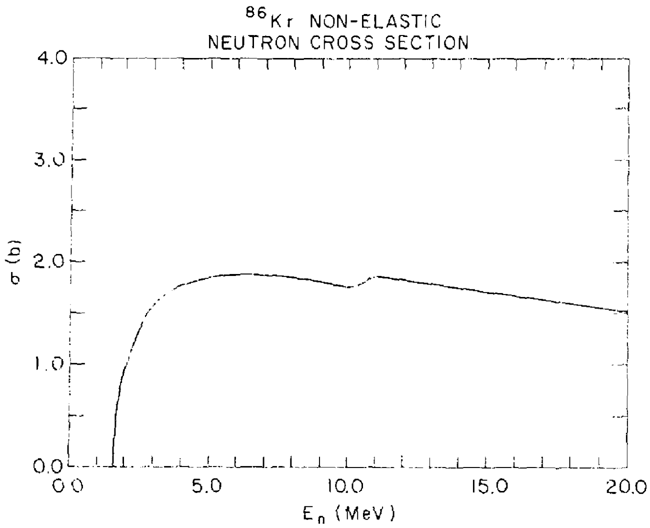


Figure 63.



^{86}Kr NON-ELASTIC
NEUTRON CROSS SECTION
σ (b)
4.0
3.0
2.0
1.0
0.0
0.0
5.0
10.0
15.0
20.0
E_n (MeV)

Figure 64.

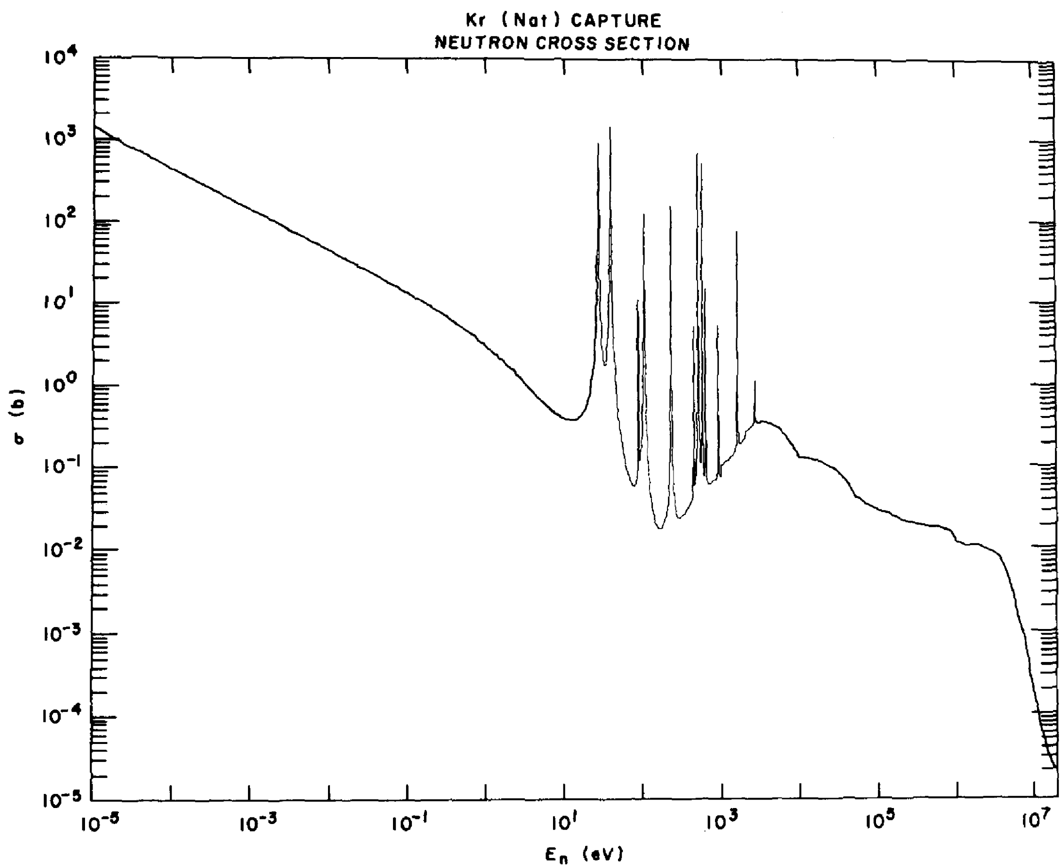

Kr (Nat) CAPTURE
NEUTRON CROSS SECTION
σ (b)
10⁴
10³
10²
10¹
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁵
10⁻³
10⁻¹
10¹
10³
10⁵
10⁷
Eₙ (eV)

Figure 65.

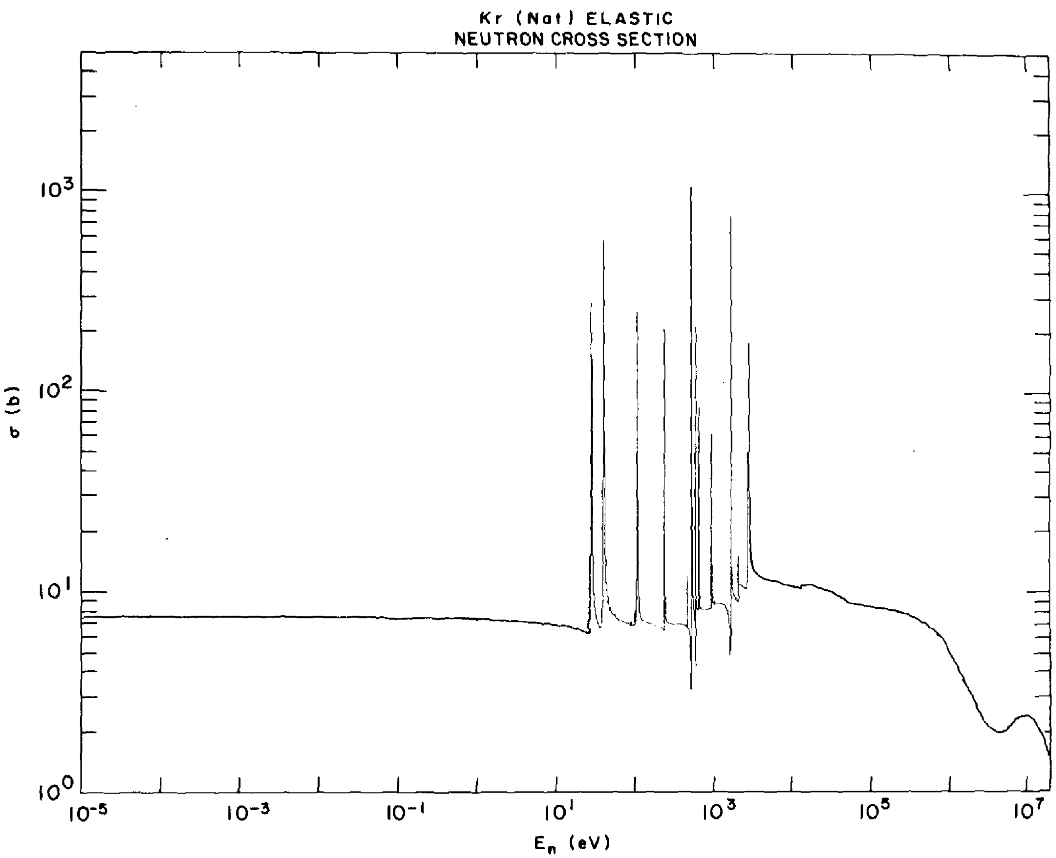

Kr (Nat) ELASTIC
NEUTRON CROSS SECTION
σ (b)
10^3
10^2
10^1
10^0
10^-5
10^-3
10^-1
10^1
10^3
10^5
10^7
E_n (eV)

Figure 66.

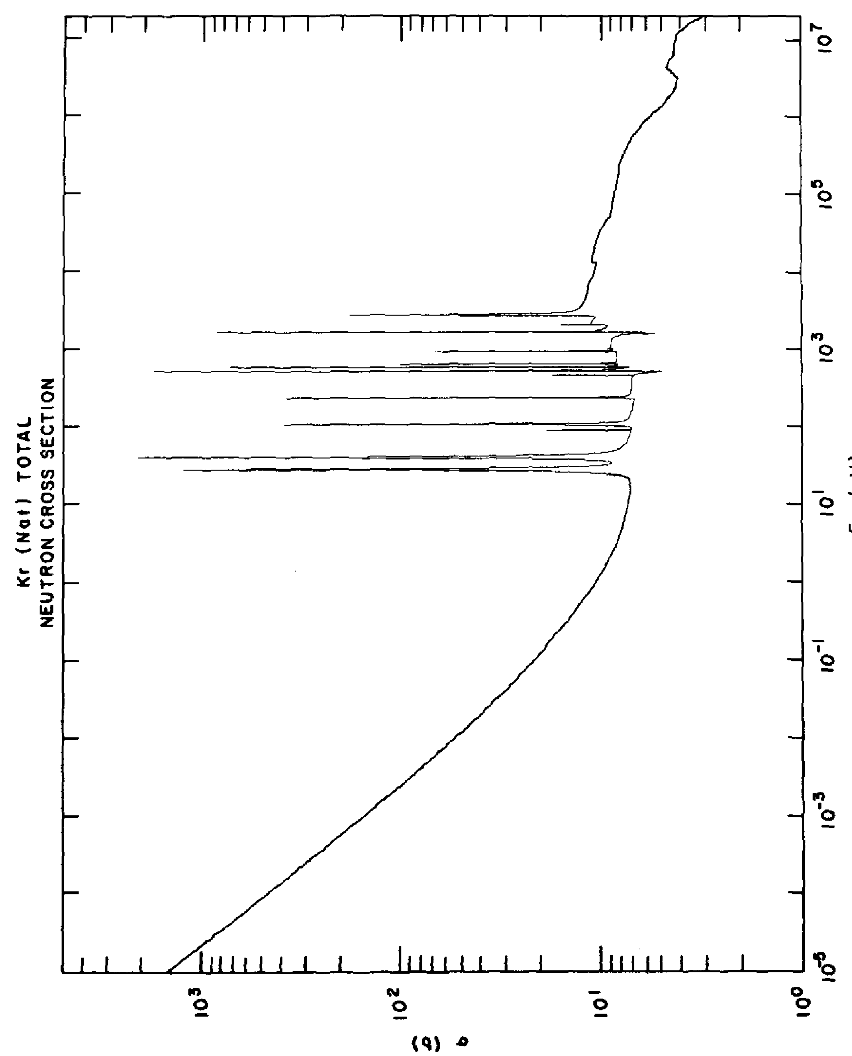

Kr (Nat) TOTAL
NEUTRON CROSS SECTION
σ (b)
10^0
10^1
10^2
10^3
E_n (eV)
10^{-5}
10^{-3}
10^{-1}
10^1
10^3
10^5
10^7

Figure 67.