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**AMES
LABORATORY
IOWA STATE
COLLEGE**

**PHYSICS. QUARTERLY SUMMARY RESEARCH REPORT
JULY, AUGUST, AND SEPTEMBER, 1954**

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QUARTERLY SUMMARY RESEARCH REPORT IN PHYSICS

For July, August, and September, 1954

by

Ames Laboratory Staff

December 21, 1954

Ames Laboratory
at
Iowa State College
F. H. Spedding, Director
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QUARTERLY SUMMARY RESEARCH REPORT IN PHYSICS
For the Period July, August, and September, 1954

This report is prepared from material
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PHYSICS

Under the direction of F. H. Spedding, G. W. Fox, G. C. Danielson, D. E. Hudson, E. N. Jensen, J. M. Keller, J. K. Knipp, S. Legvold, G. H. Miller and D. J. Zaffarano

Theoretical Physics1. Magnetic Studies (J. M. Keller)*

A previous calculation on the combined effect of crystal field and exchange energies on specific heat has been improved. The original calculation was the outcome of a suggestion by Dr. F. H. Spedding of a simple approximate way to include exchange effects. The first calculation was based on a "collective electron" approach, and this calculation was repeated on a "nearest neighbor" basis. The resulting equations are rather complicated, but a numerical example has shown that the results are not terribly different from those obtained from the simpler model. Both calculations indicate a sharp discontinuity in specific heat at the Curie temperature.

Theoretical studies on the magnetic properties of dysprosium, based on Elliott's¹ data, have been continued. Certain aspects of the data suggest an antiferromagnetic region at temperatures between the ferromagnetic region (below 92°K) and the paramagnetic region (above 176°K). The work of Smart² on cubic structures, based on the "molecular field approximation," has been extended to hexagonal structures. This type of theory seems too simple to explain the sharp rise in susceptibility as temperature is lowered, approaching the ferromagnetic Curie point. This rise is typical of ordinary (transition element) materials above a Curie point, but it is not expected in the familiar antiferromagnetic materials.

Experimental Physics1. Nuclear Studies1.1 C¹⁴ (E. N. Jensen)

The results of previous investigations on the beta spectrum of C¹⁴ have been in general agreement on the maximum beta energy, but there has been some question as to the shape of the spectrum.

The beta spectrum of C¹⁴ has been examined with the intermediate-image spectrometer. With a vacuum evaporated source (the source preparation has been described in ISC-508) consisting of $6 \pm 2 \mu\text{g/cm}^2$ Li₂CO₃ on a collodion backing of $6 \pm 2 \mu\text{g/cm}^2$

¹J. F. Elliott, S. Legvold and F. H. Spedding, Phys. Rev. 94, 1143-1145 (1954).

²J. S. Smart, Revs. Modern Phys. 25, 327 (1953).

*Name indicates group leaders in charge of work.

it was found that the Kurie plot was linear above 7 kev after correcting for the efficiency of the scintillation detector. This source was prepared from a sample kindly supplied by Dr. C. S. Wu (Columbia University, New York City, New York) and was enriched to about 40% in Cl^{14} . The maximum energy of the beta spectrum was found to be 158.5 ± 0.5 Mev. These data are consistent with the interpretation of an allowed transition for Cl^{14} according to G-T selection rules with $\Delta I = 1$, no.

1.2 A Search for Small Order Effects in Beta Spectra (E. N. Jensen)

An intermediate-image spectrometer and a thin-lens spectrometer have been used to carefully examine the beta spectra of P^{32} , K^{42} , and As^{76} .

The P^{32} spectrum was examined for a Fierz-type deviation using a vacuum evaporated source having a surface density of $3 \mu\text{g}/\text{cm}^2$ on a $30 \mu\text{g}/\text{cm}^2$ film. Within experimental error no deviation was found from a linear Kurie plot. The value of "r" describing the magnitude of the Fierz deviation as defined by Davidson and Peaslee¹ was found to be 0.00 ± 0.03 . The maximum energy of the beta spectrum was found to be 1.712 ± 0.005 Mev.

The first forbidden transitions of the lower-energy beta groups of K^{42} and As^{76} with $\Delta I = 0$, yes, were examined for deviation from a linear Kurie plot. The calculated "shape factors" of Mahmoud and Konopinski² indicate that the deviations should be largest for high energy transitions of low Z nuclei and that the deviations should be observable for K^{42} and As^{76} . Within experimental error no deviations were found. A deviation of the K^{42} Kurie plot below 500 kev was attributed to an additional beta group. The K^{42} vacuum-evaporated source had a surface density of $20 \mu\text{g}/\text{cm}^2$ on a backing of $30 \mu\text{g}/\text{cm}^2$. The As^{76} source was evaporated from solution and had an average surface density of about $0.5 \text{ mg}/\text{cm}^2$ on a $30 \mu\text{g}/\text{cm}^2$ collodion film.

The maximum energies of the K^{42} beta groups were found to be 3.545 ± 0.015 Mev and 1.985 ± 0.010 Mev. A third weak beta group had a maximum energy of about 0.5 Mev. Two gamma rays were found for K^{42} with energies of 1.53 ± 0.01 Mev and 320 ± 5 kev. The 320 kev gamma ray has an intensity of $0.8 \pm 0.4\%$ of that of the 1.53 Mev gamma ray.

The maximum energies of the three higher-energy beta groups of As^{76} were found to be 2.97 ± 0.01 Mev, 2.42 ± 0.01 Mev, and 1.77 ± 0.02 Mev.

¹J. P. Davidson and D. C. Peaslee, Phys. Rev. 91, 1232 (1953).

²H. M. Mahmoud and E. J. Konopinski, Phys. Rev. 88, 1266 (1952).

1.3 Assignment of Transition Multipole Orders from L Subshell Internal Conversion Coefficient Ratios (E. N. Jensen)

Using a variable field 180° beta spectrometer and very high specific activities, it was possible to determine L subshell conversion ratios for both the 112.0 keV transition in Lu¹⁷⁷ and the 85.1 keV transition in Tl¹⁶⁰.

Magnetic field monitoring and measurement were done in a unique manner suitable only for low energy spectrometers. Accelerated electrons from a tungsten filament were focused by the field into a semi-circle. This beam current was detected by two adjacent carbon plates connected to a balanced electrometer. The field was adjusted so as to keep the current to the two plates equal for a given accelerating voltage. Accelerating voltages of 200 to 5000 volts gave the spectrometer a range of 10 to 200 keV.

1.3.1 Lu¹⁷⁷

For the 112.0 keV transition in Lu¹⁷⁷ decay the $L_I/L_{II}/L_{III}/M$ ratio was found to be $< 0.05/1.14 \pm 0.02/1.00/0.62 \pm 0.02$. E2 theoretical estimates for these ratios are $0.11 \pm 0.03/1.14 \pm 0.03/1.00$. The conclusion that this 112.0 keV transition is E2 agrees with the identical conclusion reached by others on the basis of angular correlation and the K shell internal conversion coefficient, and the K/L ratio.

In order to give a check on the E2 assignment for the 112 keV transition in Lu¹⁷⁷, the beta and internal conversion spectra were determined with the intermediate-image spectrometer with a vacuum evaporated source having a surface density of $3 \mu\text{g}/\text{cm}^2$ on a $25 \mu\text{g}/\text{cm}^2$ collodion film. Coincidence beta spectra were also obtained. From these data the K/L/M ratio for this transition was $0.64 \pm 0.02/1.00/0.28 \pm 0.01$. Although the K/L ratio is somewhat above the empirical curve of Goldhaber and Sunyar for E2 radiation, recent re-evaluation of points on the Goldhaber and Sunyar curve suggest that the curve is possibly a bit low for this region of Z^2/E . The K conversion coefficient was found to be $\alpha_K = 0.4 \pm 0.2$. The large error is due to the uncertainty in the branching ratios.

Confirmation of the E1 assignment to the 208.7 keV transition was obtained from K conversion coefficient, $\alpha_K = 0.041 \pm 0.010$.

Coincidence spectra of the two low energy beta and total spectrum on the high energy group gave no indication of departure from a straight line in their Kurie plots. $\text{Log}_{10}[(W_0^2 - 1)\text{ft}]$ values for the three groups were too low to expect any S-shaped Kurie plots. All three beta groups, therefore, appear to be first-forbidden. Based on a $p_{1/2}$ ground state for Hf¹⁷⁷ from the shell model, the first-forbiddenness of the two high energy beta transitions, and the E2 character of the 112.0 keV transition, the ground state of Lu¹⁷⁷ is assigned to a $d_{3/2}$ level.

End points of the beta groups, in order of increasing energy as determined from coincidence and total spectra, were found to be 180 ± 2 kev, 388 ± 3 kev and 507 ± 2 kev, and the branching ratios were found to be 9%, 17%, and 74% respectively. From the conversion lines the two lower-energy gamma-rays were found to have energies of 112.0 ± 0.2 kev and 208.7 ± 1.4 kev. The energy of the highest-energy gamma ray was not determined. The decay scheme determined from these data is in agreement with that of D. G. Douglas.¹

1.3.2 Tb¹⁶⁰

The 85.1 kev transition conversion ratios in Tb¹⁶⁰ decay were found to be $L_I/L_{II}/L_{III}/M = 0.61 \pm 0.10/0.87 \pm 0.06/1.00/0.94 \pm 0.07$. $L_I/L_{II}/L_{III}$ ratios determined by theory for E2 transitions are $0.3 \pm 0.1/0.95 \pm 0.02/1.00$ and agree best with the experimental ratios. The L_I/L_{II} theoretical ratio is a rapidly varying function of Z in the region of the Tb¹⁶⁰ daughter product. Forthcoming theoretical results including screening may prove to be in better agreement with experiments. From these data it is concluded that the 85.1 kev gamma ray in the Tb¹⁶⁰ decay is an E2 transition.

1.4 Ionization Experiments (G. Miller)

1.4.1 Fission Fragment Ionization Yield

An article entitled "Relative Ionization Yields for Fission Fragments in Various Gases", was published in Phys. Rev. 95, 413-417 (1954).

Abstract

The ionizations resulting from U²³⁸ fission have been measured in He, Ne, Ar, Kr, N₂, Ar + 3% CO₂, and Ar + 5% N₂. Comparison of these values with those obtained for alpha particles in the same chamber fillings permit the calculation of ionization defect differences. It was found that about half of the 7 Mev defect previously ascribed to argon-CO₂ mixtures was due to CO₂. Nitrogen and krypton exhibited relatively large defects. No significant difference was observed between argon and helium. Several possible explanations for this are suggested and discussed.

The collimated 50 microgram/cm² source of natural uranium used previously was replaced by an uncollimated source of the same material having a thickness of about 20 microgram/cm². The results thus obtained are shown in the following table, along with the results obtained with the thicker source.

¹D. G. Douglas, Phys. Rev. 75, 1960 (1949).

Table I

Gas	New Results		$E_f = E_\alpha \frac{I_f}{I_\alpha}$		Previous Value		Difference	
	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy
Helium	95.8	64.1	92.9	61.8	2.9	2.3		
Argon	93.7	63.4	92.5	60.9	1.2	2.5		
Nitrogen	90.5	60.9	88.9	58.0	1.6	2.9		
A + 3% CO ₂	-----	-----	89.5	56.4	-----	-----		
A + 5% CO ₂	91.8	61.0	-----	-----	-----	-----		
He + 3% CO ₂	93.1	61.9	-----	-----	-----	-----		

¹ E_α = Energy of alpha particle
 I_f = Ionization by fission fragment
 I_α = Ionization by alpha particle
 E_f = Energy of fission derived from ionization

²L. Herwig and G. H. Miller, Phys. Rev. 95, 413 (1954).

It may be seen that the loss of energy within the source has been reduced by about 2 and 2.5 Mev for the average light and average heavy fragment respectively. This would indicate that perhaps another Mev should be added to each in order to correct for the remaining source thickness.

1.4.2 Ionization Yield from the B¹⁰ (n, α) Li⁷ Reaction

Using a cylindrical ionization chamber, data were taken in several gas mixtures. The source used was of natural boron and was sprayed on from a boric acid-alcohol solution. The results were not very satisfactory. A very high background appeared in the pulse height distribution, particularly in the region of the Li⁷ recoil peak. It was possible to get the following results, however. The ratio of ionizations of the alpha particle from the B¹⁰ reaction and the U²³⁴ alpha particles was compared to the known energy ratio of the same particles. For pure argon, the ionization ratio was about 2% less than the energy ratio, indicating a deficiency of ionization for the low energy alpha. For argon plus 2% CO₂, the difference was even greater, about 2.5%. In argon plus 1% nitrogen the difference was only about 0.5%.

A grid-type chamber with a smaller effective volume was constructed and is now in use. A source of enriched B^{10} has been prepared by vacuum evaporation of boron metal. The background is now quite low.

1.5 Cloud-Chamber Identification of Photodeuterons from Sulfur (D. J. Zaffarano)

A continuation of the work in this Laboratory on the ratio of photodeuterons to photoprotons ejected from various nuclei by high energy x-rays has led to additional results with sulfur. A total of 6600 stereoscopic photographs were taken of a sulfur plate of thickness equivalent to the range of a 15 Mev proton in a twelve-inch magnetic cloud-chamber. The range of each x-ray-induced track was measured and corrected to its air equivalent range by means of the stopping power of the cloud chamber atmosphere measured with 5.303 Mev alpha particles. The curvature and azimuth of each track, in a pulsed magnetic field of 4000 gauss, were measured and the curvature was corrected to that of a track in a plane normal to the magnetic field. The range and magnetic curvature of each track were used to determine its mass. A mass histogram was plotted which exhibits two well defined peaks at the mass values of a proton and a deuteron. The experimental ratio of deuterons to protons from a thick sulfur target is 0.19 ± 0.04 .

To correct this ratio for target thickness, it was assumed that the target consisted of 63 thin lamina. An energy distribution for singly charged particles emitted from a compound sulfur nucleus was assumed for each layer. The contributions from all of the layers, corrected for the energy loss in traversing the proper thickness of material, were then combined to give composite energy distributions for the protons and the deuterons that emerged from the thick target. The range-energy relations for the cloud-chamber vapor were different for protons than for deuterons and gave a different energy range available to be measured for each type of particle. These corrections were applied to the energy distributions of particles from the thick target.

The ratio of the number of protons to the number of deuterons in these two intervals is the correction that was applied to the experimental ratio. The ratio of deuterons to protons from a thin sulfur target when irradiated by 67 Mev bremsstrahlung is 0.15 ± 0.04 .

1.6 X-Ray Induced Radioactivities (D. J. Zaffarano)

The study of the decay scheme of Te^{129} (70 minutes half-life) has been completed. The decay consists of a simple beta-gamma cascade of energies 1900 and 440 kev, respectively, to the ground state of I^{129} . The decay of Sb^{129} is also being studied with coincidence scintillation spectrometers. There are apparently five beta groups, with energies 1700, 1560, 1395, 1170, and 920 kev. Gamma-rays of energies 780, 530, 310 and 160 kev from the levels after the beta transitions are fitted into a consistent decay scheme.

2. Solid State Studies

2.1 Thermal Conductivity (K) of Uranium (G. C. Danielson)

The thermal conductivity of uranium has been measured in the temperature range 100°C to 600°C by means of a static method which compares the unknown thermal conductivity to the thermal conductivity of Armco iron. The data have been found to fit the equation

$$K = 0.348 - 1.83 (10^{-4})T + 2.95 (10^{-10})T^3$$

where K is the thermal conductivity of uranium in watts/(cm)(degree K) and T is the temperature in degrees Kelvin. Over the temperature range $400^\circ\text{K} < T < 900^\circ\text{K}$ the root-mean-square deviation is 0.011. This error represents only the statistical error, however, and the total error in the thermal conductivity may be approximately 6%. This error will be reduced by means of the matched thermocouples now installed in the sample and guard tube.

2.2 Semiconducting Metallic Compounds (G. C. Danielson)

Cu_2Se samples have been prepared with room temperature resistivities as high as 0.04 ohm-cm. Resistivity as a function of temperature has been measured for one sample, but the data need verification. In the region 160°K - 240°K , the resistivity decreased as the temperature increased. The sharpest decrease occurred in the range 220°K - 225°K , in which range the resistivity varied as

$$\rho = A e^{B/kT}$$

where $B = 2.5$ electron volts and $A = 10^{-52}$ ohm-cm. This curious result raises doubt about the validity of the data. Cu_2Se has been observed to exhibit a photo-voltaic effect when in contact with phosphor bronze.

2.3 Measurement of Magnetic Field Gradients by the Hall Effect (G. C. Danielson)

The Hall effect magnetic field gradient meter has been modified to measure relative gradients $(dH/dx)/H$ as well as gradients (dH/dx) . The device responded well to relative gradients in the range 0.02 cm^{-1} to 0.20 cm^{-1} . Measurements of gradients have been made at magnetic fields as high as 10 kilogauss. Excessive dependence of Hall coefficient upon field strength seems to limit the usefulness of this gradient meter.

2.4 Electrical Properties of Thin Metallic Films (G. C. Danielson)

Three runs to determine the conductivity of sodium films have been made with the present apparatus. In all cases the resistivities of the sodium films have been extremely high (about one ohm-cm). Examination under a microscope revealed an extremely aggregated structure.

2.5 Heat of Sublimation of Dysprosium (D. E. Hudson and
F. H. Spedding)

New vacuum-cast samples of high-purity dysprosium have been studied by our mass-spectrometric technique. Seven new runs have been made on this metal, in addition to two runs previously reported. The average heat of sublimation for all nine runs is 69.4 ± 0.7 kcal/mole at a midrange temperature near 1230°K. The best corrected average value for many runs on less pure cast material was 67.1 ± 0.7 kcal/mole. It appears that the improvement in purity gives rise to a significant 2.3 kcal/mole increase in the measured value of the heat of sublimation.

APPENDIX: LIST OF REPORTS FROM THE AMES LABORATORY

1. Reports for Cooperating Laboratories

- ISC-437 (rev) G. H. Beyer, D. R. Spink, J. B. West and H. A. Wilhelm. Caustic Treatment of Zircon Sand.
- ISC-443 Philip Phipps and D. J. Zaffarano. The Half-Lives of Some Short-Lived Low Z Nuclei Formed by Photonuclear Reactions.
- ISC-468 A. L. Loeffler, Jr. and B. J. Ruth. Mechanism of Hindered Settling and Fluidization.
- ISC-474 G. H. Murphy, D. F. Young, and R. J. Burian. Progress Report on Friction Loss of Slurries in Straight Tubes.
- ISC-482 M. E. Dooley and D. F. Atkins. A New Electronic Vacuum Dilatometer.
- ISC-487 Ames Laboratory Staff. Physics. Quarterly Summary Research Report. January, February, March, 1954.
- ISC-488 D. R. Wilder and E. S. Fitzsimmons. Further Study of Sintering Phenomena.
- ISC-490 A. J. Bureau, H. A. Austrheim, and D. J. Zaffarano. An Electron Injector for a 70 Mev Synchrotron.
- ISC-491 J. T. Williams. The Vanadium-Zirconium Alloy System.
- ISC-492 K. W. Olson and G. C. Danielson. Variations of Electrophotoluminescence Phenomena with Frequency of Applied Field.
- ISC-494 M. R. Nadler and E. S. Fitzsimmons. Preparation and Properties of Calcium Zirconate.
- ISC-500 B. A. Rogers and D. F. Atkins. The Zirconium-Columbium Diagram.
- ISC-501 M. Margoshes and V. A. Fassel. Infrared Functional Group Analysis of Aryl Silanes.
- ISC-502 M. Margoshes and V. A. Fassel. The Infrared Spectra of Aromatic Compounds. I. The Out-of-Plane C-H Bending Vibrations in the Region $625-900\text{ cm}^{-1}$.
- ISC-508 Ames Laboratory Staff. Physics. Quarterly Summary Research Report. April, May, June, 1954.
- ISC-514 D. R. Wilder and E. S. Fitzsimmons. Improved Calcium Fluoride Shapes.
- ISC-516 V. A. Fassel, B. Quinney, L. C. Krotz and C. F. Lentz. Quantitative Spectrographic Analysis of the Rare Earth Elements.

2. Papers Published in Scientific Journals

- Altshuler, S. and J. F. Carlson
ISC-471 Time Dependent Variational Principle. Phys. Rev. 95, 546-548 (1954).
- Chiotti, P.
ISC-412 Adaptation of a Geiger-Counter X-Ray Diffractometer for High Temperature Investigations. Rev. Sci. Instr. 25, 683-688 (1954).
- Dickinson, J. M., O. N. Carlson and H. A. Wilhelm
AEC-3544 The Niobium-Vanadium Alloy System. J. of Metals 6, 915-918 (1954).
ISC-391
- Duke, F. R.
Qualitative Theory of Electron-Transfer Mechanism. Record of Chem. Prog. 15, 55-59 (1954)..
- Duke, F. R. and V. C. Bulgrin
ISC-441 The Kinetics of the Periodate Oxidation of Ethylene Glycol and a Series of Methylated Ethylene Glycols. J. Am. Chem. Soc. 76, 3803-3806 (1954).
- Duke, F. R. and R. Laity
ISC-496 Transport Numbers in Pure Fused Salts. J. Am. Chem. Soc. 76, 4046-7(1954).
- Duke, F. R. and P. R. Quinney
ISC-438 The Kinetics of the Reduction of Perchlorate Ion by Ti(III) in Dilute Solution. J. Am. Chem. Soc. 76, 3800-3803 (1954).
- Fassel, V. A. and R. H. Heidel
ISC-313 Fluorescence Spectrometric Determination of Terbium. Anal. Chem. 26, 1134-1137 (1954).
- Fritz, J. S. and M. O. Fulda
ISC-382 Titrimetric Determination of Zirconium. Anal. Chem. 26, 1206-1208 (1954).
- Herwig, L. O. and G. H. Miller
ISC-498 Relative Ionization Yields for Fission Fragments in Various Gases. Phys. Rev. 95, 413-417 (1954).
- Horrocks, D. L. and A. F. Voigt
ISC-479 Half-Life of Thallium²⁰⁴. Phys. Rev. 95, 1205 (1954).