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CALCULATION OF NEUTRON CROSS SECTIONS ON IRON UP TO 40 MeV

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The development of high energy d + Li neutron sources for fusion materials radiation damage studies will require neutron cross sections up to 40 MeV. Experimental data above 15 MeV are generally sparse or nonexistent, and reliance must be placed upon nuclear-model calculations to produce the needed cross sections. To satisfy such requirements for the Fusion Materials Irradiation Test Facility (FMIT), we have calculated neutron cross sections for $^{54,56}Fe$ between 3 and 40 MeV. These results were joined to the existing ENDF/B-V evaluation below 3 MeV.

In this energy range, most neutron reactions can be described using the Hauser-Feshbach statistical model[1] with corrections for preequilibrium and direct-reaction effects. To properly use these models to obtain realistic cross sections, emphasis must be placed upon the determination of suitable input parameters (optical model sets, gamma-ray strength functions, level densities) valid over the energy range of the calculation. To do this we have used several types of independent data to arrive at consistent parameter sets as described below.

Spherical optical parameters were used to calculate needed neutron and charged-particle transmission coefficients. For neutrons, such parameters must be constrained to agree with higher energy data while reproducing lower energy information. To accomplish this, we used a method[2] in which resonance data are employed simultaneously to supplement total cross-section and angular distribution data at higher energies. For protons and alpha particles, published optical parameter sets[3,4] were adjusted to better reproduce low energy (p,n) and (α,n) data and higher-energy reaction cross sections.

Gamma-ray strength functions based on the giant dipole resonance model and determined independently through fits to neutron capture data were used to calculate gamma-ray transmission coefficients. This method alleviates much of the uncertainty occurring in conventional calculations where s-wave resonance radiation widths and spacings provide normalizations for gamma-ray transmission coefficients.

The parameter sets were used in multistep preequilibrium-statistical calculations employing the GNASH code.[5] Figure 1 illustrates a sample decay chain utilized at higher incident energies. Each nucleus was described using the Gilbert-Cameron level density model[6] along with the maximum available discrete level information. Preequilibrium corrections were applied with the Kalbach master equations model.[7] The preequilibrium model does not describe excitation by inelastic scattering from collective states in ^{54,56}Fe, so we performed DWBA calculations for 27 levels using deformation parameters determined from proton inelastic scattering.[8]

With these parameters and models we made comparisons to available experimental data such as (n,n'), (n,p), and (n,2n) cross sections as well as to measured production spectra for neutrons, gamma rays, and charged particles. In addition, comparisons were made to p + ^{56}Fe reaction data up to 40 MeV. Agreement to the data was generally good, although in some cases slight parameter adjustments were made to further improve it. Final calculations were made to 40 MeV with a sample of the theroetical cross sections for n + ^{56}Fe shown in Fig. 2. In addition to cross sections, we calculated emission spectra (neutron, gamma-ray, and charged-particle) as well as angular distributions. These quantities obtained using consistent parameter sets in sophisticated nuclear-model calculations should provide realistic results to satisfy data needs for neutron-induced reactions on iron at higher energies.

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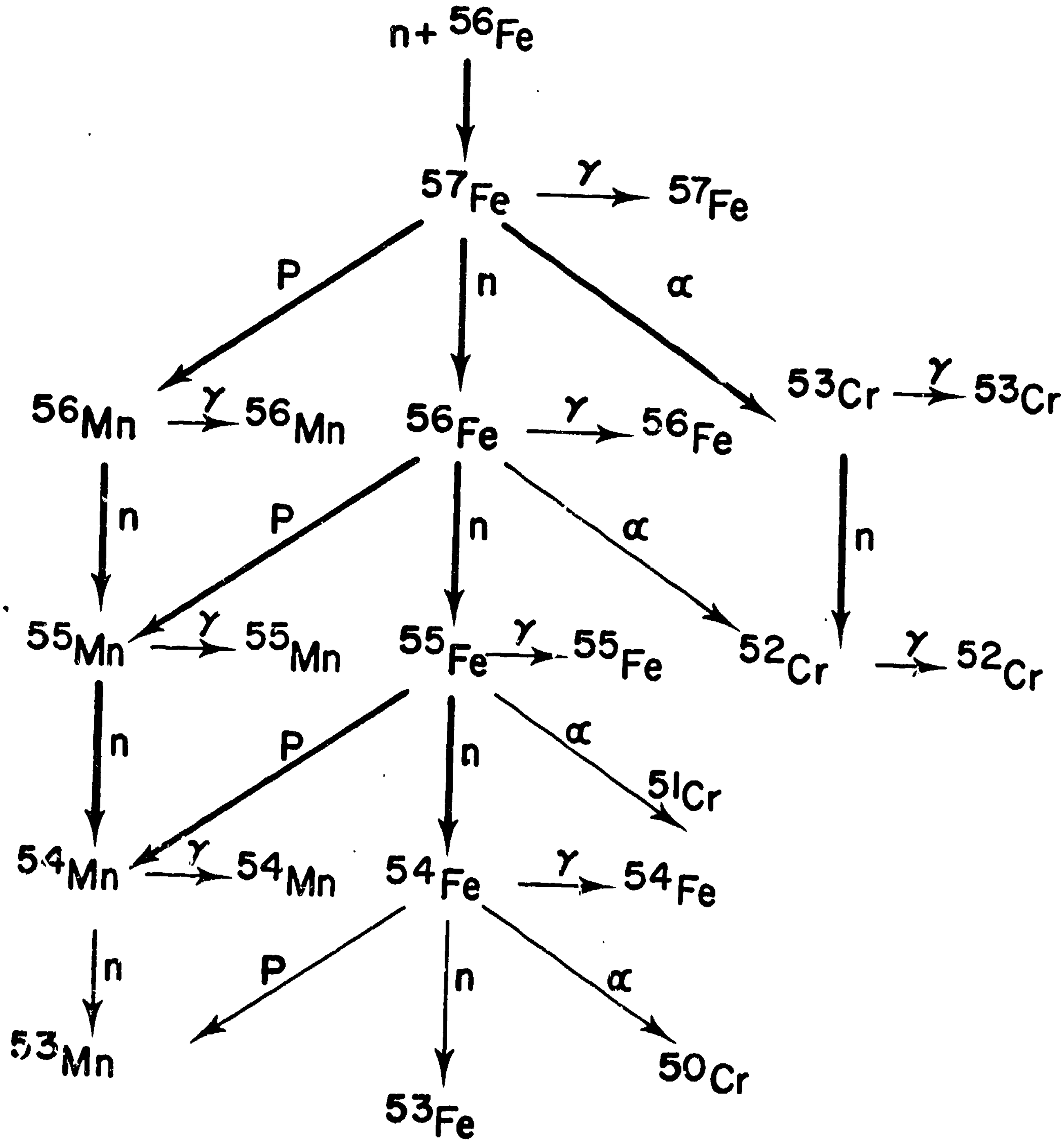
FIGURE Captions

Fig. 1. Decay chain used for n + ^{56}Fe calculations at higher energies.

Fig. 2. Calculated cross sections for major neutron induced reactions on ^{56}Fe between 10 and 40 MeV.


n+ 56Fe
57Fe
γ
57Fe
P
n
α
56Mn
γ
56Mn
56Fe
γ
56Fe
53Cr
γ
53Cr
n
P
n
α
n
55Mn
γ
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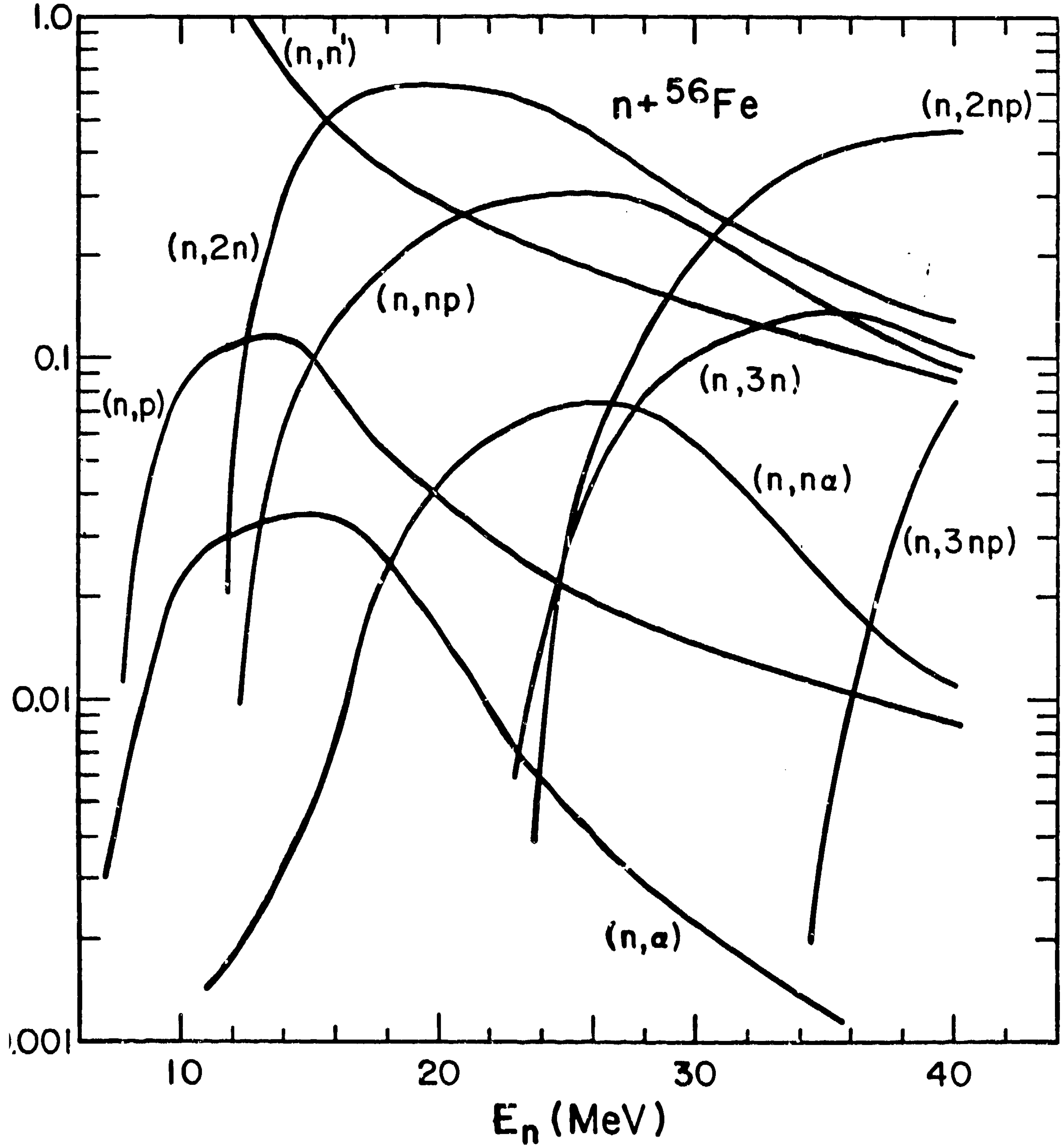

n+56Fe
(n,n')
(n,2n)
(n,np)
(n,p)
(n,2np)
(n,3n)
(n,nα)
(n,3np)
(n,α)
1.0
0.1
0.01
.001
10
20
30
40
En (MeV)