CYCLOTRON LABORATORY

HARVARD UNIVERSITY

QUARTERLY PROGRESS REPORT

1 JUNE - 31 AUGUST 1964

Part a - Cyclotron

Machine:

During the past quarter, the cyclotron was in operation 1680 hours, or about 18 hours per day. Three days were lost due to failure of the refrigerator for the cold-trap above the diffusion pumps. Another day was lost because of inadequate oil levels in the diffusion pumps. A scheduled shutdown of about one week was required to install apparatus for pulsed deflection of the internal beam. (See elsewhere in this report for details).

A. M. Koehler

Quasi-free proton-proton scattering:

We had one run in June. We obtained data for Ni^{58} at 40°, 50° and 60° and Sc^{45} at 60°. The binding energy spectrum of Ni^{58} at 40° showed a predominant peak at 11 Mev which agreed with our data taken in November of 1963. This group of protons had strong $\ell = 0$ characteristics. At 60° a peak at 8 Mev which was very weak, if present, at 40° became comparable to that at 11 Mev in intensity. This group of protons leading to the ground state of Co^{57} showed $\ell \neq 0$ characteristics. The Sc^{45} spectrum at 60° as that at 42° had one predominant peak at 12 Mev, which might be composed of two unresolved peaks. There

was some evidence that a very weak peak appeared at 8 Mev.

Further improvement in our apparatus to enable us to accumulate data at a much higher rate is in progress.

B. Gottschalk
K. Strauch
K. H. Wang

Investigation of the Faraday cup:

The 12-inch Faraday cup was modified so that blocks of either of two different materials could be placed (without disturbing the vacuum system) immediately in front of the 2-inch brass stopping plate, where they would be in electrical contact with the stopping plate. In this way the charge collected by the F. C. per unit of incident beam (measured by an ionization chamber) could be determined as a function of thickness and type of stopping material.

Measurements will begin early in the next quarter.

A. M. Koehler
J. N. Palmieri (Oberlin College)

Neutron total cross sections:

Neutron total cross sections are being measured for several nuclei (p, d, He, C, N, O, Al) in the energy range of 80 to 150 Mev using the monokinetic neutron beam described in the Annual Progress Report for 1963-1964. A 1" x 1" beam of neutrons is allowed to pass through a target (at least 3" in diameter) and is then detected by a 3"-diameter plastic scintillator, which is long enough to stop protons of about 150 Mev. A target containing one of the above materials and a corresponding "dummy"

target are alternately placed in the beam by remote control, and the ratio of transmitted beams for the target and dummy is determined.

For targets of carbon, aluminum, liquid nitrogen and liquid oxygen, sufficient data have been accumulated to yield results accurate to 2%; final calculations which include corrections (e. g., dead time losses, multiple scattering, solid angle of detector) are in progress.

A preliminary study has been made for the lighter nuclei. For hydrogen, two methods are being used: liquid hydrogen and a hydrocarbon-carbon difference. Deuterium is being investigated using the heavy-light water difference method, and liquid helium will be used for the n-α measurement. The attenuation by the targets for these light nuclei is small (about 10%) and seems to be (empirically) extremely susceptible to counting rate. It is hoped that this problem will be eliminated by the use of a more stable photomultiplier on the detector and a faster discriminator circuit.

D. F. Measday
J. N. Palmieri (Oberlin College)

n-p incoherent scattering cross section:

The pulsed spill system has been tested and preliminary measurements have been made on the time structure of the resulting beam.

A carbon target made from reactor-grade rod stock was surveyed for variations in areal density. The external proton beam was collimated to 1/8 inch diameter in the biomedical

apparatus and passed through the target. The density of various parts of the target was found in terms of its equivalent aluminum density by searching for the tail of the Bragg ionization curve. Density gradients of 1% per quarter inch near the center of the target and 2% per quarter inch near the edge were found. This experiment was sensitive to density changes of 0.2%. These density gradients and their irregular distribution render this target unacceptable for our purposes. A similar survey on samples of pyrolytic graphite is planned.

T. L. Houk
R. Wilson

A'$_t$ in n-p scattering:

A Ph. D. thesis describing this experiment is currently being written.

N. Strax, D. Miller
E. Petraske
D. Swanson

Biological uses of proton beams*:

During the past quarter there were two cyclotron runs devoted to medical and biological irradiations. The pituitaries of six patients with diabetic retinopathy were irradiated, and three patients with brain tumors were treated.

*Supported by NASA Grant NsG-262-63. Reports available from Miss Carol Webster, Massachusetts General Hospital, Boston Massachusetts

Biological irradiations are briefly tabulated below:

Item	Target	Experiment
1.	Cebus monkeys	Radiosensitivity of optic chiasm
2.	Dry enzymes	RBE and doserate effects on EPR spectra
3.	Mice	Effects of various radio-protective agents on sensitivity of transplantable murine tumors
4.	Rabbits	RBE and doserate effects in the retina
5.	Hamsters	Same as 3
6.	Ehrlich ascites cells	RBE and doserate effects
7.	Guinea pigs	Effects on resistence to infection of low dose, low rate exposure

Reported by A. M. Koehler

Test of the Chew-Low extrapolation method:

An emulsion exposure was made in the monokinetic neutron beam using an adaptation of the deuterium target used for the proton-beam experiment. Fogging of the plates has hampered scanning. It is not evident whether the fogging is due to background radiation in the beam area or to faulty developing or handling. Another group of plates has been exposed without the deuterium target to check this point. An exposure of 7 to 10 days is planned for November.

M. Widgoff (Brown University)
A. M. Cormack (Tufts University)
A. M. Koehler

Fission of medium-weight elements:

The radiochemical determination of the fissionability of In, Ag, and Rh nuclei with bombarding protons of energies 60, 100 and 140 Mev has been continued. Experimental work is nearly complete.

H. Baba, T. T. Sugihara

Isotopic ratio studies of stable elements in the marine Environment:

During the quarter 3 irradiations were carried out utilizing the internal beam. Optimum conditions for the determination of Zn in marine samples by proton activation were sought. Blanks and standards were run to check the method and its sensitivity. The data are presently being analyzed.

V. E. Noshkin
Woods Hole Oceanographic Institute

Part b - Nuclear Magnetism and Nuclear Spectroscopy

Resonant absorption of γ-rays:

A. Red-shift: During the summer months the major effort on this experiment has been directed toward evaluating sources of error The data taken over the full height of the path were in agreement with the expected result well within the 0.8 percent statistical uncertainty. About six weeks were spent on a run with only a 34-foot path between the third and the basement floors. This yielded a result well within its 1.5 percent statistical uncertainty of the predicted value. The major problems of evaluation of the overall results remain the uncertainties in the

constancy of the temperature distribution within the evacuated absorber cell and the exact value of the source velocity produced by the hydraulic calibrator. We are currently writing a brief note on the results and will then write a detailed report on the experiment.

R. V. Pound
J. L. Snider, Jr.

B. Studies of the directional correlation of the γ-ray cascade in Cs^{133} at room liquid nitrogen and liquid helium temperatures, have been made with hydrated and anhydrous $BaCl_2$ and BaO. These have revealed some cases of disturbances of the 81 kev state at low temperatures. The disturbances do not seem to be large enough to account for the failure to find recoil-free resonant absorption. This work is now being written up as a thesis.

R. Walker
R. V. Pound

C. Work has continued and good progress made on the cryostat, electronics, and temperature control system for studying the resonance of Sn^{119} vs. temperature in the liquid helium temperature region.

Mrs. Nancy Snyder
R. V. Pound

Part d - Research on the properties of nuclei

<u>Masses of isotopes</u>:

The measurements have been completed on Cl^{35} and Cl^{37} relative to the standard C^{12}, and on the difference $Cl^{37} - Cl^{35}$ determined

independently. Errors are 2 or 3 parts in 10^8 and these data, useful in structure studies, represent a distinct improvement over available published data.

The lock-in detector system was completed and in use in June, July and August to complete the chlorine measurements. It has been used also to stabilize the magnetic field and is an important advance in technique.

On September 1 Dr. J. W. Dewdney left for the University of New Hampshire and Dr. R. R. Ries, a graduate of the University of Minnesota, arrived from the Max Planck Institute in Mainz.

K. T. Bainbridge
J. W. Dewdney

Part e - Molecular beam research

Nuclear interactions in molecules:

The magnetic resonance spectrum of F_2 has been extensively studied during the past quarter. Twenty-three resonances have been observed in the vicinity of the nuclear resonance frequency, the separation of the resonances is dominantly due to the spin-rotational interaction of the molecule. The resonance spectrum has also been observed in zero magnetic field where the frequency of the line is dominantly determined by spin-rotational interaction constant c and to a lesser extent by the spin-spin magnetic interaction constant d. The rotational gyromagnetic ratio g_J has also been measured for F_2. The values obtained for these quantities are -

$c = -(157.3 \pm 0.8)$ kc/sec

$d = 8.0 \pm 0.7$ kc/sec

$g_J = -(0.1208 \pm 0.001)$ nm

A new electron bombardment detector which should have a much lower background is currently being installed in the resonance apparatus.

F. Mehran, L. Crapo,
I. Ozier, N. F. Ramsey

Atomic hydrogen maser:

During the past quarter two new masers have been made for the first time. One is the He^3 nuclear Zeeman maser which operates at a frequency of about 100 kc/sec when in a magnetic field of 30 gauss. The He^3 maser is possible because of the very long storage times - of the order of 100 seconds - achievable with polarized He^3. The nuclei were polarized by optical pumping of atoms in the triplet metastable state and by the metastability of exchange collisions.

A tritium maser has just been brought into successful operation and will be used to determine with very high precision the ratio of the hyperfine frequency of hydrogen to that of tritium.

D. Kleppner, H. Robinson,
Than Myiant, D. Burnham,
H. Berg, D. Gr[illegible]y,
B. Mathur, N. F. Ramsey

Part f - Resonance studies with free ions:

The past quarter has been devoted to making a number of improvements on the atomic beam section of the ion resonance

apparatus. The state selecting magnet has been watercooled to trap beam atoms which hit it, and modifications have been made on the monitor detector and beam detector to decrease spurious background and increase their collection efficiency.

If all goes well, we should search for a Zeeman resonance on He^4 ions this quarter.

D. Kleppner

Publications:

Calibration of 30-cm Faraday Cup, J. N. Palmieri and R. Goloskie, Rev. Sci. Inst. 35 1023 (1964).

Total Proton-proton Cross Sections, R. Goloskie and J. N. Palmieri, Nuclear Physics, 55 463 (1964).

Small-angle Scattering of 143-Mev Polarized Protons, D. J. Steinberg, J. N. Palmieri and A. M. Cormack, Nuclear Physics 56, 46 (1964).