Nuclear Inca

Complete

220

AEC RESEARCH AND DEVELOPMENT REPORT

B-46

DO NOT REMOVE THIS PAGE

REPORT NO. Mon P-3

This document contains 6 Pages of Text and 3 Pages of Figures.

This is copy 45 of 63 Series 9.

[redacted]

Gale Young

[redacted]

[redacted]

[redacted]

[redacted]

December 7, 1946

To Gale Young

From Central File

Will you please change the number on your copy of report MonP-212 (Neutron Diffraction in Water and Heavy Water by E. O. Wollan & R. B. Sawyer) to MonP-220. This was a duplication of a number already issued.

Thank You.

[redacted]

MonP-~~212~~ 220

Contract No. W 7405 - eng. 39

* * * * * * * * * * * *

Section III

E. O. Wollan, Section Chief

* * * * * * * * * * * *

NEUTRON DIFFRACTION IN WATER AND HEAVY WATER

Problem Assignment No. PX10 - 8

* * * * * * * * * * * * * *

E. O. Wollan
R. B. Sawyer

November 27, 1946

Series A. Received: 12-2-46 Series A. Issued: 12/6/46

[redacted]

[redacted]

Abstract

Measurements have been made of the scattering of a monoenergetic beam of neutrons (E = 0.07 ev) from ordinary water and from heavy water. In the case of ordinary water a diffraction peak was found at about

$$\frac{\sin \phi/2}{\lambda} = 0.16 \text{ Å}^{-1}$$

but this peak was small compared to the diffuse scattering. With heavy water two diffraction peaks were obtained at

$$\frac{\sin \phi/2}{\lambda} = 0.16 \text{ Å}^{-1} \text{ and at about } 0.25 \text{ Å}^{-1} \text{ respectively.}$$

These peaks fall at the same value of $\frac{\sin \phi/2}{\lambda}$ as the first two peaks for the case of x-ray diffraction from water where they must be due to diffraction by oxygen atoms. In the case of neutron diffraction from heavy water there is reason to believe from the height of the first peak that there may be some contribution by diffraction from deterium.

[redacted]

[redacted]

NEUTRON DIFFRACTION IN WATER AND IN HEAVY WATER

E. O. Wollan and R. B. Sawyer

Introduction

An interesting question in connection with the scattering of neutrons is whether or not one gets measurable interference effects from hydrogen or deuterium. It is to be expected from the theory of the deuteron that the coherent scattering of neutrons from hydrogen nuclei would be small even if these atoms were regularly arranged in a crystal lattice. This arises from the fact that for scattering corresponding to the singlet state of the deuteron the phase shift is negative while for the triplet state the phase shift is positive and hence there is partial destructive interference between the scattered waves from the two states. The coherent scattering by hydrogen in a liquid would also be reduced by the more or less random orientation of the atoms.

With D_2O the scattering theory is not well developed and the amount of coherent scattering to be expected in a given case cannot at present be predicted.

Experimental Arrangement

The neutrons from the pile were brought out through a slit $\frac{1}{4}$" wide by 1" high and made to fall on a rock salt crystal set to reflect at a glancing angle of about 11°. This crystal was shielded with four inches of paraffin in front. Boron carbide and cadmium were used to absorb the slow neutrons and a layer of four inches of lead surrounding

[redacted]

the whole shield eliminated most of the gamma rays. The reflected neutron beam emerged from the shield through a channel which made an angle of 22° with the main beam. This first reflected beam of neutrons for which E = 0.07 ev and λ = 1.07 Å passed over the center of a spectrometer table on which the H_2O and D_2O samples were held. The samples were contained in parallel sided cells two walls of which were made of thin Al sheet. Dummy cells of the same type were used for measuring the background. To simplify absorption corrections the normals to the cells were maintained at an angle of $\phi/2$ with the main beam where ϕ is the scattering angle.

The scattered radiation was measured with an enriched BF_3 counter 2 inches in diameter and 18 inches long filled to a pressure of about 30 cm Hg. To reduce the background the counter was shielded with a layer of boron carbide 3/8 inches thick and this was surrounded with about 3 inches of paraffin.

The slit at the counter subtended a horizontal angle from the sample of about 5°.

Results

The uncorrected data (readings with sample less readings with dummy) for the intensity of scattering of monoenergetic neutrons (λ = 1.07 Å) from H_2O and D_2O as a function of scattering angle are shown in Fig. 1.

The H_2O data were obtained with a sample thickness of about 3/16 inch for which the log of the transmission μt = 1.0. With this sample thickness there will undoubtedly be some multiple scattering in the cell and for this reason the data are only significant in showing the presence of a diffraction peak at about 22°. This peak is most probably due to interference between oxygen atoms.

For the D_2O data a cell thickness of 1/2 inch was used for which $\mu t = 0.55$. In this case there will also be some multiple scattering but it should represent only a small fraction of the single scattering intensity. With D_2O two peaks were observed, one at 20° and one at about 30°. For $\lambda = 1.07$ Å these angles correspond to

$$\frac{\sin \phi/2}{\lambda} = 0.16 \text{ Å}^{-1} \text{ and } 0.24 \text{ Å}^{-1} \text{ respectively.}$$

This corresponds to the positions of the first two peaks obtained for x-ray scattering by H_2O.

The data for D_2O corrected for the change in absorption and scattering volume are plotted again in Fig. 2 in terms of the number of neutrons scattered between ϕ and $\phi + d\phi$ as ordinate and scattering angle θ and $\frac{\sin \phi/2}{\lambda}$ as abscissa. This involved multiplying the original data by $\cos \phi/2 \exp(\mu t/\cos \phi/2) \sin \phi$. The positions of the peaks obtained by x-ray scattering from water are shown by the arrows.

Since in the case of water the diffraction peaks must be due to interference between oxygen atoms it might be logical to interpret the D_2O data in the same way. It is interesting, however, to make a further study of this point. If the interference is wholly attributable to oxygen one can subtract the scattering from D_2O which should then be spherically symmetric. From the relative scattering cross sections of oxygen and deuterium the fraction of the total scattering by deuterium has been calculated as the lower broken curve, the dashed curve being the assumed average scattering by D_2O. On this basis the scattering by oxygen should be given by the difference between the experimental curve and the dashed curve. After making this subtraction one obtains the solid curve of Fig. 3. The lower dashed curve is the x-ray scattering by H_2O on an arbitrary scale. To compare the x-ray data with the neutron diffraction data one must

SECRET

correct for the effect of the atomic structure factor on x-ray scattering. If one divides the x-ray data by the square of the atomic structure factor, f^2, one obtains the broken curve of Fig. 3. This curve should presumably be comparable to the neutron scattering curve if all the interference effects arise from oxygen.

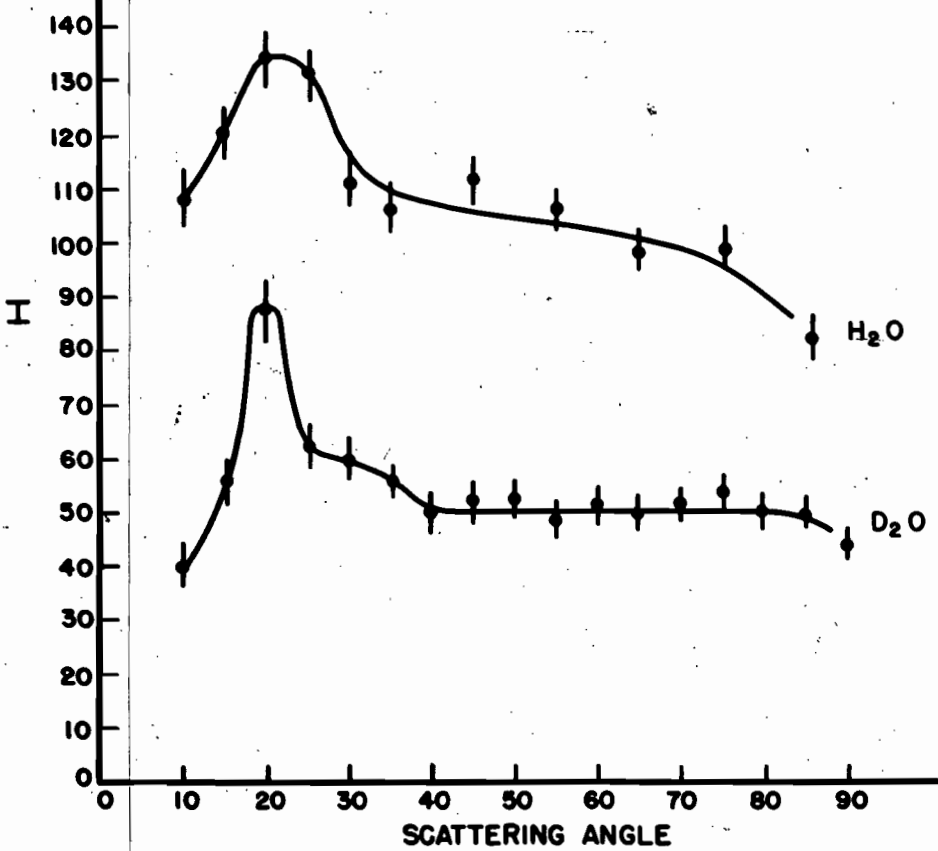
The first peak is seen to be much more pronounced in the case of the scattering of neutrons from D_2O than for x-ray scattering by H_2O. This may indicate that deuterium nuclei contribute to this interference peak. Before one can analyse such a curve it will be necessary to study the interference effects from deuterium in the more ideal situation obtaining in crystals.

SECRET

Drawing No. 3081

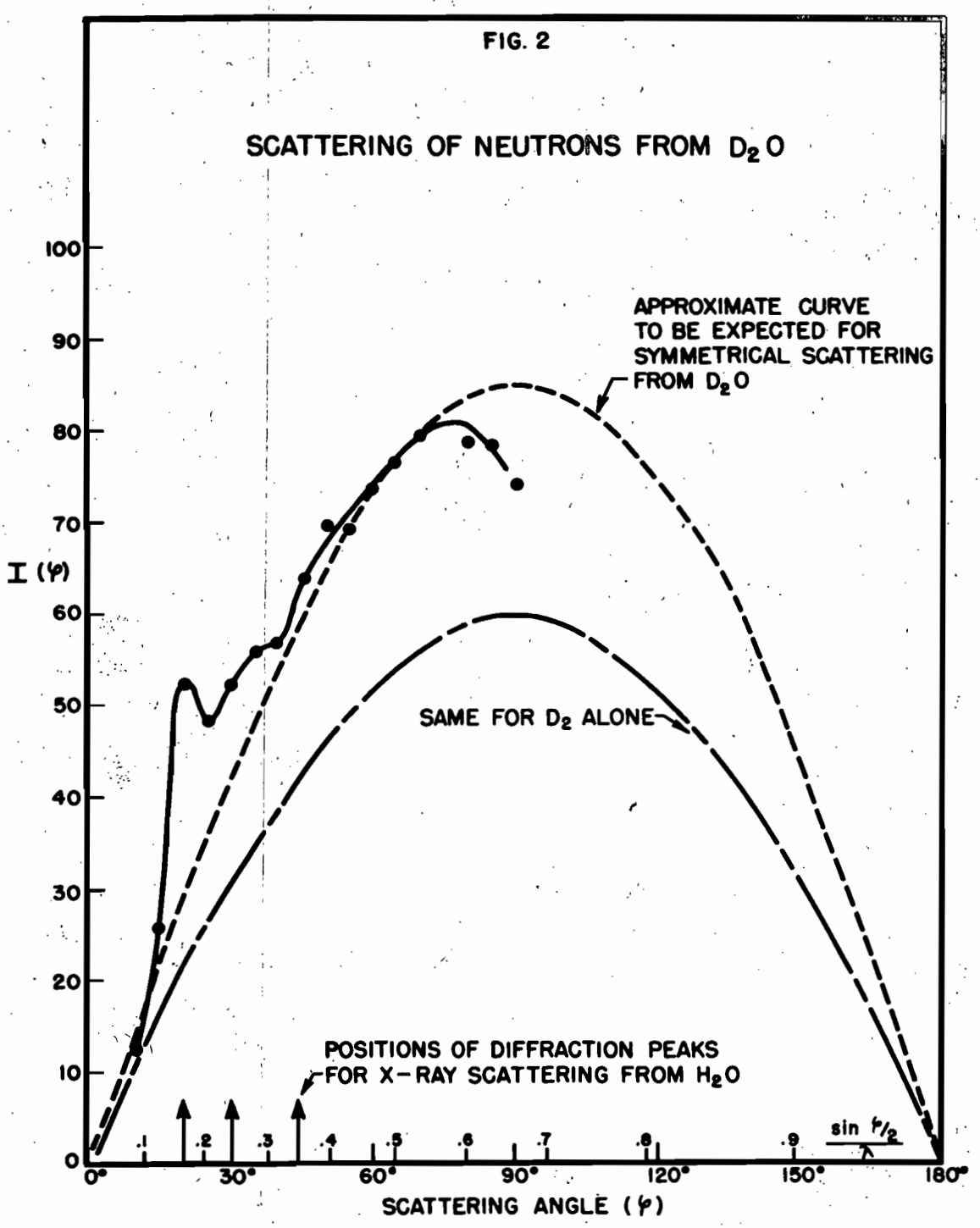
FIG. 1

SCATTERING OF MONOENERGETIC NEUTRONS
FROM H_2O AND D_2O
$\lambda = 1.07$ A°



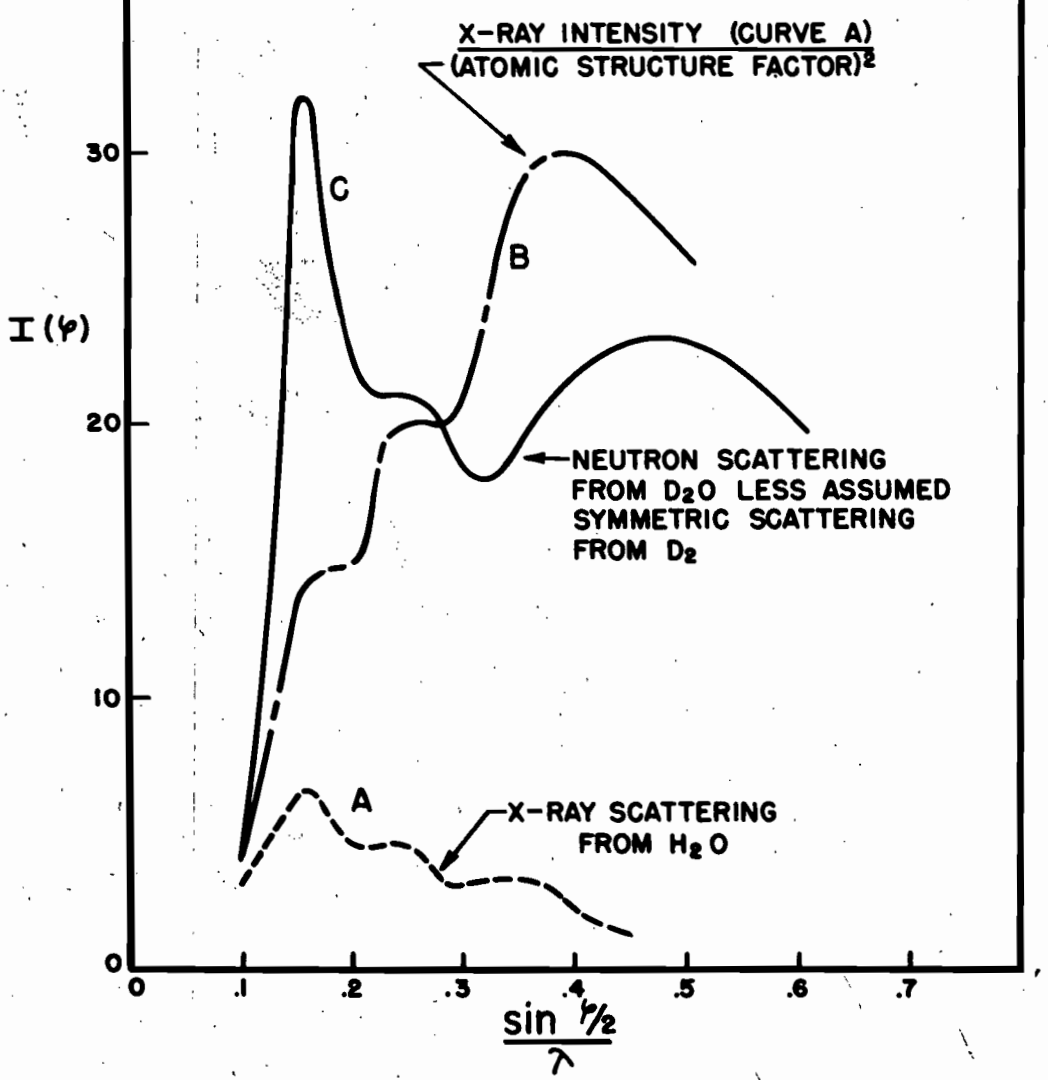
11-27-46
Dwgn. P.M.C.

Drawing No. 3082



11-27-46
Dwgn. T.M.C.

FIG. 3



11-27-46
Dwgs. P.M.C.

[redacted]

RECEIVED
MAR 26 1948
OAK RIDGE NATIONAL
LABORATORIES
CENTRAL FILES

DEC 1946
Clinton Laboratories
Central File
Bern

[redacted]