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^{54}Fe neutron elastic and inelastic scattering differential cross sections from 2–6 MeV

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Abstract

Measurements of neutron elastic and inelastic scattering cross sections from ^{54}Fe were performed for nine incident neutron energies between 2 and 6 MeV. Measured differential scattering cross sections are compared to those from previous measurements and the ENDF, JENDL, and JEFF data evaluations. TALYS calculations were performed and modifications of the default parameters are found to better describe the experimental cross sections. A spherical optical model treatment is generally adequate to describe the cross sections in this energy region; however, in ^{54}Fe the direct coupling is found to increase suddenly above 4 MeV and requires an increase in the DWBA deformation parameter by approximately 25%. This has little effect on the elastic scattering differential cross sections but makes a significant improvement in both the strength and shape of the inelastic scattering angular distribution, which are found to be very sensitive to the size and extent of the surface absorption region.
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1. Introduction

Iron is a ubiquitous material in buildings, laboratories, equipment, and devices. Because of its wide-spread usage, neutron-induced reactions on the iron isotopes have many different applications in engineering, physics, and medicine. The material properties of iron alloys such as strength, ductility, and long-term stability are determined by the defects in the material. The creation and growth of these defects depend on the elastic scattering differential cross sections and the (n, p) and (n, α) reaction rates.

Iron-54 is the second most abundant isotope in natural iron materials. Despite its only 5.5% natural abundance, the ^{54}Fe cross sections have a significant impact in fast reactor systems and energy transport and deposition in thick slabs of steel [1,2].

The ^{54}Fe total cross sections in the fast neutron region do not show clear resonance behavior above $E_n \approx 2$ MeV, but they do fluctuate. These variations occur on a small energy scale, < 0.1 MeV. In the 2 to 3 MeV energy range the average cross section is 3.39 b and the root-mean-square (rms) fluctuation is 0.57 b. In the energy range of 3 to 8 MeV the average cross section is 3.55 b and the rms fluctuation has dampened to 0.18 b. An optical model (OM) is used to describe the energy-averaged behavior of the cross sections.

While forward angle elastic scattering is dominated by diffraction that is well described by a range of OM parameters, the cross sections at angles $>120°$ are much more sensitive to model details and must be measured to know accurate values. For example, the evaluated cross sections from ENDF, JENDL, and JEFF often disagree by factors of two to three on the large-angle elastic scattering cross sections and even more when inelastic neutron scattering cross sections are compared.

Elastic scattering cross sections are rather well measured for ^{54}Fe; previous experimental efforts are listed in Table 1. Inelastic experimental data are not so abundant, and modern inelastic scattering measurements on other nuclei indicate there can be significant discrepancies. In this work, we repeat measurements of elastic and inelastic cross sections in the energy range 2 to 6 MeV and compare with databases, previous measurements, and model calculations. These newly measured inelastic scattering cross sections and their angular dependencies, provide the critical information that guides the choice of scattering potential parameters for direct-coupling collective models.

Table 1
Previous neutron scattering differential cross section measurements on ^{54}Fe.

Year	Author	Energies	Points/AD	Reference
1987	Korzh	5, 6, 7	13	[3]
1986	Guenther	36 btw 1.3–3.9	10	[4]
1982	El-Kadi	8, 10, 12, 14	26	[5]
1982	Delaroche	8, 10, 12, 14	26	[6]
1977	Korzh	1.5, 2, 2.5, 3	8	[7]
1974	Kinney	5.5, 7.0, 8.5	21	[8]
1973	Fedorov	2.9	8	[9,10]
1971	Boschung	4.0, 5.0, 5.6	10	[11]
1967	Rogers	2.33	5	[12]

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