U605?? 260502

AECD - 2359

UNITED STATES ATOMIC ENERGY COMMISSION

NEUTRON DIFFRACTION STUDIES

by

C. G. Shull
E. O. Wollan
M. C. Marney

Oak Ridge National Laboratory

This document is reproduced as a project report and is without editorial preparation. The manuscript has been submitted to The Physical Review for possible publication.

Date Declassified: September 29, 1948

Issuance of this document does not constitute authority for declassification of classified copies of the same or similar content and title and by the same authors.

Technical Information Branch, Oak Ridge, Tennessee
AEC, Oak Ridge, Tenn., 4-11-49-850-A1462

PRINTED IN U.S.A.
PRICE 5 CENTS

NEUTRON DIFFRACTION STUDIES

By C. G. Shull, E. O. Wollan and M. C. Marney

SCATTERING CROSS SECTION AND PHASE OF SCATTERING FOR Ni^{58} AND Ni^{60}

Various scattering cross-section determinations for Ni have indicated a much larger scattering than suggested by simple potential scattering. Normal nickel contains two major isotopes, Ni^{58} (68.0%) and Ni^{60} (27.2%), along with the minor isotopes Ni^{61}, Ni^{62}, and Ni^{64}. In attempting to assign the anomalous scattering cross section to a particular isotope, samples of $Ni^{58}O$ and $Ni^{60}O$ were obtained from the Isotopes Production Division at Y-12 and were examined in the neutron diffraction spectrometer.

Figure 1 shows the diffraction patterns obtained for the three nickel oxide preparations consisting of Ni^{58}, Ni^{60}, and normal Ni. The experimental data for the three samples have been corrected for specimen weight, absorption, etc., so that the patterns are directly comparable. Since nickel oxide crystallizes in the NaCl-type face centered cubic structure, a comparison of the (111) and (200) intensities permits a direct determination of the phase of scattering of the nickel isotopes. It is seen in Figure 1 that the (200 reflection is stronger than the (111) reflection for all three specimens, and hence it follows that Ni^{58}, Ni^{60}, and elemental Ni scatter neutrons with positive phase, the same as does oxygen. It is also seen that the patterns differ markedly in intensity, signifying that the scattering cross sections are widely different. From the measured intensities of the diffraction peaks, the coherent scattering cross sections for Ni^{58}, Ni^{60}, and elemental Ni have been determined as 27, 2, and 14 barns respectively. Since potential scattering according to the physical size of these nuclei should contribute a scattering cross section of only about 5.7 barns, it is seen that the anomalously high scattering for nickel is caused by the Ni^{58} isotope, in spite of the fact that the scattering by Ni^{60} is lower than the expected potential scattering.

Both Ni^{58} and Ni^{60} are even-even nuclei with presumably zero spin, and hence their coherent scattering cross sections should be the same as their total scattering cross sections. From transmission measurements on the nickel oxide samples, the total scattering cross sections for Ni^{58}, Ni^{60}, and elemental Ni were determined as 25, 3 and 17 barns respectively, as shown in Table 1.

The agreement between the two cross-section values for Ni^{58} is satisfactorily within experimental error, while the presence of uncorrected residual water in the Ni^{60} sample makes the total scattering larger than the coherent scattering. It would not be expected that the total and coherent scattering for elemental Ni should be the same because of isotopic

Table 1. Scattering Cross Sections for Isotopic and Elemental Nickel Samples

	Coherent Scattering Cross Section	Total Scattering Cross Section
Ni^{58}	27 barns	25 barns
Ni^{60}	2	3*
Ni element	14	17

*Not corrected for residual water content in sample

incoherence. A calculation of the incoherent scattering to be expected for Ni using the above coherent scattering cross sections for the isotopes leads to a value of 2.7 barns, and this, added to the coherent scattering, agrees satisfactorily with the total scattering cross section for elemental Ni.

The large value for the scattering cross section of Ni^{58}, coupled with the fact that this nucleus scatters with positive phase, suggests on the Feshbach-Peaslee-Weisskopf picture the presence of a scattering resonance at a nearby virtual energy. On the other hand, the smaller-than-expected scattering cross section for Ni^{60}, along with its positive phase of scattering, suggests the presence of a nearby resonance at a higher-than-thermal energy. Havens et al. have reported evidence for resonance at several hundred volts energy, and this presumably is to be associated with the Ni^{60} nucleus.

SCATTERING STUDIES ON THE Li ISOTOPES

The scattering of neutrons by elemental Li has been shown by Fermi and Marshall, and Wollan and Shull to occur with a reversed phase of scattering. It seemed of interest to establish the scattering properties of the individual isotopes, namely Li^6 (7.9%) and Li^7 (92.1%). Accordingly, a sample containing 99.89% of Li^7 was obtained from the Isotope Production Division at Y-12, and this was examined in the neutron diffraction spectrometer in the form of both Li^7Cl and Li^7F. Companion preparations of elemental Li were examined for comparison purposes.

Figure 2 shows the spectrometer traces for samples of Li^7Cl and LiCl. It is seen that the (111) reflections are stronger than the (200) reflections for both materials, and this indicates that the scattering phase for both Li^7 and elemental Li is opposite to that of Cl. From the peak intensities, it has been possible to calculate the coherent scattering cross sections for Li^7 and elemental Li and from these to evaluate the cross section and phase of scattering for Li^6. These results are listed in Table 2.

Table 2. Scattering Data for the Li Isotopes.

	Phase of Scattering	Coherent Scattering Cross Section
Li element	negative	0.4 barns
Li^7	negative	0.8
Li^6	positive	~ 6

Since the amplitude of scattering for Li^7 is more negative than that for elemental Li, it is established that Li^6 scatters with a positive phase and with a calculated cross section of about 6 barns. This cross section is uncertain to the extent of perhaps 50%, but the phase of scattering appears quite definite. The negative scattering amplitude of Li^7 suggests, according to the Feshbach-Peaslee-Weisskopf theory, that a scattering resonance occurs for this nucleus at a position somewhat above thermal energies. The small value of the scattering points to an interference between resonance scattering (with negative phase) and potential scattering (with positive phase), so that the scattering resonance must be located at an energy not too far above thermal, relative to the level spacing.

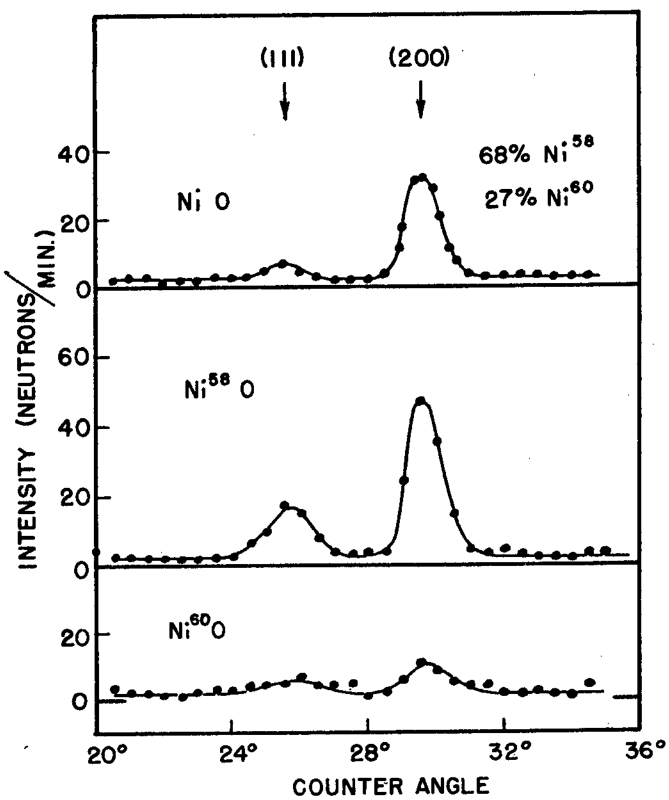

Figure 1.

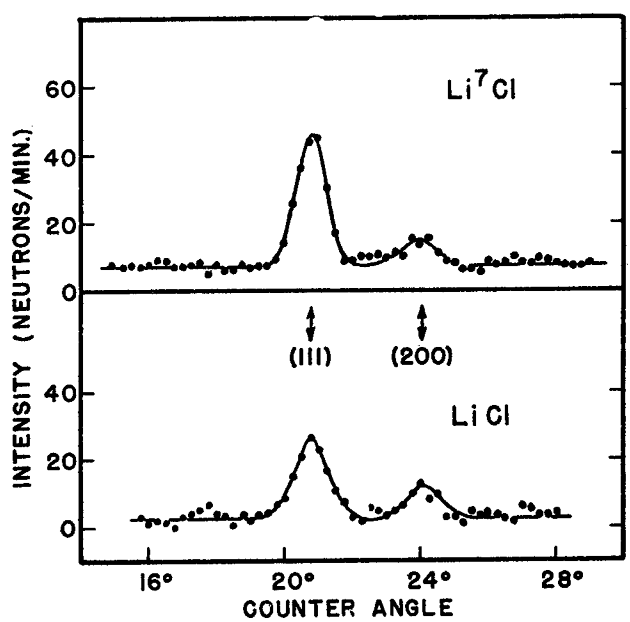

Figure 2.

END OF DOCUMENT