THE GROUND STATE AND ANGULAR DISTRIBUTIONS OF Ag^{108}

by

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Signature of Author . . . .
Department of Physics, May 21, 1965

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Accepted by . . . .
Chairman, Departmental Committee on Theses

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ABSTRACT

The M.I.T. - O.N.R. electrostatic generator and associated multiple-gap spectrograph have been used to establish the ground state Q - value of Ag^{108} at 5051 ± 11 KeV by means of the reaction $Ag^{107}(d,p)Ag^{108}$. Angular distributions were obtained for the $Ag^{107}(d,d)Ag^{107}$ reaction and for five excited states of the reaction $Ag^{107}(d,p)\ Ag^{108}$.

Thesis supervisor: H.A. Enge

Title: Professor of Physics

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I INTRODUCTION

The experiment reported herein was undertaken to resolve the descrepancy in the Q - value of the Ag^{108} ground state transition reported by the M. I. T. - L. N. S. Group and the values deduced by other sources. A very early measurement by Harvey of this transition gave 4.78± 0.20 MeV.[1] The value assigned to the transition by the M.I.T Group was 4968 ± KeV[2], later changed to 4973±10 KeV due to the adoption of a new calibration standard.[3] These values were also based upon an $Ag^{107}(d,p)Ag^{108}$ measurement. A.H. Wapstra reports this level at 5045± 12 KeV from mass data.[4] Additional (n,γ) work reports a gamma ray of energy 7270± 20 KeV from an $Ag^{107}(n,\gamma)Ag^{108}$ reaction.[5] Subtracting the deuteron binding energy from this value one arrives at 5045 KeV for the ground state level. The (n,γ) work also indicates a possible excited state at 81 KeV from the ground state.[6] It is therefore postulated that the transition observed at M.I.T. may possibly be a transition to a low-lying excited state in the region of 81 KeV. This then implies a value on the order of 5054 KeV for the ground state transition and is much more in accordance with the other reported values.

The experiment is also designed to determine absolute cross sections for deuteron scattering from Ag^{107}, and for several excited states from the (d,p) reaction. The angular distributions of these cross sections are measured, and a distorted-wave analysis fit to the (d,p) distribution data , is attempted, and neutron orbital angular momentum quantum numbers, l_n, are proposed on this basis.

The energy of the experiment, 7.5 MeV, is below the Coulomb Barrier for this nucleus and therefore one should not expect pronounced foreward peaking as is the case with lighter nuclei at this deuteron energy. However the energy is not far enough below the Coulomb barrier to give simple backangle peaking as with heavier elements such as Pb. An intermediate type of distribution is expected.

II APPARATUS

Incident deuterons for the experiment were produced by the M.I.T. - O.N.R. electrostatic generator.[7] The experimental arrangement is shown in Figure 1. Accelerated deuterons emerge from the generator and are deflected into a horizontal trajectory by an analyzing magnet, which also selects the beam energy via a slit system. The energy-defining X_4 slits were set at 0.5mm for this experiment; which gives a maximum beam energy spread of less than 10 KeV.[8]

An electrostatic quadrupole lens then focuses the beam onto the target, located in the center of a multiple-gap magnetic spectrograph, described in a previous publication.[9] Figures 2 and 3 show horizontal and vertical views of this spectrograph. Twenty-four gaps are used simultaneously to analyze reaction products at angles from 7.5° to 172.5° in 7.5° intervals. There are two 90° gaps, one in the foreward quadrant and the other in the back quadrant. These are generally referred to as the '89°' gap and the '91°' gap, respectively, for identification purposes, but both are actually at exactly 90° with respect to the incident beam. The 0° gap contains a Faraday cup which collects and integrates the beam current.

The charged particles are detected by the tracks they produce by ionization in a nuclear emulsion. This emulsion is on three plates located above each gap at the spectrograph focal surface (see Figure 2). Each set of plates permits three zones to be exposed, labeled X, Y, and Z, separated by an unexposed region of 1-2mm. These plates are counted under a microscope in ½mm strips with a magnification of about 250.

A proton-resonance fluxmeter located in the '89°' gap measures the spectrograph magnetic field. A charged particle passing through the magnetic field in each of the gaps is deflected into a circular orbit with a radius of curvature, ρ, determined by the particle momentum. The radius of curvature in turn, determines the point on the focal surface at which the particle will strike the nuclear emulsion. Since each gap has been calibrated using Po^{210} particles, a relationship has been determined between the radius of curvature (ρ) and plate distance (D) and has been found to be fairly constant over a range of field settings.

To facilitate measurements of elastic scattering cross sections, an auxiliary set of slits has been provided to redefine the solid angles subtended by the gaps in the foreward quadrant. These slits are referred to as the 'Rutherford slits'. The solid angles are reduced so as to give approximately the same number of counts at all foreward angles as are seen at the '91°' gap with no 'Rutherford slit'. The multiplication factors used to correct data with respect to this modification are presented in Table 1. The slit sizes and multiplication factors were determined from data produced by elastically scattering 3 MeV deuterons from Sn, W, Os, and Au.

TABLE I

Rutherford Slit Calibration Data

ANGLE	$\frac{1}{\text{Slit size (Relative to 91° gap)}}$	Estimated Error
22°	59.2	± 10%
30°	48.34	± 15%
37°	22.60	± 8%
45°	11.74	± 7%
52°	5.925	± 5%
60°	4.017	± 5%
67°	2.711	± 5%
75°	1.912	± 5%
82°	1.387	± 5%
89°	1.106	± 5%
91°	1.0	—

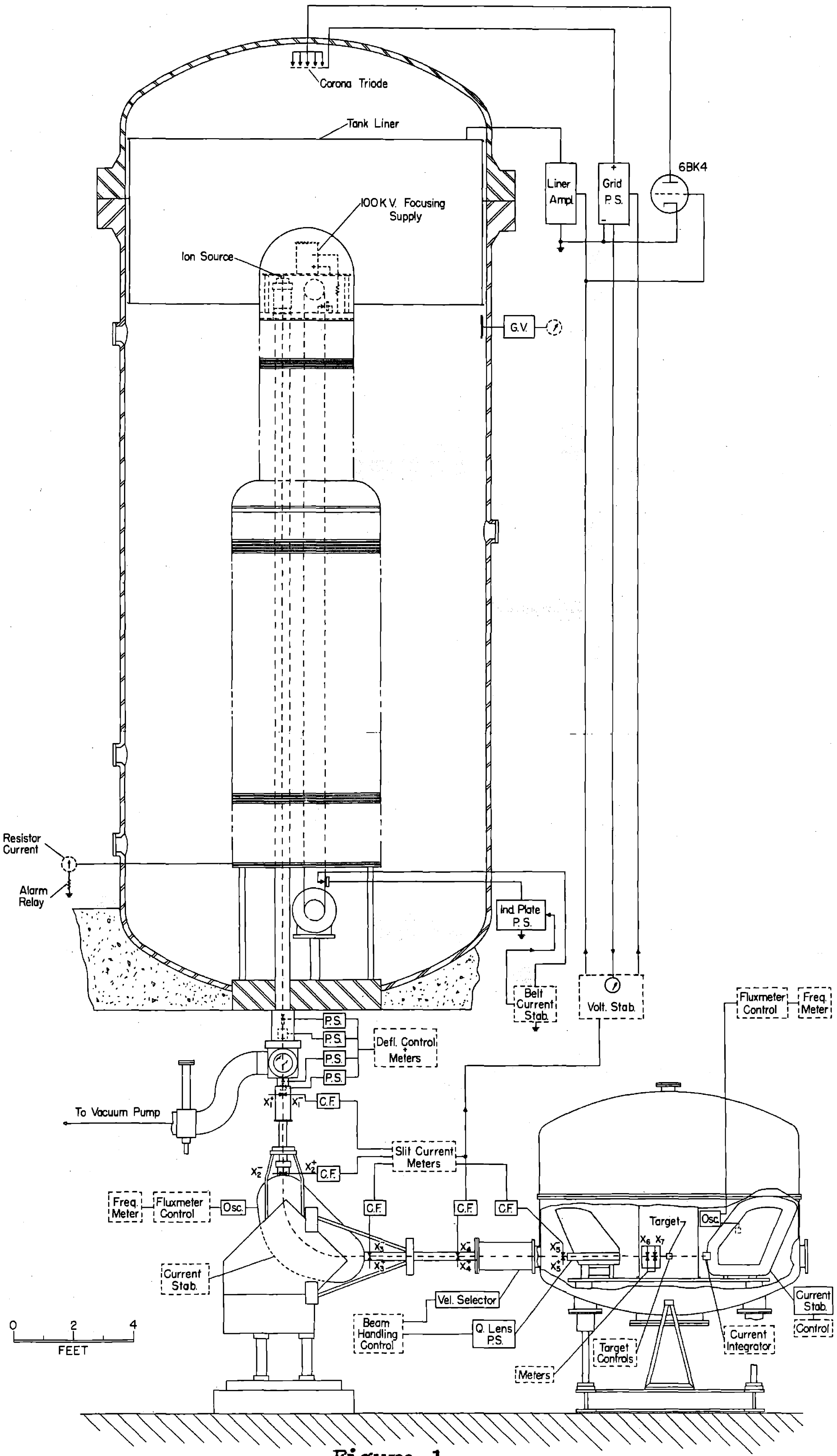
Corona Triode
Tank Liner
Liner Ampl.
Grid P.S.
6BK4
100 K.V. Focusing Supply
Ion Source
G.V.
Resistor Current
Alarm Relay
Ind. Plate P.S.
Belt Current Stab.
Volt. Stab.
Fluxmeter Control
Freq. Meter
P.S.
P.S.
P.S.
P.S.
Defl. Control + Meters
To Vacuum Pump
X_1^-
X_1^+
C.F.
Slit Current Meters
X_2^-
X_2^+
C.F.
Freq. Meter
Fluxmeter Control
Osc.
C.F.
C.F.
C.F.
Target
Osc.
X_3
X_3
X_4
X_4
X_5
X_5
X_6
X_7
Current Stab.
Vel. Selector
Beam Handling Control
Q. Lens P.S.
Meters
Target Controls
Current Integrator
Current Stab.
Control
0
2
4
FEET

Figure 1

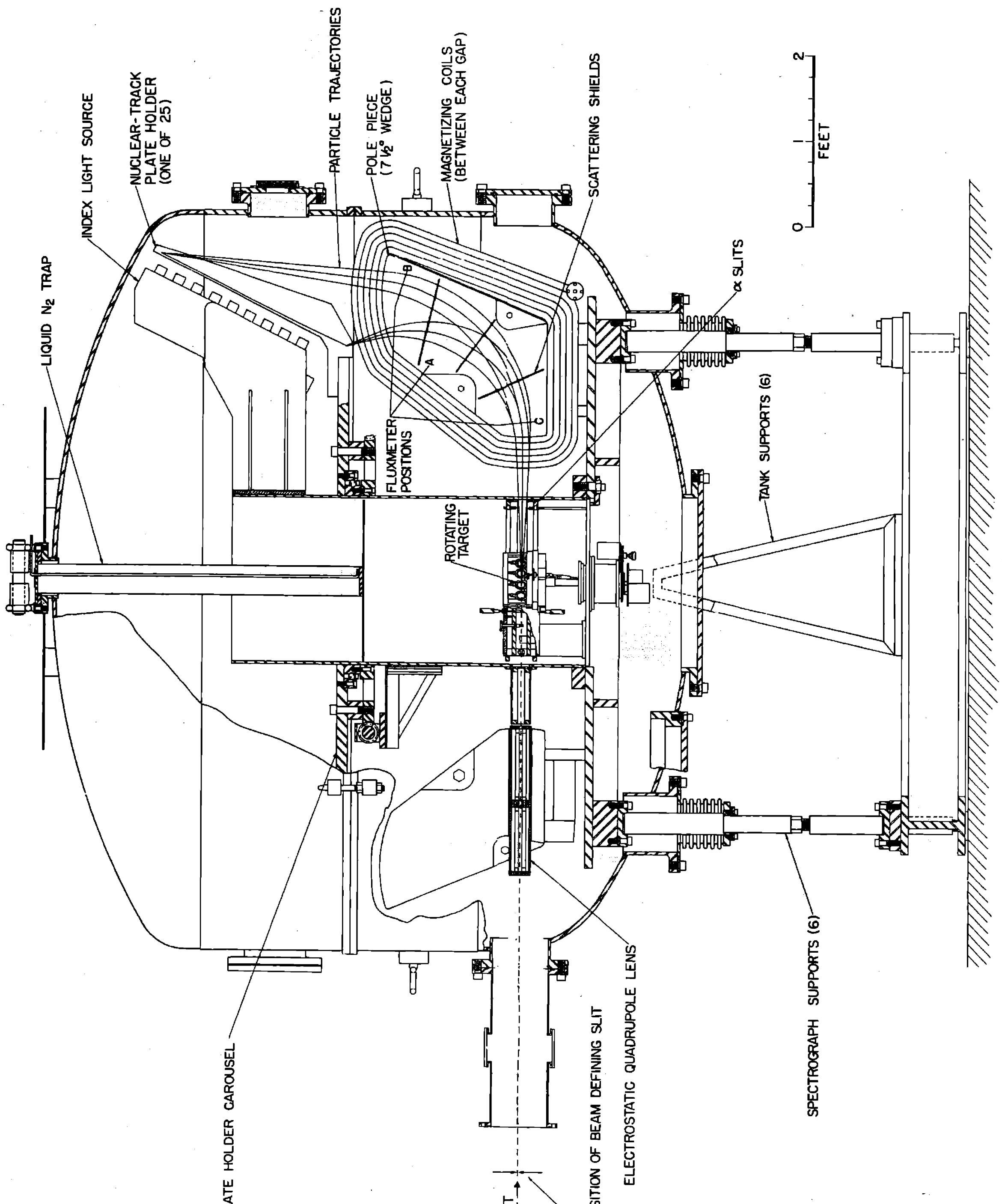
LIQUID N_2 TRAP
INDEX LIGHT SOURCE
NUCLEAR-TRACK PLATE HOLDER (ONE OF 25)
PARTICLE TRAJECTORIES
POLE PIECE (7 ½° WEDGE)
MAGNETIZING COILS (BETWEEN EACH GAP)
SCATTERING SHIELDS
α SLITS
0
1
2
FEET
A
B
FLUXMETER POSITIONS
ROTATING TARGET
TANK SUPPORTS (6)
SPECTROGRAPH SUPPORTS (6)
ELECTROSTATIC QUADRUPOLE LENS
POSITION OF BEAM DEFINING SLIT
INCIDENT BEAM
PLATE HOLDER CAROUSEL

Figure 2

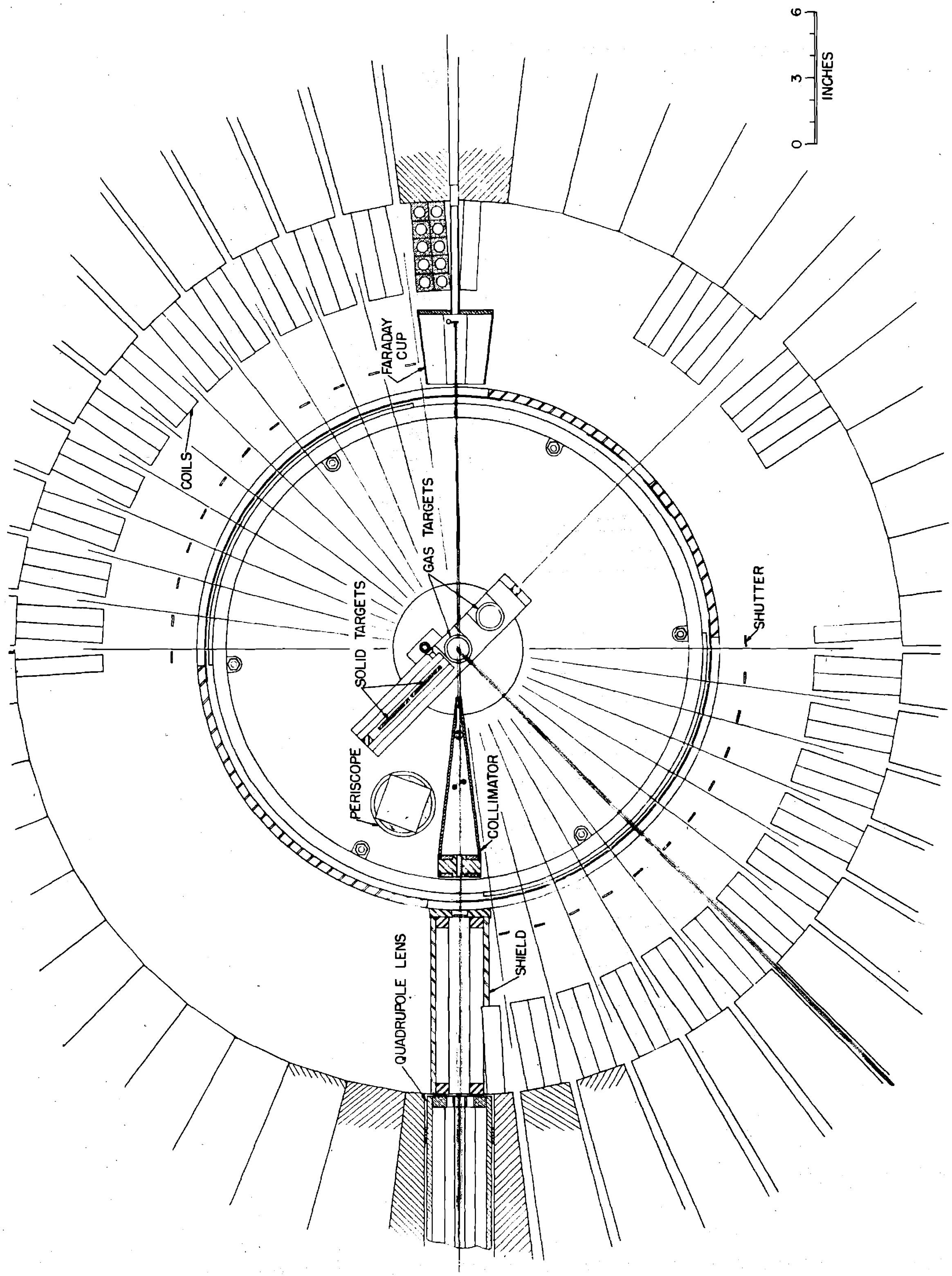
0
3
6
INCHES
COILS
FARADAY CUP
GAS TARGETS
SOLID TARGETS
SHUTTER
PERISCOPE
COLLIMATOR
QUADRUPOLE LENS
SHIELD

Figure 3

III TARGETS

Two targets were used in this experiment, one a thin film of Silver on a Formvar backing and the other a self-supporting thin silver film. The first (Ag^{107}, S-139) was evaporated directly onto the Formvar backing supported by a stainless steel target frame, and the second (Ag^{107}, X - 140) was evaporated onto a glass slide. This film was then floated off the slide by immersion into distilled water and then picked up onto an empty stainless steel target frame. The target frames have a 1/2" diameter opening.

The enriched isotope was obtained from the O.N.R. Laboratory. Natural Silver is 51.4% Ag^{107} and 48.6% Ag^{109}. The enriched isotope contained 98.8% Ag^{107} and 1.2± 0.02% Ag^{109}, according to the analysis received with the shipment.

Evaporation was achieved by heating the isotope in a Tantalum sheet boat under vacuum. The target material was then deposited on target frames or glass suspended over the boat.

Elastic scattering runs were made on each target to determine the target thickness. The Formvar-supported target was exposed to 3 microcoulombs of 3 MeV deuterons, and the self-supporting target was exposed to 2 microcoulombs of 3 MeV deuterons.

For reasons given in Section IV the data on this elastic scattering for the Formvar-supported target was rendered useless. The thickness for the self-supporting target was calculated from the above data assuming Rutherford Scattering.

As an alternative method for calculating the thickness of the Formvar-supported target, the experimental cross section for elastically scattered 7.5 MeV deuterons at the 30° reaction angle was assumed to be equal to that predicted by Rutherford scattering at that angle, and the target thickness was calculated from this value.[10] Although this method is not as desirable as the 3 MeV calculation, it does make the best use of the data available. The assumption of Rutherford scattering for the self-supporting target is supported by the general agreement found between calculations at 30°, 37.5°, and 45°. The results of the target thickness calculations were as follows:

i. Formvar - supported (Ag^{107}S-139)

$N_t = 0.58 \pm 0.06 \times 10^{18}$ atoms/cm^2,

which is approximately 103 μgm/cm^2.

ii. Self-Supporting (Ag^{107} X - 140)

$N_t = 1.17 \pm 0.01 \times 10^{18}$ atoms/cm^2,

which is approximately 208 μgm/cm^2.

Cl, S, and probably Ta were identified as contaminants. Cl and S were identified on the basis of the shift exhibited upon comparison of (d,p) data from various reaction angles. Ta was not positively identified but the presence of an elastic peak to the right of the Ag^{107} elastic peak indicates the presence of a heavier element. (See Figure 5) Since evaporation took place in a Ta boat it is proposed as the most likely candidate. Neither S nor Cl were reported in the spectrographic analysis received with the isotope but Silver's affinity for each of these elements makes their presence quite likely.

IV EXPERIMENTAL PROCEDURE AND DATA ANALYSIS

The initial run on Ag^{107} was made on the lighter of the two targets. The purpose of this run was to explore the yield from the highly improbable ground-state transition with respect to a thick target. Five exposures were planned for this run. The Z - zone was exposed to 3 microcoulombs of 3 MeV deuterons for target thickness data and 15 microcoulombs of 7.5 MeV deuterons for data on the elastic scattering cross sections, both exposures using the 'Rutherford slit' apparatus. A 2000 microcoulomb exposure was made on the X - zone for (d,p) analysis. The remaining two exposures were made on Tin targets in connection with Tin experiments.

Unfortunately after developing the plates, no tracks were seen in the region of the elastically scattered 3 MeV deuterons. Presumably this target thickness exposure was not made due to a failure to open the exposure shutter. Nevertheless, the (d,p) results were such that it was obvious that both a thicker target and a much longer exposure were required to observe the ground state transition.

The next run was made on the thicker, self-supporting target. The spectrograph carried only a partial load of plates since this run was made primarily to estimate the exposure necessary to resolve the sought-after transition. The data from the 4000 microcoulomb, 7.5 MeV exposure indicated that 10,000 to 20,000 microcoulombs were required to give conclusive results.

The final run consisted of four exposures. The Y-zone was exposed to 15,000 microcoulombs of 7.5 MeV deuterons to detect the ground state transition. The X - zone was exposed to 3,000 microcoulombs of 7.5 MeV deuterons for (d,p) analysis at other levels, and the Z - zone was exposed to 1 microcoulomb of 3 MeV deuterons and 5 microcoulombs of 7.5 MeV deuterons for target thickness and elastic cross-section measurements.

Upon examining these plates, it was found that the intensity of the 15,000 microcoulomb exposure was such that the spacing between zones was obliterated in regions near highly prominent transition peaks, particularly the elastic $Ag^{107}(d,d)Ag^{107}$ peak. Thus the amount of background on the adjacent zones varied with the intensity of the 15,000 microcoulomb exposure. Since the elastic peak on the Z - zone was at approximately the same plate distance as the corresponding elastic peak from the 15,000 microcoulomb exposure, this Z - zone elastic scattering cross section data was rendered useless by the non-constant background of scattered particles spilling over from the Y - zone.

This necessitated turning to the elastic cross section data gathered in the first run on the thin target. However, since no target thickness data was available for this target, it was necessary to calculate thickness by an indirect method. It was first proposed that by relating the number of deuterons elastically scattered by each target at a particular reaction angle and using the standard scattering formula, that one could find the thickness of the lighter target in terms of the known thickness of the heavier one. The following formula was used:

$$N_{t_1} = N_{t_2} \frac{N_{sc_1} \quad N_{b_2}}{N_{sc_2} \quad N_{b_1}}$$

where N_t = number of atoms per cm^2 in the target

N_b = number of particles in the beam

N_{sc} = number of observed elastically scattered particles at a given reaction angle.

To use this approach it was necessary to estimate the background, previously mentioned, contained in the Z - zone elastic peak. An attempt was made to relate the amount of background to the total number of observed tracks in the elastic peak, assuming that the background intensity followed the elastic peak intensity. This estimation led to an experimental elastic cross section higher than the Rutherford cross section for Ag^{107} in the forward angles. Since the experimental cross section is expected to approach the Rutherford values asymptotically with decreasing angle, this approach was abandoned in favor of the one described in Section III (see page 14).

At least the first seven centimeters of the X - zones of all 3 plates were counted for angular distributions. This included the first 10 - 12 peaks from the $Ag^{107}(d,p)Ag^{108}$ reactions. Plates 224 A 172 and 224 B 172 were fully counted on both the X and Y zones to present the full (d,p) spectrum. Plate 224 C 172 was fogged by scattered deuterons and therefore

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