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ARGONNE NATIONAL LABORATORY
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PHYSICS DIVISION
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SEPTEMBER, OCTOBER, AND NOVEMBER, 1953

Louis A. Turner, Division Director

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Preceding Quarterly Reports:

ANL-5140	June, July, and August, 1953
ANL-5141	June, July, and August, 1953 (Secret)
ANL-5080	March, April, and May, 1953
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DISCLAIMER

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

C-I-37-3 Decay Schemes of the Transuranic Elements (5211-01)

Eugene L. Church

$_{95}Am^{242m}$ is a 16-hour isomer of ~35 kev, which on the basis of previous energy-lifetime considerations corresponded to either an E3 or an M3 transition.[1] These alternatives should be clearly distinguishable on the basis of their differing L-conversion characteristics and would offer further experimental evidence for the semi-empirical rules previously proposed.[2]

Careful examination of the internal-conversion-electron spectrum of neutron irradiated $_{95}Am^{241}$ has failed to reveal the conversion lines of this transition reported in the literature.[3] Recent repetition of the original experiments at the University of California has confirmed this observation.[4] The energies of the E2 ground-state transitions observed in $_{94}Pu^{242}$ and $_{96}Cm^{242}$ have already been reported.[2]

On the basis of the present data the spin change of this isomeric transition must be ≥ 4.

The decay scheme of $_{95}Am^{242m}$ is apparently very similar to that of $_{63}Eu^{152m}$.

1 M. Goldhaber and R. D. Hill, Rev. Mod. Phys. 24, 233 (1952).
2 E. L. Church, ANL-5141.
3 O'Kelley, Barton, Crane, and Perlman, Phys. Rev. 80, 293 (1950).
4 R. W. Hoff, UCRL-2325.

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C-I-97-4 (Pile Oscillator Measurements) (5261-01)

David Rose

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

C-I-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

Lithium

At the request of Los Alamos Scientific Laboratory the total neutron cross sections of two samples of lithium have been measured. One sample of metallic Li furnished by Los Alamos has an isotopic content of 93.5% Li^6. The second sample is one of ordinary lithium metal. The cross sections were measured from 1 kev to 160 kev. No prominent resonances were observed in this energy region, although some irregularities were observed that are presumably attributable to impurities. Using the average cross sections for both samples and the known isotopic content of each, the cross sections of the separate isotopes, Li^6 and Li^7, were calculated.

The cross section of Li^7 averages slightly above one barn over the region measured up to about 135 kev, where a small dip occurs. Around 150 kev, a rise in the cross section begins.

The cross section of Li^6 falls steadily from 4 or 5 barns at 1 kev to about 1.6 barns at 30 kev and remains at this value up to about 85 kev, where a pronounced rise begins.

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Thorium

The total cross section of thorium drops steadily from a value of approximately 15 barns at 1.15 kev to about 11.5 barns at 160 kev, with no indications of a prominent resonance.

Uranium

The total cross section of uranium drops steadily from about 14.5 barns at 1.15 kev to about 11 barns at 160 kev, with no indication of a prominent resonance.

Uranium-235

The total cross section of U^{235} drops steadily from about 18 barns at 1 kev to about 11.5 barns at 160 kev, with no indication of a prominent resonance. Corrections were made for the U^{238} content of the enriched sample. The samples were prepared by A. B. Shuck of the Metallurgy Division at the Argonne National Laboratory.

Plutonium

Over the energy region from 1.15 kev to 160 kev, the total neutron cross section of Pu drops steadily from about 18.5 barns to about 11.5 barns. Correction was made for the Ni coating of the samples, which were prepared at Los Alamos.

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C-I-111-4 Measurement of the Neutron Spectra in the EBR (4110-22)

Victor E. Krohn and Roy Ringo
Reported by Victor E. Krohn

Nuclear emulsions loaded with glass specks containing Li^6 have been received, and a series of plates have been exposed to 100, 265, 400, and 600-kev neutrons. This series of plates is being used to test the energy resolution of the speck-loading technique, but the results of the study are not available at the present time. In the near future plates will be exposed to a fission spectrum (as a further test of the technique) and at various points in the EBR.

A second attempt has been made to extract a neutron beam with a representative spectrum from the core of the EBR. An assembly of U^{235} and NaK replaced the iron slugs which served as a beam "source" for the first attempt, and an optical scheme was used to check the alignment of the thimble and collimators. The ratio of U^{235} to U^{238} fissions and the ratio of Au^{197} (n,γ) Au^{198} to P^{31} $(n,p)Si^{31}$ activity were the same in the beam as in the core within the accuracy of the ratio measurements. Because of this result, we have decided that the spectrum in the beam is probably satisfactory for the desired spectrum measurements. However, as measurements in the core were made in an empty thimble, an attempt will be made to show that the same activity ratio is obtained in an empty thimble and a thimble with uranium above and below the foils. This

comparison will be made in a blanket thimble, and if no difference is observed, it will be assumed that the result applies to the core as well. Apparatus has been constructed for extracting and testing a beam from the center of a blanket thimble.

C-I-113-3 Hydrogen-Filled Cloud Chamber for Neutron Spectrum Studies (4110-22)

Charles Eggler and Charles M. Huddleston
Reported by Charles M. Huddleston

In the study of the fission spectrum of U^{235} with a cloud chamber at CP-2, a deviation from the Watt formula was observed at energies lower than about 300 kev. The deviation remained essentially the same when better geometry was used. It seemed worthwhile, therefore, to attempt a study of the neutron flux distribution as a function of the height of the uranium converter plate above the thermal column using a BF_3 proportional counter. It was found that the Cd ratio was unaffected by the height of the plate and that the counting rate of epicadmium neutrons was reduced by a factor of two when 3 feet of paraffin was introduced between converter and detector.

At this point it was decided to abandon attempts to measure the fission spectrum until the experiment could be repeated in such a manner that the cloud chamber would be shielded from the pile and could see only neutrons coming directly from the converter.

In order to work at lower energies, the cloud chamber has been enclosed in a refrigerated housing in which the temperature is

thermostatically regulated to within ± 0.5° F. Work on the refrigeration system has been completed, and its operation has been observed to be satisfactory. The cloud chamber has been successfully operated at 40° F.

The next step will be to calibrate the cloud chamber for range-energy relations at low temperatures.

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II. MASS SPECTROSCOPY

C-II-13-4 Slow Neutron Capture Cross Section of C^{12} (5261-01)

Richard J. Hayden, David C. Hess, Mark G. Inghram, Henry E. Stanton
Reported by Richard J. Hayden

Preliminary studies as to the feasibility of utilizing MA-18, the high sensitivity, high resolution gas analysis instrument, for this problem have begun. It has been determined that the instrument will completely resolve C^{13+} from $C^{12}H^{+}$ and that its sensitivity is such that C^{13} of one part in 30,000 can easily be measured in sample of size .1 cc at stp CO. Still to be determined is whether or not the C^{13+} ion background in the instrument arising from normal CO and CO_2 in the instrument can be kept low enough during measurement to make the measured numbers meaningful.

C-II-14-4 Fission Yield Determinations (5261-01)

Lawrence E. Glendenin and Ellis P. Steinberg (Chemistry Division), Richard J. Hayden, Mark G. Inghram
Reported by Richard J. Hayden

U^{235} Fission Yield Determination

The major difficulty with absolute fission yields as determined in this experiment is that when number of the fissions is determined by counting Cs^{137} in a counter calibrated by samples which have been irradiated in a fission counter, the integral of the lower fission peak is 110%.

Obviously, if the Cs^{137} yield were 10% lower than previously measured, the entire curve would be lowered by this amount. To check this possibility, the cesium samples which have previously been used in this work were remeasured. A result 3-1/2% lower was obtained. This was in the right direction but was insufficient to account for the discrepancy. The reason for the difference between the two measurements has not been determined.

As soon as neodymium work has been completed and final computations have been made, the results will be submitted to the Physical Review for publication.

C-II-15-4 Nuclear Constants of Fissionable Materials (5261-01)

David C. Hess, Charles M. Stevens (Special Materials Division), and members of the Chemical Engineering and Reactor Engineering Divisions
Reported by David C. Hess

A summary of values of α that have been obtained from EBR samples has been circulated within the Laboratory. This gives our best interpretation of the mass spectrometric and fission ratio data.

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U^{235} a

Core

Radius (cm)	$\frac{U^{236}}{U^{235}} \times 10^5$	$\frac{U^{235}\text{ fissions}}{U^{235}} \times 10^4$	a	Remarks
0	4.5 ± 0.5	4.12	0.11	All of enriched rod
0	5.4 ± 0.3	4.45	0.12	Center 1/2 of 7-1/2" rod
5.02	4.6 ± 0.7	3.65	0.13	All of enriched rod
9.4	4.4 ± 0.2	2.55	0.17	All of enriched rod
9.47	4.2 ± 0.3	2.60	0.16	Center 1/3 of 10" rod

The fraction of U^{235} fissioned is determined radiochemically and the U^{236}/U^{235} ratio is obtained mass spectrometrically.

Pu^{239} a

a. Inner Blanket

Radius (cm)	$\frac{U^{240}}{U^{239}} \times 10^5$	$\frac{Pu^{239}\text{ fissions}}{Pu^{239}} \times 10^5$	a
11.07	1.1 ± 0.2	16	0.069
15.45	1.0 ± 0.1	9	0.11
17.6	0.9 ± 0.2	7	0.13

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b. Median Brick from Stack K

Radius (cm)	$\frac{Pu^{240}}{Pu^{239}} \times 10^5$	$\frac{Pu^{239}\text{fissions}}{Pu^{239}} \times 10^5$	a	Remarks
25	4 ± 1	4.0	0.10	Inner "1/3" of brick
31	8 ± 1	2.8	0.29	Middle "1/3" of brick
36.5	35 ± 10	6.4	0.55	Outer "1/3" of brick

c. Average of Top Six Bricks of Stack K

$\frac{Pu^{240}}{Pu^{239}} \times 10^6$	$\frac{Pu^{239}\text{ fissions}}{Pu^{239}} \times 10^5$
11 ± 2	4.4

d.
Median Brick from Stack E, After Exposure of Approximately 4.3 Times That of Above Bricks

Radius (cm)	$\frac{Pu^{240}}{Pu^{239}} \times 10^5$	$\frac{Pu^{239}\text{fissions}}{Pu^{239}} \times 10^4$	a	Remarks
23.9	3.2 ± 0.2	1.9	0.17	
26.5	2.8 ± 0.3	1.5	0.19	Each sample is "1/5" (by radius) of the brick.
29.8	3.5 ± 0.4	1.2	0.29	
34.1	6.8 ± 0.7	1.3	0.52	
37.6	23.0 ± 1.6	4.3	0.53	

The fraction of Pu^{239} fissioned is calculated from Pu^{239} fission curves obtained by Reactor Engineering. These values are normalized to the U^{235} fission rate at the center of the reactor. A value

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of 4.57×10^{-4} for the U^{235} fission for the a, b, and c plutonium data above and a cross section ratio of 1.45 have been used. For the d plutonium, the exposure has been taken as 4.3 times that of the a, b, and c samples. This is taken from the reactor log and is not in agreement with radiochemical data.

The Pu^{240}/Pu^{239} ratio is obtained from mass spectrometric records.

The above values supersede our previously published values, which were based in part on copper foil activation data.

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III. CRYSTALLOGRAPHY

C-III-3-4 (Crystal Structure of Ku_2F_9) (5211-11)

H. Anne Plettinger

No further progress has been made during the past quarter.

C-III-4-4 (Crystal Structure Studies of Compounds of Elements Ac-Am) (5211-11)

William H. Zachariasen

No further progress has been made during the past quarter.

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IV. EXPERIMENTAL REACTOR PHYSICS

C-IV-1-4 (Experimental Work with the ZPR-I Reactor) (4302-22)

Frederick H. Martens

A final report on this work is in preparation.

C-IV-2-4 Thermal Zero Power Reactor Assembly - II (2812-05)

David H. Lennox

The ZPR-II program was concluded by completion of the kinetics experiment previously described. A final report, ANL-5050, has been issued; therefore, no further quarterly reports will be made.

C-IV-3-4 Anomalous Activity of the Water in ZPR-I (4302-22)

Merle T. Burgy

In the last report, the occurrence of some erratic results was mentioned. The difficulty has been cleared up by making a better comparison of counting efficiencies for the two counters which were involved. The stronger of the two active specimens is now decaying with an apparent half-life of 200 days. The decay rate of the weaker specimen is consistent with that of the stronger one, but has a greater uncertainty. The decay of the samples will be followed further. An attempt will soon be made to analyze the present data for the shorter half-lives.

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C-IV-10-1 The Fast Exponential Experiment (4110-22)

Frederick C. Beyer, Harry H. Hummel, David H. Lennox, Robert G. Nobles, Roy Ringo, Alan B. Smith
Reported by David H. Lennox, Frederick H. Martens, Alan B. Smith

General

The source reactor which supplies neutrons for the fast exponential experiment is a light water moderated, enriched uranium assembly designed to operate at a maximum of 10 kw. At this power, it will supply 10^9 neutrons/cm^2/sec to the exponential.

The construction of this assembly has been completed and some preliminary experiments conducted. As much of the ZPR-I facility was retained as was practical. The delta frame and legs were moved and rotated to support the control and safety rod drive in the proper location. The tank support was also moved, and a new tank was installed. The water system was completely revised, retaining only the sump tank, pump, flap valve, and overflow weir. A new water level control system was installed. A new hole was drilled in the floor to house the source and its positioning mechanism.

The reactor core is composed of "Borax" type fuel elements fitted inside a 6" lead reflector and gamma shield on three sides and the bottom. The front face is formed by a 3/4" aluminum window through which

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neutrons enter the pedestal. The upper reflector is light water. Criticality was achieved in 8 loadings, when 3.094 kg of U^{235} were in the core.

A series of preliminary calibrations were made to determine control and safety rod effectiveness, so that an intelligent guess might be made as to where they should be finally located. In the final configuration of the core and rods, the safety rods are worth 3.2% Δ K/K and the control rod is worth 1/1% Δ K/K. The maximum excess reactivity available is 0.44% Δ K/K, with 3.047 kg of U^{235} in the reactor.

After operation for about ten days, a considerable amount of corrosion and pitting appeared on the fuel elements, where the brazing flux had been applied during manufacture. This appeared to be quite serious, so operations have been stopped until the flux can be removed.

Fuel for the exponential array is scheduled for delivery in January, 1954.

Foil Measurements

Initial spectra explorations and buckling measurements will be made with foils of In, Au, U^{235}, Np^{237}, and Pu^{239}. For calibration, a motor-driven, circular fixture has been made so that forty-eight foils may be irradiated simultaneously at the face of the source reactor.

Several hundred U^{235} foils made from ZPR-I fuel strips ($\sim$35% by weight of U^{235} in polystyrene) are available and will be used

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if it is found that the moderating effect of the plastic is negligible. For measurements with U^{238}, it is planned to use depleted U_3O_8 powder sealed in aluminum capsules. Enough material for approximately twenty foils of Pu^{239} has been ordered and 50 mg of Np^{237} is now on hand.

Use of Miniature Fission Chambers

Miniature fission chambers are under consideration as a technique for the measurement of the neutron flux and spectra within the fast exponential. Such chambers have been developed for use in EBR (ANL-5012). They are available in a selection of fissile materials and sensitivities. The physical sizes are suited to the limited space within the proposed assembly. Detectors of this type contain very small amounts of scarce materials (i.e., Np). They require a minimum of calibration and will obtain the desired data in a fraction of the time necessary for the usual foil measurements.

The necessary electronic equipment has been assembled. Where units were not available they were constructed in Building 316. Basic components are an "Atomic" 204-C linear amplifier, low noise pre-amplifier, integral discriminator, and high-voltage source. Preliminary tests indicate the components are functioning properly. The entire system will be tested in the source reactor, particularly with respect to stability.

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C-IV-11-1 Reactivity Changes of Irradiated NRX Fuel Rods (4520-01)

Charles Eggler

Four sections of a highly irradiated NRX rod were measured for changes in reactivity in CP-2 by the danger coefficient technique. A section of unirradiated NRX rod was used as a control. The following changes in reactivity were noted:

Rod Section	Irradiation (MWD/ton)	Reactivity Change (inh/kg)
Control	0.	0.000 ± 0.002
1	297	0.000 ± 0.002
3	2028	-0.054 ± 0.002
5	2964	-0.133 ± 0.002
7	1410	-0.035 ± 0.002

As the measurements now stand, interpretation interms of eta of U^{235} and Pu cannot be made. For this, additional measurements under identical conditions are planned using enriched, depleted, and poisoned uranium. References: ANL-LAT-115, ANL-BIS-5, ANL-LAT-120.

V. THEORETICAL PHYSICS, GENERAL

C-V-50-4 Hartree Functions for Inner Shells of Ions and Atoms

Roland E. Meyerott and Lucille C. Renick (5211-14)
Reported by Roland E. Meyerott

A final paper on this work has been prepared and is being submitted to the Physical Review for publication.

C-V-52-4 Table of Rosseland Mean Opacities for Stellar Mixtures

Geoffrey Keller (Perkins Observatory) and (5211-14)
Roland E. Meyerott
Reported by Roland E. Meyerott

A table of the positions and heights of the absorption edges has been prepared for the elements of atomic numbers 1, 2, 6, 7, 8, 10, 13, 19, and 26, at temperatures and densities listed in ANL-4856. This table is now being used to compute the opacity for 12 different compositions. The results of this calculation will appear as a final ANL report on this subject.

C-V-53-4 Contributions of Line Absorption to the Rosseland Mean Opacity

Henry Margenau (Yale University) and (5211-14)
Roland E. Meyerott
Reported by Roland E. Meyerott

The theory of the broadening of spectral lines by an ionized gas is far from satisfactory, as has been indicated in the previous reports on this subject. Its weakness lies primarily at two points.

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It is customary to treat the effects of the heavy ions and those of the electrons separately. The heavy ions produce a Stark effect which Holtzmark's theory describes satisfactorily. That theory, however, is a classical one whose structure is difficult to incorporate into a general theory of line broadening that includes all effects. It is statistical, to be sure, and has similarities with quantum statistical theories with which it is frequently classified. This similarity, however, is superficial, for Holtzmark computes the probability of a given electric field resulting from all possible ion configurations and assumes it to be proportional to the line intensity at the Stark frequency corresponding to that field, whereas the statistical quantum theories fix attention upon the probability of a given energy pertubation ΔE, a scalar quantity, and identify this probability with the intensity of the line at $h\Delta\nu$.

The second moot point in the treatment of plasma effects on lines is the role it assigns to the electrons. These are admittedly hard to handle, even separately. Hence they are often ignored on the supposition that they move too fast to cause line broadening.

A paper entitled "Quantum Theory of Line Broadening by an Ionic Plasma" which treats these effects more completely, has been prepared for publication in the Physical Review.

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VI. REACTOR THEORY

C-VI-1-4 (Lattice Constants for Natural U) (4520-01)

Bernard I. Spinrad

There are no changes to report on this project at this time.

C-VI-2-4 (Doppler Effect and Resonance Escape Probability) (4105-21)

Edwin A. Crosbie

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

C-VI-5-4 Analysis of EBR and Fast Critical Assemblies (4110-21)

Elwin Dershem, Harry H. Hummel, Norbert Rosenzweig
Reported by Harry H. Hummel

The four-group Serber calculation set-up has been compared with two additional numerical integral theory calculations from Los Alamos. One is the three-group solution for Godiva reported in LA-1272. The Serber calculation gives a critical radius that is 5.7% low and gives the group fluxes accurately out to positions near to the outer boundary. The other comparison is with a four-group solution for Topsy. In this case the critical radius from the Serber calculation appears to be 7 to 8% low, but the integral theory radius itself is probably not accurate because only two radial divisions were used in the core. It is unlikely that the error is actually more than 3%. The flux is given accurately in the center and seems to be good to about 10% asymptotically in the tamper.

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It would be desirable to have other comparisons with multi-group numerical integral theory solutions, preferably with finer radial divisions. On the basis of comparisons so far available, however, the critical radius and group fluxes given by the Serber calculation seem to be good enough to justify the use of the method in at least preliminary evaluation of cross sections from spectral data on fast assemblies.

The next phase of the program, to be carried out in collaboration with David Okrent of the Reactor Engineering Division, is to compare the Serber calculation with diffusion theory for various assemblies, and to use it in evaluating cross sections from available detector data. Some preliminary results of comparisons with diffusion theory are available. In all cases so far, including Topsy and Godiva, diffusion theory gives the same spectrum at the center of the core as the Serber calculation, for reasons not yet clear. The normalization of the U^{238} fission group in the tamper relative to its value at the center of the core is about twice as large for diffusion theory as for the Serber calculation.

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VII. ELECTRONIC DIGITAL COMPUTERS

C-VII-9-4 (Monte Carlo Calculation with the AVIDAC) (4520-02)

This project has been inactive in the last quarter while awaiting availability of the AVIDAC.