**AMES
LABORATORY
IOWA STATE
COLLEGE**

**PHYSICS. QUARTERLY SUMMARY RESEARCH REPORT.
JANUARY, FEBRUARY, AND MARCH, 1954**

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U N I T E D S T A T E S A T O M I C E N E R G Y C O M M I S S I O N

QUARTERLY SUMMARY RESEARCH REPORT IN PHYSICS

For January, February and March, 1954

by

Ames Laboratory Staff

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Ames Laboratory
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QUARTERLY SUMMARY RESEARCH REPORT IN PHYSICS
For the Period January, February, and March, 1954

This report is prepared from material
submitted by the group leaders of
the Laboratory

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PHYSICS

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

Experimental Physics1. Nuclear Studies1.1 Spectrometer Studies (E. N. Jensen)1.1.1 Radiations from Ce^{141}

The radiations from Ce^{141} have been examined by means of a thin lens spectrometer, an intermediate image spectrometer adapted for coincidence counting, and a scintillation spectrometer. The beta decay was found to be complex with two beta groups having maximum energies of 0.574 ± 0.003 Mev and 0.431 ± 0.002 Mev. The lower-energy beta group is in coincidence with a single gamma-ray having an energy of 145.4 ± 0.7 kev. The spectrum of the lower-energy beta group was obtained by counting the betas in coincidence with the gamma-ray.

The higher-energy beta group has a $\log ft = 7.8$ and is assigned as a $\Delta I = -1$, "yes" transition. The Kurie plot appears to be a straight line. The lower-energy beta group has a $\log ft = 6.9$ and is assigned as a $\Delta I = 0$, "yes" transition. The Kurie plot is a straight line. The relative intensities of the higher and lower-energy beta groups were found to be 25 per cent and 75 per cent respectively. From the internal conversion coefficient ($\alpha_K = 0.22$) and the K/L ratio of 6.4, the gamma-ray transition is thought to be magnetic dipole.

An $f_{7/2}$ state, with odd parity, is assigned to the ground state of Ce^{141} ; a $g_{7/2}$ state, with even parity, is assigned to the excited state of Pr^{141} ; a $d_{5/2}$ state, with even parity, is assigned to the ground state of Pr^{141} .

These results are in essential agreement with the results of Freedman and Engelkemeir.¹

1.1.2 The Lower-Energy Beta Spectra of Rb^{86} and Tm^{170}

The lower-energy beta groups of Rb^{86} and Tm^{170} have been examined for deviations from a straight line. Limits on the value of ϕ defined by H. M. Mahmond and E. J. Konopinski² for the Fierz

¹M. S. Freedman and D. W. Engelkemeir, Phys. Rev. 79, 897 (1950).

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

interference effect were determined. For the 680 kev group of Rb^{86} , ϕ was -0.05 ± 0.10 . For the 886 kev group of Tm^{170} , ϕ was 0.05 ± 0.08 . The error given is the probable error determined by statistics. Within experimental error no deviation from a straight line was observed. Both are first forbidden transitions with $\Delta I = -1$, "yes" for Tm^{170} and $\Delta I = 0$, "yes" for Rb^{86} .

1.2 Ionization Experiments (G. H. Miller)

1.2.1 Continuous Flow Chamber

Due to spurious effects arising in the aperture of the continuous flow chamber, it has become necessary to modify the method of measuring the incoming beam intensity. In the original method of measurements, the beam was considered as being the current from the two isolated chamber electrodes to ground, and hence measurable by an electrometer circuit. It now appears that the current measured in this manner contains, in addition to the beam current, secondary electrons produced from the edge of the aperture as well as a part of the ionization produced in the aperture.

The present method consists of measuring the beam current and the ionization current separately, instead of simultaneously. The beam particles are actually counted, by using the chamber as a proportional counter. A fast amplifier is connected to the center electrode and the potential raised until gas multiplication is obtained. At these pressures (about 5 mm Hg) the voltage range over which stable multiplication can be obtained is relatively small, but is adequate. The method consists of counting particles for a certain time interval and then reducing the voltage to the ionization chamber region and measuring the ion current. By successive measurements of this type, beam fluctuations are averaged out to a good approximation. It has been found that average counting rates as high as 10^4 particles per second can be tolerated for 120 kev protons in nitrogen. It is hoped that a careful revision of the electronics may permit the extension of this rate to as much as 3×10^4 particles per second. The measurements which have been made thus far are completely preliminary, but indicate an energy per ion pair of about 58 ev for 120 kev protons in nitrogen.

1.3 Nuclear Emulsion Experiments (D. J. Zaffarano)

Analysis of the data from photodisintegration stars found in nuclear emulsions which have been bombarded with 70 Mev bremsstrahlung was continued. Momentum calculations have been completed on 778 three-prong stars under the assumption that they represent the reaction $\text{Cl}^{35}(\gamma, 3\alpha)$. The selection criterion used is that the momentum unbalance shall not exceed two units of Mev times mass number. Of the 778 stars analyzed, 292 of them were found to meet the requirements and are believed to represent the reaction mentioned above. A histogram was plotted of number versus photon energy for 292 stars in order to get an idea of the variation in cross section for this reaction. The histogram was found to agree in all

major details with that given by Goward and Wilkins [Proc. Phys. Soc. A, 217, 357 (1953)], but the curve is shifted about one Mev towards the high energy side. It is believed that the range-energy tables used are not exactly applicable; they are being corrected for the present experimental conditions.

All three-prong stars from the first plate were assumed to be due to the reaction $N^{14}(\gamma, 2\alpha)Li^6$, and each prong in turn was taken as Li^6 . Three sets of momentum unbalances were calculated with the help of IBM computing machines. The calculations have not been corrected for the momentum of the photon as yet but seem to indicate that the number of stars which may be identified with the above reaction is large.

1.4 Radionuclide Studies

1.4.1 Irradiation of Scandium (D. J. Zaffarano)

A search has been made for the nuclide Sc^{42} , which should have a predicted half life of several seconds, from isotopic spin considerations. This should be produced by the reaction $Sc^{45}(\gamma, 3n)Sc^{42}$. A very pure sample of scandium metal, as well as one of Sc_2O_3 , was irradiated in the synchrotron. A scintillation spectrometer was used to discriminate against all beta-rays below 1.8 Mev (the end point of the Sc^{42} beta spectrum is expected to be approximately 5 Mev), and a very weak activity with a half life of 0.9 second was found. The calculated threshold for the desired reaction is 34.5 Mev. When the maximum energy of the X-ray beam was adjusted to be lower than this energy, the 0.9 second activity still appeared.

It is known that the scandium used in this experiment may contain as much as 0.09% Ca. The reaction $Ca^{40}(\gamma, n)Ca^{39}$ has a threshold of 13.9 Mev, and Ca^{39} has a known half life of about 0.9 seconds. Hence no definitive evidence of the presence of Sc^{42} has been found. The experiment is being continued.

1.4.2 Decay Scheme of Sb^{125} (S. A. E. Johansson)

A report (ISC-432) entitled "The Decay Scheme of Sb^{125} " by Sven A. E. Johansson was distributed.

Abstract

The radiations from Sb^{125} have been studied by means of a coincidence scintillation spectrometer. The energy values of three beta rays and eight gamma rays have been determined, and their coincidence relations have been completely investigated. A decay scheme is proposed. Assignments of spin and parity to the different levels have been made.

1.4.3 Transmission of Electrons by Thin Films (D. J. Zaffarano)

A report (ISC-439) entitled "Transmission of 0-50 Kev Electrons by Thin Films with Application to Beta-Ray Spectra" by R. O. Lane and D. J. Zaffarano was distributed.

Abstract

The transmission of electrons by thin films as a function of the incident energy of the electrons was measured using thermal electrons which were accelerated across a known potential difference. The electrons transmitted by the film were detected by a Faraday collector. The extrapolation of the linear portions of the transmission curves to zero transmission gave practical values of energy, E_p , for the films which were shown to correspond to practical ranges of electrons in Al as given by Schonland, whose thinnest film was 0.25 mg/cm² in area density. The ranges of electrons in films of area density as low as 0.023 mg/cm² was measured, which is considerably lower than the area densities reported in previous range-energy measurements. It is found that all values of E_p fall within 15% of those calculated from the relation $E_p = 22.2R^{0.6}$, where E_p is in kev and R is in mg/cm². This relation holds between 1.5 and 25 kev. Transmission experiments on a 0.012 mg/cm² collodion film which was not coated with Al indicated that it was essentially a conductor under the conditions of the experiment. Similar measurements on an uncoated 0.3-mg/cm² Formvar film resulted in a hysteresis effect, indicating a considerable accumulation of charge on the film. One of the Al-coated Formvar films for which the transmission curve had been measured was employed as the window in a G-M counter in a thin-lens β -ray spectrometer. When the transmission curve for the window was applied to the β -ray spectrum of a 0.0002-mg/cm² source of Pm¹⁴⁷ on a 0.006-mg/cm² collodion backing, an over-correction resulted in the Fermi plot. Multiple scattering calculations estimate that most of this over-correction may well be accounted for by the fact that the counter and Faraday collector subtend different solid angles of collection. The Fermi plot of Cl¹⁴ was found to be linear for energies above 40 kev. The thinnest source had an effective thickness of about 1.5 mg/cm², so that little can be said from this investigation concerning the true shape of the Cl¹⁴ Fermi plot below 40 kev.

1.5 Improved New-Type Synchrotron Injector (D. J. Zaffarano)

A new record of 800 Roentgens per minute at one meter has been obtained for the intensity of the synchrotron beam at 65 Mev. It is thought that the improved injector which has been designed and built here is primarily responsible for the increased intensity. The injector stem is all metal, except for small insulators, and utilizes tungsten filaments held in collets which may be easily opened for filament replacement.

2. Solid State Studies

2.1 Measurements of Magnetic Field Gradients (G. C. Danielson)

The new device for measuring magnetic field gradients by measurements of Hall voltage differences has been tested semi-quantitatively. The corrected readings of the device compared very well with gradients obtained by taking slopes of a magnetic field versus distance curve. This was done for the gradient at the edge of the pole pieces of an electromagnet. It is planned to compare the readings of the device with a calculable gradient obtained from a step pole arrangement.

2.2 Mass Spectrometric Study of Metallic Phase Transitions (D. E. Hudson and F. H. Spedding)

A vacuum-distilled sample of dysprosium metal was obtained in order to ascertain the effects of purity on our measured heats of sublimation (ΔH). Two determinations of ΔH gave 68.4 and 68.0 kilocalories per mole. The previous mean value for cast Dy (not vacuum distilled) was 67.1 kilocalories per mole. Apparently the purer samples show a somewhat higher ΔH value.

2.3 Latent Heats of Metals (D. E. Hudson and F. H. Spedding)

A report entitled "Mass Spectrometric Determination of Latent Heats of Metals," (ISC-293) by R. G. Johnson, D. E. Hudson, and F. H. Spedding was distributed.

Abstract

A modification of the Knudsen method of determining vapor pressures was made. The modified method gave heat of vaporization measurements and melting point measurements for certain metals of low volatility. The technique which was developed made use of a 60° Nier-type mass spectrometer with a hot tungsten filament as the ionizing mechanism. Atoms from a Knudsen effusion vessel were allowed to fall upon a hot, clean filament and evaporate. A certain fraction of the atoms became ionized in the evaporation process, and this fraction constituted the ion beam in the mass spectrometer. The ion beam was directly proportional to the vapor pressure in the effusion vessel since the geometry of the system and ionizing efficiency of the filament were maintained constant. Latent-heat values were obtained utilizing the fact that only a quantity directly proportional to the vapor pressure need be known. The latent heats of vaporization of aluminum, praseodymium, and neodymium were measured from 900 to 1200°C. The heat of vaporization of aluminum was found to be 80.02 ± 0.39 kcal/mole at 1059°C. In the work on praseodymium it was possible to obtain heat of vaporization values in agreement with the value found earlier by Daane using the Knudsen method. However, inconsistencies between the data obtained from different samples of praseodymium and from the same samples with different amounts of heating in the effusion

crucible remain unexplained. The neodymium data also exhibited unexplained variations, but they were of a much lesser extent. The heat of vaporization of neodymium under the usual Knudsen conditions was found to be 70.6 ± 0.4 Kcal/mole at 1075°C . A phase transition in the condensed state was found in praseodymium at $919 \pm 2.5^\circ\text{C}$. A previously unreported transition was found in neodymium at $1019 \pm 2.5^\circ\text{C}$. On the basis of subsequent independent and as yet unpublished work done at this laboratory, it has been demonstrated conclusively that this corresponds to the melting point transition. A transition was also observed at a temperature of $869 \pm 2.5^\circ\text{C}$. Preliminary measurements were made of the first ionization potentials of praseodymium and neodymium using surface ionization theory and data obtained mass spectrometrically. Values of 5.4 and 5.5 v, respectively, were found.

2.4 Low Temperature Studies (S. Legvold and F. H. Spedding)

ISC-424, "Low Temperature Dilatometric Study of Some Rare Earth Metals," by F. Barson, S. Legvold and F. H. Spedding was distributed.

Abstract

A sensitive dilatometer was designed and constructed. Employing the principle of interference of light, this dilatometer made possible the measurement of changes in length on the order of 10^{-5} cm. The coefficients of linear thermal expansion of several rare earth metals were determined between 100 and 340°K . The metals tested and their coefficients of linear thermal expansion at room temperature are given. The trend seems generally to be toward an increase in the coefficient of expansion with increasing atomic number, the only exception being Gd, which is anomalously low at room temperature due to the Curie point of this metal at 289°K . Dysprosium also exhibited this extraordinarily low coefficient of expansion in the region of a magnetic anomaly at 175°K . Below room temperature, the coefficients of expansion of these metals decreased in value. Exceptions to this general rule were Pr and Nd, whose expansion increased slightly below about 220°K . The limits of error were estimated from the probable errors in the experimental readings and from the reproducibility obtained between successive runs on the respective metals.

APPENDIX: LIST OF REPORTS FROM THE AMES LABORATORY

1. Reports for Cooperating Laboratories

- ISC-293 Mass Spectrometric Determination of Latent Heats of Metals. R. G. Johnson, D. E. Hudson, and F. H. Spedding.
- ISC-313 Fluorescence Spectrometric Determination of Terbium. V. A. Fassel and R. H. Heidel.
- ISC-355 Conductances, Transference Numbers and Activity Coefficients of Some Rare Earth Chlorides in Aqueous Solution. J. L. Dye and F. H. Spedding.
- ISC-358 The Preparation, Purification and Some Analytical Applications of α , β , γ , δ -Tetraphenylporphine. J. H. Priesthoff and C. V. Banks.
- ISC-379 Heats of Solution and Related Thermochemical Properties of Some Rare Earth Metals and Chlorides. J. P. Flynn and F. H. Spedding.
- ISC-422 Physics. Quarterly Summary Research Report. July, August, and September, 1953. Ames Laboratory Staff.
- ISC-424 Low Temperature Dilatometric Study of Some Rare Earth Metals. F. Barson, S. Legvold and F. H. Spedding.
- ISC-428 Temperature Distribution in a Metal Cylinder Containing a Heat Source. L. R. Pletke and G. Murphy.
- ISC-430 A New Approach to Direct Reading Spectrochemical Analysis. R. K. Brehm and V. A. Fassel.
- ISC-431 A Coincidence Scintillation Spectrometer. Sven A. E. Johansson.
- ISC-432 The Decay Scheme of Sb^{125} . Sven A. E. Johansson.
- ISC-433 The Use of Copper as the Retaining Ion in the Elution of Rare Earths with Ammonium Ethylenediaminetetraacetate Solutions. F. H. Spedding, J. E. Powell and E. J. Wheelwright.
- ISC-434 Measurement of the Electrical Resistance of Metals and Alloys at High Temperatures. P. Chiotti.
- ISC-435 The Effect of Stray Light in Prism and Grating Spectrographs on Emulsion Calibration Curves and Its Significance in Spectrographic Analysis. R. N. Kniseley and V. A. Fassel.

- ISC-439 Transmission of 0-50 Kev Electrons by Thin Films with Applications to Beta-Ray Spectra. R. O. Lane and D. J. Zaffarano.
- ISC-438 The Kinetics of the Reduction of Perchlorate Ion by Ti(III) in Dilute Solution. F. R. Duke and P. R. Quinney.
- ISC-441 The Kinetics of the Periodate Oxidation of Ethylene Glycol and a Series of Methylated Ethylene Glycols. F. R. Duke and V. C. Bulgrin.
- ISC-446 Molecular Calculations. III. A Modification of the Naive Semi-Empirical MO Method. L. Goodman and H. Shull.
- ISC-455 A Precision Pulse Generator. C. E. Harper.

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