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INELASTIC COLLISION AND TRANSPORT CROSS SECTIONS FOR SOME LIGHT ELEMENTS

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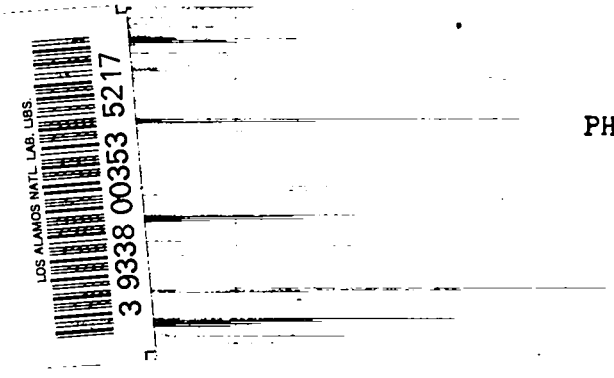

PHYSICS

For the past few months an experiment has been underway for the purpose of measuring inelastic collision and transport cross sections with threshold fission detectors and the fast neutron beam from the Fast Reactor. This report will describe some of the preliminary results of the experiment.

The inelastic collision cross section is arrived at by comparing the total cross section σ_t as measured by a transmission-type experiment with the total elastic scattering cross section obtained separately by integrating a measured angular distribution of scattered neutrons over the entire sphere. These two measurements are made with the same fission detector. The difference between the cross sections is largely made up of the cross section for inelastic scattering. Energy limits for the inelastic scattering are determined by combining the energy distribution of the neutrons from the reactor with the energy dependence of the detector's sensitivity. Figure 1 is a plot of the energy spectrum of the neutrons in the beam from the reactor weighted by the energy dependence of the fission cross section of U^{238}, where $nv(E)dE$ is taken from LA-1234 and $\sigma_f(E)$ from LA-994.

With the detector placed directly in the neutron beam the observed counting rate is

$$I_o = An\bar{v}\bar{\sigma}_f \quad ,$$

where $\bar{\sigma}_f$ is the fission cross section of the material in the detector averaged over the energy spectrum of the neutrons and A is a constant which contains factors for the amount of material in the detector and

the efficiency for counting fissions. If a scatterer which contains N_s total scattering centers is substituted for the detector and if the detector is moved to a distance r from the scatterer, then the observed counting rate becomes

$$I = \frac{nvAN_s\sigma_{el}(\theta)\overline{\sigma_f}}{r^2} ,$$

where θ is the angle included by the direction of r and the direction of the neutron beam, and $\sigma_{el}(\theta)$ is the differential elastic scattering cross section. Combining these two equations yields

$$\sigma_{el}(\theta) = \frac{r^2 I}{N_s I_o} .$$

Here it is assumed that the energy spectrum of the elastically scattered neutrons is the same as that of the incident neutrons. Also, the neutron beam clearly must be larger in cross sectional area than either the scatterer or the detector.

The difference $\sigma_t - \int\sigma_{el}(\theta)d\Omega$ will be called the inelastic collision cross section σ_i. This cross section will differ in three ways from a well-defined inelastic scattering cross section: 1) no accounting is made of those neutrons which undergo capture processes, 2) those neutrons which are scattered inelastically from a detectable energy to a lower but still detectable energy are counted as being elastically scattered, and 3) a correction must be made for the dependence of detection efficiency on scattering angle for the elastically scattered neutrons.

Transport cross sections are obtained by integrating the measured differential cross sections thus:

$$\sigma_{tr} = \sigma_i + 2\pi \int (1 - \cos\theta)\, \sigma_{el}(\theta) \sin\theta d\theta .$$

It is assumed here that the angular distribution of the inelastic scattering is isotropic.

Table I lists the total cross sections obtained from the transmission measurements, together with the inelastic collision and transport cross sections obtained from the angular distributions. These

TABLE I

Scatterer	σ_t	σ_i	σ_{tr}
Be	2.18 ± .052 b.	0.38 ± .09 b.	1.39 ± .11 b.
C	1.73 ± .05	-0.02 ± .07	1.45 ± .086
Al	2.67 ± .063	0.05 ± .16	1.57 ± .21
Cr	3.43 ± .09	0.22 ± .16	2.05 ± .18
Fe	3.19 ± .06	0.39 ± .14	1.99 ± .25
Ni	3.24 ± .06	1.06 ± .12	2.46 ± .13
Cu	3.26 ± .065	0.85 ± .11	2.28 ± .13

results were all obtained with a U^{238} detector and with the geometry diagramed in Fig. 1a. The individual angular distributions are plotted in Figs. 2 through 8. A correction for the loss in detection efficiency because of energy loss through elastic scattering was applied to the data for the cases of Al, Cr, and Fe. The modified inelastic collision and transport cross sections are listed in Table II. No

TABLE II

Scatterer	σ_i	σ_{tr}
Al	-0.06 ± .16 b.	1.64 ± .21 b.
Cr	0.16 ± .16	2.09 ± .18
Fe	0.37 ± .14	1.97 ± 25

attempt to apply the correction was made in the cases of Be and C because of the uncertainty in the spectrum of the scattered neutrons. The effect of the correction for Fe was not large enough to justify its application to heavier elements.

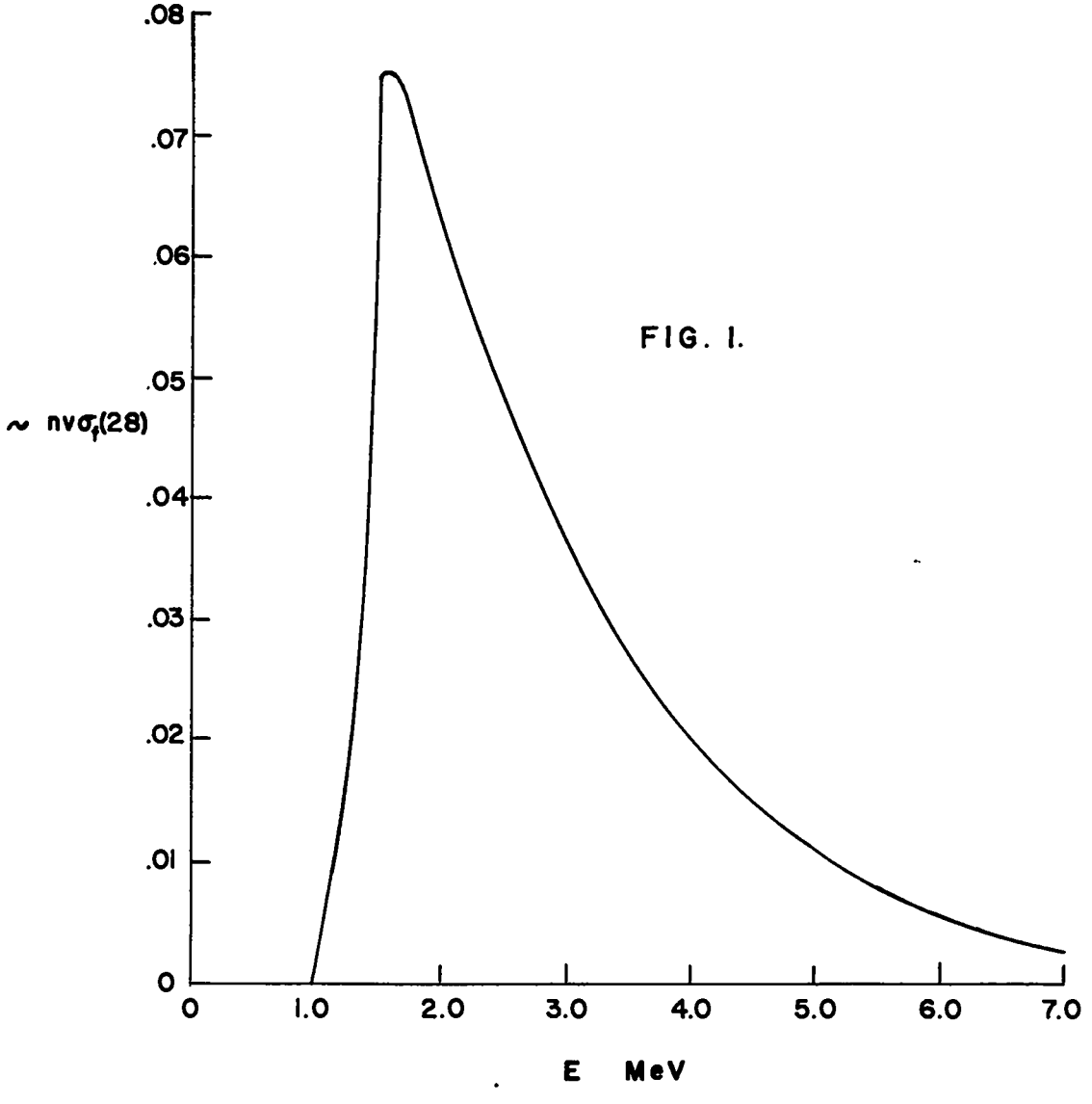

FIG. 1.

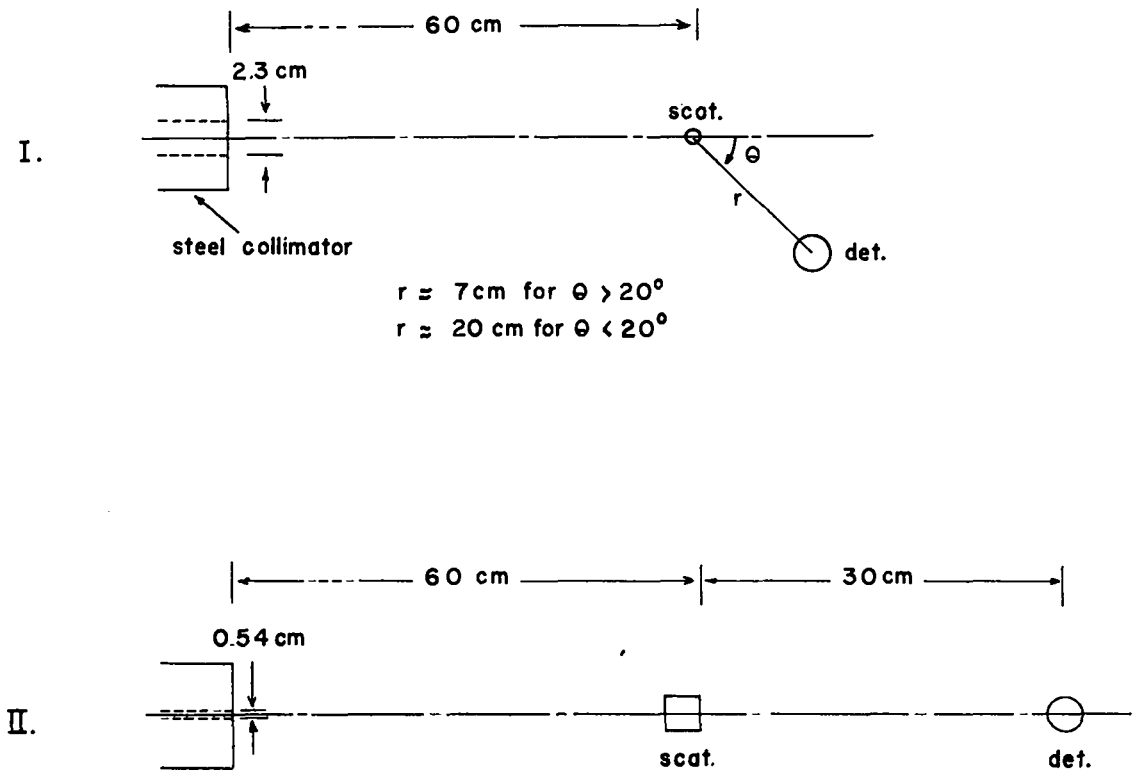

Fig. Ia. I. Geometry for measurement of $\sigma(\theta)$
II. Geometry for measurement of σ_t

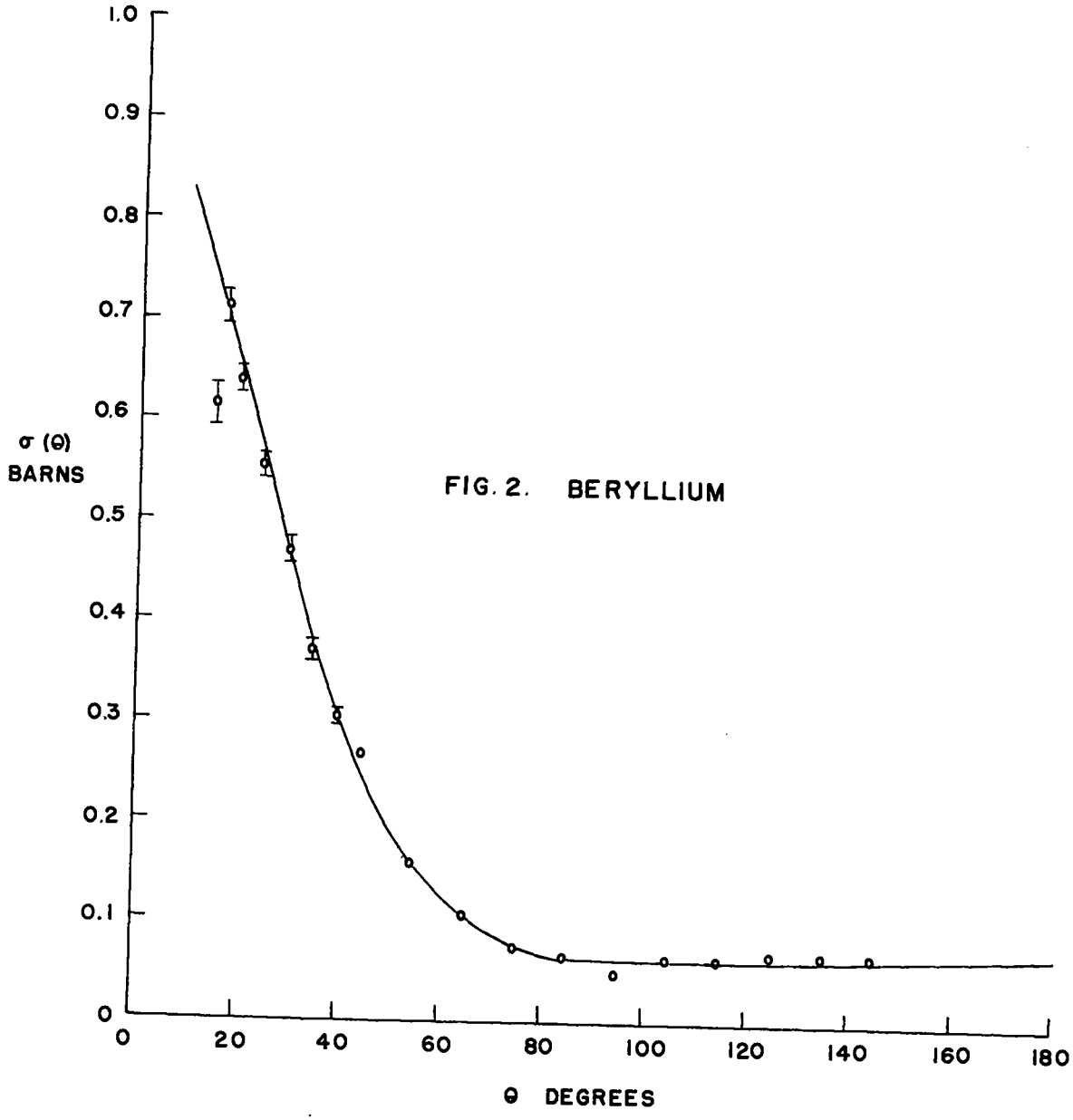

FIG. 2. BERYLLIUM

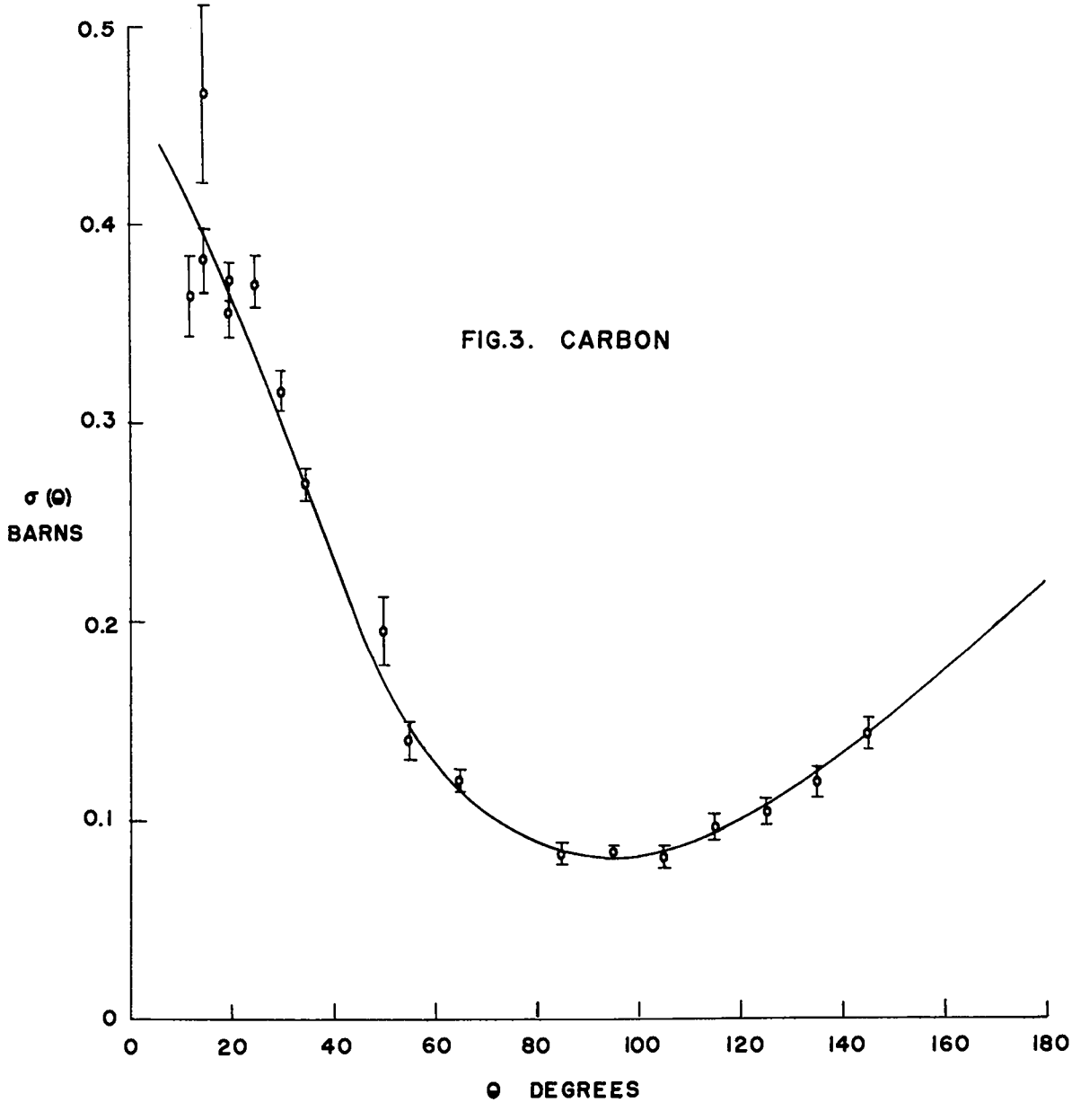
0.5
0.4
0.3
0.2
0.1
0
σ (θ)
BARNS
0
20
40
60
80
100
120
140
160
180
θ DEGREES

FIG.3. CARBON

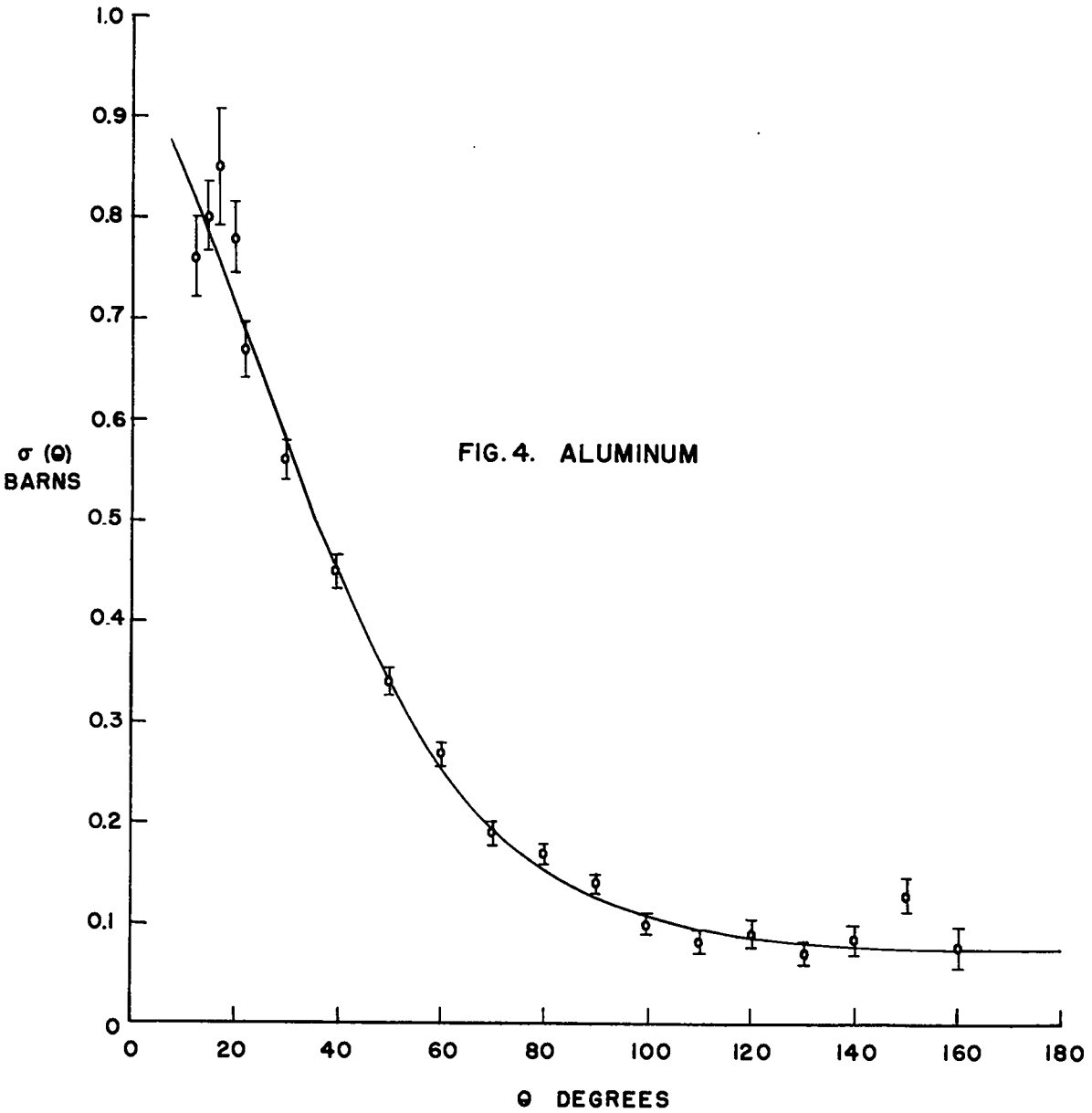

FIG. 4. ALUMINUM

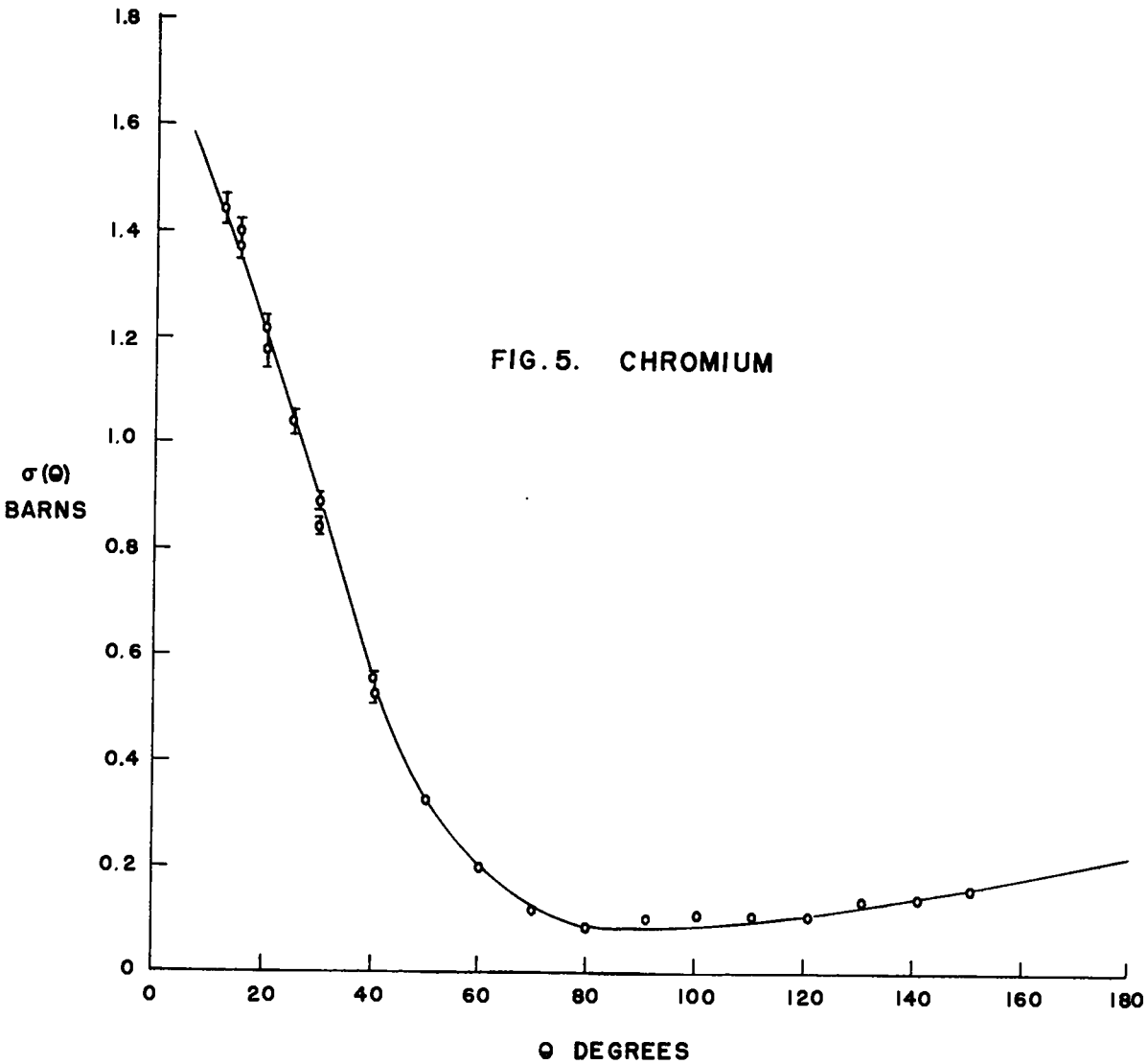

FIG. 5. CHROMIUM

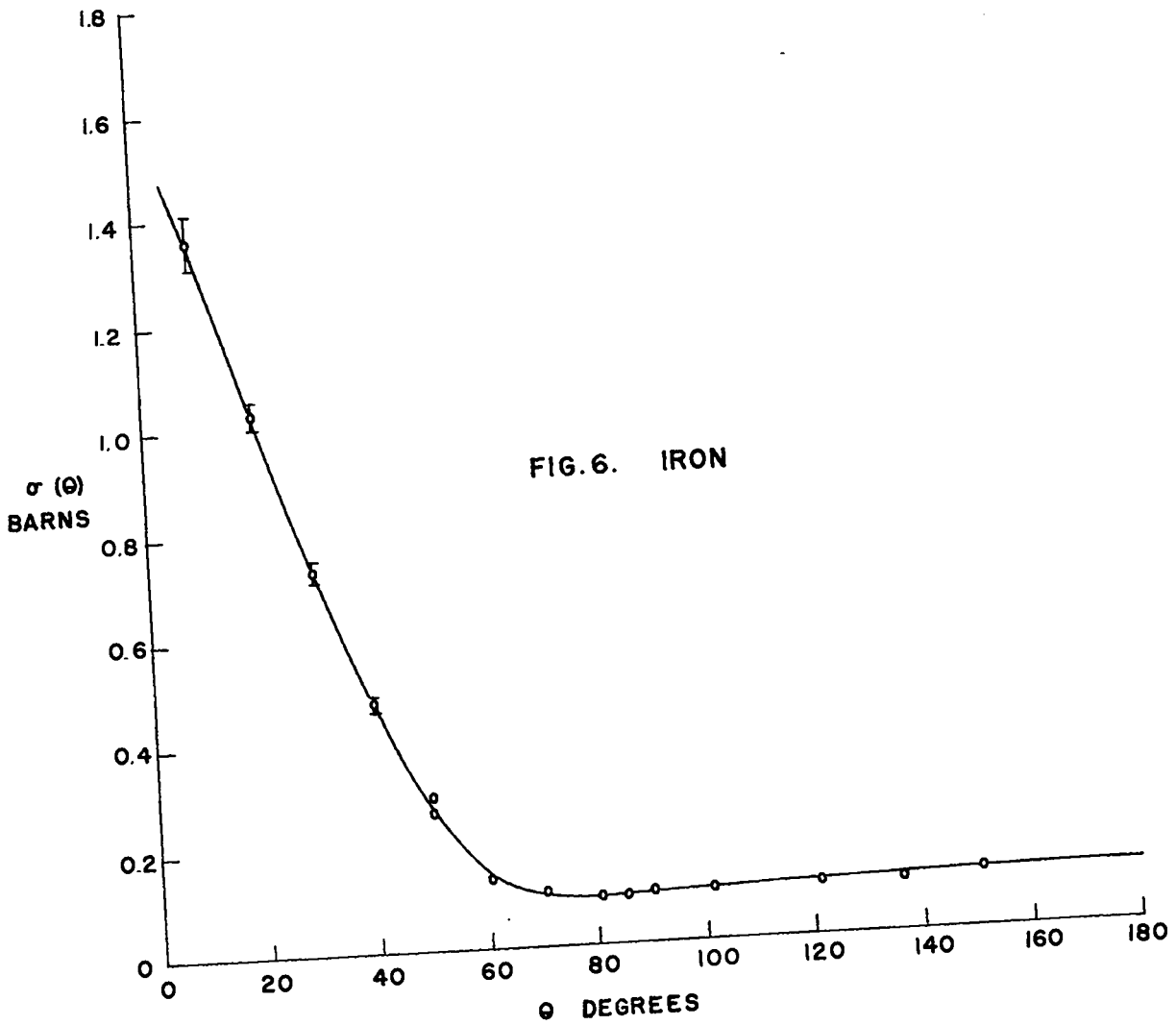
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
σ (θ)
BARNS
0
20
40
60
80
100
120
140
160
180
θ DEGREES

FIG. 6. IRON

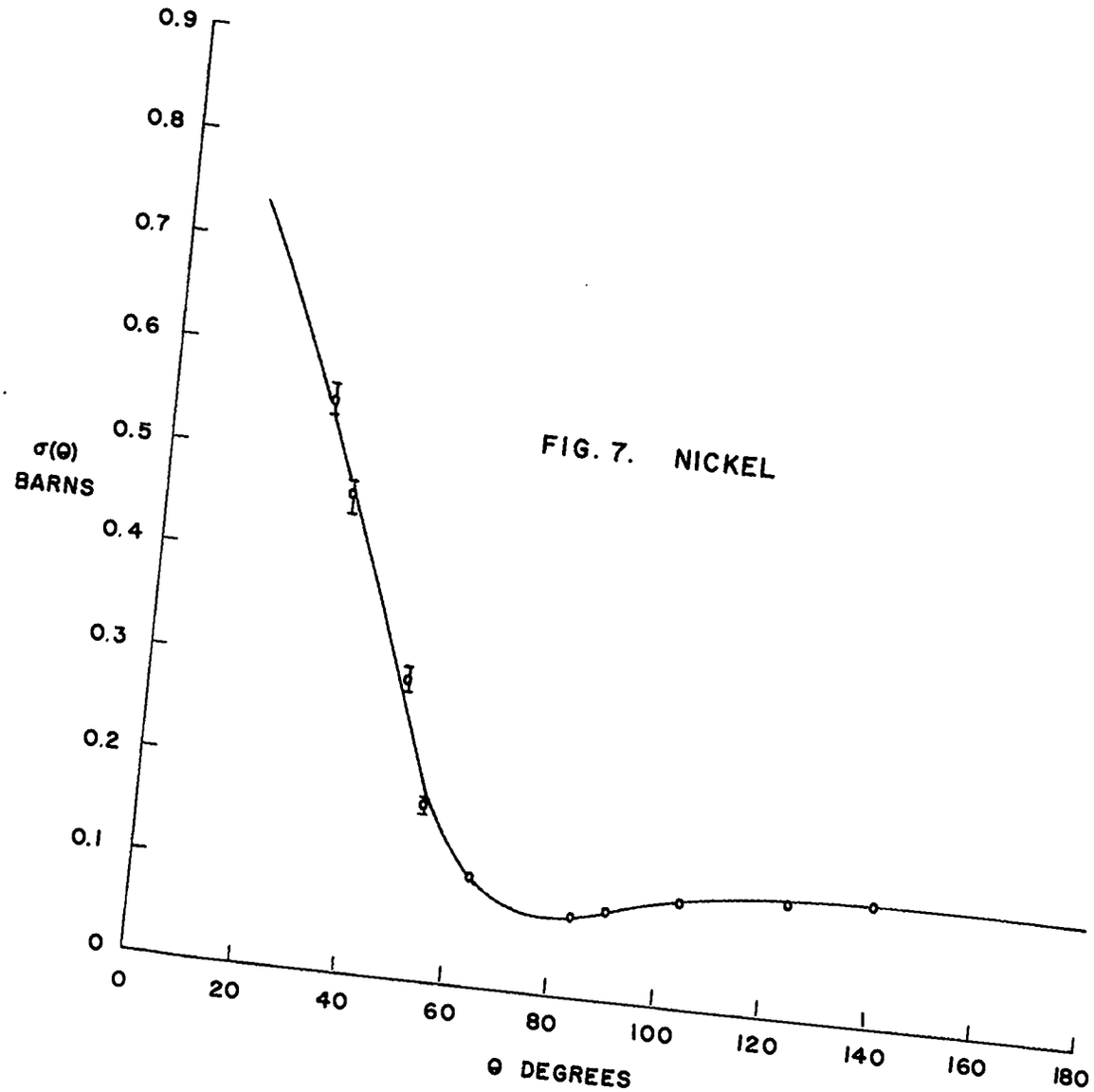
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
σ(Θ)
BARNS
0
20
40
60
80
100
120
140
160
180
Θ DEGREES

FIG. 7. NICKEL

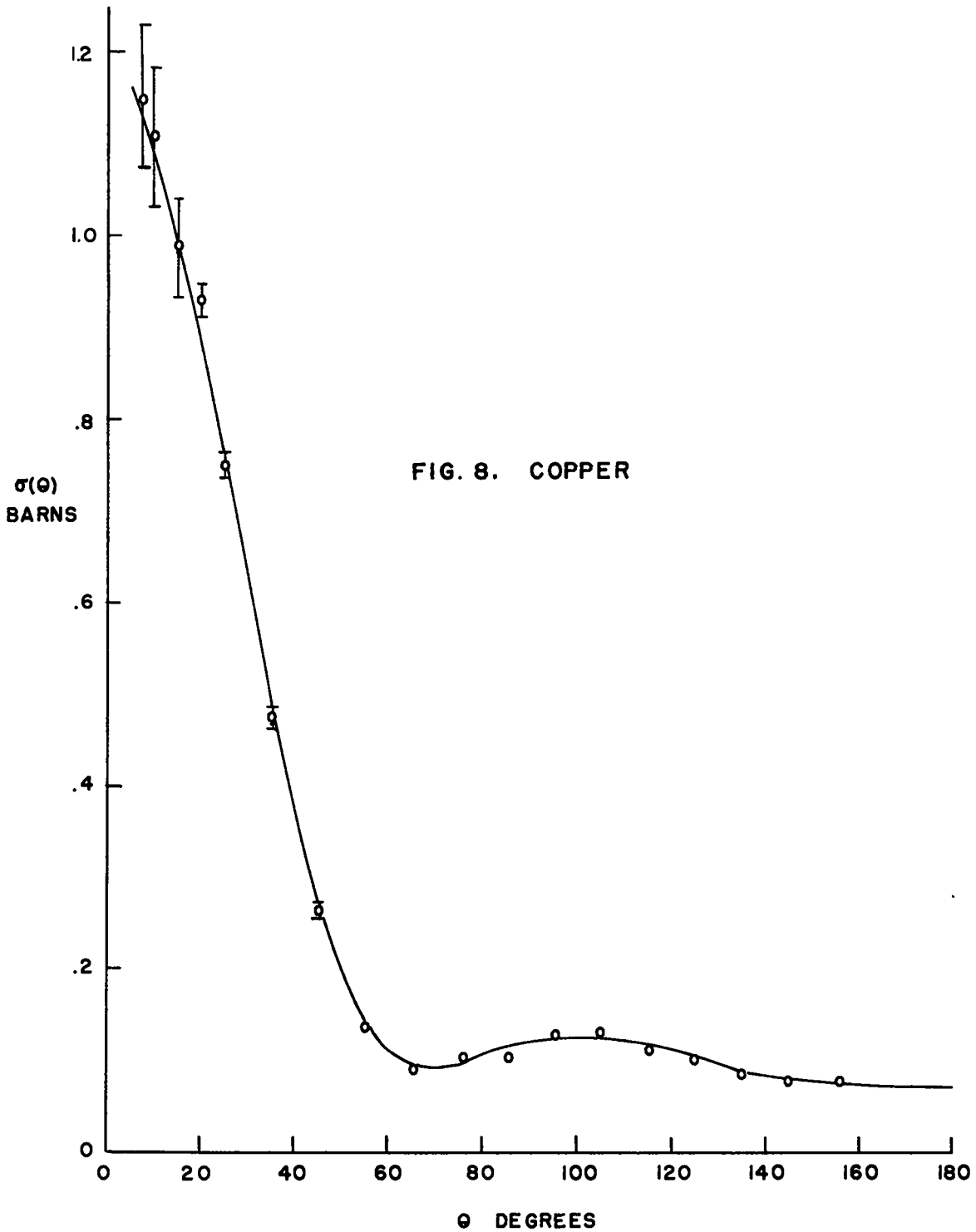

FIG. 8. COPPER

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