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Titles given in parentheses are those of continuing programs, in which no progress has been made, either in work done or in publication during the current quarter.

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I. EXPERIMENTAL NUCLEAR PHYSICS

1-4 (The Argonne Fast Neutron Velocity Selector) (5211-01, 5261-01)

Lowell M. Bollinger

There is nothing new to report for the past quarter.

2-4 Liquid Scintillation Neutron Detector (5211-01, 5261-01)

Lowell M. Bollinger and George E. Thomas, Jr.
Reported by George E. Thomas, Jr

In order to collect at the photomultiplier the maximum quantity of light emitted by the scintillator, one must use the best possible reflector on the inside of the counter. A systematic investigation of the reflectivities of possible materials to be used as the surface coating of large volume liquid scintillation counters has, therefore, been undertaken and completed. The measurements were made using the radiation produced by Co^{60} gamma-rays in a liquid scintillator consisting of 4 gms/l of 2, 5 diphenyloxazole and 16 mgs/l of diphenylhexatriene dissolved in toluene of high purity.

Figure 1 illustrates the equipment used. Both spaces A and B are filled with the scintillating liquid. The surface of B is coated all over with the material to be tested except for the small hole at the top. The whole inner assembly of photomultiplier and regions A and B can be moved up and down as a unit inside the lead shield so that the gamma-ray beam can pass either through A or through B. From the distribution of pulse heights, the average value of the pulse height for each position is determined, and the value of the ratio $(\overline{\text{P. H.}})_B / (\overline{\text{P. H.}})_A$ is found. From this ratio the reflectivity

FIG. 1
SYSTEM FOR MEASURING POSSIBLE
COUNTER REFLECTORS

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B.G.

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of the coating of region B is calculated as follows.

Consider an enclosure having walls coated with material of reflectivity R but with uniformly distributed transparent openings, the area of such openings being a fraction, α , of the total area. If a scintillation anywhere inside the enclosure produces an amount of luminous energy E_0 , an amount $E_0 \alpha$ will escape without reflection, and $E_0 (1-\alpha)$ will be reflected, leaving energy $E_0 (1-\alpha) R$ after reflection. Of this latter amount $E_0 (1-\alpha) R \alpha$ will escape, and so on. The total amount escaping will be represented by an infinite geometrical series which totals to $E = \frac{\alpha E_0}{1 - R (1-\alpha)}$. A similar argument applies for an enclosure with a small hole in it, like the B enclosure of the apparatus, although it is difficult to compute the precise value of α in terms of the diameter of the small hole. In computing the results, α has been taken to be the ratio of the area of the hole to the total area of the surface of the container. This will not give entirely correct results for the absolute values of R , but will give almost exactly correct relative values of $(1-R)$ for the different reflectors. It is further assumed that light escaping from the hole in B will be detected with the same efficiency by the photomultiplier as the light emitted in A when the gamma-ray beam passed through that region. This also may not be strictly accurate, but errors arising from this assumption will not affect the relative values of $1-R$. The measured ratio $(\overline{P.H.})_B / (\overline{P.H.})_A$ is set equal to the attenuation ratio $\alpha / 1 - R (1-\alpha)$, and R is calculated for the known value of α . The results are shown in the following table.

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Table I

Reflectivity of Counter Surface Coatings

<u>Reflector Material</u>	<u>Form</u>	<u>(P. H.)_B / (P. H.)_A</u>	<u>α</u>	<u>R</u>
Aluminum	foil	0.072	0.0132	0.827
Linde A (aluminum oxide)	in water glass	0.169	0.0132	0.934
"	powder (outside)	0.304	0.0104	0.976
TiO ₂	in water glass	0.140	0.0132	0.918
TiO ₂	powder	0.193	0.0104	0.956
MgO	in zapon (outside)	0.196	0.0104	0.957
MgO	powder (outside)	0.236	0.0104	0.966
TiO ₂	porcelain	0.193	0.0132	0.944

Since the use of metal containers of large volume is contemplated in the future, the porcelain reflector made of porcelain containing TiO₂ seems to be a good choice. The Chicago Vitreous Enamel Company has been very cooperative in coating this reflector surface for counters.

Tests show pure toluene to be as satisfactory as phenylcyclohexane as the solvent for scintillators.

Our program for the near future includes:

- 1) Testing of new counters now completed or under construction.
- 2) Design and construction of counters of large area for use at CP-5 with the fast chopper.

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3-4 Transmission Measurements with the Fast Neutron Velocity Selector (5211-01, 5261-01)

Lowell M. Bollinger, Duane Dahlberg, R. Ronald Palmer
Reported by Lowell M. Bollinger

Transmission measurements have been made with the fast
neutron velocity selector during the present quarter as follows:

<u>Sample</u>	<u>Thickness</u> (gm/cm ²)	<u>Resolution</u> (μ s/m)	<u>Energy</u> Range (ev)	<u>Comments</u>
Antimony	12.5 12.5	0.14 0.19	45-300 200-10,000	Transmission dips were observed at 50.5, 53.5, 64.0, 74.0, 76.5, 90.0, 105, 113, 128, 147, 166, and 190 ev. It is probable that those below 128 ev are caused by single resonances.
Antimony-123	1.27	0.14	45-300	Transmission dips were observed at 50.5, 76.5, and 105 ev. See below for summary of antimony isotopic assignment.
Bismuth	2.37 49.1	0.14 0.14	205-30,000	
Magnesium	8.83	0.13	3,000-30,000	No resonance, except the known resonance at 20 kev, was observed
Manganese	7.71 0.099 0.0302	0.14 0.14 0.14	200-30,000	No unreported resonances were observed.

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<u>Sample</u>	<u>Thickness (gm/cm²)</u>	<u>Resolution (μs/m)</u>	<u>Energy Range (ev)</u>	<u>Comments</u>
Niobium	21.6	0.14	45-300	Resonances were observed at 35.8, 119, and 195 ev. Comparison with transmission data for thin tantalum sample shows that neither these nor previously reported resonances at higher energy can be due to Ta. Small $\sigma_0 \Gamma^2$ values of observed resonances suggest that they are capture resonances.
Vanadium	15.7	0.13	300-30,000	Large resonances were observed at 4230, 6500, and 11,300 ev. Also very weak resonances were observed at 168 and 1440 ev. These latter resonances must be due to the 1/4% abundant isotope, V ⁵⁰ .
	8.3	0.14	100-30,000	
	1.03	0.14	300-30,000	

Summary of Isotopic Assignments for Antimony Resonances

<u>Resonance Energy (ev)</u>	<u>Isotopic Assignment</u>	<u>Resonance Energy (ev)</u>	<u>Isotopic Assignment</u>
6.28	121	76.5	123
15.3	121	90.0	121
21.6	123	105	123
30.0	121	113	121
50.5	123	128	121
53.5	121	147	---
64.0	121	166	---
74.0	121	190	---

Future Work

The separated isotopes of zinc will be studied.

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5-3 (The Absorption and Scattering of Neutrons by Hafnium) (5211-01,
5261-02)

Lowell M. Bollinger, Sigmund P. Harris, Carl T. Hibdon
Carl O. Muehlhause

The article on this subject is in the process of publication in
The Physical Review.

6-3 Spiral Velocity Selector for Slow Neutrons (5211-01)

Roy Ringo

The rotor for this velocity selector has been made sufficiently
rigid by an excellent copper brazing job done by the General Electric
Company in Schenectady. The Central Shops Department is now completing
the machine.

11-4 Installation and Operation of the Van de Graaff Generator (5211-01,
5261-02)

1. Instability of the Position of the Ion Beam - F. Paul Mooring

The aluminum rings mentioned in the last quarterly report
have been installed in the high voltage section of the accelerator tube.
Simultaneously, the pumping system was improved. One or the other of
these changes cured the beam jumping problem, most probably the installation
of the rings. Whether or not additional troubles have been introduced is
yet to be seen. Two that might be expected are a limitation of the maximum
voltage that can be reached and an initial dependence of the position of the
beam on the energy of the generator.

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2. The Corona System - F. Paul Mooring

The generating voltmeter, which allows the operator to monitor the belt charging conditions, has been reinstalled. No further corona studies are contemplated.

3. Increase of Voltage - F. Paul Mooring

No attempt to reach proton energies greater than 3.55 Mev has been made so far.

4. The 90° Electrostatic Analyzer - R. Ray Weeks

The 90° electrostatic analyzer having a radius of 40 inches has been completed far enough, on November 14, to run a beam through it and control the energy of the Van de Graaff machine. Thus far no attempt has been made to determine experimentally the characteristics of this analyzer. Short cuts have been made in order to get the analyzer running and make the east beam line immediately available. At present the maximum resolving power of the analyzer is not needed. A 4-inch diffusion pump, a 4-inch valve, the interior of the cold trap, and the vacuum protective circuits are yet to be delivered from the suppliers. They will be installed as soon as practical after receipt.

5. Beam Current Integrator - Alexander Langsdorf, Jr.

The precision beam current indicator has been completed and is in regular use, and an instruction manual has been prepared for it.

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6. Operational Experience - Jack R. Wallace

During this quarter the Van de Graaff machine has been operating successfully in the energy range of approximately two million volts with a proton beam current up to fifteen microamperes. These conditions fulfilled the requirements of those experiments scheduled for this period.

The time distribution for the various experiments is as follows:

1. Total neutron cross sections - Carl T. Hibdon	187.0 hrs.
2. Self detection experiment - William A. Reardon	117.0 hrs.
3. Proportional counter checking - Gilbert J. Perlow	5.1 hrs.
4. Crystal counters - Robert E. Holland and F. Paul Mooring	17.1 hrs.
5. Lining up of 90° electrostatic analyzer - R. Ray Weeks	8.7 hrs.
6. Neutron exposure of Li plates - Victor E. Krohn	9.6 hrs.
7. Lining up proton spectrometer - Robert E. Malm	<u>1.4 hrs.</u>
Total machine time	345.9 hrs.
Experimental set up time	31.3 hrs.
Time out of operation attributable to difficulties with the machine	90.0 hrs.
Start-up time and daily maintenance	45.8 hrs.
Time available : 64 days x 8 hours =	<u>512.0 hrs.</u>
	<u>512.0 hrs.</u>

The "out-of-operation" time was mainly caused by three difficulties.

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1) The Freon and moisture percentages were too high in the insulating gas. This led to a chemical reaction on all brass parts in the machine. The pulleys over which the nylon control strings travel were brass. The nylon strings disintegrated. The pulleys have been replaced with aluminum ones, and we are now keeping the gas mixture drier and have reduced the percentage of Freon.

2) Failure of the 35 TG tubes in the oscillator for the ion source. The filament press in the tubes cracked and allowed gas to enter. The cause of these cracks has not yet been definitely determined, but we are endeavoring to find and eliminate this source of trouble.

3) Jumping of the ion beam was corrected by installation of rings on the electrodes in the high voltage end of the accelerating tube. The pumping speed of the accelerating tube was increased by the removal of a baffle.

12-4 (R. F. Ion Source for the Van de Graaff Generator) (5211-01,
5261-02)

F. Paul Mooring

The ion source is in regular use, and no further developmental work is planned. This report is the final one for this program.

14-3 Pulsed Neutron Beams (5211-01, 5261-02)

Robert E. Holland

The ion source for the pulsed system has been operated on the test setup, and the oscillator and power supplies have been found to be satisfactory. However, the arrangement for measuring the output

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of the ion source was not satisfactory and is being rebuilt.

20-4 Energy States of Light Nuclei from Charged Particle Reactions
(5211-01)

David R. Inglis, Robert E. Malm, Lillian Darlington
Reported by Robert E. Malm

Preliminary measurements of the stabilizing system for the magnetic field and of the focussing properties of the 16-inch proton spectrometer have been made by observing the shape and position of the alpha-particle lines from Pu^{238} . The proportional counter previously used as a detector was replaced by a sodium iodide crystal and photo-multiplier obtained from Mr. Robert Swank of the Instrument Research and Development Division. When the proper image position was obtained, the half-widths of the observed alpha-particle groups were almost entirely the result of widths of the source ($\sim .040$ inches) and of the detector slit ($\sim .040$ inches).

The variation in temperature of the Alnico magnet in the magnetic fluxmeter during operation was found to be much greater than had been anticipated. This temperature variation introduced appreciable errors in our field measurements. A fluxmeter, in which the temperature of the Alnico magnet will be regulated, is being constructed.

A number of targets have been prepared for use in experiments during the next quarter.

35-4 Decay Schemes of Long-Lived Rare-Earth Isotopes (5211-01)

Eugene L. Church

Examination of the gamma spectrum of fission europium by means of critical absorption and with the curved-crystal spectrometer in the Chemistry Division¹ has failed to reveal the samarium x-rays which should follow the internal conversion of the 244.4-kev transition previously reported² in ${}_{62}\text{Sm}^{154}$. Long re-exposure of the conversion-electron spectrum of normal and fission europium at $\sim 0.2\%$ momentum resolution indicates that two previously unresolved gamma-rays are present, one converting in ${}_{62}\text{Sm}^{152}$ and the other in ${}_{64}\text{Gd}^{154}$. These transitions have K-conversion lines which are identical within the above resolution and are distinguishable only on the basis of their previously undetected difference in L-conversion energies.

The previous assignment of the 244.4-kev transition as the ground-state transition in ${}_{62}\text{Sm}^{154}$ is in error. The present study indicates that this transition is in ${}_{62}\text{Sm}^{152}$, in agreement with the results of Katz and Lee.³ The above results, as well as the remeasured energies of the corresponding ground-state transitions in ${}_{62}\text{Sm}^{152}$ and ${}_{64}\text{Gd}^{154}$, are shown in Table II.

¹ Analysis performed by P. P. Day.

² ANL-5080, p. 32.

³ R. Katz and M. R. Lee, Phys. Rev. 85, 1038 (1952).

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Table II

Transition Energies in kev

Nucleus	1st Excited State	2nd Excited State	Ratio
$^{62}\text{Sm}^{152}$	121.8	244.4	2.00_7
$^{64}\text{Gd}^{154}$	123.4	247.7	2.00_7

The E2 character of the transitions observed, as well as the known energy systematics of even-even nuclei in this region of the periodic table,⁴ make probable the E2-E2 cascade assignment indicated in Table II. The deviation of the energy ratios from the value $7/3$ predicted by Bohr and Mottelson⁵ for pure rotational states is also characteristic of the rare-earth region.

The striking similarity of the excited states of the nuclei considered is in agreement with G. S. Goldhaber's observation that the addition of two protons may have little effect on the energy level spectrum of even-even nuclei.⁴

36-4 The Decay Schemes of Mass 48 Nuclei (5211-01)

Harvey Casson, Leonard S. Goodman, Victor E. Krohn
Reported by Harvey Casson

A paper on this work is expected to appear in the Physical Review for December 15, 1953.

⁴ G. S. Goldhaber, Phys. Rev. 90, 587 (1953).

⁵ A. Bohr and B. Mottelson, Phys. Rev. 89, 316 (1953).

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38-2 The Radiations from $_{65}\text{Tb}^{160}$ (5211-01)

S. Bradley Burson

Further internal conversion studies yielded lines for gamma-rays of 93 and 391 kev, as well as more accurate energy values for some of the transitions already reported.

Further gamma-gamma coincidence studies indicate that the 196-kev gamma-ray is in coincidence with the 215-kev radiation, and that the 298-kev peak is not in coincidence with either of these as was thought earlier. There is some indication that 759-kev gamma-ray is in coincidence with the 196 and 215-kev gamma-rays.

Decay Scheme The decay scheme indicated in the figure 2 is well substantiated by the experiment in most respects. The portion indicated by heavy lines is considered to be well established, while the remainder is not so certain.

The six transitions forming the dark portion of the scheme are grouped as follows: the energy difference from internal conversion between the 1.17 and the 1.26-Mev transitions is equal to 86.3 kev within experimental limits. The same is true for the difference in energy between the 873 and 960-kev transitions. In both cases, coincidences are shown to exist between the 86.3-kev radiation and the lower energy gamma-ray of each pair. The difference in energy between the 960-kev and the 1.26-Mev transitions is equal within experimental limits to 298 kev, and the latter radiation is found to be in coincidence with the 873 and 960-kev gamma-rays, as well as the 86.3-kev radiation. Thus the six transitions

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form a closed system consistent with both energy differences and coincidence experiments. The 86.3-keV transition is considered to be the ground state transition. Its strong intensity along with theoretical considerations are in support of this assumption. The energy difference of 298 keV required between the two beta branches is considered to be within experimental limits of the measurements of the beta spectrum. The previously reported low energy beta component of 396 keV does not fit into the scheme; its existence is now considered to be doubtful.

In the light of the conclusions already discussed, it is difficult to explain the experiment indicating that the 215-keV is in coincidence with the 960-keV radiation. It can be seen, however, that if the 215-keV transition is correctly placed above the 86.3, the energy difference between the 301-keV state and the highest excited state is about 957 keV, and a transition between these two states can account for the coincidences. A gamma-ray of this energy would, of course, be indistinguishable from the 960-keV radiation and extremely difficult to resolve from it by internal conversion measurements.

That the 196-keV gamma-ray belongs immediately above the 215-keV gamma-ray is indicated by the existence of the 410 transition (the sum) and the fact that they are in coincidence with each other.

The coincidence measurements involving the 759-keV gamma-ray are inconclusive and difficult to interpret because of the intense Compton peak from the higher energy radiations. The experiments do provide corroborative evidence, however, that the arrangement is correct. The other transitions are fitted in on the basis of their energies alone.

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The study is considered complete, and the final results have been written up and are in the process of being submitted for publication in the Physical Review.

40-2 The Decay Scheme of $_{23}\text{V}^{52}$ (5211-01)

S. Bradley Burson, J. M. Cork (University of Michigan),
Willard C. Jordan, James M. LeBlanc
Reported by James M. LeBlanc

A more careful study of the gamma spectrum of 3.7-min V^{52} has been made with the 10-channel scintillation spectrometer. This spectrum shows the presence of the 1.41-Mev gamma-ray reported in the last quarterly report. No other gamma-rays were observed. The 1.41-Mev gamma-ray was found to be in coincidence with beta-rays.

It was expected that the 2.6-min activity reported by Renard¹ might be observed in samples irradiated with neutrons for periods of about 1 or 2 minutes. Irradiation of V in CP-3' for periods of 1 minute, 3 minutes, and 10 minutes were made and found to produce activities of half-lives 3.7, 3.5, and 3.7 min, respectively, with no indication of the presence of an activity with a half-life of 2.6 min.

In a recent paper², Schwager and Cox report that they find no evidence for such a 2.6-min metastable state resulting from a (d,p) reaction on V.

¹ G. A. Renard, *Amm. Phys.* 5, 385 (1950).

² J. E. Schwager and L. A. Cox, *Phys. Rev.* 92, 102 (1953).

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41-2 The Decay Scheme of $_{48}\text{Cd}^{117}$ and $_{49}\text{In}^{117}$ (5211-01)

S. Bradley Burson, J. M. Cork (University of Michigan),
James M. LeBlanc
Reported by James M. LeBlanc

Work on this decay chain has been completed, and a paper will be written for submission to the Physical Review. The information obtained is summarized in the energy level scheme shown in Figure 3. The only gamma-gamma coincidences expected but not observed are those between the 0.425 and 0.84-Mev gamma-rays; the 0.84-Mev gamma-ray, however, was too weak for such coincidences to be observable. There are, however, two gamma-rays of energy 0.276 and 0.330 Mev which were found to follow beta decay from Cd^{117} that are not included in the scheme. Furthermore the energy fit for the 2.0-Mev gamma-ray is rather poor, so that its placement as indicated must be considered doubtful.

43-1 The Decay of the 3.5-min Metastable State of Sb^{122} (5211-01)

S. Bradley Burson, J. M. Cork (University of Michigan),
Willard C. Jordan, James M. LeBlanc
Reported by James M. LeBlanc

The 3.5-min metastable state in Sb^{122} has been previously studied by two groups, one with a scintillation spectrometer¹ and the other with an ion chamber.² The results with the scintillation spectrometer indicated one gamma-ray of 68 kev, whereas those of the ion chamber study indicated two gamma-rays of 59 and 74 kev.

¹ E. der Mateosian and M. Goldhaber, Phys. Rev. 82, 115 (1951).

² J. H. Kahn, Oak Ridge National Laboratory, ORNL-1089, (Nov. 1951).

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FIG. 3

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Samples of this activity were obtained by irradiating enriched Sb^{121} in the CP-3'. They were then studied with a 180° photographic spectrometer and the 10-channel coincidence scintillation spectrometer. Two conversion electron lines were observed which are interpreted as K and L lines for a 76-kev gamma-ray. The scintillation spectrometer study showed a strong x-ray peak plus a gamma peak at about 60 kev. The gamma peak was distorted on the high energy side, apparently by the presence of the 76-kev gamma-ray. X-ray gamma coincidence experiments were performed and showed that the gamma peak was in coincidence with the x-rays. Since the 60-kev gamma-ray itself is not internally converted to any considerable extent, these coincidences indicate prompt successive emission of 60-kev gamma-rays and x-rays produced by internal conversion of the 76-kev gamma-rays. Apparently, the metastable state decays by emission or conversion of the 76-kev gamma-ray, this transition being followed promptly by emission of the 60-kev gamma-ray. The contrary hypothesis would require no appreciable internal conversion of a 3.5-min metastable state and considerable internal conversion of a very short-lived succeeding one, both somewhat improbable.

Longer exposures are being made with the 180° spectrometer with the hope of detecting the 60-kev gamma-ray and obtaining good enough K and L lines for the 76-kev gamma-ray to allow a K/L measurement.

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45-1

The Short-Lived Activities of Zn

(5211-01)

S. Bradley Burson, J. M. Cork (University of Michigan),
Willard C. Jordan, James M. LeBlanc
Reported by James M. LeBlanc

The short-lived activities of Zn have been previously studied with varying degrees of completeness. The 14-hr and 52-min activities of Zn^{69} have been investigated in some detail by several groups, whereas Zn^{71} has been examined only by absorption and half-life studies. Zn^{69} has been found to have a metastable state which decays by the emission of a 437-kev M4 transition to the ground state. The ground state then decays by beta emission to Ga^{69} . No gamma-rays have been found to follow this beta-ray. In the case of Zn^{71} , a half-life of 2.2 min has been assigned and a beta-ray of 2.1 Mev measured by absorption. Gamma-rays were detected but not measured.

The present work has been concerned mainly with the study of Zn^{71} . The sources were obtained by irradiating both ordinary Zn and enriched Zn^{70} (48.4% Zn^{70} and 29% Zn^{68}) in CP-3'. Since ordinary Zn contains only 0.62% Zn^{70} and its cross section for neutron capture is 0.09 b, very little Zn^{71} is formed by neutron capture in ordinary Zn.

The gamma spectra of these sources were studied with the 10-channel scintillation spectrometer, and the beta-rays were studied by absorption in Al. In all, four activities were found in the enriched Zn^{70}

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samples, 2.2 min, 1 hr, 3 hr, and 14 hr. The 1-hr and 14-hr activities are due to Zn^{69} and appeared both in enriched Zn^{70} and in ordinary Zn sources. On the other hand, the 2.2-min and 3-hr decays were found only in the enriched Zn^{70} sample, and are therefore to be assigned to Zn^{71} .

Since the 14-hr and 1-hr activities appeared in all of the samples, it was necessary to examine their photon spectra and coincidence spectra, in order that there be no confusion.

14 h

The photon spectrum of the 14-hr decay was obtained and compared with that of Au^{198} , which has a strong gamma-ray of energy 411-kev. It was found that the 14-hr activity has only one gamma-ray of about 435 kev as previously reported, and that it is not coincident with beta-rays. This is in agreement with previous results.

52 m

There were no gamma-rays detected which could be assigned to this activity. Very strong beta-rays were found and their energy measured by absorption to be about 0.85 Mev. This agrees with previous work.

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2.2 m

The photon spectrum of the 2.2-min activity is found to show the presence of four gamma-rays of energy 0.12, 0.51, 0.90, and 1.05 Mev. Of these gamma-rays the 0.51-Mev one is the strongest. Beta-gamma coincidence measurements showed that all of the gamma-rays are coincident with beta-rays. The results of Al absorption experiments on the beta-rays indicate a maximum beta energy of 2.4 ± 0.2 Mev. The Al absorption curve for the beta-rays coincident with the 0.51-Mev gamma is not significantly different from the absorption curve for single counts. Because of the rapid decay of the sample, statistics on these curves are not good enough to determine if there is any branching to the ground state. The 0.12-Mev gamma-ray is not in coincidence with the 0.51-Mev gamma-ray.

3 h

The three-hour activity is found to decay by the emission of a 1.5-Mev beta-ray which is followed by three gamma-rays of energy 0.38, 0.49, and 0.61 Mev. It is found that all three of these gamma-rays are in coincidence with each other, indicating that they are in cascade. In addition, the beta-gamma coincidence absorption curves indicate that the 1.5-Mev beta-ray is in coincidence with all three of these gamma-rays.

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46-1 The Decay of $_{32}\text{Ge}^{77}$ (12 hr) and $_{32}\text{Ge}^{77\text{m}}$ (59 sec) (5211-01)

S. Bradley Burson, Willard C. Jordan, James M. LeBlanc
Reported by S. Bradley Burson

Neutron bombardment of $_{32}\text{Ge}^{76}$ results in the production of $_{32}\text{Ge}^{77}$, which exists as a metastable state with a half-life of 59 seconds and a ground state with a half-life of 12 hours. The metastable state decays both by an isomeric transition of about 380 kev to the ground state of Ge^{77} and by a beta transition of about 2.8 Mev to As^{77} . The ground state of Ge^{77} decays by means of 3 beta branches to As^{77} . Numerous gamma-rays have been reported to be associated with the excited states of As^{77} . We have undertaken to study these activities by means of our photographic spectrometers and the scintillation coincidence spectrometer.

To date we find that two radiations of about 213 and 268 kev, associated with the 12-hour activity, are in coincidence with each other. The 213-kev gamma-ray seems also to be in coincidence with a gamma-ray of about 410 kev. Both the 213 and 268-kev radiations are also in coincidence with other gamma-rays whose energy is in excess of 800 kev.

The gamma-ray of about 73 kev reported by Smith¹ is not found to be present. It is suspected that the radiation of this energy reported in that study was in fact K x-rays of Pb caused by conversion in the lead radiator, rather than a transition in As^{77} .

¹ A. B. Smith, Phys. Rev. 86, 98 (1952).

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60-4 Eight-Meter Bent Crystal Spectrometer (5261-02)

Bernard Hamermesh and David Rose
Reported by Bernard Hamermesh

The detailed design was completed during the quarter, and all of the sub-assemblies are under construction. One-half of the shop work has been completed.

When the base casting has been located properly in building 330, which will be done in the next month, it will be possible to assemble all of the heavy sections of the instrument and install the shielding. This work will be done and the various drive systems will be tested during the next quarter.

70-4 Measurements of Nuclear Moments by Angular Correlation (5211-01)

Victor E. Krohn and Sol Raboy
Reported by Sol Raboy

The angular correlation between the two gamma-rays emitted in cascade from the isomeric state of Pb^{204} is being studied. The initial phase of the work included the study of the effects of various liquid media and finally the effect of a magnetic field. This last effect can yield a quantitative measure of the magnetic moment of the first excited state of Pb^{204} .

The results reported in the last quarterly were not in agreement with those obtained by Frauenfelder.¹

¹ Frauenfelder, Jentsche, Lawson, and DePasquali, preprints of letter submitted to The Physical Review for publication; Frauenfelder, Jentsche, Lawson, and DePasquali, Phys. Rev. 92, 513 (1953).

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Since further measurements of the anisotropy of the two gamma-rays (900 kev and 370 kev) did not reproduce his results, a series of experiments was performed to gain information as to the various activities present in the bombarded Tl foil.

A new set of operating conditions was determined. One counter accepted everything above 600 kev, and the second counter was set to accept pulses in the region of 320 kev to 420 kev. Furthermore, the first counter was delayed by $0.3 \mu\text{sec}$. Ta foil and Pb sheet were combined to shield the counters from low energy gamma-rays and x-rays.

The anisotropy of the two gammas was measured for foils dissolved in concentrated HNO_3 and also in concentrated H_2SO_4 . The anisotropy is measured by the ratio of the number of coincidences at 180° to the number at 90° . Since the measurements were done in the presence of the magnet, similar data were taken for the two liquid media on a plywood table with the amount of neighboring scattering material minimized. The results are as follows. They have not been corrected for solid angle.

<u>Anisotropy</u>	<u>Liquid medium in which source is dissolved</u>	<u>Experimental conditions</u>
$1.25 \pm .03$	Concentrated HNO_3	In presence of magnet but without magnetic field.
$1.24 \pm .03$	" H_2SO_4	
$1.26 \pm .04$	" HNO_3	On bare plywood table.
$1.23 \pm .04$	" H_2SO_4	

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These results indicate that within the experimental error there is no difference between HNO_3 and H_2SO_4 solutions. Furthermore, scattering by the magnet does not lead to a significant change in the observed anisotropy. The differences between these results and Frauenfelder still exist and are not understood.

Some data with the magnetic field applied have been obtained. The effect of the magnetic field on the angular correlation has been observed and is being studied quantitatively as a function of field strength. The meager data obtained so far do not permit plotting of a meaningful curve. These studies will be carried on in the next quarter.

It is planned to study the cascading gamma-rays from $\text{Pb}^{204\text{m}}$ in liquid Tl, i. e., melted Tl, since such melts should give minimum distortion of the angular correlation.

71-4 The Angular Correlation of β -Rays and Delayed Neutrons from Br^{87}
(5211-01)

Leonard S. Goodman

No further work has been done on this during the past quarter.

80-4 Molecular Beam Studies (5211-01)

John A. Dalman, Leonard S. Goodman, Sol Wexler
Reported by Leonard S. Goodman

Measurement of the spin of $\text{Cs}^{134\text{m}}$ was started in the last quarter. Although a radio frequency resonance was observed, the definite assignment of the spin of this isotope will require further work.

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The difficulties of interpretation have involved a combination of properties of the equipment and properties of this particular nucleus.

The experimental method,^{1,2} when realized in a practical apparatus, causes a breadth of the resonance due both to the finite length of time the atom is exposed to the R. F. field and to inhomogeneities of the ideally uniform magnetic field.

In this particular apparatus, the inhomogeneous magnetic fields are energized by electronically regulated current supplies. The inhomogeneous magnets induce considerable magnetic field in the gap of the homogeneous magnet. This induced field must be biased out by adding current in the windings of the homogeneous magnet. Small percentage drifts of the inhomogeneous fields occurred and caused drifts in the homogeneous field which were large enough to make the resolution of the apparatus much poorer.

For many isotopes the resolution would still have been sufficient to resolve between the various possible nuclear spins. For $\text{Cs}^{134\text{m}}$, however, the spin is large (7 or 8 is predicted from γ and β -ray systematics) and, as will be shown below, the demands on the resolution become greater.

For very small magnetic field the resonance which will allow us to detect a change in state occurs at the frequency $\nu = \frac{1.4 H}{F}$ mc/sec.

¹ J. R. Zacharias, Phys. Rev. 61, 270 (1942).

² L. Davis, Jr., D. Nagle, J. R. Zacharias, Phys. Rev. 76, 1068 (1949).

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For the electronic $J = 1/2$ the maximum F for spins 6, 7, 8 would be 6.5, 7.5, 8.5, the reciprocals of which are 0.154, 0.133, 0.118. The small differences between the reciprocals means small differences between the resonant frequencies. If a field were to be used so that the resonance for spin 7 would come at 1 mc/sec, the differences would be less than the width at half maximum for the best similar apparatus so far described in the literature.

The obvious thing to do is to go to higher magnetic fields. Unfortunately the deviation from linearity for small homogeneous fields is proportional to the spin, $\nu = \frac{1.4 H}{F} \left[1 + \frac{1.4 H}{F} \frac{2 I}{\Delta\nu} \right]^2$. If the hyperfine splitting, $\Delta\nu$, is at all small the quadratic field term becomes prominent at relatively small fields. Theoretical predictions by Dieter Kurath are that a very likely value for $\Delta\nu$ would be as small as 1200 mc/sec. Assuming this value for $\Delta\nu$ and ν at resonance for $I = 7$ as 10 mc/sec, we would have ν at resonance for $I = 6$ and $I = 8$ as 11.5 and 8.8 mc/sec, respectively, or $\nu_6 - \nu_7 = 1.5$ mc/sec and $\nu_7 - \nu_8 = 1.2$ mc/sec. The quadratic term, assuming $I = 7$, contributes approximately $\frac{10 \times 10 \times 14}{1200} = 1.17$ mc/sec. The hyperfine splitting may of course be either smaller or larger than the assumed value, and since we do not know $\Delta\nu$ a priori, the experiment must be extended to the finding of resonances over a wide range of fields, but will eventually permit the determination of both $\Delta\nu$ and I .

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96-4 (Pile Absorption Cross Sections) (5261-01)

David Rose

No work has been done on this program during the past quarter.

98-3 Total Neutron Cross Sections in the kev Region (5211-01, 5261-02)

Alexander Langsdorf, Jr.

See complete report by Carl T. Hibdon.

The tantalum cups are on hand and will be used in future work.

The 36 new boron trifluoride proportional counters are on hand and will be installed in anticipation of future work.

98-3 Total Neutron Cross Sections in the kev Region (5211-01, 5261-02)

Carl T. Hibdon and Alexander Langsdorf, Jr.
Reported by Carl T. Hibdon

Measurements of total neutron cross sections in the kev energy region as described in ANL-5080, I-98-2, have been continued. For the present work the only monitor used was a long counter placed beyond the target along the direction of the proton beam, the monitor previously used with its axis at an angle of 120° with respect to the proton beam having developed troubles which were not readily reparable.

Although the exact energy resolution attained in these measurements is not known accurately, it can be inferred from certain of the observed variations of cross section with energy that the spread of energy is some-

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what less than the measured thickness of the target. (The neutrons in the 120° direction have a smaller spread of energy than that of the incident protons because of the motion of the center of mass of the interacting particles.) The measured target thickness varied from 1 to 2 kev, and was mostly around 1.3 kev.

The actual energy region covered was for most elements from approximately 1 kev to 160 kev. Since Ti and Ni have a number of well known resonances, one or the other of these elements was usually measured along with each of the other samples, the location of the resonances in Ti or Ni serving as a check on the energy scale. Insofar as possible samples were chosen to allow a transmission near 50%.

The one outstanding result of this program is that generally all resonances observed are much narrower than they had previously been observed to be.

All the neutron energies given in the following are mean neutron energies.

The theoretical interpretation of the data is being worked on.

Beryllium

Transmission cross sections for beryllium were measured in the energy region from 1.6 to 55 kev. The cross sections in this energy region averaged to slightly less than 6 b. No indications of a resonance were found.

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Boron

The cross section of B_4C was measured up to 160 kev. At each energy setting the cross section of C was also measured. The cross section of B was then calculated from the two measurements. Small irregularities in the cross section curve below 10 kev were observed. The trend of the cross section ranged from about 6 b at low energies to less than 4.5 b at 160 kev.

Since a small amount of B^{10} (96% enriched) was available, the neutron transmission cross section of this isotope was measured from about 1 kev to 10 kev. The total cross sections found are quite irregular and may indicate the presence of narrow resonances. These indications should be regarded as tentative until further measurements are made, particularly since the transmissions of the sample were high, ranging from about 65 to 89%. Peaks were observed at 1, 1.8, 2.5, 3.5, 4.5, 6, and 8 kev. The general trend is not in accord with the $\frac{1}{v}$ law.

Carbon

The transmission cross section of carbon does not indicate the presence of any resonances. The cross section drops slightly but steadily from about 5 b near 1.5 kev to less than 4-1/2 b at 160 kev.

Fluorine

Measurements were made with teflon ($\sim CF_2$) and corrected for the effect of scattering by the carbon atoms to get the cross sections for fluorine.

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The total cross section of fluorine in the region from 1.5 to 160 kev exhibits three large resonances at 28, 49, and 98 kev. The measured peak cross sections of these resonances are 28, 33, and 26 b, respectively, and the measured widths at half maximum are 2.5, 5, and 12 kev, respectively. These resonances have been observed previously but with poorer resolution (AECU-2040). An attempt was made to assign $\mathcal{L}$ values to these resonances based on the maximum observed peaks. On the basis of the peak height of the resonance at 28 kev, its possible theoretical height, and the spin of the fluorine atom (1/2), the $\mathcal{L}$ value is indeterminate favoring $\mathcal{L} = 1$. The peak height of the resonance at 49 kev indicates a value of $\mathcal{L} = 0$ with $J = 1$ and $g = 3/4$ where $g = \frac{2J + 1}{(2I + 1)(2S + 1)}$ = the statistical weight factor. The measured peak height of the resonance at 98 kev is of the correct height for $\mathcal{L} = 0$, $g = 3/4$, $J = 1$.

The observed cross section of fluorine up to 25 kev is constant at about 3.7 b.

Titanium

Cross sections for Ti were measured for energies up to 55 kev. In addition to the previously known prominent resonances at 18 and 22 kev, others were found at ~ 3.5 , ~ 8.7 , 38, and 52 kev.

The peak values found for the two large resonances at 18 and 22 kev are 106 and 66 b, respectively. The respective widths at half maximum of the two resonances are 4 and 3 kev (as estimated crudely from the half-value positions on the high and low sides of the pair). The increase of the peak value for the 18-kev resonance over the previously

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observed value of 85 b is to be attributed to improved resolution in the present experiments. If these two resonances are to be attributed to the relatively abundant isotope Ti^{48} , the corresponding isotopic peak cross sections are 144 and 90 b, respectively.

Both the 38 and 52-kev resonances show the anti-resonance dips characteristic of S neutrons. Their widths at half maximum are less than 4 kev.

Nickel

Cross sections were measured for Ni for energies up to 160 kev. The following table gives the principal results.

Table III

<u>Energy of peak (kev)</u>	<u>Comments</u>
4.5	
5.5	Probably Co impurity
7.8	" " "
~12.5	
16	Peak value 85 b
29	Small but clearly resolved
65	Deep S-wave anti-resonance dip
98	
110	
125	
140	Anti-resonance S-wave dip
160	" " " " "

The peak at 65 kev is highly resolved with a deep (2.08 b at 58 kev) anti-resonance dip. This dip together with the observed peak assigns the ℓ value equal 0 with $g = 1$ and $J = 1/2$. Five other resonances

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are resolved: one at 98 kev, one at 110 kev, one at 125 kev, one at 140 kev, and one at 160 kev. The latter two are clearly S-wave with a minimum at about 155 kev of 1.3 b. This minimum is probably an interference dip between the two resonances.

Zirconium

The total cross section of zirconium from about 1 kev to 9-1/2 kev shows resonances clearly at 2.8, 4.6, 7.3, and less clearly at 6 and 8.8 kev. Resonances are also indicated in the 1 to 2-kev region. The sample of zirconium used has a hafnium content of less than 300 ppm.

Bismuth

The total neutron cross section of bismuth from 1 to 55 kev shows prominent resonances at 2.5, 12.5, 16, 34, and 47 kev with lesser ones near 4 to 5 kev, several between 20 and 30 kev, and one at 43.5 kev. The ones at 12.5 and 34 kev are preceded by deep anti-resonance dips.

99-2 Standards for Measurement of Thermal Neutron Absorption
Cross Sections (5261-01)

Roy Ringo

This problem is waiting rechecks of their work by
Harwell and A. B. Atomenergi, Stockholm.

49100-1 The Cross Section of the Li^6 (n, α) T Reaction (5211-01)

Robert E. Holland and F. Paul Mooring
Reported by F. Paul Mooring

It was proposed to measure the Li^6 (n, α) T cross section in the following manner. Since a lithium iodide crystal counts neutrons by means of the Li^6 (n, α) T reaction, its counting efficiency is proportional to the cross section of that reaction. The efficiency of the crystal can be determined if one measures coincidences between neutron pulses produced in the LiI scintillator and pulses produced in another counter by gamma-rays that accompany the neutrons. As in other coincident counting, the efficiency of the neutron detector is given by the ratio of the coincidence rate to the single counting rate for the gamma-rays. This efficiency is a measure of the desired cross section.

It was proposed to use as a neutron source the neutron group of low energy produced when protons of sufficient energy strike a thin lithium target. These neutrons are accompanied by 430-kev gamma-rays emitted from the residual Be^7 nuclei. If the experiment is to be feasible, one must be able to detect the 430-kev gamma-rays in the presence of any other radiation that might be present.

A search for the 430-kev gamma-rays was made using a sodium iodide gamma-ray spectrometer. The 430-kev gamma-rays could not be resolved from the 478-kev gamma-rays resulting from the inelastic scattering of protons from Li^7 in the neutron source. The intensity of

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these latter gamma-rays was approximately four times that of the gamma-rays accompanying the low energy neutron group. It was concluded that the experiment was not practical using lithium as a neutron source. No further work on this experiment is being contemplated.

101-1 A Proposed Method for Measuring Radiative Capture Cross Sections

Robert E. Holland and F. Paul Mooring
Reported by F. Paul Mooring

To measure radiative capture cross sections by detecting the capture gamma-rays, one must be able to identify and count the capture gamma-rays in the presence of other radiation. A method is proposed which should allow one to do this in certain cases.

A capturing material is to be illuminated by a well collimated beam of monoenergetic neutrons. The capturer is to be surrounded by a counter consisting of large sodium iodide scintillators giving as near as 4π geometry as possible. For each capture process a certain definite energy is released which appears as a sequence of capture gamma-rays. These are caught in the scintillators, and the resultant pulses are added. If the counter were 100% efficient, a single pulse would result which would be proportional to the energy released in the capture process. Thus, by pulse-height analysis, the capture gamma-rays should be easily selected from other gamma-producing processes originating in the capturing material.

There are several difficulties that one can expect to encounter in this experiment. The counter efficiency, partly because of solid angle

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effects, can not be made to be 100%. This will reduce the number of counts in the capture peak; but if the counter efficiency is large enough, one should still be able to resolve it.

A capturing material, however, also acts as a neutron scatterer. Since iodine has a very large capture cross section, there will always exist a strong iodine capture peak corresponding to the iodine capture energy of about 8 Mev. For this reason the method is applicable only to materials whose capture energy is distinguishably different from that of iodine. Also the low counting rates to be expected forces one to use materials with large capture cross sections. These two conditions mean that the method is best suited for measuring the capture cross section of heavy isotopes.

Work is now in progress to test the method. Arrangements have been made with Bernard Hamermesh to borrow seventeen two-inch cubes of sodium iodide for the counter. Plans for the set up have been worked out, capture samples have been procured, electronic equipment is under construction, and various mechanical parts are being made. It is hoped to try the method in the near future.

102-1 Self Detection of Neutron Cross Sections (5211-01)

Alexander Langsdorf, Jr. James E. Monahan, William A. Reardon
Reported by William A. Reardon

A group of samples including Au, Ag, Zr, S, Pb, Ni, and Al were collected to perform the experiments referred to by Langsdorf in ANL-4397 and ANL-4680.

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A short run was made at 120° to find proper thicknesses and to check on the observability of self-detection effects.

A longer run at zero degrees covering neutron energies from 0.1 to 1.0 Mev has been completed on Au, Pb, Zr, S, and Ni. A 50-kev target was used to insure effective averaging of the cross section. The analysis will be reported in the next report.

109-3 Neutron Diffraction Apparatus (5211-01)

Robert W. Holmes (Central Shops), Roy Ringo, Surain S. Sidhu
(Metallurgy Division)
Reported by Roy Ringo

The construction of this apparatus is nearly complete. The principal work remaining is the installation at CP-5.

110-3 (Crystal Spectrometer for 0.1 to 100-ev Neutrons) (5211-01)

Sol Raboy and Roy Ringo
Reported by Sol Raboy

Nothing was done on the crystal spectrometer for neutrons during this quarter. It is planned to move it to CP-5 in the next quarter.

112-4 (The Neutron Spectrum of a Standard Ra-Be Photo Source) (5261-01)

Charles Egger

Work on the self-triggering cloud chamber is still delayed because of intensive work on equipment for fast neutron spectra determination.

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114-2 Development of a Recoil Type Neutron Spectrometer (5211-01)

Gilbert J. Perlow

Work is continuing on the scheme described in the last quarterly report, wherein the recoil in a proportional counter is collimated by coincidence with the scattered neutron, the latter's direction being appropriately chosen.

In the present arrangement the proportional counter contains deuteromethane. The detector for the scattered neutrons is a Lucite slab containing 7 $B^{10}F_3$ counters, and it is placed to detect neutrons scattered into the backward hemisphere. The delay between a scattering event and the subsequent detection of the scattered neutron is taken care of by stretching the recoil pulse for 50 microseconds.

A trial of the system at present is awaiting the preparation of tritium-free CD_4 , the CD_4 on hand having been found somewhat excessively contaminated with CD_3T .

115-2 Neutron Counters Containing Boron Trimethyl (5211-01)

Alexander Langsdorf, Jr. and William A. Reardon
Reported by Alexander Langsdorf, Jr.

Active work on counters of this type is in abeyance at the laboratory since it is being pursued actively at the University of Chicago. No further reports will be made again until work on such counters is again being done at the laboratory.

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120-4 Calibration of a Ra-Be Neutron Source (5211-01)

Willard C. Jordan

Using the technique described by Sigmund P. Harris in previous reports on this project, six additional calibration runs on Ra-Be neutron source No. 312 have been made. (The results of the first three runs were reported last quarter.) A variety of counting equipment troubles, some of which may have been present during the first three runs, cast doubt on the accuracy of the results obtained to date. An average value for Q (the number of neutrons emitted per second) obtained from the results of all runs is 5.5×10^6 . In view of the spread in the data it is believed that the probable error is at least 5%.

For a substantial reduction in this error, refinements in the counting technique will probably be necessary. The replacement of the end-window Geiger counter with a gas flow counter or a thin anthracene scintillation counter and the use of pulse-height discrimination are under consideration.

One source of systematic error is the detection of coincidences between knock-on Compton electrons and their corresponding back-scattered photons. Discrimination on both sides of the coincidence circuit against low energy ($\leftarrow 250$ kev) radiations should eliminate this source of error without seriously affecting the efficiency of the detectors for the Na^{24} radiations.

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131-4 Average Charge of Daughter Atoms After Nuclear Excitation (5211-01)

Sol Wexler

The paper on this work is scheduled to appear in The Physical Review for January 1, 1954.

132-4 (Chemical Service Work) (5211-03)

Sol Wexler

No work in this field was performed during this quarter.

133-3 Design Study of a Multi-Bev Proton Synchrotron (5211-01)

John J. Livingood and Morton Hamermesh
Reported by John J. Livingood

Lectures on the fundamental principles of magnetic accelerators have started, with an initial enrollment of sixty from the various divisions of the Laboratory. It is anticipated that four to six sessions will be adequate to cover the conventional types. Afterwards attention will be directed to the alternating gradient variety, with early emphasis on the theory involving linear equations, as it seems important that this be thoroughly understood before embarking on the non-linear possibilities.

134-3 Optical Excitation Spectra of He³ Species After β^- Decay of T₂ (5211-03)

Mark S. Fred (Chemistry Division), Fred T. Porter
(Chemistry Division), Sol Wexler
Reported by Sol Wexler

In the previous quarterly report were listed fourteen "lines" in the ultra-violet and visible radiation found in the spectrum of tritium gas at high pressure. Search of tables of wavelengths of atomic and molecular

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spectra has now made possible the probable assignment of most of the lines to certain electronic transitions as follows:

Table IV

Line	Probable electronic transition
3914 Å	N_2^+ (0,0 transition)
4087	H_γ
4165	N_2^+ (3,4)
4277	N_2^+ (0,1)
4305	
4339	H_α
4433	
4500	N_2^+ (4,6)
4643	N_2^+ (1,3)
4707	N_2^+ (0,2)
4853	H_β
5009	N_2^+ (3,6)
5300	
5610	

Since the seven N_2^+ "lines" show a band head structure and their wave lengths agree within experimental variation with known nitrogen bands, they are probably members of the negative band spectrum of N_2^+ , which has been observed previously when traces of N_2 are present in He excited by various ionizing discharges. In our experiment the initially

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excited helium may be produced by beta -rays emitted in the gas volume and/or excited He^3 species resulting from the beta transition in tritium. The excitation is transferred to a nitrogen molecule by collision; the ionized, excited N_2^+ then radiates. Since nitrogen was undoubtedly present in low concentration in our experiments, the expected He spectrum was probably masked by these collisions of the second kind.

The three tritium atomic lines listed in the table are probably due to dissociation, by beta particles, of T_2 into excited tritium atoms. Four of the observed lines are as yet unidentified.

Since stringent precautions are necessary to exclude traces of nitrogen, a new apparatus is being planned.

135-3 Electron-Neutron Interaction (5211-01)

Roy Ringo

Our measurement of the electron-neutron interaction by the asymmetry of the neutron scattering by the noble gases depends on the coherent neutron scattering amplitudes of these gases.

Preliminary work on the measurement of these coherent amplitudes is now under way. A system has been built with which it is hoped to produce krypton and xenon powders of crystals of appreciable size and random orientation.

In the next quarter this will be tested by x-ray diffraction.

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If successful, this system will be used to produce powders for neutron diffraction measurements from which the desired scattering amplitudes can be obtained.

59II. MASS SPECTROSCOPY1-4 Mass Spectrometric Techniques (5211-08)

David C. Hess and Mark G. Inghram
Reported by David C. Hess

An investigation was carried out to check the feasibility of examining copper by means of the "triple filament" ion source. This subject was made of immediate interest by the necessity of detecting very small amounts (less than one ppm) of copper in germanium. Our experiments showed that normal copper can be measured in the amount probably available (25 micrograms per sample) and use of the isotopic dilution technique is possible. Further work will probably be done by W. H. Johnston at Purdue, whose interest caused us to make the current tests.

2-4 Construction of MA-17 (5211-08)

Henry E. Stanton

Early in this quarter it became apparent that the hydrocarbon background in MA-17 was excessive for any precise experimentation. The mass spectrometer was accordingly shut down for a thorough cleaning.

In addition, a new source closure has been completed in the shop, and a separate source pumping system is being installed. This will permit relatively high pressures in the source while maintaining the lowest possible pressures in the electrostatic deflecting system and spectrometer tube. This latter is essential to reduce gas scattering of the ion beam

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which may have only a few hundred volts energy.

During the next quarter the cleaning and remodeling process should be completed and studies of the chemical properties of carbon resumed.

10-4 A Search for Rare Naturally Occurring Isotopes (5211-08)

David C. Hess and Mark G. Inghram
Reported by David C. Hess

Since MA-16 is not yet in operating condition, only one element has been examined. Aluminum-26 is not present with an abundance of greater than one part in 2,000,000 of Aluminum-27. This was measured on MA-15, and a lower limit is expected when MA-16 is applied to the problem.

11-4 Technetium in Nature (5211-08)

Mark G. Inghram

The results given in report II-11-2, (ANL-5080), were reported to the Nuclear Geophysics Conference at Yerkes Observatory in September and will appear in the proceedings of the conference.

12-4 (Double Beta Disintegration of Te^{130}) (5211-08)

Richard J. Hayden and Mark G. Inghram
Reported by Richard J. Hayden

No progress has been made on this problem this quarter.

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30-4 The Heat of Vaporization of Carbon (5211-08)

Mark G. Inghram

Preliminary testing of the Knudsen furnace has begun but no reportable results have been obtained to date.

(The previous report on this program was included by mistake in the classified supplement ANL-5141, rather than in the unclassified report ANL-5140, where it should have appeared.)

31-4 (Studies of Electron Impact) (5211-08)

William A. Chupka

There are no results to report at this time.

33-4 (Molecular States in Rare Gases) (5211-08)

David C. Hess and Mark G. Inghram
Reported by David C. Hess

Nothing has been done which was exclusively concerned with this project.

34-4 Argon Age Determinations (5211-08)

Gerald Wasserburg (University of Chicago) and Richard J. Hayden
Reported by Richard J. Hayden

After another series of vacuum and electronic difficulties, MA-18 was again put in operating order. The rock samples which were obtained from the University of Toronto were processed and analyzed. Our results are in agreement with the old value for the K^{40} branching ratio of

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0.13. They cannot be interpreted to agree with the value of 0.06. Details have been submitted in a letter to the editor of the Physical Review.

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III. CRYSTALLOGRAPHY

1-4 (Crystal Studies of Technetium Compounds) (5211-11)

William H. Zachariasen

No further progress has been made during the past quarter.

2-4 (Structural Studies of Boric Acids) (5211-11)

H. Anne Plettinger

No further progress has been made during the past quarter.

20-2 (Table of Squared Sines) (5211-11)

H. Anne Plettinger

No further progress has been made during the past quarter.

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V. THEORETICAL PHYSICS, GENERAL1-4 Interpretation of the Energy States of Light Nuclei (5211-07)

David R. Inglis

The application of the droplet model of nuclei to dynamical problems, while empirically quite successful, has not seemed entirely satisfactory because of the ad hoc nature of the assumption that nuclear matter behaves like a classical irrotational fluid. The collective kinetic energy of a nucleus in the act of being deformed may be described quantum mechanically by means of deformations of the central model with oscillator wave functions in the adiabatic approximation. This equivalent kinetic energy, depending on the square of the rate of change of the deformation parameter or on the square of the angular velocity of a rotating deformation, arises from the temporary and partial excitation of higher oscillator states in the non-stationary problem. The adiabatic approximation is found not to be valid for an oscillation between prolate and oblate shapes of a closed-shell nucleus (such as might describe the first excited state of O^{16}), but is valid and useful in describing the low rotational states of all but the light nuclei.

2-4 Energy States of Light Nuclei (5211-07)

Dieter Kurath

The contributions of all lp shell configurations to the ground state wave function were calculated for the simple case of mass number

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A = 14 and also for A = 13. It is found that the perturbation procedures used previously are inadequate and that diagonalization of the interaction matrix must be carried out. This, then, becomes an intermediate coupling calculation.

The resulting magnetic moments remain quite close to the values given by the simple jj-ground configurations, although other states are mixed into the ground state wave function to a considerable extent. The necessity for including higher excitation jj-wave functions is indicated by the results for C^{13} , where the zero order jj-ground state $(1p_{3/2})^8 (1p_{1/2})^1$ gives $\mu = 0.64$. Mixing in only $(1p_{3/2})^7 (1p_{1/2})^2$ gives $\mu = 0.02$; but including $(1p_{3/2})^6 (1p_{1/2})^3$ and $(1p_{3/2})^5 (1p_{1/2})^4$ as well gives $\mu = 0.72$. Experimentally $\mu = 0.70$.

The states which mix in most strongly with $(1p_{3/2})^m (1p_{1/2})^n$ are those from $(1p_{3/2})^{m-2} (1p_{1/2})^{n+2}$. If these are found to be the major contributors to the level spacing of C^{13} as well, one may hope to have a procedure for approximating features of the more complicated structures at A = 10, 11, and 12, particularly the low magnetic moment of B^{11} .

4-4 (Investigation of Nuclear Structure) (5211-07)
 5-4 (Book on Nuclear Shell Structure)

Maria G. Mayer

Dr. Mayer being on extended leave, there is no report to be made on these programs.

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7-4 Collective Description of Nucleon Interactions (5211-07)

Melvin Ferentz

In collaboration with David Pines (University of Illinois) and Murray Gell-Mann (University of Chicago) work on the quantum mechanical reformulation of the collective description has been continued. In the last quarter the formalism has been generalized by being expressed in terms of any complete set of solutions of the equation

$$[\nabla^2 + k^2] F(\vec{r}) = 0$$

satisfying boundary conditions such that any arbitrary constant is a solution. The choice of base functions natural to a spherically symmetric nucleon-nucleon interaction is the set consisting of products of spherical harmonics and spherical Bessel functions. The only allowable boundary condition is that at some arbitrary distance from the center of the nucleus the derivative of the function in the radial direction must vanish. This boundary condition is all that is needed to determine the nature of the collective oscillation levels, both as to wave number and angular momentum, in terms of the inter-nucleon potential and the boundary condition radius. The lowest level, which fits quite well the photonuclear resonance, is shown to be pure dipole as had been conjectured for the resonance level by Goldhaber and Teller.¹

¹ M. Goldhaber and E. Teller, Phys. Rev. 74, 1046 (1948).

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8-4 Monoenergetic Neutrons from Charged Particle Reactions
(5211-07)

William A. Reardon

This project is now essentially complete as it pertains to the $\text{Li}^7(p,n)\text{Be}^7$ reaction. The calculations are complete and are being listed in tabular form by the computer group. A set of graphs for zero angle has been prepared for the use of the Van de Graaff group and may be reproduced for any other interested persons. The graphs cover the proton energy range from 1.882 Mev to 3.560 Mev (or neutron energy from .030 to 1.875 Mev).

This graph will be extended to proton energies up to 5 Mev and neutron energies to 3.4 Mev.

Consideration is being given to performing a similar calculation for the $\text{H}^3(p,n)\text{He}^3$ reaction.

9-2 Nuclear Cross Sections by the Clouded Crystal Ball Formalism
(5211-07)

Bernard I. Spinrad

The data available on the cross sections of heavy elements against which a theory can be checked are quite scarce; compilation of data on total and reaction cross sections is continuing.

To form a self-consistent theory including as many data as possible, the parameters used by Weisskopf are not applicable. In particular, the depth of the potential well has no a priori justification. Preliminary computations are being made with potential wells whose depth

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gives the proper location for the ground state of the compound nucleus. These wells are rather shallow, and a larger imaginary component than used by Weisskopf and Porter is required.

Formulation of the problem for easier computation is being investigated.

28-3 Angular Distribution of Elastically Scattered Neutrons (5211-07)

Morton Hamermesh

Explicit formulas have been obtained for the angular distributions of neutrons scattered near resonance, for target nuclei of spin $1/2$, 1 , $3/2$, and orbital angular momentum up to $C = 3$. They are needed in the planning and analysis of experimental studies to be made with the Van de Graaff generator. The formulas are too voluminous to give in detail here.

29-3 Internal Conversion in the L and M Sub-Shells (5211-07)

Eugene L. Church, Roland F. Herbst, James E. Monahan
Reported by Eugene L. Church

1. Introduction

Internal conversion is the most important mode of de-excitation of the excited states of heavy nuclei. The elucidation of the level schemes of such nuclei depends on an understanding of the conversion properties of low-energy transitions in the L and M shells. Presently available exact calculations are inadequate for this purpose. An attempt is being made, therefore, to extrapolate these results by means of a critical examination

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of appropriate non-relativistic approximations which are amenable to numerical computation. Emphasis is being placed on the relative conversion in the various sub-shells, which may be less sensitive to the approximations employed than the corresponding absolute conversion coefficients.

2. Threshold Values of K-Shell Internal-Conversion Coefficients

To assess the effects of relativistic corrections in the calculation of internal-conversion coefficients (ICC's) at low energies, absolute non-relativistic K-shell coefficients have been computed at threshold for comparison with the analogous relativistic results of Spinrad and Keller.¹

The threshold value of the K-shell ICC for E ℓ radiation is given by²

$$\alpha_K^{(\ell)} = \frac{16 \pi}{137} \left(\frac{274}{Z}\right)^{2\ell+2} \frac{\ell}{\ell+1} \left[\frac{\phi(2; 2\ell+2; -2)}{\ell! (2\ell+1)} \right]^2,$$

where ϕ is the relevant confluent hypergeometric function, and by

$$\beta_K^{(\ell)} = \frac{16 \pi}{137} \left(\frac{274}{Z}\right)^{2\ell} \frac{\ell+1}{(\ell-1)!^2 (2\ell+1)}$$

for M ℓ radiation.³

The above formulas have been used in the computation of

Table V. *

¹ B. I. Spinrad and L. B. Keller, Phys. Rev. 84, 1056 (1951).

² M. H. Hebb and G. E. Uhlenbeck, Physica 5, 605 (1938).

³ S. D. Drell, Phys. Rev. 75, 132 (1949).

* The numbers in parentheses are the powers of ten by which the entries should be multiplied.

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Table V

Threshold Values of K-Shell Internal-Conversion Coefficients

Z	$\alpha_K^{(1)}$	$\alpha_K^{(2)}$	$\alpha_K^{(3)}$	$\alpha_K^{(4)}$	$\alpha_K^{(5)}$
10	1.895 (+3)	3.079 (+5)	1.975 (+7)	7.137 (+8)	1.684 (+10)
20	1.185 (+2)	4.811 (+3)	7.713 (+4)	6.970 (+5)	4.112 (+6)
40	7.404 (0)	7.517 (+1)	3.013 (+2)	6.807 (+2)	1.004 (+3)
60	1.463 (0)	6.600 (0)	1.176 (+1)	1.180 (+1)	7.738 (0)
80	4.627 (-1)	1.175 (0)	1.177 (0)	6.647 (-1)	2.451 (-1)
100	1.895 (-1)	3.079 (-1)	1.975 (-1)	7.137 (-2)	1.684 (-2)
Z	$\beta_K^{(1)}$	$\beta_K^{(2)}$	$\beta_K^{(3)}$	$\beta_K^{(4)}$	$\beta_K^{(5)}$
10	1.837 (+2)	1.242 (+5)	2.221 (+7)	1.802 (+9)	8.307 (+10)
20	4.592 (+1)	7.761 (+3)	3.470 (+5)	7.040 (+6)	8.113 (+7)
40	1.148 (+1)	4.851 (+2)	5.422 (+3)	2.750 (+4)	7.923 (+4)
60	5.102 (0)	9.582 (+1)	4.760 (+2)	1.073 (+3)	1.374 (+3)
80	2.870 (0)	3.032 (+1)	8.473 (+1)	1.074 (+2)	7.737 (+1)
100	1.837 (0)	1.242 (+1)	2.221 (+1)	1.802 (+1)	8.307 (0)

The values listed in Table V differ from the results of Spinrad and Keller¹ by factors of less than ~ 4 over the entire range of Z considered. This discrepancy may be due to a known computational error of this magnitude in the latter paper,⁴ so that no detailed comparison can be made.

⁴ B. I. Spinrad, private communication (November, 1953).

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The effects of screening have been neglected in all cases.

One such effect is the lowering of the experimental K-shell binding energy⁵ relative to the corresponding hydrogenic value of $\frac{1}{2} (Z/137)^2 mc^2$. The magnitude of this difference, representing the positive electron kinetic energy for which the results in Table V are applicable, is shown in Table VI.

Table VI

Z	10	20	40	60	80	100
T	0.49	1.40	3.77	5.41	3.99	<0

3. Threshold Conversion in the L and M Sub-Shells

Extending the work previously reported⁶ to all electric transitions of practical interest, relative L and M sub-shell ICC's have been computed at their respective thresholds in the non-relativistic limit. Although the expressions obtained are strictly valid only for $Z \ll 137$ and vanishing electron momentum, the relative conversion in the various sub-shells may be indicative of the situation in cases of more physical interest. This has been verified by explicit calculation in the case of the L shell.⁷

The results obtained are summarized in Tables VII and VIII, where the intensity of the most strongly converted sub-shell has been taken as unity.

⁵ Hill, Church, and Mihelich, Rev. Sci. Instr. 23, 523 (1952).

⁶ANL-5080, p. 92.

⁷ANL-5141, p. 6.

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Table VII
Relative Threshold Internal Conversion in the L Sub-Shells

Transition	E1	E2	E3	E4	E5
$S = L_I$	0.364	0.002	0.003	0.001	8×10^{-4}
$P = L_{II} + L_{III}$	1	1	1	1	1

Table VIII

Relative Threshold Internal Conversion in the M Sub-Shells

Transition	E1	E2	E3	E4	E5
$S = M_I$	0.278	0.001	2×10^{-4}	4×10^{-7}	3×10^{-6}
$P = M_{II} + M_{III}$	0.864	1	1	0.168	0.031
$D = M_{IV} + M_V$	1	0.036	0.456	1	1

The results obtained for the L shell are in qualitative agreement with the relativistic unscreened calculations of Gellman et al,⁸ and the empirical classification of Mihelich.⁹ In the several cases identified thus far, the above predictions are also in accord with experimental results for extremely heavy elements in both the L and M shells.¹⁰

Extension of the above calculations to magnetic multipoles is under consideration.

An abstract of the above results has been submitted for presentation at the New York meeting of the American Physical Society in January, 1954.

⁸ Gellman, Griffith, and Stanley, Phys. Rev. 85, 944 (1952).

⁹ J. W. Mihelich, Phys. Rev. 87, 646 (1952).

¹⁰ ANL-5081, p. 7.

- 30-4 (Consultation on Miscellaneous Theoretical Problems) (5211-07,
5211-14)

Morton Hamermesh

No further progress has been made on this project during the past quarter.

- 31-4 (Configuration Interaction in Iron Group Elements) (5211-14)

Jean F. Hall and Norbert Rosenzweig
Reported by Norbert Rosenzweig

Work on this project will be resumed when the AVIDAC becomes available for computations.

- 32-4 Plural Scattering of Electrons at Oblique Incidence (5211-14)

Morton Hamermesh and James E. Monahan
Reported by James E. Monahan

A paper on this subject is scheduled to appear in the March 1 issue of the Physical Review.

- 34-4 Quantized Space Time (5211-14)

Emil J. Hellund and Katsumi Tanaka
Reported by Katsumi Tanaka

A manuscript entitled "Quantized Space Time" has been accepted for publication in the Physical Review. This contained the formulation of the operators and commutators of the space time operators, the determination of the eigenfunctions and eigenvalues of the space time operators, and the time spectrum of the plane wave solutions of the Dirac equation. Finally, for the solution of the problem of particle coupled to

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field, a convergent perturbation analysis is proposed by means of a unitary transformation matrix which is necessary to obtain time localizable solutions of the Dirac equation.

A note on the method of obtaining time localized wave functions is being prepared and expected to be submitted. This method follows from a variational principle.

Application of this method is undertaken.

37-3 On the Relation of the Schrodinger and Boltzmann Equation (5211-14)

Emil J. Hellund and Katsumi Tanaka
Reported by Katsumi Tanaka

In a paper by Hellund and Brachman that is to appear in the Physical Review, it was demonstrated that the Schrodinger equation can be transformed into a continuity equation of the Boltzmann type, less the collision term, thus formulating quantum mechanics in such a way as to make explicit use of the concept of trajectories.

This is being generalized in the following manner to include the collision term and thus complete the correspondence. We set up the analogue of the collision term in the new representation, transfer back to the Schrodinger representation and get the usual form of the Schrodinger equation.

38-2 Cerenkov Radiation (5211-14)

Katsumi Tanaka

Research was terminated last quarter. The submitted paper is scheduled to appear in the February 1 issue of the Physical Review.

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39-2 Applications of the Theory of Angular Correlation (5211-07)

Melvin Ferentz and Norbert Rosenzweig

Reported by Norbert Rosenzweig

In connection with the experimental work of S. Raboy and V. E. Krohn we have calculated some γ - γ angular correlation functions which are pertinent to the study of Pb^{204} , and we give here the results¹ which were obtained.

Let j_1 , j and j_2 be the initial, intermediate and final angular momenta of the decaying nucleus. The transition between j_1 and j is assumed to be a mixture of 2^{l_1} and $2^{l_1'}$ multipoles. Let δ^2 (δ is real) denote the intensity ratio of $2^{l_1'}$ to 2^{l_1} pole radiation. The transition between j and j_2 is assumed to be pure 2^{l_2} pole radiation. The cascade is abbreviated as $j_1 (l_1, l_1') j (l_2) j_2$.

The angular correlation function has the form²

$$W(\theta) = \sum_j A_j P_j(\cos \theta) + 2\delta \sum_j B_j P_j(\cos \theta) + \delta^2 \sum_j C_j P_j(\cos \theta)$$

$$(\cos \theta) \quad A_0 = C_0 = 1 \quad B_0 = 0$$

The coefficients A_j , B_j , and C_j are products² of Clebsch-Gordan and Racah coefficients with the angular momenta as their arguments.

The coefficients for the five cascades which we have treated to date are given in the adjoining table, which has been prepared with the assistance of L. C. Renick.

¹ C. F. Sunyar, et al, Phys. Rev. 79, 181 (1950). H. Frauenfelder, to be published in Phys. Rev. Helpful correspondence with Dr. Frauenfelder is greatly acknowledged.

² L. C. Biedenharn and M. E. Rose, Rev. Mod. Phys. 25, 729 (1953).

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Coefficients in W (θ)

	7(56)2(2)0	6(45)2(2)0	9(67)3(3)0	8(56)3(3)0	8(67)2(2)0
A ₂	.2472	.2208	.4643	.4327	.2653
A ₄	-.02931	-.01798	.01833	.0140	-.0384
A ₆	-	-	-.003518	-.0015	-
B ₂	-.1674	-.1974	-.2187	-.2537	-.1452
B ₄	.08931	.09106	-.03508	-.03694	.08540
B	-	-	.02155	.01847	-
C ₂	-.2653	-.2720	-.2087	-.2321	-.2585
C ₄	.2177	.1758	-.08220	-.07334	.2485
C ₆	-	-	.04948	.03342	-

40-2 Compton Scattering (5211-14)

Katsumi Tanaka

The content of the previous report will appear in Professor J. M. Jauch's forthcoming book on Quantum Electrodynamics, thus terminating the project. J. M. Cook has a program for the AVIDAC which will verify these calculations.

41-1 Solutions of the Dirac Equation for a Free Particle (5211-14)

Emil J. Hellund and Katsumi Tanaka
Reported by Katsumi Tanaka

Various authors have thoroughly discussed the motion of free

particles obeying the Dirac equation.¹ Stationary solutions of the Dirac equation form the basis of any relativistic treatment of fermions.. In the absence of any coupling with other fields, the solutions of the free particle type govern the motion of the particle. Textbooks discuss, usually in some detail, the relatively simple case of plane wave solutions. It is the purpose of the present note to point out that for the general case the derivation of solutions is equally simple. This is accomplished by retention of the complete factorization of the Klein-Gordon operator. The resolving point is the simple observation that, in the absence of any external fields, the algebra of the momentum operators is identical with that of their eigenvalues. Hence, for example, to a plane wave solution of form,

$$\chi = \begin{pmatrix} E + m \\ 0 \\ p_z \\ p_x + i p_y \end{pmatrix} e^{i (\vec{p} \cdot \vec{r} - E t)} \quad (1)$$

where $\hbar = c = 1$ there can be written the corresponding general solution, φ ,

$$\varphi = \begin{pmatrix} i \partial/\partial t + m \\ 0 \\ -i \partial/\partial z \\ -i \partial/\partial x + \partial/\partial y \end{pmatrix} F \quad (3)$$

¹ C. G. Darwin, Proc. of the Royal Society A 118, 654, (1928). E. L. Hill and R. Landshoff, Rev. Mod. Phys. 10, (1938). W. Pauli and H. Bethe, Handbuch Der Physik 24, 1 (1943).

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where F satisfies the Klein-Gordon equation,

$$(\partial^2/\partial x^2 + \partial^2/\partial y^2 + \partial^2/\partial z^2 - m^2) F = \partial^2 F / \partial t^2 \quad (4)$$

As an example, a spherical wave with a singularity on the light cone $r^2 = c^2 t^2$ is derived by setting F equal to

$$F = \frac{K_1 \left[(m \sqrt{r^2 - c^2 t^2}) \right]}{\sqrt{r^2 - c^2 t^2}} \quad (5)$$

where K_1 is the Bessel function of the second kind, with a singularity for a null argument, and going exponentially to zero for infinite argument.

The behavior of fermions in an enclosure thus is reduced to the corresponding acoustical problem.

A paper will be submitted for publication in the Physical Review.

77VI. REACTOR THEORY7-1 Lectures on Neutron Transport Theory (4520-01)

Bernard I. Spinrad

A course on this subject is being presented. Lectures so far have included the general introductory material and an exposition of various techniques for deriving the diffusion approximation. Unclassified notes are being issued concurrently with the lectures, and from time to time more carefully revised notes will be issued. It is hoped by this means to partially fill the gap in the literature which exists between the elementary expository texts and the advanced monographs on this subject and to present the topic of transport theory in such a way as to be particularly useful in reactor calculations.

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VII. ELECTRONIC DIGITAL COMPUTERS

0-2 Report on the Digital Computer Symposium (4520-02)

J. C. Chu

Manuscripts for twenty-one of the twenty-three papers presented during the symposium in August have been received and will be included in the Proceedings of the Symposium to be published as an ANL report.

1-4 (Report on the Design of the AVIDAC) (4520-02)

Raymond F. Kramer

No further progress has been made on preparation of this report.

2-4 Improvements of the AVIDAC (4520-02)

Carl J. Bergstrom, J. C. Chu, David H. Jacobsohn,
Raymond F. Kramer
Reported by Carl J. Bergstrom

Electronic Commutator

The new commutator has been bench tested and installed in the arithmetic unit of the AVIDAC. Changes and installations in the console due to this have been also completed. No testing of the new units since installation has been done.

Reader, Punch, and Re-perforator

The Ferranti reader has not as yet been received from the manufacturer.

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The fast punch mechanism is at present under construction and will be installed as soon as shop work is completed.

A re-perforator is being built, using parts obtained from the original punch and reader.

Power Supply Revisions

It became apparent during machine operation that certain voltages obtained from taps on the battery supply system were varying to an excessive degree. As the loads presented by the machine under operating conditions vary, no proper equalization which would correct this drift was possible. Therefore, it was decided that as many of these voltages as possible should be derived instead from regulated sources. Changes were made in the regulators to allow this to be done and two new regulators were added to complete the required list. These changes are complete but to date have not been tested over any but very short intervals.

Control

Several circuits in connection with the control section of the AVIDAC were modified in such manner as to improve the safety and reliability of operation. These changes were made in accordance with knowledge gained from machine breakdowns and/or re-evaluation of standards in locations where failure might possibly occur.

Logical changes were also made necessary by the installation of the new input-output equipment and associated orders. These changes have been made but have not yet been tested.

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3-4 Operation and Maintenance of the AVIDAC (4520-02)

Carl J. Bergstrom, J. C. Chu, David H. Jacobsohn,
Raymond F. Kramer
Reported by David H. Jacobsohn

Cathode Ray Tube Selection

A second batch of one hundred Dumont 5CPIA's was obtained. At present, one-third of these tubes has been tested. Of the tubes tested, two-thirds passed the test of 256 read-arounds or better. One-half of the tubes passing the read-around test were impurity free. Some attempt will be made to recover the remaining tubes by sparking. These results are similar to those obtained on the first batch of Dumont tubes previously reported.

Modifications were made in the memory test rack to facilitate automatic impurity detection.

Schematic Drawings

An over-all print revision project was made to bring all control prints into a standard form and up to date, in order to facilitate easier servicing and understanding of the control.

4-4 (Test Routines for the AVIDAC) (4520-02)

Jean F. Hall

No new routines were added this quarter.

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5-4 Sub-Routine Library for the AVIDAC (4520-02)

James Alexander, Jean F. Hall, Robert H. McDowell
Reported by Jean F. Hall

One new routine was machine tested this quarter. It is
S-11.1, trapezoidal integration.

6-4 (Coding Manual for the AVIDAC) (4520-02)

James Alexander, Donald A. Flanders, Jean F. Hall
Reported by Donald A. Flanders

No work has been done since the previous report.

7-4 The Auxiliary Memory for the AVIDAC and ORACLE (4520-02)

Raymond F. Kramer and Leslie C. Merrill
Reported by Leslie C. Merrill

Recording head production is well under way. Many, if not all,
of the ten heads should be finished in the next quarter.

The results of life-tests on a prototype head assembly indicate
that a life of 2,000 running hours can be expected between overhauls. The
head bodies will have to be rebuilt after four overhauls, while the center
pieces should be good for twenty overhauls. The lifetime of the recording
tape running on the head only is on the order of 10^5 passes.

Modification in the design of the tape driving units are
complete. Production of the drive units has started. It is anticipated that
they will be finished in the coming quarter. Tests of a prototype drive
indicate that the units themselves have an indefinite life, while the tape

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can be expected to take 2,000 clutching operations at any point before failure.

The main frames of the auxiliary memories are about 50% complete.

A prototype wind-up reel and basket tape storage mechanism is nearly finished. After tests and possible changes, the entire set of storage units will be constructed and placed on the main frames. No great difficulty is anticipated since the storage units are very simple in design and operation.

A sample and drawings of the basic electronic reading-writing chassis have been completed in order that bids for the construction of 80 such units may be sent out. The sample passed all acceptance tests.

Design of the electronic clutch driving units has been completed. A model of the unit must be built and tested.

No work was done on power supplies or control for the auxiliary memories.

8-4 (A Problem in Partitions) (5211-14)

Donald A. Flanders

No work has been done since the previous report.

13-1 New Memory for the AVIDAC (4520-02)

Raymond F. Kramer

The AVIDAC memory, which is essentially a copy of the Princeton-Williams tube memory, has not been as reliable nor does it have the capacity and high read-around ratio of the ORACLE memory. Several

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proposals have been made for improving the AVIDAC memory. Among these is the proposal to build an "ORACLE Type" memory using the special RCA cathode ray type storage tubes. Cost and time estimates were prepared and submitted for this purpose. The cost is estimated at \$128,000.00 and the construction time at nine months.

20-3 Report on Research, Development, and Design of the ORACLE

J. C. Chu

(4520-02)

A report on the ORACLE is being prepared.

Part I, on logical design, is essentially complete.

Part II, on engineering design, is to be completed during the ensuing quarter.

21-4 Operation of the ORACLE (4520-02)

Raymond F. Kramer

The ORACLE was in operation on problems prepared by the Oak Ridge staff until September 11, 1953. One of these problems used the memory in its 2048 -word mode. It operated successfully for three hours in this manner.

The ORACLE was in operation until midnight of September 16th on a reactor problem prepared by the ANL staff. Work on the problem was not completed because of previous promises to Oak Ridge to start dismantling the machine on September 17th preparatory to shipping.

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Preparation for shipping the ORACLE was started as promised on September 17th. The packing contractor began the work of boxing and crating the machine and the excess material on September 24th. His work was completed on October 1st. The packing required 105 wooden boxes and crates. It was loaded on two thirty-foot truck trailers and started its trip to Oak Ridge on October 6th, arriving there safely on the evening of October 7th.

No further reports will be made.

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VIII. APPLIED MATHEMATICS AND COMPUTATION, GENERAL1-4 IBM Methods and Procedures (5211-14)

N. Frank Morehouse

Special boards were wired for the computation of $\frac{\Delta s}{D}$ to be used by R. Meyerott in his opacity computations. The computations will be analyzed and reported on by R. Meyerott.

2-4 Report on Technical Details of General Purpose Boards (4520-02)

N. Frank Morehouse

The write-up of the fixed point board has been finished. This completes the write-ups of the general purpose boards.

10-3 (Three-Group Calculation of Critical Mass and Flux Plots) (4520-01)

Bernard I. Spinrad and Katsumi Tanaka
Reported by Katsumi Tanaka

No work has been done on this project during the quarter.

A manuscript will be submitted for publication in the Journal of Reactor Science and Technology in the next quarter.

11-2 (Computations of the Absorption of β Rays in Air) (5211-07)

The results of these computations are to be included in a paper to be written later by S. S. Brar of the Division of Biological and Medical Research.

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12-2 Computation of Traces of Gamma Matrices (5211-12)

Donald A. Flanders and Joseph Cook
Reported by Donald A. Flanders

Flow charts along slightly different lines have been constructed
by each of the above. Neither flow chart has been programmed.