Minutes of the Pacific Northwest Meeting, Held at Seattle, Washington, and on Mount Painter, July 7, 8, 9, and 10, 1954

(Corresponding to *Bulletin of the American Physical Society*, Volume 29, No. 6)

The 1954 Summer Meeting of the American Physical Society was held at Seattle on the Campus of the University of Washington, on Wednesday, Thursday, and Friday, July 7, 8, and 9, and on Mount Rainier on Saturday, July 10. The meeting was very well attended and the local arrangements were excellent. The Secretary wishes to thank Professor E. A. Uehling and his local committee for their part in the planning of the meeting and in making these fine arrangements. The sessions arranged by our Division of Fluid Dynamics were its first in the Pacific Northwest, and they were excellent and well-attended sessions. Post-deadline papers were given by K. Krishnamurty of the California Institute of Technology on "Production of Sound at Cut-Outs on an Aerodynamic Surface"; by E. Segrè, R. Tripp, C. Wiegard, and T. Ypsilantis of the University of California, Berkeley, on "Depolarization on Scattering of Polarized Protons from Hydrogen"; and by M. Schein, D. M. Haskin, and R. G. Glasser of the University of Chicago on "Narrow Beam of Pure Photons Probably Arising from the Annihilation of a High Energy Cosmic Ray Particle Close to the Top of the Atmosphere." Papers F14 and L14 were ready by title.

The demonstration cruise of the *HMCS Cedarwood*, the research ship of the Royal Canadian Navy, an outdoor salmon barbecue, and the luncheon of the Society, combined with the relatively leisurely tempo of the meeting, made this one of the most enjoyable ones of recent years.

J. Kaplan, *Local Secretary for the Pacific Coast*

Errata Pertaining to Papers I12 and N3

I12, by S. A. Heiberg. In the next to the last line, 30 millibarns should read 10 millibarns.

N3, by B. H. Muller and Myer Bloom. In line 9, 4.3 A should read 4.2 A. In line 10, 2.27 A should read 2.19 A.

PROGRAMME

WEDNESDAY MORNING AT 9:30

Guggenheim Hall

(R. T. ELLICKSON, presiding)

Contributed Papers

A1. Adiabatic Theorems in Field Theory. S. DESER,* *Institute for Advanced Study.*—The effect of a particle in the limit of infinite mass is investigated field theoretically. Using a technique expressing the relevant exact propagation functions as functional integrals, the desired limiting process need only be performed on a simple propagator for one particle in an external field to get the result for the exact functions. By comparing the resultant propagator for n particles of which m become infinitely heavy with that for n-m particles in an external field, it is shown that the heavy particles act as point sources of static fields determined by the nature of the intermediate particles (maxwell, scalar meson, etc.) and the usual vacuum polarization effects due to virtual pairs of any lighter fields. In the case of mesons with no nonrelativistic limit, as $ps(ps)$, the situation is more complicated. By means of a Foldy transformation and absorption of the mass into the coupling constant, a nonzero resultant potential may be obtained. Weak and strong coupling limits thereof will be discussed. Further applications of the functional technique are in progress.

* On summer leave at University of California, Berkeley.

A2. Critical Flow Rate and Zero Entropy of Helium Superfluid. WILLIAM BAND, *State College of Washington.*—A Bose-Einstein assembly with nondegenerate energy spectrum has only one symmetrized wave function for any distribution-in-energy: the entropy is therefore absolutely zero at all temperatures. The Heisenberg uncertainty relation may blur the energy levels until they overlap each other, validate the usual approximations, and produce entropy. This mechanism may fail in liquid helium superfluid. B. E. statistical fluctuations into the lowest states may be localized with linear dimensions L, energy levels spaced roughly $h^2/8\pi m^*L^2$, where m^* is effective mass required to give the observed lambda transition temperature: $m^*=1.55m_{He}$. The fluctuation life time τ is long enough to keep the levels distinct and destroy entropy if $\tau h/8\pi m^*L^2 > 1$. Assuming τ given by thermal conductivity relaxation times,[1] $\tau u_s^2=0.05$ cm²/sec at 2°K, where u_s is the speed of transport of superfluid. Substitution yields $u_sL=10^{-3}$ cm²/sec. The fluctuations can therefore be fed into a capillary of width 3×10^{-5} cm at a speed 30 cm/sec, all entropy filtered out. A higher speed would force shorter relaxation time, broaden the energy levels and restore normal entropy in the capillary.

[1] L. Meyer and W. Band, Phys. Rev. **74**, 394 (1948).

A3. Electrohydrodynamics. I. Equilibrium of a Charged Gas in a Container. JOSEPH B. KELLER, *Mathematics Branch, Department of the Navy, Washington 25, D. C.*—Since phenomena involving the equilibrium or motion of fluids in which magnetic forces are important are called magnetohydrodynamic phenomena, it seems appropriate to designate as electrohydrodynamics that class of phenomena in which the equilibrium or motion of a fluid is involved and in which electric forces are important. A typical phenomenon of this type is the equilibrium of a charged gas within a container. In this example, equilibrium is achieved when electrostatic and pressure forces balance each other. It is, therefore, necessary to determine the pressure p, the electric field E, and the electric charge density ρ, in order to solve this problem. These quantities satisfy the equilibrium equation and Poisson's equation which are $\nabla p=\rho E$, $\nabla\cdot E=4\pi\rho$. Furthermore, according to the equation of state, p is a function of the mass density which is assumed to be $(m/e)\rho$, where m/e is the mass-charge ratio of the charged particles constituting the gas. Thus, $p=p[(m/e)\rho]$. For a perfect gas in which p is proporitonal to ρ, both p and E can be eliminated from the preceding equations leading to the following equation for q which is essentially $\log\rho$: $\nabla^2q=e^q$. In addition to the preceding equations, the total charge within the container must be specified, and if the container is a perfect conductor, the tangential component of electric field must be required to vanish on its surface. It is shown that for every value of the total charge there is one and only one solution of the preceding equations, satisfying the conditions just stated. The density and pressure are both constant on the surface of the container for each value of the total charge and $|\rho|$ assumes its maximum value on this surface. Furthermore, at each point of the container ρ increases as the total charge does.

A4. Oscillation and Stability in Certain Nonlinear Systems. WILLIAM M. WHYBURN, *University of North Carolina and U. S. Naval Ordnance Test Station* (introduced by J. Kaplan).—A simple pendulum is an elementary example of a nonlinear system which oscillates and is stable in the sense that amplitudes remain bounded for all time. This system is a special case of a class of nonlinear systems discussed in the present paper. Conditions are given under which solutions of such systems oscillate and are stable. Under other conditions, the solutions are shown to be unstable. Special consideration is given to the second order differential system $y'=K(t,y,z)z$, $z'=G(t,y,z)y$ and principal results are stated for this system. Some reference is made to nth order systems where conditions of uniqueness fail and solutions of critical types exist.

A5. A Semiautomatic Apparatus for Thermocouple Comparison and Calibration. T. M. DAUPHINEE, *National Research Council, Ottawa.*—Several thermocouples are continuously intercompared with a standard couple of the same type over a wide temperature range. A permanent record of the total emf of the standard thermocouple and the emf difference between the standard and each of the other thermocouples appears on a recorder strip chart, the accuracy of the difference measurement being better than $\pm1\mu v$. If desired, comparison between the corresponding individual elements of the standard and test thermocouples may be obtained at the same time. Temperature is varied at any required rate by means of a motor controlled variac. The hot junctions of the thermocouples are welded together to ensure identity of temperature in spite of the nonequilibruim conditions in the furnace. An isolating potential comparator[1] allows the emf difference measurements to be made in spite of this electrical connection at the junction.

[1] T. M. Dauphinee, Can. J. Phys. **31**, 577 (1953).

A6. The Creep of Aluminum Under Cyclotron Irradiation.* A. ANDREW,† M. R. JEPPSON,‡ R. L. MATHER,§ AND H. P. YOCKEY.‖—The effect of cyclotron irradiation on the steady-state creep rate of aluminum has been measured at beam densities up to 1.2×10^{13} alpha particles per cm² per second. The

data show a slight decrease in rate (up to 19 percent) during irradiation. Since the effect is small, apparently independent of beam density, and is comparable to the usual deviations in the absence of radiation, it can be considered a null result. A description of the apparatus and techniques used will also be given.

* This work was based on studies conducted for the U. S. Atomic Energy Commission.
† North American Aviation, Inc., Atomic Energy Research Department, Downey, California.
‡ Now at Applied Radiation Corporation, Walnut Creek, California.
§ Now at NRDL, San Francisco, California.
‖ Now at ORNL, Oak Ridge, Tennessee.

A7. Reversibility of the Additive Coloring Reaction in KCl.* D. R. Westervelt, *Atomic Energy Research Department, North Americal Aviation, Inc.*—Shamovsky, Rybakova, and Gosteva[1] recently have reported experiments which suggest that the additive coloring process is irreversible. This conclusion was based on observations that the *F*-center concentration obtained was independent of the metal used in coloring, hence, on the atomic concentration in the vapor; and that after coloring at one temperature further heating at a lower temperature did not result in a decrease in the *F*-center concentration. Because of the importance of these assertions, which tend to invalidate the present theory of additive coloring, some of the Russian experiments have been repeated. It was found that crystals of KCl colored in saturated K vapor at 575°C contained 3.0 times the *F*-center density of crystals colored at 520°C, but those colored first at 575°C and subsequently heated in the vapor at 520°C did not differ in concentration from those heated only at 520°C by more than 10 percent. Equilibrium was verified at each temperature. KCl colored in saturated K and Na vapors at 725°C agreed in *F*-center density within 50 percent, whereas the atomic concentrations in the vapor differ by a factor of 5. An explanation for this result is given within the framework of an extension of the equilibrium theory of the reaction between alkali metal vapor and alkali halides.[2] The results obtained thus do not confirm the reported irreversibility of the additive coloring reaction.

* This report is based on studies conducted for the U. S. Atomic Energy Commission.
1 Shamovsky, Rybakova, and Gosteva, Doklady Akad. Nauk SSSR, **91**, 67 (1953).
2 D. R. Westervelt, "Theory of the reaction between alkali metal and alkali halides," NAA-SR report (to be published).

A8. Application of the Engravement Method to the Study of Particle Velocity Distribution in Explosively Loaded Cylinders. John Pearson and John S. Rinehart, *Michelson Laboratory, U. S. Naval Ordnance Test Station.*—The engravement method for measuring high-intensity transient stress wave particle velocities in impulsively loaded bodies[1] has been used to study the particle velocity distribution in the walls of modified thick-walled metal cylinders internally loaded with explosive charges. Particle velocity measurements have been obtained to within $\frac{1}{2}$ inch from the metal-explosive interface. Even though each of the modified cylinders broke into a number of fragments, the engravements were well enough preserved to furnish considerable data. Temporal and spatial particle velocity distribution curves have been obtained for cylinders of annealed low-carbon steel and brass.

1 J. S. Rinehart and J. Pearson, J. Appl. Phys. **24**, 462 (1953).

A9. A Critical Angle Associated with High Speed Impact of a Sphere on a Thin Plate. William A. Allen, Joe M. Mapes, and Wesley G. Wilson, *Michalson Laboratory, U. S. Naval Ordnance Test Station.*—Steel spheres $\frac{1}{2}$ in. in diameter have been fired at velocities in excess of 3000 ft/sec through thin steel plates. The recovered projectile is marked by a series of concentric circular rings caused by lateral plastic deformation. All rings are characterized by radii $r>r_0(v)$, where r_0 is a critical radius that depends upon the velocity v of the sphere. Spacing of a given ring from its neighbor can be approximated by a term of an infinite geometrical series. The sum of the infinite series is used to determine the critical radius. This radius bears a relation to the critical angle obtained by a Los Alamos Scientific Laboratory group from another kind of experiment.[1] The phenomenon of the critical radius is explained by means of hydrodynamical concepts of compressible flow of steel treated as a fluid without viscosity or heat conduction. The experimental evidence has been compared with predictions from two published[1,2] theoretical equations of state for iron.

1 Walsh, Shreffler, and Willig, J. Appl. Phys. **24**, 349 (1953).
2 Pack, Evans, and James, Proc. Phys. Soc. (London) **60**, 1 (1948).

A10. Ablation from Ultra-Speed Pellets. William C. White, *Michelson Laboratory, U. S. Naval Ordnance Test Station.*—It has been observed on continuous motion picture photographs of ultra-speed pellets[1] that some of the ablated material appears as luminous streaks. These streaks were measured to determine the velocities of the ablated particles. From aerodynamic considerations, particle radii and masses were determined. A count of the number of streaks per unit path length yields ablated mass per unit length and rate of ablation.

1 Allen, Rinehart, and White, J. Appl. Phys. **23**, 132 (1952).

A11. The Rittinger's Number for Several Minerals. M. E. Backman and H. L. Morrison, *Michelson Laboratory, U. S. Naval Ordnance Test Station.*—Rittinger's number[1] is known for many common materials but is still undetermined for some minerals and ores. The values for five materials have been obtained using the method of Gross and Zimmerly[2] for determining the energy of fracture and a flow permeability method for obtaining the surface created during fracture. These values are as follows: volcanic breccia 15.2 cm^2/kg cm, limestone 16.5 cm^2/kg cm, an iron ore 6.0 cm^2/kg cm, pyrophyllite 33.2 cm^2/kg cm, and quartzite 11.2 cm^2/kg cm. The method of measurement is reviewed, changes in equipment and details of the procedure are discussed.

1 von Rittinger, *Lehrbuch der Aufbereitungskunde* (Berlin, 1867).
2 J. Gross and S. R. Zimmerly, Am. Inst. Mining Met. Engrs. Tech Pub No. 126 (1928).

Wednesday Morning at 9:30

Physics 320

(G. M. Shrum, presiding)

Contributed Papers

B1. The Spectra of Indium. R. A. Nodwell and A. M. Crooker, *University of British Columbia*.—Approximately 350 indium lines have been measured in the spectral region from 1200A to 6900A. Many lines previously reported in indium I and indium II have been confirmed, and several lines not previously reported have been classified in indium II. Most of the lines measured are high excitation and attempts are being made to classify them in the indium III spectrum. An electrodeless discharge has been used as a source, and the light analyzed by means of a vacuum grating spectrograph in which the test sample is exposed through a slit with an angle of incidence at 80° and a comparison source is exposed simultaneously through a slit with angle of incidence at 21°, thus making it possible to compare the wavelength in the vacuum ultravoilet region directly with known wavelengths in the visible or near visible region.

B2. Spectra of Arsenic. R. E. Bedford and A. M. Crooker, *University of British Columbia*.—The spectra of arsenic in the visible and ultraviolet regions have been photographed with a 21-foot grating and a Littrow prism spectrograph using an electrodeless discharge. The wavelengths of approximately 1000 lines ranging from 2300–6500 A have been measured relative to iron standards. Many of these have previously been classified by A. S. Rao[1] and several others have been assigned to transitions in AsII, AsIII, and AsIV. From preliminary investigations it appears that the following new terms have been located in AsIII.

$4s^25g\ ^2G$	39.00 cm^{-1}
$6g\ ^2G$	27.535
$7g\ ^2G$	20.253
$6d\ ^2D_2$	37.223 (called $5g\ ^2G$ by K. R. Rao).[2]

In AsIV the multiplet $4s5d^3D-4s6p^3P$ has been identified leading to the new terms

$4s6p^3P$	87.574 cm^{-1}
$^3P^0$	87.478
$^3P_2$	87.296.

Further analysis is currently in progress, including the photography of the spectra in the infrared and vacuum ultraviolet regions.

[1] A. S. Rao, Ind. J. Phys. **16**, 561 (1932).
[2] K. R. Rao, Proc. Phys. Soc. (London) **43**, 68 (1931).

B3. The g Factors of the ^3P Terms of Atomic Oxygen. K. Kambe and J. H. Van Vleck, *Harvard University*.—Abragam and Van Vleck[1] have calculated the deviations of the g factors of the $2p^4\ ^3P$ terms of atomic oxygen from the simple Lande formula which arise from a variety of causes, *viz.*, relativity, spin-orbit interaction, diamagnetic screening, the motion of the nucleus, and the Schwinger quantum-electrodynamical correction. However, for simplicity they nelgected exchange and assumed that the charge distribution in which any $2p$ electron moves in centro-symmetric despite the fact that the three other $2p$ electrons do not really form a closed shell. The present paper refines the calculations by no longer making these two simplifying assumptions. The procedure consists in expanding the correction terms in the Hamiltonian in a finite series of spherical harmonics in a fashion very similar to that in the standard Slater expansion of $1/r_{ij}$. The diagonal matrix elements in the $1sm_lm_s$ system are first calculated, and those in the LSJM scheme obtained from the invariance of the diagonal sum. The most important integrals have already been computed for a Hartree-Fock self-consistent field by Hartree, Hartree, and Swirles,[2] while the remaining integrals have been estimated by employing modified Slater-type wave functions. We find $g(^3P_1)=1.500974$, $g(^3P_2)=1.500913$ to be compared with the experimental[3] values $g(^3P_1)=1.500971$, $g(^3P_2)=1.500905$.

[1] A. Abragam and J. H. Van Vleck, Phys. Rev. **92**, 1448 (1953).
[2] Hartree, Hartree, and Swirles, Trans. Roy. Soc. (London) **A238**, 229 (1939).
[3] E. B. Rawson and R. Beringer, Phys. Rev. **88**, 677 (1952).

B4. Magnetic Interactions in $'\Sigma$ Molecules.* Robert L. White,† *Columbia University*.—In a second-order approximation the electronic angular momentum of a rotating $'\Sigma$ molecule is not zero. The associated magnetic field is on the same order of magnitude as the field arising from the rotation of the positively charged nuclear frame. The total resultant field interacts with the magnetic moments of the nuclei of the molecule to produce an interaction of the form $W_{\text{mag}}=[c_1+(c_2-c_1)K^2J^{-1}(J+1)^{-1}]\mathbf{I}\cdot\mathbf{J}$ for a nucleus on the symmetry axis of a symmetric top molecule. The c_i may be of either sign, depending upon both nuclear and molecular parameters. The algebraic values of c_i for the molecules $O^{17}CS$, OCS^{33}, $OCSe^{79}$, $Cl^{35}CN^{14}$, $Cl^{35}CN^{15}$, CH_3Cl, SiH_3Cl, and GeH_3Cl have been measured on a high resolution bridge-type microwave spectrometer. A correlation between measured and theoretical c_i for these molecules and for a number of others for which c_i is known (primarily from molecular beams data) will be given. The molecular parameters thus obtained will be compared with those inferred from molecular g factors and diamagnetic susceptibilities.

* This research supported jointly by the U. S. Army, U. S. Navy, and U. S. Air Force under contract with Columbia University.
† Present address, Hughes Research and Development Laboratories, Culver City, California.

B5. Ground-State Potential Constants of ClO_2,† J. K. Ward, *Agricultural and Mechanical College of Texas** (introduced by J. B. Coon).—Sufficient information is available to compute the four harmonic potential constants of the ground state of ClO_2. Coon's[1] ultraviolet rotational structure analysis furnishes $2\bar{B}''=0.612\pm0.003$, $2(\bar{B}'-\bar{B}'')=-0.0615\pm0.001$, and $2(A'-A'')=-1.250\pm0.006$ cm^{-1}; a least-square treatment of Nielsen and Woltz's[2] infrared rotational structure data yields $2(A''-\bar{B}'')=2.831\pm0.01$ cm^{-1}. From this data one obtains $2\theta''=117.4\pm0.2°$, $r_0''=1.472\pm0.005$A, $2\theta'=107.4\pm0.4°$, $r_0'=1.620\pm0.015$A. By using $2\theta''$ in conjunction with $\omega_1''=964.8$, $\omega_2''=451.8$, and $\omega_3''=1127.3$ cm^{-1} given by Coon and Ortiz,[3] and one isotope shift $\Delta\omega_1''=-6.41$ cm^{-1},[4] the ground-state valence potential constants are determined: $k=6.990$, $k_\theta=0.649$, $k_1=-0.191$, $k_2=-0.035\times(10)^5$ dyne-cm^{-1}. Poor agreement exists with potential constants determined using three ground-state frequencies and the criterion of Glockler and Tung:[5] $k=7.411$, $k_\theta=0.803$, $k_1=0.230$, $k_2=0.930\times(10)^5$ dyne-cm^{-1}. Disagreement also exists with the prediction of Duchesne and Nielsen[6] that k_1 and k_2 should be positive.

† This research was supported by the U. S. Air Force through the Office of Scientific Research of the Air Research and Development Command.
* Now at Boeing Airplane Company, Seattle, Washington.
[1] J. B. Coon, J. Chem. Phys. **14**, 665 (1946).
[2] A. H. Nielsen and J. H. Woltz, J. Chem. Phys. **20**, 1878 (1952).
[3] J. B. Coon and E. Ortiz, Phys. Rev. **82**, 766 (1951).
[4] J. B. Coon (to be published).
[5] G. Glockler and J.-Y. Tung, J. Chem. Phys. **13**, 388 (1945).
[6] J. Duchesne and A. H. Nielsen, J. Chem. Phys. **20**, 1968 (1952).

B6. Polarized Infrared Absorption Spectrum of Gypsum. D. S. WEBBER, *University of California, Los Angeles.*—The absorption spectrum of gypsum, $CaSO_4 \cdot 2H_2O$, has been obtained in the region from 3000 cm^{-1} to 9000 cm^{-1} using polarized radiation. A detailed analysis of the structure observed in the broad water band in the 3000 cm^{-1} to 4000 cm^{-1} region is reported in this paper. The high-resolution prism grating spectrometer described by Lyon and Kinsey[1] was used in this work. Polarization was achieved with a pile of selenium films placed in front of the exit slit of the spectrometer. The samples were placed just behind the exit slit. This arrangement of polarizer and sample eliminates spurious polarization effects. Samples were prepared with faces parallel to the perfect cleavage plane in the gypsum. Components of the band have been identified with the fundamentals of the symmetric and asymmetric stretching modes and the first overtone of the bending mode of water. Other components have been interpreted as bands caused by the couplings of three hindered translations and two hindered rotations with the molecular vibrations of the water molecule.

[1] W. K. Lyon and E. L. Kinsey, Phys. Rev. **61**, 482 (1942).

B7. Energy Parameters of Two-Dimensional Graphite. G. S. COLLADAY, *Michelson Laboratory, U. S. Naval Ordnance Test Station.*—In the theoretical study of the 2-dimensional model of graphite[1,2] certain energy parameters, E_0, γ_0, γ_0', occur which cannot be explicitly evaluated due to a lack of knowledge concerning the lattice potential function. These parameters are evaluated by combining the energy expression $E(\mathbf{K})$ for the valence π electrons with experimental data, e.g., work function of graphite, soft x-ray emission spectrum, thermochemical data. In calculating $E(\mathbf{K})$, first and second nearest neighbors have been included in the overlap and resonance integrals.

[1] P. R. Wallace, Phys. Rev. **71**, 622 (1947).
[2] C. A. Coulson and R. Taylor, Proc. Phys. Soc. (London) **A65**, 815 (1952).

B8. Thermal Conductivity of Single Crystalline Silicon. G. W. HULL AND T. H. GEBALLE, *Bell Telephone Laboratories.*—Measurements of the thermal conductivity k of single crystal silicon have been made from liquid hydrogen temperatures to room temperature on a filament cut from a crystal pulled in the (100) direction. Analysis of Hall data for this crystal indicates a total impurity concentration of 10^{-6} atom percent. A room temperature value of $k=1.48$ watt units for this sample is to be compared with the current literature value of 0.84 watt units. k rises to a value of 9 at 80°K and 19.5 at 30°K with no sign of reaching its maximum value. The relative thermal conductivities of a series of samples in which arsenic atoms have been added up to 0.05 atom percent as determined by Hall measurements have also been observed. Isotherms of k decrease rapidly in the concentration range above 10^{-4} atom percent, while there seems to be little variation in k at lower concentrations even at 30°K. The room temperature value of k for the 0.05 atom percent sample is down to 0.90 watt unit; at 75°K it is less by a factor of 5 than k for the 10^{-4} atom percent sample.

B9. Seebeck Effect in Single Crystal Silicon. T. H. GEBALLE AND G. W. HULL, *Bell Telephone Laboratories.*—The Seebeck effect has been investigated in single crystal silicon as a function of excess concentration of charge carriers produced by addition of arsenic atoms. Measurements have been made from liquid hydrogen temperatures to above room temperature and compared with Hall data for the same samples. The results show a very large rise in Q, the Seebeck voltage per degree difference between junctions, as the temperature decreases. This is the same behavior previously observed in germanium.[1] The large values of Q are attributed to the type of phonon-electron interaction postulated for germanium. A sample of large dimension in which boundary scattering effects are reduced reaches a value of 59 millivolts per degree at 30°K and varies as $T^{-2.1}$. Consideration of the Hall data indicates that the $T^{-2.1}$ behavior is approximately characteristic of the phonon-electron interaction all the way to room temperature. Q passes through zero and becomes positive below 13°K for a sample with 2.2×10^{18} arsenic atoms per cc. This together with an abnormal drop in Hall mobility at 16°K previously observed by Morin and Maita[2] for the same sample suggests impurity band conduction.

[1] T. H. Geballe and G. W. Hull, Phys. Rev. (to be published).
[2] F. J. Morin and J. P. Maita, Phys. Rev. (to be published).

B10. Dependence of Signal-to-Noise Ratio in Photoconductive PbSe Layers on the Temperature of the Black-Body Source.* A. M. CROOKER AND E. B. DORLING, *University of British Columbia.*—We have prepared sensitive PbSe photoconductive cells and measured the signal/noise ratio obtained with a black body source at 200°C and 500°K. This experiment has been done with the cell at room temperature and at liquid air temperature. The results are compared with what one calculates assuming that the long wave cutoff of the cell is linear and that this cutoff shifts as reported by Moss.[1]

* This work is supported by the Defence Research Board, Ottawa.
[1] T. S. Moss, Proc. Phys. Soc. (London) **B62**, 741 (1949); **B63**, 167 (1950).

B11. Microwave Properties of Manganese-Ferrite Single Crystal.* P. E. TANNENWALD, *M.I.T.*—Resonance absorption and anisotropy measurements have been carried out on a single crystal of Mn-ferrite (~10 ohm-cm resistivity) between room temperature and 4.2°K. A 0.42-mm sphere was rotated in an X-band waveguide-type cavity in such a way that the dc magnetic field always lay in a (110) plane of the crystal but along different crystallographic axes. At room temperature the dispersion has also been measured, and the Kramers-Krönig relations are found to be satisfied. Comparison of the real and imaginary parts of the susceptibility with the Bloch-Bloembergen theory gives fair agreement. ΔH, the full width at half-power absorption, decreases from 260 oersteds at 20°C to 130 oersteds at 4.2°K and is the same in the three principal crystal directions at each temperature. The anisotropy increases sharply as the temperature is lowered but decreases again slightly below 77°K. The g factor is practically constant at a value of 2.00. A secondary peak has been observed at low temperatures and in certain crystal directions. Details of this peak will be presented and its possible origin will be discussed.

* Supported jointly by the U. S. Army, Navy, and Air Force under contract with the Massachusetts Institute of Technology.

B12. Fermi-Dirac Degeneracy in Liquid He^3 below 1°K.* W. M. FAIRBANK, W. B. ARD, G. K. WALTERS, *Duke University.*—The temperature dependence of the nuclear magnetic susceptibility of liquid He^3 has been measured directly down to 0.2°K. by observing the strength of the nuclear magnetic resonance absorption signal. These measurements give an answer to the much discussed question of the extent to which liquid He^3 behaves as an ideal Fermi-Dirac gas. At sufficiently low temperatures the spins of the particles of an ideal Fermi-Dirac gas would be expected to line up antiparallel and this would cause the spin magnetic susceptibility to deviate from the classical $1/T$ law and finally to become temperature-independent. Previous measurements by us[1] indicated than no measureable degeneracy occurs in liquid He^3 down to 1.2°K, although the calculated degeneracy temperature for an ideal Fermi-Dirac gas of the same atomic mass and density as liquid He^3 is 4.7°K. The present measurements indicate that below 1°K the nuclear spins of the liquid He^3 begin to line up antiparallel with the same temperature dependence as an ideal Fermi-Dirac gas with a degeneracy temperature of 0.45°K. At 0.25°K the He^3 nuclei are approximately 40 percent antiparallel aligned. The temperature was independently checked by the nuclear resonance signal from protons in a salt in contact with the He^3.

* Work supported by a contract with the Office of Ordinance Research, U. S. Army.
[1] Fairbank, Ard, Dehmelt, Gordy, and Williams, Phys. Rev. **92**, 208 (1953).

WEDNESDAY MORNING AT 9:30

Physics 334

(F. N. FRENKIEL, presiding)

Contributed Papers

C1. Hot-Wire Measurements of Turbulence in the Ocean. R. W. STEWART, *Pacific Naval Laboratory.*—Ordinary constant temperature hot-wire anemometry techniques have been adapted to measure oceanic turbulence. Two channels have been built so that cross correlation studies are possible and Pacific Naval Laboratory's very large playback/record speed ratio tape recorder has been employed for measurements of spectra. Some preliminary results have been obtained in inshort waters.

C2. Metastable Jet-Tone States of Jets from Sharp-Edged, Circular, Pipe-Like Orifices. A. B. C. ANDERSON, *Naval Ordnance Test Station.*—Characteristics of spectra from relatively thick orifices differ from those from relatively thin. In a given range of Reynolds number, the jet may often exist in any one of several reproducible jet-tone states (metastable states) characteristic of the orifice. The dependence of the component frequencies of the jet-tone spectra (expressed in terms of the orifice-number $fd/(\Delta p/\rho)^{\frac{1}{2}}$ on Reynolds number $[\rho d/(\Delta p/\rho)^{\frac{1}{2}}]/\mu$ is shown, where d is diameter of orifice; f, frequency; Δp, pressure difference across orifice; ρ, density; and μ, viscosity of gas. The orifice numbers of the components of the jet-tone spectra generally tend to fall on the orifice-number levels of a single array of equally spaced orifice-number levels. Jet tones from the same orifice plates, characteristic of both thin as well as thick orifice plates, are found to coexist over a small transition range of orifice thickness-diameter ratio. If the orifice number of the head of the most probable mode for a given orifice thickness-diameter ratio is noted, the same will be found again for the head of the most probable mode at approximate orifice thicknesses $t\pm nd$, where n is a small integer.

C3. The Transition Through a Contact Region. J. G. HALL, *Institute of Aerophysics, University of Toronto* (introduced by G. N. Patterson).—An approximate treatment is given of temperature and density transition through the one-dimensional contact region of shock tube flows. The simple model considered is a homogeneous gas having step change in density and temperature but constant pressure at time zero. Behavior for subsequent time is determined from the three conservation equations for a viscous, compressible, heat-conducting gas. Simplifying assumptions are ideal gas, zero body forces, linear viscosity-temperature relation, and negligible pressure change. For very weak transitions, complete linearization of the differential equations gives spacially monotonic and antisymmetric temperature and desnity change with the transition region spreading as the square root of time. For stronger transitions, a von Mises transformation followed by linearization in the transformed plane leads to closed solutions exhibiting nonlinear effects in the physical plane. Nonlinearities give asymmetric temperature and density change; the square root of time growth becomes dependent on the initial discontinuity. Experimental shock-tube results are noted for two types of contact regions. Piezocrystal pressure recordings indicate pressure effects as slight. Experimental density transitions from interferometry are compared to theory where possible. Agreement is qualitatively good for the weak transitions studied.

C4. The Incompressible Laminar Boundary Layer on a Spinning Cylinder at Small Angles of Attack. HOWARD R. KELLY, *U. S. Naval Ordnance Test Station.*—An approximate solution is found for the Navier-Stokes equations for the boundary-layer flow along a cylinder spinning slowly on its axis, including the case where the free stream is inclined at a small angle α to the cylinder axis. By a perturbation method, the velocity profiles and displacement effects are evaluated to second order in α and in the spin ω. The effects of wall curvature are treated in much the same manner as was done by Seban and Bond.[1] The velocity profiles are described in terms of a dimensionless parameter η, analogous to that used by Blasius.[2] The results of this study are basic to a better understanding of the aerodynamics of bodies of revolution.

[1] Seban and Bond, J. Aeronaut. Sci. **18**, No. 10, 671 (1951).
[2] Blasius, Math. Phys. Bd. **56**, 1 (1908).

C5. The Displacement Effect of a Three-Dimensional Boundary Layer of Moderate Thickness. ELDON L. DUNN AND HOWARD R. KELLY, *U. S. Naval Ordnance Test Station.*—A method is developed for determining the "displacement surface" of a known three-dimensional compressible boundary layer flow in terms of the mass-flow defects associated with the profiles of the two velocity components parallel to the body surface. The results are given in a form for use in any coordinate system, and are applicable for boundary layers of moderate thickness. The development parallels that of Moore,[1] whose results are given in Cartesian coordinates and are applicable only in the case of an extremely thin boundary layer. Using generalized orthogonal coordinates x_1, x_2, x_3 with scale factors e_1, e_2, e_3, the general relation between the displacement surface and the mass-flow defects is given by

$$\frac{\partial}{\partial x_1}\left[\int^{\Delta}\rho_1 e_2 e_3 u_1 dx_2-\delta x_1\right]+\frac{\partial}{\partial x_3}\left[\int^{\Delta}\rho_1 e_1 e_2 w_1 dx_2-\delta x_3\right]=0,$$

where δx_1 and δx_3 are quantities characterizing the mass-flow defects, $x_2=\Delta$ is the displacement surface, u and w are velocity components in the x_1 and x_3 directions, respectively, ρ is density, and $x_2=0$ is the equation of the body surface. The subscript 1 refers to conditions of inviscid flow. Applications of the method are considered for shapes of interest in aerodynamic theory.

[1] Franklin K. Moore, Natl. Advisory Comm. Aeronaut. NACA Report 1124 (1953).

C6. Response of Pressure Gauges to Dust-Laden Shock Waves. J. R. BANISTER AND C. D. BROYLES, *Sandia Corporation.*—A series of shock tube studies demonstrate that two types of pressure gauges respond to dust carried with shock waves by indicating an increase in dynamic pressure. This contribution to the dynamic pressure is approximately the product of the dust density and the square of the dust velocity under the experimental conditions. Besides this information the studies give insight into the interaction of a square shock wave with dust when that dust is placed in a plane before and parallel to the shock front. It is found that the shape of the pressure wave is little changed except for a rounding of the front. The dust, after accelerating, is carried as a pulse with the mass flow velocity of the air.

C7. The Shape of a Shock Wave Derived from a Spherical Shock Wave Incident on a Concave Wedge. JAY TODD, JR., AND RALPH SCHELLENBAUM, *Sandia Corporation.*—A 13.5-gram charge is detonated above a rigid plane which is

bounded by a second plane making an angle of 5.7° with the first. This forms a concave wedge with an interior angle of 174.3°. Successive shadowgraph pictures of the shock were obtained near the intersection of the two planes. The shape of the diffracted wave differs slightly from that found in the similar case for plane shocks,[1] in that the Mach stem is less highly concave. This is accentuated as the wave progresses up the plane until the curvature is reversed. The data are sufficiently accurate to permit a determination of shock strength as a function height above the inclined plane.

[1] D. R. White, "An experimental survey of the Mach reflection of shock waves," Princeton Department of Physics, Tech. Report II-10, August 21, 1951.

C8. Two-Fluid Flow with Application to Dust-Laden Air. M. L. Merritt and J. R. Banister, *Sandia Corporation.*—We wish to consider the flow of two mutually interfering and interpenetrating fluids of different equations of state and different heat contents. Such a two-fluid flow might be that of air carrying a dust burden. If the two are constantly in thermal equilibrium and move with the same velocity (this implies that the dust is of small size, and that one does not examine too small intervals of time) it is possible to write equations expressing their joint equation of state, hydrodynamic flow, shock flow, etc. The effective γ of the combination is reduced, the density increased, the heat content per volume increased, and the resultant velocity of sound decreased. If the two fluids are not in thermal and momentum equilibrium. they will interact with each other so as to approach that equilibrium. The hydrodynamic equations of the combination are twice as many in number. The velocity of sound in the mixture is but little reduced. The effect on the shock conditions is similar to those of the relaxation effects of CO_2 and of hydrocarbon gases, that is, the pressure first jumps as if the noncontributing fluid were not there then adjusts flow to the presence of the other. The most direct check of these ideas will be the experimental study of the velocity of sound in a two-fluid situation and a study of shocks passing through them.

C9. Path of Triple Point for Spherical Shocks Above a Rigid Plane. Ralph Schellenbaum and Jay Todd, Jr., *Sandia Corporation.*—Lincoln Smith[1] has shown that similarity solutions are valid in the case of plane shocks incident on a wedge. As a consequence the path of the triple point is a straight line. The angle between this line and the surface of the wedge (X) is a function of the shock strength and the angle of incidence. During the course of experiments at Sandia Corporation the path of the triple point for spherical waves incident on a flat plane has been measured. Comparisons are made between the slope of this trajectory and X as determined by Lincoln Smith for plane waves.

[1] OSRD-6271.

C10. On the Stability of the Spherical Shape of a Vapor Cavity in a Liquid.* M. S. Plesset and T. P. Mitchell, *California Institute of Technology.*—The stability of the spherical shape of a gas bubble in a liquid is investigated for the case in which the difference between the pressure in the bubble p_i and the pressure in the liquid p_0 is constant. These conditions apply approximately to a vapor bubble growing ($p_i > p_0$) or collapsing ($p_i < p_0$) in a liquid at constant external pressure. The general solution for the behavior of a small deformation in the spherical shape of the cavity is readily obtained when surface tension is neglected. For a growing bubble, the deformation increases slowly and monotonically; for a collapsing bubble, the deformation oscillates with small amplitude until the mean radius of the bubble approaches zero when the magnitude of the deformation increases rapidly. The consistency and applicability of the small amplitude theory for a significant range of bubble radius change is demonstrated. A solution may also be obtained which includes the effect of surface tension. In this case the distortion amplitude decreases monotonically for the expanding bubble; the singularity in the distortion amplitude for the collapsing bubble for small radius persists.

* This study was supported by the U. S. Office of Naval Research.

C11. Free Molecule Flow of a Nonuniform Gas. S. Bell and S. A. Schaaf, *University of California.*—Heat transfer and aerodynamic force characteristics of a cylinder are calculated for the case of free molecule flow of a nonuniform monatomic gas, i.e., a gas which is not in Maxwellian equilibrium but which has viscous stresses and heat flux present. It is shown that a shear stress will induce an aerodynamic lift and that a heat flux produces a force (the "radiometer" force) in the direction of the heat flux. These nonuniformities also affect the heat transfer to the cylinder and its equilibrium temperature. Applications to the use of small wires for supersonic wind tunnel probes are discussed. This work was sponsored by the U. S. Office of Naval Research and the U. S. Office of Scientific Research.

Wednesday Afternoon at 2:00

Health Sciences Auditorium

(S. H. Neddermeyer, presiding)

Cosmic Rays and High Energy Physics

Invited Papers

D1. Experimental Findings at the Brookhaven National Laboratory. C. N. Yang, *Institute for Advanced Study, Princeton.* (30 min.)

D2. The Identification of Heavy Mesons. W. B. Fretter, *University of California, Berkeley.* (30 min.)

D3. Recent Results on V-Particles. R. W. Thompson, *Indiana University.* (30 min.)

D4. V-Particles with Neutral Secondaries. E. W. Cowan, *California Institute of Technology.* (30 min.)

THURSDAY MORNING AT 9:00

Guggenheim Hall

(R. F. CHRISTY, presiding)

Medium Energy Nuclear Physics

Invited Papers

E1. Investigations with the University of Washington Cyclotron. F. H. SCHMIDT, *University of Washington.* (30 min.)

E2. Deuteron Reaction Studies with the Pittsburgh Cyclotron. R. S. BENDER, *University of Pittsburgh.* (30 min.)

E3. Elastic Scattering of Protons by Medium and Heavy Nuclei. P. C. GUGELOT, *Princeton University.* (30 min.)

E4. Cross-Section Measurements with 29-Mev Nitrogen Ions. ALEXANDER ZUCKER, *Oak Ridge National Laboratory.* (30 min.)

THURSDAY MORNING AT 9:00

Physics 320

(C. L. UTTERBACK, presiding)

Contributed Papers

F1. Hf and Zr Total Cross-Section Measurements.* E. G. JOKI AND J. E. EVANS, *Atomic Energy Division, Phillips Petroleum Company.*—The MTR crystal spectrometer has been used to measure σ_t from 0.04 to 10 ev with a Hf metal sample. Our measurements give 92.4b at 0.4 ev and 64.4b at 0.1 ev which are lower than corresponding Harwell data.[1] A possible explanation for the discrepancy will be discussed. The new data are consistent with the tabulated thermal value of 123 ± 15b in U. S. Atomic Energy Commission AECU-2040. The energies of the first two resonances have been measured to be 1.095 ± 0.005 and 2.378 ± 0.016 ev, consistent with the recent work of Bollinger *et al.*[2] Single level Breit-Wigner parameters, corrected for Doppler broadening and instrument resolution, will be given. σ_t for Zr is essentially flat at 6.2b from 0.02 to 60 ev. These results are lower than Harwell results[1] but agree with recent Argonne fast chopper results.[3] The sample used was 18.9 g/cm^2 of Zr metal which contained 400 ppm by weight of Hf.

* Work carried out under the auspices of the United States Atomic Energy Commission.
[1] Egelstaff and Taylor, Nature **167**, 896 (1951).
[2] Bollinger *et al.*, Phys. Rev. **92**, 1527 (1953).
[3] Progress Report, Argonne National Laboratory Report ANL-5140, November 1953.

F2. Contour Diagrams of Thermal Neutron Absorption Cross Sections*. J. E. EVANS, *Atomic Energy Division, Phillips Petroleum Company.*—Separate contour diagrams showing lines of equal thermal neutron absorption cross sections have been drawn for nuclei having even-even, even-odd, odd-even, and odd-odd numbers of protons and neutrons. In general, the higher neutron cross sections are found to occur for the neutron-poor and proton-rich nuclei. A striking feature of the study is that in nearly all cases there is a gradual change of cross section values from one nucleus to an adjacent nucleus of the same type. The most outstanding exception is the Xe^{135} nucleus, which lacks one neutron of having a magic number (or closed shell) of neutrons. The diagrams should prove helpful in estimating cross sections of nuclei for which no measurements exist if the cross sections for some of its neighbors are known. Some possible implications of the study to nuclear theory are discussed.

* Work carried out under the auspices of the U. S. Atomic Energy Commission.

F3. MTR Crystal Spectrometer Data Printing System.* G. L. SMITH AND L. G. MILLER, *Atomic Energy Division, Phillips Petroleum Company.*—Operating automatically, the MTR Crystal Spectrometer can accumulate up to 1500 separate counting meausrements with 0.3 percent statistics in a week-end period. This imposes a serious data handling problem. A data printing system using glow-transfer counters and an electric typewriter has been installed to replace the commercial scaler and traffic counter system. The 1-microsecond scaler has scales of 1 to 16 preceding the 6 glow-transfer counters. After a count, a motor driven scanning switch connects the 10 points of each glow-transfer tube simultaneously through triode-operated relays to the solenoid actuators of the 10 numbers on the typewriter. Only the point having the glow discharge will record. The system will handle up to 10^6 cpm and print 6 digits without the attendant short lifetimes of electric reset registers and traffic counters. In addition, the scaling factor, time, crystal position, arm angle, and sample wheel position are printed on folded and perforated teletype sheets which are later bound to form a permanent record. A special spacing is used which permits calculations to be made on the data sheets without data transfer.

* Work done under the auspices of the U. S. Atomic Energy Commission.

F4. The Photoproduction of Charged Mesons from Deuterium.* M. SANDS, J. G. TEASDALE, AND R. L. WALKER, *California Institute of Technology.*—The yield of charged mesons of each sign produced in a high-pressure deuterium target by the x-ray beam of a 500-Mev synchrotron has been measured at 73°, laboratory angle, for several meson energies. Mesons were selected by the magnetic spectrometer used previously in this laboratory.[1] The preliminary results for the ratio of the yield of negative mesons to that of positive mesons

are given in the table. The mesons observed are those which would be produced at an angle of 90° in the center-of-momentum system of a photon of energy "k" and a single nucleon initially at rest.

T_π(Mev, lab)	43	71	103	147	200
N_-/N_+	1.25 ± 0.03	1.15 ± 0.03	1.09 ± 0.02	1.13 ± 0.03	1.16 ± 0.07
"k" (Mev)	207	247	293	363	451

Ratios measured at laboratory angles of 29° and 140° will also be reported.

* Supported in part by the U. S. Atomic Energy Commission.
[1] Walker, Teasdale, and Peterson, Phys. Rev. 92, 1090 (1953).

F5. Photostar Production Up to 500 Mev.* VINCENT PETERSON, *California Institute of Technology.*—The production of stars in G-5 nuclear emulsions by high-energy bremmstrahlung photons is being studied for various maximum synchrotron energies (k max) up to 503 Mev. The beam was monitored by a thick wall Cornell-type ionization chamber whose energy sensitivity varies slowly with k(max). The total star yield was counted and corrected for measured scan efficiency and pre-exposure background. Results obtained from several runs give for the integral cross section for producing stars of 3 or more prongs (errors are standard deviations):

k max in Mev	σ (mb per equiv. quantum)
309	2.85 ± 0.30
376	4.60 ± 0.34
420	5.11 ± 0.30
503	5.95 ± 0.35

The excitation function per photon *vs* photon energy may be derived from the integral curve. The data are consistent with, but do not necessarily prove that, the photostar cross section exhibits the resonance shown by the free nucleon photomeson production cross sections.

* This work was supported in part by the U. S. Atomic Energy Commission.

F6. Photoproduction of Mesons from Hydrogen Near Threshold.* VINCENT PETERSON AND I. GEORGE HENRY, *California Institute of Technology.*—Mesons produced by 500-Mev bremsstrahlung photons incident upon a high-pressure hydrogen gas target were observed at laboratory angles of 30°, 51°, 73°, 104°, and 140°. Tungsten slits defined the target volume, and the low-energy mesons were detected at the end of their range in C-2 nuclear emulsions. Corrections for decay, nuclear absorption, slit penetration, and scattering from collimator walls are small. Duplicate scanning reduced efficiency corrections below 5 percent. Measured meson background was $1\frac{1}{2}$ percent. Minimum detectable target meson energy is 11.3 Mev at 73°. The absolute cross section at this angle, measured continuously between 167- and 233-Mev photon energy wlth $\sim$10 percent statistics per point, is in good agreement with the CIT counter data[1] taken above 200 Mev. Below 200 Mev the data furnishes additional evidence[2] for preponderance of S-wave interaction, as does the angular distribution at 187 Mev. The yield of negative (i.e., star producing) mesons at 73° is 11 ± 2 percent of the positives, with negligible background. Analyzed gas impurities appear to account for less than 1 percent. The negative mesons energies are dynamically allowed by pion-pair production.

* This work was supported in part by the U. S. Atomic Energy Commission.
[1] Walker, Teasdale, and Peterson, Phys. Rev. 92, 1090(A) (1953).
[2] G. Bernardini and E. L. Goldwasser, Phys. Rev. 94, 729 (1954).

F7. The High-Energy Photodisintegration of the Deuteron. Procedure.* A. V. TOLLESTRUP, J. C. KECK, and W. R. SMYTHE, II, *California Institute of Technology.*—The reaction $\gamma+D\rightarrow p+n$ is being investigated in the energy region from 100 to 450 Mev at laboratory angles from 38 to 160 degrees. A high-pressure low-temperature deuterium gas target is irradiated by 500-Mev synchrotron x-rays, and the emitted protons are identified by their ionization and range in a scintillation counter telescope. The proton energy, as determined by its range in copper, and the angle of emission fix the energy of the interacting photon. Energy momentum considerations serve to exclude the disintegrations in which free mesons are produced. Care must be taken to exclude those protons produced by other particles in the material of the telescope and also a correction for nuclear absorption of the protons in the wall of the target and in the telescope must be made. Backgrounds obtained with the target evacuated were in general ess than 5 percent.

* This work was supported in part by the U. S. Atomic Energy Commission.

F8. The High-Energy Photodisintegration of the Deuteron. Results.* J. C. KECK, A. V. TOLLESTRUP, AND W. R. SMYTHE, II, *California Institute of Technology.*—The photodissociation of the deuteron is being investigated by the technique described in the preceding paper. Measurements of the differential cross section in the center-of-mass system have been made for angles of 170, 150, 130, 110 degrees for photon energies in the laboratory system from 100 to 450 Mev. The energy distributions at a given angle are characterized by a weak minimum at 150 Mev followed by a maximum at 250 Mev. At 450 Mev the cross section is a factor of 5 smaller than at the maximum. The cross section decreases from 110° to 170° at all energies. The magnitude of the cross section at 250 Mev and 110 degrees is 5 ub/ster in agreement with results of workers at Cornell. The results suggest a connection with the process of photomeson production which may be interpreted in terms of the idea of an excited state of the nucleon which can decay either by meson production or collision with the second nucleon in the deuteron.

* This work was supported in part by the U. S. Atomic Energy Commission.

F9. Magnetic Analysis of the $O^{18}(d,p)O^{19}$ and $N^{15}(d,p)N^{16}$ Reactions.* JACQUES THIRION, RENÉ COHEN, AND WARD WHALING, *Kellogg Radiation Laboratory, California Institute of Technology.*—Enriched isotopic targets have been used with a double focusing magnetic spectrometer to measure the energy of the protons emitted from the (d,p) reactions with O^{18} and N^{15}.[1] At $\theta=140°$ and deuteron bombarding energy 2.18 Mev, three groups of protons were observed from the $O^{18}(d,p)O^{19}$ reaction with Q values 1.732 ± 0.008, 1.632 ± 0.008, and 0.263 ± 0.010 Mev. More energetic proton groups were not observed, and we attribute these Q values to the ground state and excited states at 0.100 and 1.469 Mev in O^{19}. The proton spectrum shows no other states in O^{19} with excitation energy $\leqq 2.4$ Mev. At $\theta=60°$ and deuteron bombarding energy 2.0 Mev three proton groups were observed from the $N^{15}(d,p)N^{16}$ reaction with preliminary Q values 0.158, -0.022, and -0.118 Mev. These Q values indicate a level spacing in N^{16} similar to that found by Ahnlund and Meleikowsky[2] for the first, second, and third excited states of N^{16}. Further work is in progress to observe more energetic protons accompanying the ground-state transition in the presence of an interfering group of protons from the $N^{14}(d,p)N^{15}$ reaction.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] We are indebted to A. O. C. Nier for furnishing the enriched O^{18}.
[2] Curt Meleikowsky (private communication).

F10. An Easily Reproducible Thermal Neutron Density Standard. RENÉ COHEN,* *Centre d'Etudes Nucléaires de Saclay.*—The use of a copper foil whose thickness is greater than the range of the ^{64}Cu β particles with a 4π beta counter enables one to have a very reproducible (± 1.5 percent) standard of thermal neutron density. The standard thermal density we

use is such that once established in a copper disk of 15.00-mm diameter and 500 mg cm^{-2} thick[1] it produces a saturated β activity (^{64}Cu) which produces 1 pulse per second when measured in a 4π counter. This standard density as measured in absolute value at Saclay is equal to $(5.70\pm0.19)\cdot10^{-3}$ n. cm^{-3}. The use of this standard facilitates the intercalibration of absolute measurements.[2]

* Present address: Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California.
[1] The activity increases by less than 1 percent for an increase of 50 ug cm^{-2}.
[2] D. J. Hughes, Pile Neutron Research (Addison-Wesley, Cambridge, 1953); A. Wattenberg, Ann. Rev. Nuclear Sci. **3**, 119 (1953).

F11. Hole Configurations in Light Nuclei.* R. F. Christy and W. A. Fowler, *Kellogg Radiation Laboratory, California Institute of Technology.*—The low-energy (114 kev) negative parity ($\frac{1}{2}^-$) excited state[1] in F^{19} points to a need to reexamine the shell model in this region. We consider this state as a proton hole in the $p_{\frac{1}{2}}$ shell with four (s,d) particles coupled to $T=J=0$ outside it. We estimate the energy of the $\frac{1}{2}^-$ state in F^{19} from the ground-state energy of Ne^{20} and the binding of the last $p_{\frac{1}{2}}$ proton given by the $N^{15}-O^{16}$ mass difference, so $M_{19}(\frac{1}{2}^-)=M_{20}-M_{16}+M_{15}$. This neglects the change in kinetic energy and the change in the $p-(s,d)$ interaction and gives a $\frac{1}{2}^-$ state $\frac{3}{4}$ Mev below the ground state of F^{19}, accounting for a low $\frac{1}{2}^-$ state. Similarly, the series of excited states, $O^{16}(0^+$ at 6.05 Mev), $O^{17}(\frac{1}{2}^-$ at 3.07 Mev), $F^{17}(\frac{1}{2}^-$ at 3.10 Mev), $F^{19}(\frac{1}{2}^-$ at 0.114 Mev) and $Ne^{20}(0^+$ ground state) may be considered as the addition of four (s,d) particles to the ground states of C^{12}, C^{13}, N^{13}, N^{15}, O^{16}, respectively. There results a series of numbers for the binding of the four particles which increases by only 3.5 Mev from C^{12} to O^{16}.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Peterson, Thirion, Sherr, and Christy, Phys. Rev. **94** (to be published).

F12. Elastic Scattering of Protons by F^{19}.† T. S. Webb, F. B. Hagedorn, W. A. Fowler, and C. C. Lauritsen, *Kellogg Radiation Laboratory, California Institute of Technology.*—The differential cross section for the elastic scattering of protons by F^{19} has recently been measured using magnetic analysis of the protons scattered by thick targets of LiF. Measurements have been made for proton energies from 0.55 to 1.8 Mev at scattering angles of 90°; 125°18′ and 159°46′ in the center-of-mass system. Marked anomalies have been observed at proton energies corresponding to known gamma-ray resonances at $E_p=0.669$; 0.831; 0.874; 0.935; 1.355; 1.381; 1.431; and 1.69 Mev. The behavior of the cross section off resonance is approximately in agreement with the calculated Rutherford cross section. Further experimental work is planned to cover forward scattering angles and a more detailed investigation of these regions where known gamma-ray resonances occur which did not give sufficient scattering anomalies to be conclusively identified. In addition, theoretical analysis of the data has been started.

† Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

F13. Inelastic Proton Scattering Cross Section of F^{19}.† C. A. Barnes, W. A. Fowler, C. C. Lauritsen, and R. W. Peterson, *Kellogg Radiation Laboratory, California Institute of Technology.*—The excitation functions of the 114 kev and 200 kev gamma rays, resulting from inelastic scattering of protons by fluorine,[1] have been studied with NaI scintillation counters from 330-kev to 1750-kev bombarding energy. Most of the well known high-energy gamma ray, nuclear pair, and long-range alpha particle resonances appear as resonances for one or both of the low-energy gamma rays. Cross sections for some of the prominent resonances are given in the table, superseding the approximate values given in reference 1. The cross sections for the other observed resonances will be reported. Observation of the inelastically scattered protons yields $\sigma_{114}=(1.9\pm0.2)\times10^{-25}$ cm^2 at 1431 kev, and $\sigma_{200}=(4.3\pm0.4)\times10^{-26}$ cm^2 at 1381 kev, in good agreement with the gamma-ray results.

Proton Energy	(kev)	873	935	1381	1431
$\sigma_{114\text{ kev}}$	(cm^2)	$<10^{-27}$	$(1.3\pm0.3)\times10^{-25}$	$(2.4\pm0.5)\times10^{-26}$	$(1.7\pm0.3)\times10^{-25}$
$\sigma_{200\text{ kev}}$	(cm^2)	$(9\pm2)\times10^{-26}$	$(1.1\pm0.4)\times10^{-27}$	$(3.8\pm0.8)\times10^{-26}$	$(9\pm3)\times10^{-27}$

† Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Peterson, Barnes, Fowler, and Lauritsen, Phys. Rev. (to be published).

F14. Measurement of π^- Mass with Mesonic X-Rays.* M. Stearns, M. B. Stearns, L. Leipuner, S. DeBenedetti, *Carnegie Institute of Technology.*—The critical absorption technique is being used for precise measurements of upper and lower limits of mesonic x-ray lines of L and M series. Thin absorbers are inserted in front of the NaI crystal,[1] and the transmission of the x-rays is studied as a function of the Z of the absorber. We find the energy of the $4f\rightarrow3d$ line of π^- mesons captured by phosphorus above the K edge of $_{58}$Ce (40.40 kev).[2] This corresponds to $m_\pi\geq272.5m_e$ as calculated from the Klein-Gordon equation using a point charge Coulomb potential. Similarly the π^- Potassium $4f\rightarrow3d$ line is lower than the Hf K edge (65.08 kev) corresponding to $m_{\pi-}\leq273.3m_e$. Many other lines (e.g., Al, Fl, and Mg $3d\rightarrow2p$) have also been studied and have verified the technique. From these measurements it follows $272.5m_e\leq m_{\pi-}\leq273.3m_e$. When these values have been corrected for vacuum polarization effects the main error will be due to the uncertainty in the K edges of Ce and Hf. Experiments are in progress for determining closer limits and will be reported.

* Supported by U. S. Atomic Energy Commission.
[1] Stearns, DeBenedetti, Stearns, and Leipuner, Phys. Rev. **93**, 1123 (1954).
[2] Landolt-Börnstein (Springer-Verlag, Berlin, 1952).

F15. The Reaction $D(T,\alpha)n$ at 1.5 Mev.* H. V. Argo and A. Hemmendinger, *Los Alamos Scientific Laboratory.*—The differential cross sections at 1.5-Mev triton energy, and for laboratory angles of 10, 20, 30, $\cdots$, 140, have been measured. A reaction chamber 14 inches in diameter with a movable and a fixed proportional alpha particle counter was used. The Pyrex entrance foil to the deuterium gas target was 10.5 kev thick for 1.5-Mev tritons. The argon filling in the movable counter was separated from the target gas by a glass foil of about 2.5-mm air equivalent. Preliminary results for differential cross sections in the center-of-mass system at the angles 14.4°, 28.7°, 42.8°, 56.5°, 69.8°, 82.5°, 94.6°, 105.8°, 116.2°, 125.8°, 134.6°, 142.5°, 149.8°, 156.5° are 23.8, 23.5, 23.7, 23.4, 23.3, 22.7, 22.4, 21.7, 21.3, 20.3, 19.6, 19.0, 18.5, 18.6 mv/ster, with probable errors of 2 percent. The total cross section, from integration of the above data, is 0.275 ±0.005 barn.

* Work done under the auspices of the U. S. Atomic Energy Commission.

THURSDAY MORNING AT 9:00

Physics 334

(S. A. SCHAAF, presiding)

Invited Paper

G1. On the Interactions of Shock Waves. OTTO LAPORTE, *University of Michigan.* (30 min.)

Division of Fluid Dynamics

Symposium on Hypersonic Flow

G2. Review of Experimental Methods in Hypersonic Research. P. P. WEGENER, *Jet Propulsion Laboratory, California Institute of Technology.* (45 min.)

G3. A Low Density Wind Tunnel Study of Shock-Wave Structure and Relaxation Phenomena in Gases. F. S. SHERMAN, *University of California, Berkeley.* (45 min.)

G4. Boundary Layer Problems in Hypersonic Flow. F. K. HILL, *Applied Physics Laboratory, The Johns Hopkins University.* (45 min.)

THURSDAY AFTERNOON AT 2:00

Guggenheim Hall

(R. T. BIRGE, presiding)

Invited Paper

H1. The Bevatron at the University of California. E. J. LOFGREN, *University of California, Berkeley.* (30 min.)

Contributed Papers

H2. Grain Density and Ionization Loss in Nuclear Track Emulsions.* JOHN R. FLEMING AND J. J. LORD, *University of Washington.*—Grain density measurements in Ilford G5 plates of accelerated particles have been extended.[1,2] Now, over 400 000 grains have been counted for pion energies of 224, 121, 83, and 28 Mev. Measurements with plates exposed to the Cosmotron pion beams are now in progress and will be reported. Preliminary results for 500-Mev pions give good agreement with the Sternheimer theory.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] We are indebted to Professor Marcel Schein for plates from the Chicago Cyclotron and Dr. R. K. Adair for plates from the Cosmotron.
[2] J. R. Fleming and J. J. Lord, Phys. Rev. 92, 511 (1953).

H3. Direct Creation of Electron Pairs by Electrons of Great Energy. I. Experimental Observations. D. T. KING, W. WADA, AND M. M. BLOCK,* *Naval Research Laboratory.*—Data on the direct creation of electron pairs by cosmic-ray electrons has been collected in nuclear emulsions by a track following method. The plates, Ilford G5 400 microns thick, were flown at altitudes exceeding 95 000 feet for 6 hours at geomagnetic latitude 55°N. The search was confined to flat tracks of low grain density. Sixty-one tridents with primary energies between 0.1 and 10 Bev, as determined from the sum of the three secondary energies, were found. The electron trident mean free path was evaluated through a comparison of the number of tridents (14 our of the 61) which occurred on arms of pairs, with the total track length of pair particles originating in the emulsion within our energy interval. This insured that the path length considered in the m.f.p. (mean free path) determination was electronic. After consideration of substantial corrections for the estimation of path length, and for the inclusion of pseudotridents,[1] a maximum likelihood estimate of 134 ± 42 cm was found for the m.f.p. This corresponds to a cross section of $0.93\pm0.29\times10^{-25}$ cm^2 in G5 emulsion.

* On military leave of absence from Duke University, Durham, North Carolina.
[1] D. T. King and M. M. Block, Bull. Am. Phys. Soc. 29, No. 4, S13, 14 (1954).

H4. Direct Creation of Electron Pairs by Electrons of Great Energy. II. Theoretical Considerations. W. WADA, M. M. BLOCK,* AND D. T. KING, *Naval Research Laboratory.*—Predictions of cross section for direct pair production by fast electrons given by Bhabha[1] and Racah[2] have been evaluated. In the energy range 0.1–10 Bev it is found that there is a disagreement by a factor of ~2 between the total cross sections of these authors. A more detailed integration of the differential cross section given by Bhabha was made, and the result was in substantial agreement with Racah's prediction. The modified cross section was averaged over an assumed spectrum of the form $E^{-1.6}dE$ for the incident electrons within our energy interval. The result was 0.82×10^{-25} cm^2 for G5 emulsion, in good agreement with the determination in (I). The effect of screening for these energies is small. A study has also been made of the distribution of the primary energy among the secondary particles by the introduction of the variables, $R=E_{\text{pair}}/E_{\text{primary}}$ and $r=E_+/E_{\text{pair}}$, into the differential cross section. Experimental comparison is discussed in III.

* On military leave of absence from Duke University, Durham, North Carolina.
[1] H. J. Bhabha, Proc. Roy. Soc. (London) A152, 559 (1935).
[2] G. Racah, Nuovo cimento 14, 93 (1937).

H5. Direct Creation of Electron Pairs by Electrons of Great Energy. III. Internal Energy Distributions. M. M. BLOCK,* D. T. KING, AND W. WADA, *Naval Research Laboratory.*—The differential cross section, expressed in terms of either R or r defined in II, has been evaluated as a function of primary energy. A simple comparison of theory with our experiment is possible when the differential distributions in R and r are normalized to the total cross section and averaged over primary energies between 0.1 and 10 Bev. This procedure allows us to utilize all 61 tridents for energy partition studies. Energies of the three secondaries of each trident were measured by multiple scattering. In the determination of the experimental values of R and r, we employed the convention that the two secondary particles of lowest energy represented the created pair. The experimental probability distributions in R and r were compared with the averaged theoretical distributions modified to take account of the convention. Reasonable agreement was obtained. Our collected results on total cross section, its variation with primary energy, and the internal energy partitions lead us to conclude that the theory gives a satisfactory prediction of trident processes in our energy interval.

* On military leave of absence from Duke University, Durham, North Carolina.

H6. Electromagnetic Events of High-Energy Particles at Sea Level. S. H. NEDDERMEYER AND ERLE HOWELL, JR., *University of Washington.*—A cloud chamber with a magnetic field in the middle part and with one aluminum and two lead plates 1 cm thick has been used with a triple coincidence counter system including one discriminated group which triggers on 3 or more particles. The system accepts both nuclear and *EM* events, and for the latter has a strong discrimination against low-energy "primary" mu's. Thus, about half the primaries of the *EM* events of energy above 0.5 Bev have momenta above 20 Bev, according to the magnetic deflections. The observed momentum distribution for the primaries is, in the low momentum region, much lower than that calculated from the theoretical cross sections for bremsstrahlung and secondaries, assuming a detection efficiency of one, but is in rough agreement at momenta above 15 Bev. On the other hand the absolute number of events observed (above 0.5 Bev) is in agreement for the aluminum but low for the Pb by a factor 2–3. Statistical uncertainties are still large; however both discrepancies are partially explainable by geometrical factors and energy loss and scattering in the Pb, which have the effect of decreasing the detection efficiency at low energy.

H7. Sidereal Time Variations in Cosmic Ray Intensities Produced by Fermi's Acceleration Mechanism. LEVERETT DAVIS, JR., *California Institute of Technology.*—If $\mathbf{B}_g$, the galactic magnetic field in the earth's neighborhood, is roughly uniform and if cosmic rays are accelerated by Fermi's[1] mechanism, then any anisotropy should be correlated with $\mathbf{B}_g$ rather than with stellar distributions. Assume that for very high-energy particles (unaffected by the earth's field) the flux per steradian in the direction $\mathbf{A}$ is $N-D\cos 2\theta$, where θ is the angle between $\mathbf{A}$ and $\mathbf{B}_g$. Suppose $\mathbf{A}$ is now fixed in apparatus and rotates with the earth. Let $(\pi/2)-\phi$ be the angle between $\mathbf{A}$ and $\mathbf{E}$, the earth's axis. (For measurements of vertical intensity, ϕ is the latitude.) Let $(\pi/2)-\beta$ be the angle between $\mathbf{E}$ and $\mathbf{B}_g$. If D is not too small, the observed intensity should show Fourier components of amplitudes $D\sin 2\phi \sin 2\beta$ (period 1 sidereal day), and $D\cos^2\phi\cos^2\beta$ (period $\frac{1}{2}$ sidereal day), both minima coinciding. If $\mathbf{B}_g$ lies parallel to the nearest spiral arm (oscillations of 10° or more would not be surprising), $\beta=35°$ and, for $D>0$, the minimum would come at 20^h local sidereal time in the northern hemisphere and at 8^h in the southern.

[1]E. Fermi, Astrophys. J. 119, 1 (1954).

H8. Unstable Cosmic-Ray Particles Observed in a Double Cloud Chamber Arrangement.* W. H. ARNOLD, J. BALLAM, H. GURSKY, A. L. HODSON, R. RONALD RAU, GEORGE T. REYNOLDS, AND S. B. TREIMAN, *Princeton University.*—A double cloud-chamber arrangement similar to that of the Ecole Polytechnique group,[1] consisting of one cloud chamber in a magnetic field of 5500 gauss placed above a second multiplate cloud chamber having seven one-half inch Pb plates, has been in operation at 10 600 feet (Inter-University High Altitude Laboratory, Echo Lake, Colorado) for several weeks. During this period approximately 60 unstable V^0 and $V^{\pm}$ particles have been observed. Several of the more interesting cases will be discussed.

* Supported by U. S. Office of Naval Research and U. S. Atomic Energy Commission.
[1] Report of the *Congres International sur le Rayonnement Cosmique* held at Bagnères-de-Bigorre, July, 1953, p. 101.

H9. Cascade Decay of a Negative Hyperon.* W. B. FRETTER AND E. W. FRIESEN, *University of California, Berkeley.*—The cascade decay of a negative hyperon into a meson and a Λ^0 particle, previously reported by the Manchester[1] and C.I.T.[2] groups, has been observed in which the meson has been identified by momentum and ionization measurements as a negative π meson with a mass of $(268\pm15)m_e$. The ionization measurements were made by droplet counts along the track of the particle in a cloudchamber filled with helium. The measured ionization was I/I min$=1.66\pm0.07$ and the measured momentum was (132 ± 4) Mev/c. The Λ^0 was identified by measurements of angles and ionization, since the tracks were too short for momentum measurements. Both decay events were coplanar within the error of coplanarity angle determination of $\pm2°$. The Q value for the reaction $Y^-\rightarrow\pi^\mp\Lambda^0+Q$ was 66 ± 6 Mev, in agreement with results reported by the C.I.T. group.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Armenteros, Barker, Butler, Cachon, and York, Phil. Mag. 43, 597 (1952).
[2] E. W. Cowan, Phys. Rev. 94, 161 (1954).

H10. Long Term Studies of the Neutron and Ionizing Cosmic Ray Intensities.* E. L. CHUPP,† *University of California, Berkeley.*—Intensity monitors have been developed at Berkeley for the study of time variations by various cosmic-ray components. The neutron component is monitored by BF_3 counters surrounded by Pb which acts as a local star producing medium thereby increasing the neutron counting rate. Simpson found that the low-energy primary cosmic radiation is the principal source of the sea level neutron component; thus measurements of the variations in this component permit one to study the fluctuations in the low-energy primaries. We have demonstrated the existence of a long term variation in the neutron component (barometer corrected) similar to the 27-day periodicity reported by Simpson. This variation is typified by several series of intensity minima (separated by $\sim$30 days), which may be associated with periods of maximum geomagnetic activity. We have also monitored the total and hard ionizing intensities with conventional GM counter telescopes. An example of the magnetic storm effect shows a decrease in the neutron intensity approximately three times larger than a simultaneous decrease in the hard intensity.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
† Now at the University of California Radiation Laboratory, Livermore, California.

H11. Absolute Differential Range Spectrum of Low-Energy Cosmic-Ray μ-Mesons.* N. T. SEATON, *University of California, Berkeley.*—An absolute differential range spectrum in the region from 1 to 150 g/cm² has been obtained for cosmic-ray μ mesons at sea level. The apparatus consisted of a tray

A, 30×30 cm, of Geiger counters above a liquid scintillation counter B, of 10-cm diameter and 6-cm depth, with the intervening space of 30 cm occupied by varying amounts of lead absorber. The photomultiplier pulses were fed to a four-channel delay discriminator covering the total interval 0.2 to 10 μsec. The results were checked for evidence of spurious counts from photomultiplier after-pulsing and amplifier overloading. The events recorded were $A+B+$(B delayed) and $B+$(B delayed); the latter to provide an estimate of the required zenith angle correction. The results were found to agree very well with the spectrum estimated by Rossi.[1] This work was evidently somewhat similar to that recently reported by Fafarman and Shamos.[2]

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] B. Rossi, Revs. Modern Phys. **20**, 537 (1948).
[2] A. Fafarman and M. H. Shamos, Bull. Am. Phys. Soc. **29**, No. 4, S12 (1954).

H12. Identification of Primary Cosmic-Ray Heavy Nuclei.* R. F. Hoard, J. R. Fleming, and J. J. Lord, *Department of Physics, University of Washington.*—Primary cosmic-ray heavy nuclei tracks in Ilford G5 emulsions have been identified by the photoelectric method of measurement. Results utilizing this measuring technique will be compared with grain, gap length, and delta-ray intensities of the tracks. Results will also be given on the application of this technique to the problem of the primary flux of cosmic-ray heavy nuclei at magnetic, latitude 10° North.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

H13. Geiger-Mueller Counter Tube Age Characteristics.* W. C. Roesch and J. S. Reddie, *General Electric Company.*—Three age characteristics of Geiger counters were investigated. The curve of maximum pulse height from a Geiger counter on exposure to a beta-ray source was observed as a function of counter voltage after various total counts; in the Geiger region these curves were found to shift fairly regularly to higher voltages as the counter aged. The Geiger threshold voltage was found to vary logarithmically with the counting rate. The change in threshold voltage per factor of ten increase in counting rate, the "threshold coefficient," varied linearly with the total number of counts. It was found that the pulse height at a fixed counter voltage varied approximately as a power of the counting rate, and that the logarithm of the ratio of the pulse heights corresponding to counting rates differing by a factor of ten, the "amplitude coefficient," varied linearly with the total number of counts.

* This paper describes in part work conducted under contract between the General Electric Company and the U. S. Atomic Energy Commission.

Thursday Afternoon at 2:00

Physics 320

(S. T. Stephenson, presiding)

Contributed Papers

I1. Electron Scattering from Hydrogen, Deuterium, and Carbon at 190 Mev.* J. A. McIntyre and R. Hofstadter, *Department of Physics, and W. W. Hansen, Laboratories of Physics, Stanford University.*—The recoil of the proton or deuteron permits solid targets of light and heavy polyethylene to be used in studying the elastic scattering of high energy electrons from the nuclei of hydrogen and deuterium, as distinguished from the elastic scattering from carbon nuclei. Inelastic electron scattering peaks have been observed in carbon at 4.5 Mev and 9.7 Mev and add a background below the carbon elastic peak which must be subtracted from the hydrogen and deuterium peaks. Angular distributions of the elastic electron scattering have been observed in hydrogen between 35° and 100° at 190 Mev in the laboratory frame. The proton appears to be a point charge since the experimental points fit the Mott formula. The deuteron definitely appears as not a point charge. Its finite size is exhibited by a fivefold reduction from the Mott formula at 105° in the center-of-mass system. The rms radius of the observed charge distribution is $1.5\pm0.2\times10^{-13}$ cm. This "radius" is a measure of the rms distance between the center of mass of the deuteron structure and the position of the proton.

* This research was supported jointly by the U. S. Navy (Office of Naval Research) and the U. S. Atomic Energy Commission, and by the U. S. Air Force through the Office of Scientific Research of the Air Research and Development Command. It was also aided by a grant from the Research Corporation.

I2. Electron Scattering in Hydrogen and Helium.* R. Hofstadter, R. McAllister, and E. Wiener,† *Department of Physics, and W. W. Hansen, Laboratories of Physics, Stanford University.*—To investigate the elastic scattering of high-energy electrons from hydrogen, helium, and other gases we have constructed a stainless steel scattering chamber containing gas at high pressure. The target is a right cylinder of length 2½ inches, diameter ¾ inch with walls 15 mils thick and end windows of thickness 5 to 10 mils. Operation at 1000 psi has proved quite convenient. The end effects are easily subtracted out by emptying the gaseous contents and are not important except at small angles (∼35°). Studies of the angular distribution in hydrogen and helium have been carried out at 190 Mev in the laboratory frame of coordinates and show agreement with the Mott point-charge formula for hydrogen but distinct deviations from the Mott formula for helium. These studies thus demonstrate the finite size of the helium nucleus (the alpha particle). A preliminary estimate of the size of the alpha particle gives $1.40\pm0.2\times10^{-13}$ cm for the rms radius of the alpha particle. The rms radius is taken with respect to charge.

* This research was supported jointly by the U. S. Navy (Office of Naval Research) and the U. S. Atomic Energy Commission, and by the U. S. Air Force through the Office of Scientific Research of the Air Research and Development Command. It was also aided by a grant from the Research Corporation.
† Miss Eva Wiener met a tragic death in an automobile accident in 1953.

I3. The K-Capture/Positron Ratio of Na^{22}. W. E. Kreger and C. Sharp Cook, *U. S. Naval Radiological Defense Laboratory.*—Using a gamma-ray scintillation spectrometer, the annihilation radiation and 1.3 Mev gamma ray from Na^{22} have been studied with a view toward determining the K-capture/positron ratio for this isotope. The ratios of photopeak have been studied with a view toward determining the K-capture/positron ratio for this isotope. The ratios of photopeak to total areas for a 4-in. diameter, 4-in. high NaI(Tl) crystal have been measured using collimated monoenergetic gamma rays from six sources.[1] Using these data and experimental measurements of the photopeak areas associated with the annihilation radiation and the 1.3-Mev gamma quanta from Na^{22}, the relative intensities of these two radiations

have been compared and indicate a K-capture/positron ratio of approximately 11 percent in agreement with Sherr and Miller.[2]

[1] W. E. Kreger and L. McIsaac, Phys. Rev. **93**, 943 (1954).
[2] R. Sherr and R. H. Miller, Phys. Rev. **93**, 1076 (1954).

I4. The Gamma Radiation Following the Decay of Pr^{144}. C. SHARP COOK AND W. E. KREGER, *U. S. Naval Radiological Defense Laboratory*.—The gamma radiation following the decay of Pr^{144} has been studied using a 4-in. diameter, 4-in. high cylindrical NaI(Tl) crystal, and single-channel pulse-height analyzer. With the aid of photopeak to total ratios as determined for this crystal[1] from collimated monoenergetic gamma rays from six sources, the relative intensities of the three gamma rays following the decay of Pr^{144} have been determined in terms of the 0.134-Mev gamma ray of Ce^{144}. If we assume the 0.134-Mev transition to occur during 22 percent of the Ce^{144} disintegrations[2] and that six percent of these transitions appear in the form of internal conversion,[3] the relative abundance of the 0.696-Mev gamma ray is 1.8 percent of the total number of Pr^{144} transitions; that of the 1.49-Mev gamma ray is 0.32 percent; and that of the 2.185-Mev gamma ray is 0.83 percent.

[1] W. E. Kreger and L. McIsaac, Phys. Rev. **93**, 943 (1954).
[2] Auth, Emmerich, and Kurbatov, Phys. Rev. **94**, 794 (1954).
[3] F. T. Porter and C. S. Cook, Phys. Rev. **87**, 464 (1952).

I5. Spin-Orbit Interactions in Many-Body Nuclear Shell Theory.* INGRAM BLOCH AND YÜ-CHANG HSIEH, *Vanderbilt University*.—A nuclear model with Hooke's-law forces between the nucleons has the same shell structure as if the nucleons all moved without interacting in a common harmonic-oscillator central field. Therefore a study has been made of some effects of spin-orbit interactions of the form $(a_pM_p+a_nM_n)\cdot(b_pS_p+b_nS_n)$, where the subscripts p and n refer, respectively, to the protons and the neutrons, M and S are, respectively, orbital and spin angular momenta, and the a's and b's are constants. The latest available results on these interactions will be reported.

* Assisted by the Office of Ordnance Research, U. S. Army.

I6. Internal Conversion Coefficients in Decay of Mn^{52}, Co^{60}, and Sc^{46}.* GLENN L. KEISTER,† *University of Washington*.—Conversion coefficients of the Cr^{52} gamma rays have been measured using sources of Mn^{52} produced in the University's 60-inch cyclotron. In addition, the coefficients of the well-known gamma rays of Ni^{60} and Ti^{46} were remeasured using very thin sources of high specific activity Co^{60} and Sc^{46} obtained from Oak Ridge. The measurements were made in a high resolution beta-ray spectrometer. The N_γ were determined from the known decay schemes[1] by integrating the beta spectra. Compton and external photoelectrons were negligible for Co^{60} and Sc^{46}; some error from these effects are present in Mn^{52}. The measured total coefficients (error$\pm$10 percent) are tabulated in Table I, together with theoretical K plus L coefficients for EQ radiations as determined from tables of Rose, Goertzel, and Swift:

TABLE I.

	E Mev	Total $\times10^4$	$EQ_{K+L}\times10^4$
Mn^{52}	0.74	2.95	3.60
	0.93	1.80	1.75
	1.46	0.72	0.69
Co^{60}	1.17	1.55	1.69
	1.33	1.18	1.29
Sc^{46}	0.89	1.55	1.61
	1.12	0.82	0.89

* Supported in part by the U. S. Atomic Energy Commission.
† Now at Boeing Airplane Company.
[1] Hollander, Perlman, and Seaborg, Revs. Modern Phys. **25**, 469 (1953).

I7. Elastic and Inelastic Scattering of 14-Mev Neutrons by Deuterons. JOHN D. SEAGRAVE, *Los Alamos Scientific Laboratory*.—A counter-telescope consisting of two proportional counters and a thin NaI scintillator in triple coincidence has been used to study the angular distribution of scattered deuterons and disintegration protons from the interaction of 14-Mev neutrons with deuterium. Simultaneous observation of particle energy E and dE/dx permitted unequivocal identification of charged reaction products. Thin radiators of deuterated and normal polyethylene were used, the latter to investigate the incident neutron spectrum and n-p scattering at 14 Mev. The absolute differential cross sections observed over the angular range 0 to 55 degrees in the laboratory system for elastic n-d and n-p scattering are in good agreement with recent measurements using nuclear emulsions.[1] Disintegration protons from the $D(n,2n)H$ process were observed over the (lab) angular range 0 to 80 degrees, with energies between the lower limit of detection (about 2 Mev) and the allowed maxima. The energy distribution over this range appears more nearly uniform than that estimated by Frank and Gammel,[2] and the forward-peaked differential cross section somewhat larger.

[1] Allred, Armstron, and Rosen, Phys. Rev. **91**, 90 (1953).
[2] Frank and Gammel, Phys. Rev. **93**, 463 (1954).

I8. The Decay of Rh^{102}.† D. B. KOCHENDORFER AND DONALD J. FARMER, *University of Washington*.—The radiations emitted by 210-day Rh^{102} have been examined using a solenoidal beta-ray spectrometer and a NaI(Tl) scintillation spectrometer. Rh^{102} was produced in the University's 60-inch cyclotron by both $Ru(p,n)$ and $Ru(d,xn)$ reactions, and the activity separated chemically. The decay of the rhodium fraction has been observed for a period of 190 days and exhibits a 220-day period. Gamma-ray transitions, arranged in order of decreasing intensity and having the following energies, are found: 0.474$\pm$0.001, 0.198$\pm$0.001, 0.127$\pm$0.001, 1.11$\pm$0.02, 1.07$\pm$0.02, 0.62$\pm$0.01, 0.76, 0.70, 158$\pm$0.02 Mev. The 0.127-Mev transition is highly internally converted. The presence of the weak 0.70- and 0.76-Mev transitions is inferred from the shape of the gamma-ray spectrum as observed with the scintillation spectrometer. Previous work[1] suggests the existence of only the 0.474-Mev transition. The positron and negatron spectra are both complex and have maximum end-point energies of 1.27$\pm$0.01 and 1.12$\pm$0.01 Mev, respectively.

† Supported in part by the U. S. Atomic Energy Commission.
[1] Sullivan, Sleight, and Gladrow, *National Nuclear Energy Series*, (McGraw-Hill Book Company, Inc., New York, 1951), Division IV, Vol. **9**, paper 330.

I9. One-Quantum Annihilation of Positrons. DONALD J. FARMER AND J. F. STREIB, *University of Washington*.—5.0-mc C^{11}, carried by N_2 gas (145.0 cm³, 0.5 atmos), wherein it was produced by the (p,α) reaction in the cyclotron, is introduced, after a 25-minute "cool-off" period, into chambers lined with Pb, Ta, or Al. The resulting gamma-ray spectrum, presumably entirely the result of positron (0.99-Mev max) absorption, is filtered by 2.5 cm Pb and observed with a 5.0-cm thick NaI(Tl)-6292 spectrometer. Corrections for background and decay are made. Decay measurements show that the number of spurious high-energy counts due to pileup is small. Source intensities are determined by ordinary annihilation radiation; a calibration of the relative efficiency for detecting this radiation and higher-energy radiation is made with the positron-gamma (2.31-Mev) cascade of O^{14} produced by the $N(p,n)$ reaction, and carried by N_2 gas from which the C^{11} has been absorbed. Preliminary data for gamma-ray energies above 1.4 Mev indicate reasonable agreement with available theoretical results[1] for 1-quantum annihilation and 2-quanta annihilation in flight, which should have gamma ray energies up to 1.9 and 1.7 Mev, respectively.

[1] J. C. Jaeger and H. R. Hulme, Proc. Cambridge Phil. Soc. **32**, 158 (1936); H. Bethe, Proc. Roy. Soc. (London) **150**, 129 (1935).

I10. Elimination of the Pair Interaction in the Pseudoscalar Meson Theory. C. H. CHANG AND B. A. JACOBSOHN, *University of Washington*.—The pair interaction $\int d\tau\rho\varphi^{\alpha}\varphi^{\alpha}$ is eliminated from a Hamiltonian of pseudoscalar symmetric meson theory with an extended source (not extended interaction). The result is an equivalent Hamiltonian with pseudovector interaction only, but with a renormalized coupling constant and a modified source function. The scattering phase shifts are the sum of the shifts due to the core alone and those of the equivalent pseudovector interaction. The renormalized coupling constant and the modified source function is examined in detail in the case in which the original source is square. Some effects of the change in source shape will be briefly discussed. The foregoing result is applied to the classical calculation of nucleon isobar energy for several pair strengths and for a square source function of several sizes. In this particular calculation the effect of the change of the source shape is given approximately by a further renormalization of the coupling constant. The classical excitation energies of isobars in the moderate coupling region are in strong disagreement with the quantum-mechanical results.[1]

[1] F. H. Hawlow and B. A. Jacobsohn, Phys. Rev. 93, 333 (1954).

I11. The Pulse Amplitude Distribution in a BF_3 Counter Irradiated with 4.87-Mev Neutrons. D. B. JAMES, W. KUBELKA, AND S. A. HEIBERG, *University of British Columbia*.—The amplitude distribution of pulses produced by 4.87-Mev neutrons in two BF_3 proportional counters has been studied; one counter contained normal boron and the other enriched boron with 96 percent B^{10}. In addition to the expected reaction $B^{10}(n,\alpha)Li^7$ ($Q=2.79$, 2.31). The reactions $F^{19}(n,\alpha)N^{16}$ and either or both of $B^{10}(n,t)Be^8$ and $B^{10}(n,p)Be^{10}$ were detected. The Q value for the F^{19} reaction was found to be -1.77 ± 0.13 Mev in agreement with the Q from mass values[1] if we assume the alpha emission to occur to the excited state of N^{16} at 0.3 Mev. For the B^{10} reaction $Q=0.51\pm0.15$ Mev, slightly higher than the Q from mass values for $B^{10}(n,t)Be^8$ and $B^{10}(n,p)Be^{10}$.

[1] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. 24, 321 (1952).

I12. The Reaction $B^{11}(n,\alpha)Li^8$. S. A. HEIBERG, *University of British Columbia*.—Neutrons from a pulsed deuterium beam impinging on a tritium target were used to bombard a boron trifluoride proportional counter containing the normal ratio of B^{11} to B^{10}. The half-life of the activity and the energy of the particles indicated that they were due to the immediate breakup of Be^8 into two alphas after the 0.88-sec beta decay of the Li^8 formed by the $B^{11}(n,\alpha)Li^8$ reaction. The process was found to have a cross section of the order of 30 millibarns for 14-Mev neutrons.

I13. Beam Escape from Synchrocyclotrons. WARREN FENTON STUBBINS, *Radiation Laboratory, Department of Physics, University of California, Berkeley*.—A study of the large synchrocyclotrons reveals that only in three a small part, from one-half percent to ten percent, of the circulating beam is accelerated to the limit of radial stability and then spirals out of the cyclotron. The analysis of the conditions at the end of the acceleration cycle shows the following requirements for particles to escape: (a) a rapid rate of expansion of the synchronous orbit, (b) a small first harmonic in azimuthal variation of the magnetic field at the outer radii, and (c) a small amplitude of radial oscillation about the synchronous orbit. The dependence upon these factors is very strong as determined from experimental measurements, and the analysis of the equations of axial and radial oscillations which includes nonlinear terms in axial and radial amplitudes and their derivatives and the azimuthal variation in the magnetic field.

I14. Neutron-Proton Scattering at 90 Mev. CHUNG YING CHIH, *Radiation Laboratory, Department of Physics, University of California, Berkeley, California*.—An investigation of 90-Mev neutrons scattered by protons has been conducted with a cloud chamber filled with hydrogen and a mixture of methane and hydrogen, respectively, in a magnetic field of 22 000 gauss. The neutron energy spectrum has a full width at half-maximum of about 30 Mev. The neutron scatter angles range from 8° to 180° in the center-of-mass system. The differential scattering cross section is found to have a symmetry about 90° in the center-of-mass system. Detail results with a likely theoretical inference will be presented. This work was performed under the auspices of the U. S. Atomic Energy Commission.

I15. A Cerenkov Counter for Electron Detection. R. K. SQUIRE, B. J. MOYER, AND J. E. OSHER, *Radiation Laboratory, Department of Physics, University of California, Berkeley, California*.—A counter has been developed at this laboratory for the detection of electrons with energies from 20 Mev, up to a tested limit of 300 Mev, and which should be useful for much higher energies. It consists of a Lucite shaft 40 cm long and 25 cm in cross section. The radiation is divided at one end and viewed by 2 photomultipliers which operate a coincidence circuit which has a resolving time of 5×10^{-9} second. Tests show that electron energies from 20 to 80 Mev can be determined by pulse-height analysis, and above 90 Mev, simple detection with an almost constant efficiency of 80 percent is possible. 300-Mev electrons give a 0.5-volt pulse. The instrument is quite insensitive to heavy-particle background and was designed specifically for operation in regions of high neutron flux. Tests show that it has no response to the full intensity neutron beam of the 184-in. cyclotron. The counter can be expected to efficiently detect any charged particle which can traverse 10 cm or more of Lucite with a velocity of at least 0.8 c. This work was done under the auspices of the U. S. Atomic Energy Commission.

Thursday Afternoon at 2:00

Physics 334

(H. W. Liepmann, presiding)

Invited Paper

J1. Turbulence and Atmospheric Pollution. F. N. Frenkiel, *Applied Physics Laboratory, The Johns Hopkins University.* (30 min.)

Division of Fluid Dynamics

Symposium on Problems in Acoustics Related to Fluid Dynamics

J2. Experiments on Sound Propagation in Rarefied Gases. Martin Greenspan, *National Bureau of Standards.* (45 min.)

J3. Attenuation of Very High Amplitude Sound Waves. I. Rudnick, *University of California, Los Angeles.* (45 min.)

J4. Turbulent Boundary Layer Noise. O. K. Mawardi, *Massachusetts Institute of Technology.* (45 min.)

Friday Morning at 9:00

Guggenheim Hall

(J. H. Van Vleck, presiding)

Electron Spin Relaxation

Invited Papers

K1. Some Dilemmas in Electron Spin Relaxation. J. H. Van Vleck, *Harvavd University.* (30 min.)

K2. Electronic-Lattice Interaction in Paramagnetic Crystals. K. W. H. Stevens, *Nottingham University, England.* (30 min.)

K3. Relaxation Processes in Ferromagnetic Resonance. Frederic Keffer, *University of Pittsburgh.* (30 min.)

K4. Motion of Individual Ferromagnetic Domain Walls. John K. Galt, *Bell Telephone Laboratories, Murray Hill.* (30 min.)

Friday Morning at 9:00

Physics 320

(E. A. Yunker, presiding)

Invited Paper

L1. Nuclear Spectroscopy. K. C. Mann, *University of British Columbia.* (30 min.)

Contributed Papers

L2. Gamma Radiation from the Proton Bombardment of Oxygen. J. B. Warren, K. A. Laurie, D. B. James, and K. L. Erdman, *University of British Columbia.*—The nuclear gamma radiation following the nonresonant capture of a proton in O^{16} has been studied with protons of energies from 800 kev to 2.1 Mev and found to consist of three components. The main transition goes, via a gamma ray of energy that varies with proton bombarding energy, to the $J=\frac{1}{2}+$ state of F^{17}. This state, 487 kev above the ground state, radiates directly to the ground state. In addition, there is a weaker direct radiative transition from the capture configuration to the ground state. At energies above $E_p=1.8$ Mev oxide targets bombarded with protons give rise to a radiation of 873 kev attributed to the presence of the O^{17} isotope via the reaction of $O^{17}(p,p')O^{17*}$, the radiation corresponding to the transition from the first excited state of O^{17} to the ground state.

L3. Gamma Rays from Li^1+p. K. L. ERDMAN, J. B. WARREN, D. B. JAMES, AND T. ALEXANDER, *University of British Columbia*.—We have studied the gamma rays emitted when a metallic Li^6 target on a backing of platinum is bombarded with protons of energy from 400 kev to 2.2 Mev. Gamma rays of various energies from 430 kev to 6 Mev were emitted. The gamma-ray decay scheme is quite complex, with a large percentage of the gamma rays cascading through the 430 kev first excited state of Be^7. The cross section at $Ep=400$ kev is in the neighborhood of 10^{-30} cm^2. Details of the decay scheme and excitation function will be given.

L4. Spins of Excited States of Some Odd A Nuclei According to the Collective Model.* RICHARD L. MOORE, *Los Alamos Scientific Laboratory, Los Alamos, New Mexico*.—The procedures used in recent papers[1] to estimate the spins of the excited states of Np^{237} and Np^{239} and the rotational energy $\hbar^2/2\mathfrak{J}$ have been applied to levels of other isotopes as observed in α decay. The levels and spins of Ac^{227} are as proposed by Moore.[2] The results which are consistent with the predictions follow:

Isotope	Level energy in kev and (spin)	$\hbar^2/2\mathfrak{J}$ (kev)
Po^{215}	0 (5/2) 270 (7/2) 622 (9/2)	38.7
Ac^{227}	0 (3/2) 38 (7/2) 97 (11/2)	3.1
	323 (7/2) 387 (11/2)	2.6
Th^{229}	0 (5/2) 42 (7/2) 96 (9/2)	6.0
Pu^{239}	277 (3/2) 321 (5/2) 382 (7/2)	8.8

Em^{219}, Ra^{223}, U^{235}, and Am^{241} are also considered.

* Work done under the auspices of the U. S. Atomic Energy Commission.
[1] J. O. Rasmussen, Jr., Arkiv Fysik **7**, 185, 1953. Frank Asaro and I. Perlman, Phys. Rev. **93**, 1423 (1954).
[2] Richard L. Moore, dissertation, The Ohio State University, 1953.

L5. Decay of Ta^{183}.† J. J. MURRAY, P. SNELGROVE, P. E. MARMIER, AND J. W. M. DUMOND, *California Institute of Technology*.—The β^- decay of ${}_{73}Ta_{110}{}^{183}$ into an excited state of ${}_{74}W_{109}{}^{183}$ has been observed, using the curved crystal gamma spectrometer, and the axial focusing homogeneous field β spectrometer. A unique energy level scheme for this mode of decay of W^{183} has been constructed on the basis of energies and conversion properties of 27 transitions. Spin and parity has been assigned to all levels. The γ energies in kev, decay fractions in percent, and multipolarities of the transitions are as follows: 40.97 (10.3) M1, 46.48 (61.4) M1, 52.59 (41.7) M1, 82.92 (2.5) M1, 84.70 (14) M1, 99.07 (31.9) E2, 101.94 (1.5) M1, 103.14 (0.5) E2, 107.93 (45.7) M1, 109.73 (2.9) M1, 120.38 (0.25) M1, 144.12 (6.4) M1, 160.53 (4.4) E2, 161.36 (18.2) M1, 162.33 (9.8) M1, 192.64 (0.4) M1, 203.27 (0.4) M1, 205.06 (1.4) M1, 208.81 (1.1) M1, 209.87 (5.4) E2, 244.26 (10) E2, 246.05 (35.6) M1, 291.71 (5.4) E2, 313.03 (8.8) M1, 354.04 (12) M1, 365.60 (0.8) M1, 406.58 (0.9) E2. The energy uncertainties are given by $\pm 0.15E^2\times 10^{-2}$ in volts or 10 ev, whichever is larger, where E is the energy in kev. The multipolarity assignments for the 82.92, 109.73, 365.60, 406.58, and 103.14 kev transitions were inferred from the decay scheme. All others were determined from conversion properties. The principal features of the scheme are no parity change throughout, frequent violation of single-particle selection rules, and several examples of competition between E2 and M1 transitions. The foregoing results provide an amplification of and corrections to preliminary results reported earlier.[1]

† Research worked supported by contract with Office of Ordnance Research, and U. S. Atomic Energy Commission.
[1] DuMond, Hoyt, Marmier, and Murray, Phys. Rev. **92**, 202 (1953).

L6. Rotational Levels in W^{183}.† R. F. CHRISTY, *Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California*.—Recent investigations by Murray, Marmier, Boehm, Snelgrove, and DuMond[1] of the decay of Ta^{183} reveal an energy-level diagram in W^{183} consisting of 8 excited states below 500 kev. The possibility of relating some of these levels to the rotational states discussed by A. Bohr[2] is being studied. Such an explanation requires alternating deviations of the form $(-1)^{I+\frac{1}{2}}\times(I+\frac{1}{2})\epsilon$ from the simple $I(I+1)$ scheme. However, the magnitude of ϵ requires a mixing of j values. It can be explained by a strong mixing of $p_{\frac{1}{2}}$ and $p_{\frac{3}{2}}$ particle states coupled to a distorted core so that the particle better approximates definite m_l, m_s than j, m_j. The magnitude of the ratio of spin orbit to orbit surface interaction is determined and is fairly small. Further features of the level scheme are being investigated.

† Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Abstract L5, this meeting, Murray, Snelgove, Marmier, and DuMond.
[2] A. Bohr, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. **26**, No. 14.

L7. Radiations from Some Odd-Odd $N=Z$ Nuclei.† DAVID GREEN AND J. REGINALD RICHARDSON, *University of California, Los Angeles*.—P^{30}, Cl^{34}, and K^{38} were produced by p,pn reactions on P_4S_3, NaCl, and KI, respectively, and were studied in a large double-lens magnetic spectrometer and in a NaI scintillation spectrometer. Data with higher precision than those previously published[1] are reported in this paper. Short half-lives encountered required beta-ray source preparation in final form before bombardment. These sources, evaporated on 3 mg/cm^2 aluminum foil backings, had an average areal density of about 10 mg/cm^2 and were about 3 mm in diameter. Data secured were: P^{30} half-life, 2.56 ± 0.15 min; simple positron spectrum end point, 3.24 ± 0.06 Mev; no gamma rays. Cl^{34*} half-life, 32.40 ± 0.04 min; complex positron spectrum end points, 4.50 ± 0.03 Mev, 2.48 ± 0.07 Mev, 1.33 ± 0.10 Mev. K^{38} half-life, 7.7 ± 0.3 min; simple positron spectrum end point, 2.68 ± 0.04 Mev; no conversion line present. Estimated maximum errors are quoted above. Evidence for the position of the $J=0$, $T=1$ level in K^{38} will be discussed. Magnetic spectrometer calibration included measurements on the photopeak of the thorium-converted 4.44-Mev gamma ray from C^{12}, available from a RaD-Be source.

† Supported in part by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Hollander, Perlman, and Seaborg, Revs. Modern Phys. **25**, 469 (1953).

L8. 15.2-Mev Gamma Emission from Carbon-12. CHARLES WADDELL, HARLAN SHAW, DAVID COHEN, AND B. J. MOYER, *Radiation Laboratory, Department of Physics, University of California, Berkeley*.—Pair spectrometer studies of photon emission from a carbon target bombarded by high-energy protons has revealed a 15.2 ± 0.2 Mev gamma line. It has been observed for proton energies extending from 340 Mev down to 30 Mev, and in the energy region from 60 down to 30 Mev the yield rapidly increases. Proton energies below 30 Mev have not yet been available in this experiment. This gamma line is also seen in the deuteron bombardment of B^{11}, but not of B^{10}. This fact, together with energetics arguments, and with clear spectrometer separation from known gamma lines from excited Be^8, indicates strongly an excited C^{12} origin for the line. It is proposed tentatively that the excited C^{12} level here involved is a $T=1$ state for which isotopic spin selection rules forbid a disintegration into three alpha particles. Decay by neutron or proton emission is energetically forbidden. This work was done under the auspices of the U. S. Atomic Energy Commission.

L9. High-Energy Gamma Ray Studies with Nuclear Track Emulsions. HARRY H. HECKMAN, PETER C. GILES, AND WALTER H. BARKAS, *Radiation Laboratory, Department of Physics, University of California, Berkeley*.—A study of high-energy photons emitted from targets when bombarded by the 330 Mev proton and bremsstrahlung beams has been undertaken. The detection of the gamma rays is accomplished by observing electron pairs created by the photons in electron sensitive emulsions. When the gamma rays enter near grazing

incidence, the electron pairs have sufficiently long paths in the emulsion to enable one to estimate the electron pair energy by multiple scattering measurements. The experimental arrangements have been to place the emulsions at distances of 13 to 30 in. from the target in a straight or tapered channel at 90° to the beam direction. The channel is placed in a clearing magnetic field to eliminate the charged particle background originating in the target. Investigations have included observation of gamma rays, principally π^0 decays, emitted from the vicinity of targets bombarded by the 330-Mev proton beam and selective scattering of photons from the bremsstrahlung beam by carbon and lead nuclei. The energy resolution of this technique is also being determined experimentally, using the line spectrum of gamma rays obtained by bombarding LiF with 657-kev protons. This work was done under the auspices of the U. S. Atomic Energy Commission.

L10. Emulsion Tables. WALTER H. BARKAS AND GEORGE HAHN, *Radiation Laboratory, Department of Physics, University of California, Berkeley.*—Each measurable feature of a heavy charged particle track in emulsion may be normalized by functions of the particle mass and charge so as to become a function of the velocity alone. Since each is a known function of the velocity, a knowledge of one normalized quantity implies a knowledge of all others. This observation provides a basis for the systematic utilization of nuclear track emulsion as a quantitative instrument. An analysis of particle range, ionization, range, straggling, multiple scattering, delta-ray density, maximum delta-ray energy, grain density, residual time, momentum, magnetic curvature, kinetic energy, and total energy has been carried out. Tables and graphs have been constructed giving each quantity as a function of every other quantity. Supplementary information necessary for the correct and rapid utilization of the data has been tabulated. This work was done under the auspices of the U. S. Atomic Energy Commission.

L11. Production of Deuterons in High-Energy Nuclear Bombardment of Nuclei. W. N. HESS AND B. J. MOYER, *Radiation Laboratory, Department of Physics, University of California, Berkeley.*—The production of deuterons when various elements are bombarded with 300-Mev protons or 300-Mev neutrons has been studied at angles of 25° and 40° to the beam. The scattered particles have been identified by using either $H\rho$ and range or by using E and dE/dx. The dependence of the deuteron cross section on A and the shape of the deuteron energy spectra indicate that the production mechanism for forming these deuterons is the indirect pickup process of Bransden.* The A dependence of the deuteron cross section shows that the deuterons are formed on the surface of the nucleus. Because of this fact the cross sections for incident neutrons and for incident protons when compared can give information about the variety of nucleons found on the nuclear surface. The following values have been obtained for the fraction of surface nucleons that are neutrons:

$$\begin{aligned} &\text{Carbon} &&= 0.47 \pm 0.09, \\ &\text{Cadmium} &&= 0.59 \pm 0.07, \\ &\text{Lead} &&= 0.78 \pm 0.12, \\ &\text{Uranium} &&= 0.75 \pm 0.10. \end{aligned}$$

For lead and uranium these values are significantly larger than the volume fraction of neutrons. This implies that at least for heavy elements there is a nuclear skin rich in neutrons. This work was done under the auspices of the U. S. Atomic Energy Commission.

* B. H. Bransden, Proc. Phys. Soc. (London) **A65**, 738 (1952).

L12. Elastic Scattering of 9.7-Mev Protons by Alpha Particles. BRUCE CORK AND WALTER HARTSOUGH, *Radiation Laboratory, Department of Physics, University of California, Berkeley.*—The differential cross section for the scattering of 9.7-Mev protons from helium has been measured over the range from 17° to 154° in the center-of-mass system. The new 9.8-Mev proton linear accelerator, which is now used as an injector for the Bevatron, was used as a source of incident protons. A scattering chamber has been used which has the solid angles at the various scattering angles determined by fixed slits. The scattered particles were detected with sodium iodide scintillators and RCA 6199 photomultiplier tubes. The detectors were conveniently arranged so that each scintillator could be well shielded, and background runs could be made easily. The counters were arranged so that they could be interchanged and three angles have been measured simultaneously, with a statistical accuracy in the forward direction of better than ± 1 percent. The differential cross section measurements of the forward angles are in good agreement with published data in this energy region. However, the cross section for protons scattered in the background direction is approximately 75 percent of the published value. This work was done under the auspices of the U. S. Atomic Energy Commission.

L13. Radiative Capture of 300-Mev Neutrons in Hydrogen.* JOHN DEPANGHER,† *University of California, Berkeley.*—In the course of performing an n-p scattering experiment[1,2] at Berkeley with 300-Mev neutrons, six deuterons were observed starting in the collimated region of the cloud chamber.[1,3] Three possible reactions in which deuterons may appear in hydrogen are $n+d \rightarrow n+d$ (impurity scattering), $n+p \rightarrow \pi^0+d$ (neutral-meson production), and $n+p \rightarrow \gamma+d$ (radiative capture). One of these events clearly was an impurity-scattering event. A detailed analysis has been made in an attempt to distinguish the cases of neutral-meson production and of radiative capture from one another. An argument based on this analysis and on the shape of the neutron-energy spectrum will be presented to show that two of these deuterons were formed in the radiative-capture process while the remainder lies in the category of neutral-meson production. The present work, it is believed, is the first to demonstrate clearly[4] the radiative capture of neutrons by protons for neutron energies other than thermal.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
† Now with the Hanford Atomic Products Operation, General Electric Company, Richland, Washington.
[1] University of California Radiation Laboratory Report UCRL-2153 (unpublished).
[2] J. DePangher, Phys. Rev. **92**, 1084 (1953).
[3] J. DePangher, Phys. Rev. **88**, 894 (1951).
[4] W. E. Crandall and B. J. Moyer, Phys. Rev. **92**, 749 (1953).

L14. Small-Angle n-p Scattering at 400 Mev.* R. T. SIEGEL, A. J. HARTZLER, AND W. OPITZ, *Carnegie Institute of Technology.*—The angular distribution of 400-Mev neutrons scattered at small angles from hydrogen has been studied for laboratory angles between 5.8° and 27.8°. A polythene converter and scintillation counter telescope were used as neutron detector, with a large anticoincidence counter preceding the array in order to screen out charged particles. Variable copper absorbers in the coincidence telescope provided a 365-Mev low-energy cutoff for the primary neutrons. Results show an essentially constant cross section between 12.7° and 50° (neutron scattering angle) in the center-of-mass system, (statistical standard deviation ~10 percent at each angle). This is quite different from the behavior at supplementary angles, where a cross section rising steeply towards 180° has been observed.[1]

* Supported in part by the U. S. Atomic Energy Commission.
[1] A. J. Hartzler and R. T. Siegel, Phys. Rev. **91**, 928 (1954); also Phys. Rev. (to be published).

FRIDAY MORNING AT 9:00

Physics 334

(R. GEBALLE, presiding)

Excitation and Ionization Phenomena

Invited Papers

M1. Mechanism of the Electric Spark. L. H. FISHER, *New York University.* (30 min.)

M2. Particle Induced Laboratory Auroral Phenomena. A. B. MEINEL, *Yerkes Observatory, Williams Bay, Wisconsin.* (30 min.)

M3. On the Morphology of Auroral Displays in Alaska. C. T. ELVEY, *Geophysical Institute, College, Alaska.* (30 min.)

Contributed Papers

M4. Solar X-Ray Emission. E. T. BYRAM, T. A. CHUBB, AND H. FRIEDMAN, *U. S. Naval Research Laboratory.*—Solar x-ray emission between 8 A and 60 A was measured with photon counters carried in 3 high altitude rockets flown at White Sands Proving Ground in November and December of 1953. Tubes equipped with Al foil windows were sensitive to 8 A–14 A x-rays. Windows of Mylar film (polyethylene terphthalate, 0.7 mg/cm^2) were used for transmission of a relatively narrow band extending from the carbon K edge at 43 A to about 55 A. Thinner windows of Glyptal (0.2 mg/cm^2) were used which were capable of transmitting a broader band from 10 to 80 A except for the region in the neighborhood of the carbon K absorption. Maximum solar x-ray emission was observed in the 43–50 A region. The intensity over the entire x-ray spectrum was of the order of 10^{-1} erg cm^{-2} sec^{-1}. A previous experiment[1] had indicated an order of magnitude greater intensity in the short wavelength portion of the spectrum. Both rocket measurements of solar x-rays appear to correlate with the intensity of the coronal green line as recorded at the Sacramento Peak and Climax observatories during the periods of the flights.

[1] Byram, Chubb, and Friedman, Phys. Rev. 92, 1066–1067 (1953).

M5. Excitation of Air Glow by Electronic Impact.* C. Y. FAN, *Yerkes Observatory, University of Chicago.*—A spectrographic study has been made of the optical emission from a rarefied air sample under the bombardment of an electron beam of energy from 10 ev to 8000 ev. The spectral range covers 3800 A to 9000 A. It was found that the spectra are quite different from that excited by protons or heavier ions. In particular, the Meinel system of N_2^+ and the first negative system of O_2^+ are so distinctive in the former spectra for electron energy greater than 100 ev while they are *practically* missing in the later ones. This finding as related to the excitation mechanism of aurora borealis will be discussed.

* This investigation is supported in part by the Geophysical Research Directorate of the Air Force Cambridge Research Center under contract No. 19(122)-480.

M6. Electromagnetic Radiations from Hydrocarbon Flames.* SAMUEL C. LAWRENCE, JR., *Physical Research Unit, Boeing Airplane Company.*—Random radio-frequency noise generated in ramjet flame has been observed in the ultrahigh-frequency spectrum. Some correlation of intensity of radiation and temperature exists. The effect, being several orders of magnitude greater than expected from Planck's distribution law, is attributed to electron plasma oscillations. Thermal disassociation of combustion products plus thermal radiation from combustion chamber walls produce sufficiently great electron densities to account for the frequencies observed. Part of the amplitude variations observed is believed due to attenuation effects of the flame. The Hamiltonian for the flame system is expressed in general form, from which it is believed that effects of temperature discontinuities due to shock waves and uneven burning can be evaluated.

* Work supported by U. S. Air Force Contract.

M7. Detection of Mercury Vapor by Resonance Ionization. K. C. CLARK AND L. KANAL, *University of Washington.*—It is known that mercury ions are produced on irradiation of mercury vapor by the resonance line 2537 A when an inert gas such as nitrogen is present at considerable pressure. The ions are derived from three-body collisions involving two excited atoms and at a rate proportional to the second power of the intensity at the core of the resonance line. This process of ionization by inelastic collision provides a sensitive monitor of the intensity of resonance radiation. Absorption of this line by mercury vapor in a sample of air is detected using this means in a balanced double path arrangement. Unfiltered light from commercial germicidal lamps can be used because of the selective wavelength response of the process. The detector contains mercury at room temperature, purified nitrogen at 50 mm, and molybdenum screen electrodes. The effect of Lorentz broadening in the absorption cell and in the detector is computed. Calibration with an absorption path of 10 in. shows that concentrations as low as 1 percent of the toxic limit of 0.1 mg/m^3 can be measured.

SATURDAY MORNING AT 10:00

Community House, Longmire

Mt. Rainier National Park

(E. A. UEHLING, presiding)

Contributed Papers

N1. Relative Contributions of *K*-Shell and other Electrons to the Stopping Power of Light and Heavy Elements. EDWIN A. UEHLING, *University of Washington.*—The correction to the stopping power formulas caused by the binding of *K*-shell electrons has been calculated by Walske.[1] Walske has also estimated the effect of the *L* and higher shell electrons. Independent evidence of the importance of the higher shell electrons can be deduced from the Lindhard-Scharff[2] plot of stopping power data. Such a plot exhibits the deviations from logarithmic behavior of the stopping number. These deviations occur over a certain range of the parameter $\zeta = v^2/v_0^2 z$ and they are independent of the energy of the penetrating particle and of the atomic number regarded as independent parameters. The parameter ζ is related to Walske's parameter η_k. The *K*-shell corrections are determined by the values of η_k. There is a correspondence between the range of variation of η_k in which *K*-shell corrections are important and the range of variation of η in which the deviations from logarithmic behavior occur. These intervals overlap for the light elements but fail to do so for the heavy elements. An interpretation in terms of over-all corrections can be given.

[1] M. C. Walske, Phys. Rev. **88**, 1283 (1952).
[2] J. Lindhard and M. Scharff, Kgl. Danske Videnskab. Selskab. Mat.-fys. Medd. **27**, 15 (1953).

N2. Nuclear Electric Quadrupole Interactions of B^{11} in Kernite.* H. L. BLOOD AND W. G. PROCTOR, *University of Washington.*—Kernite, a monoclinic crystal of space group $P2/c$, has four molecules $Na_2B_4O_7 \cdot 4H_2O$ in a unit cell. Rotation of the crystal about the symmetry axis when perpendicular to a strong magnetic field H_0 reveals a pattern of 11 lines for the transitions between the magnetic energy levels of B^{11} ($I=3/2$), strongly perturbed by the nuclear electric quadrupole interaction. Rotation about an axis perpendicular to the symmetry axis reveals a pattern of 21 lines, which, when related to the above, establish four nonequivalent sites for the boron nuclei in the unit cell. One rotation is sufficient to specify the electric field gradient tensor (except for signs) at a nuclear site if, as is the case for two of the sites, the transitions are such that second perturbation methods may be used in the analysis.[1] In this way we have obtained a tentative value for the quadrupole coupling constant at one site to be 1250 kc. Rotation about a third axis is now in progress.

* This research was supported by the U. S. Air Force, through the Offic of Scientific Research of the Air Research and Development Command.
[1] G. M. Volkoff, Can. J. Research **31**, 820 (1953).

N3. Nuclear Spin Lattice Relaxation in Supercooled Menthol.* B. H. MULLER† AND MYER BLOOM,‡ *University of Illinois.*—The nuclear spin lattice relaxation time (T_1) of liquid and supercooled *l*-menthol has been measured between 33.8°C and 49.0°C within an accuracy of ±2 percent. The relaxation theory of Bloembergen, Purcell, and Pound has been applied to this case. This theory adequately predicts the magnitude of T_1 (about 0.2 sec) as well as the temperature dependence if 4.3 A is chosen as the "radius" of the menthol molecule and 2.27 A as the "average" interproton distance. An investigation of the structure of the menthol molecule and the amendment of the theory to take into account the CH_3 rotations within the molecule allows a prediction of 1.87 A for the "average" interproton distance. No unusual changes in T_1 or T_2 (the phase memory time) were observed as the temperature was changed through the normal freezing point (42.5°C). These measurements were done at too high a frequency (30 megacycles) to be able to determine whether or not the reported viscosity transition[1] is reflected in the magnetic resonance experiment.

* Research supported in part by the U. S. Office of Naval Research.
† Now at the University of Wyoming.
‡ Holder of a Province of Quebec Postgraduate Travelling Fellowship.
[1] E. N. da C. Andrade, Proc. Roy. Soc. (London) **A215**, 36 (1952).

N4. Temperature Dependence of the Nuclear Resonance in Metals.* W. D. KNIGHT, *University of California, Berkeley.*—The fractional frequency shift in cubic metals may be expressed[1] as $\Delta H/H = (8\pi/3)\chi_p P_f$, where χ_p is the Pauli spin susceptibility per atom, and P_f is the square of the electronic *s*-wave function averaged over the Fermi surface. Measurements of $\Delta H/H$ on Na, Al, Cu, V, and Nb between 1.2 and 300°K show small decreases with decreasing temperature. For Na, the value of $\Delta H/H$ drops (by about 10 percent of its 300° value) between 75° and 25°K. This behavior may be associated with a crystal structure change in this element.[2] No resonance is observed in Nb at 4°K, presumably because of superconducting domains. The temperature changes in $\Delta H/H$ for the other metals are much smaller than for Na. $\Delta H/H$ should be nearly independent of temperature, but χ_p, in a free electron approximation, will go as (volume)$^{\frac{2}{3}}$ (in rough agreement with the experiments), and P_f may be a weak function of atomic volume. Also, since both χ_p and the electronic heat are proportional to the density of electron states at the Fermi surface, one expects a correlation in the temperature dependencies of these quantities, and any positive peaks in density of states, as Frölich has proposed,[3] should show up in both. No evidence for an appreciable electron-lattice interaction, such as Frölich proposes, is found in these data.

* Supported in part by the U. S. Office of Naval Research.
[1] Townes, Herring, and Knight, Phys. Rev. **77**, 852 (1950).
[2] C. S. Barrett, Mineralogist **33**, 749 (1948).
[3] H. Fröhlich, Phys. Rev. **79**, 845 (1950); M. J. Buckingham, Nature **168**, 281 (1951).

N5. Nuclear Magnetic Resonance in CuAl Alloys.* D. R. TEETERS AND W. D. KNIGHT, *University of California, Berkeley.*—We have observed the nuclear resonances of Cu and Al in several quenched, unordered CuAl alloys. The following results are quoted for $\Delta H/H$: pure Cu, (0.23 percent), pure Al (0.17 percent), 10–90 Cu-Al (Cu 0.27 percent, Al 0.17 percent), 90–10 Cu-Al (Cu 0.23 percent, Al 0.11 percent). We see, first, that the resonance frequency of the solvent is relatively unaffected by a 5–15 percent solute concentration. Second, the solute frequency is changed appreciably. The Cu line shift is increased in an Al environment, while the reverse is true for Al in a Cu environment. By way of interpretation, we may say that small solute concentrations behave like impurities and leave the average electronic structure, as seen by the solvent, relatively unaffected.[1] On the other hand, both P_f and χ_p (see previous abstract) for the solute metal may be considerably altered. If we calculate, from experimentally derived susceptibilities, the expected change in $\Delta H/H$ for either Cu or Al in solution, we find that the direction of the effects is correct. However, to explain the magnitudes of the

effects, it is necessary to assume that changes in the volume per electron in the alloy alter the value of P_f. For example, we should expect P_f to be relatively larger in a half-filled zone, where the p-wave function admixtures are small. Data on alloys of Cu and Al in Ag and Au will be presented.

* Supported in part by the U. S. Office of Naval Research.
[1] J. Friedel, Phil. Mag. 43, 153 (1952); N. Bloembergen and T. J. Rowland, Acta Metallurgica 1, 732 (1953).

N6. Nuclear Magnetic Resonance in Kernite. H. WATERMAN, *University of British Columbia* (introduced by G. M. Volkoff).—The dependence of B^{11} nuclear resonance frequencies in a single crystal of kernite ($Na_2B_4O_7\cdot 4H_2O$) on the angles of rotation of the monoclinic crystal about its b and c axes has been studied in a magnetic field of 7000 gauss perpendicular to the rotation axis. Eleven lines, some showing slight splitting, were observed in the b rotation. In the c rotation twenty-one lines were observed, which coalesced into eleven when the b axis was perpendicular to the magnetic field, suggesting that the slight doubling of some lines in the b rotation might be due to a slight misalignment of axes. An analysis of these results will be given which shows that they are consistent with the reported symmetry properties of kernite. Four independent sets of quadrupole coupling constants and asymmetry parameters, and four pairs of different orientations of the principal axes of the electric field gradient tensor at the boron sites are indicated. Of the four boron nuclei in a molecule two appear to be in regions of much more strongly inhomogeneous field than the other two.

N7. DC Prebreakdown Currents in Gases of High Dielectric Strength.* M. L. REEVES AND RONALD GEBALLE, *University of Washington.*—Measurements of dc prebreakdown currents[1] between plane parallel electrodes have been extended to the gases isopentane, SF_6, $SiCl_4$, and CCl_4. The first of these yields semilogarithmic graphs of current *vs* electrode separation which are linear, indicating that ionization by collision takes place without competition. Similar graphs for the other gases show curvature. In SF_6 and CCl_4 the curves actually saturate for a certain range of E/p, showing that electron attachment is the predominant reaction. Curves for $SiCl_4$ do not exhibit this feature over the range of E/p amenable to this method. Values of ionization and attachment coefficients are derived from the above data in SF_6 and CCl_4. In the latter gas each coefficient has a minimum when plotted against E/p. Evidence will be discussed that dissociation into ions, as well as ionization and attachment, is important in $SiCl_4$.

* Assisted by the U. S. Office of Ordnance Research.
[1] M. A. Harrison and R. Geballe, Phys. Rev. 93, 1 (1953).

N8. Back Diffusion of Electrons to a Plane Emitting Surface. ROBERT P. STEIN, *U. S. Naval Ordnance Test Station, Inyokern, China Lake, California.*—A program has been set up for the 701 Computer wherein the current flux from a flat plate of infinite extent may be determined in terms of the electron liberation per unit area per unit time, the mean free path of the electron, and the impressed electric field. A description of this program and its results will be made.

N9. Some Experimental Facilities and Techniques Used at the Berkeley 60-in. Cyclotron for Irradiation Effects Studies.* W. S. GILBERT AND J. H. PEPPER, *North American Aviation, Inc.*—In the study of irradiation effects caused by high energy charged heavy particle bombardment of pure metals, alloys, and semiconductors, the electronic phenomena are of fundamental interest. Apparatus and procedures have been developed which enable us to measure electrical resistivity and thermoelectric power simultaneously while the target is in place at the cyclotron. These measurements can be rapidly made with relatively high precision under well-controlled temperature conditions. Excellent target cooling, coupled with control of the emergent proton beam shape permits us to bombard targets with beams of several microamperes/cm² while maintaining the targets within 5°C of a prescribed temperature. Details of the target configuration, the measuring equipment, the precision of data, and beam shape studies will be presented.

* This work was based on studies conducted for the U. S. Atomic Energy Commission.

N10. Disintegration of Arsenic-76. M. SAKAI, B. MURRAY, AND J. D. KURBATOV, *The Ohio State University.*—The disintegration scheme of arsenic-76 has been previously reported by many authors. While the main disintegration scheme is well established, the low-energy beta components and associated gamma rays are in doubt. A thick lens magnetic spectrometer, scintillation spectrometer, and coincidence scintillation spectrometer were used to clarify the disintegration scheme. Beta-ray spectrum, photoelectron spectrum, scintillation gamma-ray spectrum, gamma-gamma coincidence, and beta-gamma coincidence measurements were made. Gamma-ray energies of 549 ± 4 kev, 643 ± 6 kev, 1200 ± 6 kev, 1402 ± 15 kev, and 2053 ± 18 kev, were obtained. The relative intensities of these gamma rays are 1/0.22/0.27/0.02/0.05, respectively. No gamma rays in the 1700–1800 kev region were obtained. By beta-gamma coincidence measurements the beta-ray end-point energies associated with the 549 kev and 1200 kev gamma ray were clearly defined. The relative intensity and *ft* values for each beta component were obtained by subtraction of the Fermi plot using the beta-ray end point energy of the associated gamma ray. A disintegration scheme will be presented and energy levels discussed. All activities were obtained from Oak Ridge National Laboratories and were chemically purified.

N11. ZnS(Ag) Phosphor Mixtures for Neutron Detection. P. G. KOONTZ,* G. R. KEEPIN, AND J. E. ASHLEY, *University of California, Los Alamos Scientific Laboratory.*—In a search for a fast neutron detector with minimum gamma response, the scintillation characteristics of ZnS(Ag) were reexamined. The principal decay constant of ZnS(Ag) was measured as $\sim 0.04\mu$ sec with a fast scope (Tektronix 517) and short anode time constant ($\sim 5\times 10^{-9}$). τ was found to be independent of the mode of excitation (alphas or electrons from gammas) and, as expected, measured values of τ increased with slower electronics. ZnS(Ag) thus appeared sufficiently promising to warrant a brief survey of various mixtures of this phosphor with boron, lithium, and fissionable compounds for neutron detection. Various atomic ratios and thicknesses were tested for each mixture. 100 mg/cm² of a mixture of finely ground boric acid powder and ZnS(Ag) powder (atomic ratio 1B/1.5 Zn) yielded the highest neutron counting efficiency, $\epsilon_n\sim 1$ percent, with a ratio of neutron-to-gamma counting efficiency $>10^5$. Increased ϵ_n is obtained at the expense of $\epsilon_n/\epsilon_\gamma$ ratio. Various mixtures of boric acid and ZnS(Ag) were compression-molded into thin disks using a hydrogenless binding agent. Optimum counting efficiencies for these disks fell considerably below that of the powder mixtures.

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