Proceedings of the American Physical Society

Minutes of the Meeting at Berkeley, California, December 27–29, 1951

THE 310th meeting of the American Physical Society was held at Berkeley, California, on Thursday, Friday, and Saturday, December 27, 28, and 29, 1951. The actual registrations came to 431, with many of those attending having come from considerable distances. In view of the bad weather prior to and during the meetings, this large attendance was surprising. The programme was the largest in the history of the West Coast, with one hundred and twenty-five contributed papers, nine invited papers, and three post-deadline papers. Dr. Robert F. Christy was unable to be present because of illness, and his time was given to Dr. Erwin W. Müller, Chief of the Kaiser-Wilhelm-Institut of Berlin and Professor at the Free University of West Berlin, who gave a very interesting description of his important work on point projection microscopes.

The local arrangements were unusually effective, with the new Le Conte Hall Annex providing a perfect setting for the meetings. Professors Birge, White, and the capable office staff of the Department of Physics took care of arrangements and most of the running of the meeting. The Thursday and Friday afternoon sessions had been arranged so as to allow a short recess before the sessions for invited papers. This allowed the Berkeley people to arrange for about thirty minutes of coffee and tea, very refreshing and pleasant interludes. Almost 200 were served each day. Arrangements had also been made for trips to the Radiation Laboratory. The Society is indebted to Dr. Cooksey for arranging these trips. We are also greatly indebted to the Berkeley Chamber of Commerce for providing us with badges and literature concerning Berkeley and the Bay region.

The first West Coast meeting of our Division of Electron Physics was a successful and well-attended one, adding considerably to the success of one of the best meetings ever held on the West Coast.

Many of our members received the Bulletin for this meeting just before, during, or even after the meeting. Such delays are inevitable when the Bulletin is mailed during the Christmas rush. The only ways to avoid them are (a) to transfer the winter meeting on the West Coast to some other time than the holiday week, and (b) to increase by two or possibly three weeks the interval between deadline and meeting. Any member who feels strongly for or against either of these changes is asked to notify the Local Secretary for the Pacific Coast.

J. Kaplan
Local Secretary for the Pacific Coast
University of California
Los Angeles 24, California

Errata Pertaining to Papers B7, D6, K5, Q11, and Q13

B7, by Kenneth James Harker. The next to the last sentence should read: When two or more eigenfunctions have the same L and S the method still yields all eigenfunctions possible.

D6, by W. D. Perkins and M. Kent Wilson. In line 8, $\nu_1(A_g)=1342$ should read $\nu_1(A_g)=1334$. In line 9, $\nu_4(A_u)=70$ should read $\nu_4(A_u)=??$.

K5, by W. D. Knight. In line 19, two orders of magnitude greater than . . . should read twice as great as . . . .

Q11, by Arthur L. Bennett, Ivar Highberg, Ernest Barkofsky, and Lucien M. Biberman. The title of the abstract should read: The Aeroballistics Laboratory of the U. S. Naval Ordnance Test Station.

Q13, by W. C. Barber, G. E. Becker, and E. L. Chu. A footnote should be added reading: Assisted by the joint program of the ONR and AEC.

PROGRAMME

THURSDAY MORNING AT 10:00

Room 310, Le Conte Hall

(L. B. LOEB presiding)

Meeting of the Division of Electron Physics

Forty minutes will be allowed for presentation and ten minutes for the discussion of each paper.

A1. Space Charge Phenomena in High Density Electron Beams. M. CHODOROW, *Stanford University.*

A2. Ejection of Electrons by Ion Impact. H. D. HAGSTRUM, *Bell Telephone Laboratories.*

A3. Field Emission; a Comparison between Theory and Experiment Including Pulsed Emission at Large Densities. W. P. DYKE, *Linfield College.*

THURSDAY AFTERNOON AT 1:30

Room 4, Le Conte Hall

(W. M. POWELL presiding)

B1. Anisotropy Energy in a Cubic Lattice of Spin Dipoles. JACK R. TESSMAN, *University of California, Berkeley.*—Classically there is no anisotropy energy in a saturated cubic lattice of spin dipoles. However, as has been pointed out by Kittel,[1] anisotropy arises quantum mechanically from the requirement that, for each dipole, S_x, $S_y \neq 0$ even for maximum polarization in the z-direction. The spin-wave method as developed by Heller and Kramers[2] and by Klein and Smith,[3] and applied by them to ferromagnetic exchange interactions, is here applied to paramagnetic dipole interactions for which the interaction energy is given by

$$H_{ij} = J[\mathbf{S}_i \cdot \mathbf{S}_j - 3(\mathbf{S}_i \cdot \mathbf{r})(\mathbf{S}_j \cdot \mathbf{r})/r^2].$$

The simplifying assumption is made of nearest neighbor interactions only. Expressions are obtained for the anisotropy energy for a plane square lattice and for a cubic space lattice.

[1] C. Kittel, Phys. Rev. **82**, 965 (1951).
[2] G. Heller and H. A. Kramers, Proc. Roy. Acad. Sci. (Amsterdam) **37**, 378 (1934).
[3] M. J. Klein and R. S. Smith, Phys. Rev. **80**, 1111 (1950).

B2. Elastic Scattering of 190-Mev Deuterons by Protons.* MARTIN O. STERN, *University of California, Berkeley.*—Experiments on elastic scattering of the 184-inch cyclotron's 190-Mev deuterons reported earlier[1,2] while in progress, have been completed. Differential scattering cross sections between 15° and 170° in the center of mass have been measured by the polyethylene-carbon subtraction method in stilbene scintillation counters feeding fast amplifiers. The range 40° to 160° was covered by observation of coincidences between the deuteron and its partner proton. The intervals 15° to 45° and 150° to 170° were covered with a single crystal preceded by aluminum absorber. The change in hydrogen effect with varying absorber was observed. An elastic scattering cross section between 10° and 180° of $(29\pm3)\cdot10^{-27}$ cm^2 was obtained. Agreement with the theory of Chew[3] is excellent for the range 50° to 120°. At smaller angles the observed effect is about 0.7 of the calculated one; in the "pick-up" region near 180° a peak is found which is a factor of five lower than that theoretically predicted.

* Assisted by the AEC.
[1] A. L. Bloom and M. O. Stern, Phys. Rev. **81**, 660 (1951).
[2] M. O. Stern and A. L. Bloom, Phys. Rev. **83**, 178 (1951).
[3] G. F. Chew, Phys. Rev. **74**, 809 (1948).

B3. Inelastic and Total Scattering of 190-Mev Deuterons by Protons.* ARNOLD L. BLOOM,† *University of California, Berkeley.*—Total and differential inelastic cross sections for $d-p$ scattering have been measured at the 184-in. cyclotron, using stilbene counter techniques similar to those used for elastic $d-p$ scattering.[1] The total cross section was obtained by measuring the differential cross section for scattering of charged particles and integrating over all solid angles; since any $d-p$ collision scatters two charged particles, the integral is twice the total cross section. This method gives $\sigma=(92\pm7)\times10^{-27}$ cm^2, Rutherford scattering excluded. Inelastic collisions in which both protons suffer large changes of momentum were examined by measuring coincidences between protons. The angles between scattered protons have a narrow distribution near 90° in the laboratory system; the differential cross sections $\sigma(\Phi)$ for scattering one of the protons through an angle Φ are about one-third the corresponding free $p-p$ cross sections at comparable momenta.[2]

* This work was performed under the auspices of the AEC.
† Now at Varian Associates, San Carlos, California.
[1] M. Stern and A. Bloom, Phys. Rev. **83**, 178 (1951).
[2] Birge, Kruse, and Ramsey, Phys. Rev. **83**, 274 (1951).

B4. Locating Buried Radioactive Sources. J. D. GRAVES AND RICHARD I. CONDIT, *Broadview Research and Development, Burlingame, California.*—Expressions have been obtained for the nuclear radiation intensity above the surface of the ground (assumed plane) from buried point sources of cobalt 60. The optimum procedure for expeditiously locating such sources from large distances by detecting their gamma-radiation depends chiefly upon the depth of burial and is expressed in terms of the angle between the detector-source line and the ground surface. This optimum angle is 0 degrees for sources on the surface, 30 degrees for sources at a depth of about 8 cm, 60 degrees for sources at about 100 cm, and approaches 90 degrees for sources at very great depths. Thus, the maximum radiation intensity at any given large distance parallel to the ground from a source buried a finite depth occurs above the surface, and accordingly the search for buried radioactive materials is best attempted with detectors at elevated positions. About the elevation of maximum intensity, the intensity decreases more rapidly with decreasing elevation than with increasing elevation. Where actual field conditions involve extended sources and nonplanar topography, the advantages of elevated detection are even more pronounced. These results have important applications in the search procedures for radioactive ores, contamination, and tracers.

B5. Isotope Effects in the Decarboxylation of Malonic Acids. PETER E. YANKWICH, EDWARD C. STIVERS, AND ROBERT F. NYSTROM, *Department of Chemistry and Radiocarbon Laboratory, University of Illinois, Urbana.*—Malonic and bromomalonic acids carboxyl-labeled with carbon fourteen have been decarboxylated at their melting points. Effluent carbon dioxide and carbon dioxide obtained from combustion of the resulting acetic acid were subjected to radioactivity and isotope-ratio determination. The intramolecular isotope effects for carbon thirteen and fourteen were calculated from the results of these determinations.

For malonic acid, both the carbon thirteen and carbon fourteen effects are in agreement with earlier work,[1–3] but the agreement for carbon fourteen is not complete.[4] For bromomalonic acid, the carbon thirteen effect agrees with that predicted,[5] but the carbon fourteen effect disagrees both with the prediction and with previous observation.[3]

[1] Jacob Bigeleisen and Lewis Friedman, J. Chem. Phys. **17**, 998 (1949).
[2] Lindsay, Bourns, and Thode, Can. J. Chem. **29**, 192 (1951).
[3] Peter E. Yankwich and Melvin Calvin, J. Chem. Phys. **17**, 109 (1949).
[4] Arthur Roe and Max Hellmann, J. Chem. Phys. **19**, 660 (1951).
[5] Jacob Bigeleisen, J. Chem. Phys. **17**, 425 (1949).

B6. Pulse Analysis with the Aid of a Mechanical Synthesizer-Analyzer. S. LEROY BROWN, *University of Texas.*—The method of utilizing a mechanical harmonic synthesizer to perform harmonic analysis[1] has been modified so that the harmonic content of a pulse may be readily determined. The amplitudes of the fifteen sine components of the synthesizer are set to the values of fifteen equispaced ordinates of a short pulse. For example, if the pulse is considered to be 1/48th of its repetition period, a few hundred sine components may be evaluated from a single trace made by the machine as its fundamental turns through not more than 90°. Similarly, a a few hundred cosine components are evaluated from a second trace with the cosine components of the machine set to the values of the equispaced ordinates of the pulse. The sine and cosine components of shorter and shorter pulses, of the same shape, may be evaluated from these two original traces. By suitable change of scale, these curves represent the sine and cosine Fourier transforms of the pulse; i.e., they represent the continuous spectrum of the pulse. Since both sine and cosine components are found, the phase angles as well as the amplitudes are determined.

[1] S. Leroy Brown, J. Franklin Inst. **228**, 675 (1939).

B7. LSM_LM_S Eigenfunctions of an Atom. KENNETH JAMES HARKER, *University of California, Los Angeles. (Introduced by E. Lee Kinsey.)*—Gray and Wills[1] have described a method for finding the LSM_LM_S[2] eigenfunctions of an atom whose outer shell contains n equivalent electrons with angular momentum l, n and l arbitrary. A more direct method using group theory is introduced here to solve the same problem. One starts from a single electron basis with a central field only. An electrostatic interaction perturbation is next introduced. The products of single electron orbital wave functions are transformed to a new basis according to the complete reduction of the direct product of the rotation group: $D_l\times D_l\times D_l\times\cdots=\Sigma D_L$. Likewise, the products of single electron spin functions are transformed to a new basis according to the reduction: $D_{\frac{1}{2}}\times D_{\frac{1}{2}}\times D_{\frac{1}{2}}\times\cdots=\Sigma D_S$. The products of these reduced spin and orbital functions transform as $D_L\times D_S$. The latter products are then made antisymmetric by a straightforward process. If no antisymmetric function transforming like $D_L\times D_S$ exists, the answer is zero. The method also provides automatically for accidental degeneracy. The method has been successfully applied to the d^3 and f^3 configurations.

[1] N. M. Gray and L. A. Wills, Phys. Rev. **38**, 248 (1931).
[2] E. U. Condon and G. H. Shortley, *Theory of Atomic Spectra* (Cambridge University Press, London, 1935), Section 58.

THURSDAY AFTERNOON AT 1:30

Room 1, Le Conte Hall

(A. C. HELMHOLZ presiding)

C1. Aluminum-24, A Delayed Heavy-Particle Emitter. ANN C. BIRGE, *Radiation Laboratory, Department of Physics, University of California, Berkeley.*—The beam of the 32-Mev linear accelerator was run through a proportional counter and into its Mg wall. A delayed heavy-particle activity was observed with a half-life of 2.3±0.2 sec, and threshold of 15.4±0.3 Mev. By a consideration of the energy available, it can be shown that the only possible heavy-particle emitter that can be formed with this threshold energy from a stable Mg isotope is Al^{24}. The reaction is $Mg^{24}(p, n)Al^{24}$. The mass of Al^{24} calculated from the threshold energy is 24.0075. As in the other delayed alpha-particle emitters reported previously by Alvarez,[1] the observed life-time is that of the beta-decay that precedes the heavy particle. The energy available in this case would allow either a proton or alpha-particle to be emitted, but there is more energy available for the latter.

[1] L. W. Alvarez, Phys. Rev. **80**, 519 (1950).

C2. Interpretation of Photonuclear Experiments. L. EYGES, *University of California, Berkeley.*—An analysis of the experiments to date on photonuclear reactions suggests the following picture for heavy nuclei ($Z\gtrsim 50$). The emission of particles (mainly neutrons) is governed by the statistical model. The photon total absorption cross section drops off rapidly above about 20 Mev and begins to rise again near the threshold for meson production. In the experiments on total neutron yields with 330-Mev bremsstrahlung[1] there are as many neutrons produced by photons with energies above the meson threshold as by photons with lower energies. The integrated total cross sections for $Z_n{}^{64}$, Sb, and Ta^{181} can be evaluated and by comparison with the Levinger-Bethe formula[2] lead to values of 0.5, 0.4, and 0.7, respectively, for the fraction of exchange force in the $n-p$ interaction.

[1] Terwilliger, Jones, and Jarmie, Phys. Rev. **82**, 820 (1951); D. W. Kerst and G. A. Price, Phys. Rev. **79**, 725 (1950).
[2] J. S. Levinger and H. A. Bethe, Phys. Rev. **78**, 115 (1950).

C3. Photodissociation of Deuteron by High Energy Gamma-Rays. SEISHI KIKUCHI, *University of California, Berkeley.*—An analysis was made on proton tracks found in the photographic emulsion, which had been exposed by S. White to secondary particles from a deuterium gas target bombarded by high energy synchrotron gamma-rays of maximum energy of about 320 Mev to investigate photomesons from deuterons. The energy spectra of protons at the emission angles of 45, 90, and 135 degrees were obtained. In each case it shows a fairly sharp cutoff at the energies 190, 140, and

95 Mev, respectively. These energies correspond to the energy of the proton expected, if it were produced by the splitting of a deuteron into a proton and a neutron by the absorption of a photon of energy 320 Mev. The angular distribution of protons shows a fairly strong forward asymmetry. The cross section per photon for the photodisintegration increases steeply with the increasing photon energy above the meson threshold. The absolute value of the cross section is of the order of magnitude of the meson production cross section. The author's thanks are due S. White for placing the plates at his disposal.

C4. Some Differential Analyzer Methods for Orbit Problems in the Cyclotron. BAYARD RANKIN, JOHN KILLEEN, AND WALTER H. BARKAS. *University of California, Berkeley.*—The equations of motion for a charged particle in a magnetic field have been solved previously in some special cases.[1] These solutions amost always lead to numerical methods. However, the median and vertical plane motion for any axially symmetric field can be obtained quickly on a differential analyzer after transforming the equations by a few simple devices. Only resets on the integrands are required for each set of initial conditions, and an orbit can be drawn every five minutes. The horizontal motion is solvable on an analyzer of six integrators and three input tables. It is necessary simply to introduce the variable $\lambda=\dot{\varphi}+eH/mc$ in the equation $\dot{r}=\int r\dot{\varphi}d[\int\dot{\lambda}dt]$ and effect a transformation which leaves the relativistic mass independent of the initial conditions without changing the momentum. The vertical motion is handled similarly but demands more integrators. An approximation to the vector potential is necessary. Of special interest are the paths of 30–100-Mev π-mesons which are produced in a target at a radius of 80 inches in the 184-inch cyclotron. 200 of these have been obtained on a selsyn-driven analyzer by using the methods described. Various focusing points have been examined at seven different energies.

[1] E.g., Norman D. Coggeshell and Morris Muskat, Phys. Rev. **66**, 187 (1944), and Walter H. Barkas, Phys. Rev. **78**, 90A (1950).

C5. Influence of Well Shape on the Pickup Process in Deuterium. IRA L. KARP, *University of California, Berkeley.*—Calculations of the pickup process at high energies in deuterium,[1] carried out in Born approximation with an approximate deuteron wave function, exceed the experimental values for 90-Mev incident nucleons by a factor of roughly three to five.[2] In an effort to account for this discrepancy the momentum distribution of the deuteron has been recalculated using exponential and square wells fitted to the low energy data. The results are negative, i.e., all three distributions lie within a few percent of each other for 90-Mev incident nucleons (although at higher energies the Chew distribution lies well above the other two). It is probable that in the calculation of the pickup process the Born approximation must be especially poor. On the one hand, the pickup process depends on high momentum components in the deuteron wave function and on correspondingly small separation of the deuteron particles, and, on the other hand, the use of the Born approximation implies that the deuteron particles are far enough apart so that in the scattering by one particle the interaction with the other can be neglected. An estimate of the correction for this interaction is being made.

[1] G. F. Chew, Phys. Rev. **74**, 809 (1948).
[2] M. O. Stern, University of California Thesis (UCRL-1440).

C6. A Generalization of the WKB Method to Radial Wave Equations. R. H. GOOD, JR., *University of California, Berkeley.*—The usual radial WKB approximations are based on the exponential function, perhaps because of the linearity of the equations. Instead one may use the function which arises in solving the corresponding free particle problem. This insures that the approximation will give the exact result in the free particle problem and consequently that it will be useful at high energy. This point of view may be applied uniformly to the radial Dirac equation, the radial Schrödinger equation, and the one-dimensional Schrödinger equation. In the last case the familiar WKB approximation is the result. In this treatment of the radial equations connection formulas are not required. Also the eigenvalue condition arises from a comparison of asymptotic developments in such a way that one would expect the approximate eigenvalues to be close to the correct ones. In predicting the wave functions themselves the approximation is poor near the turning points. For a Coulomb potential the approximation reproduces the Bohr and Sommerfeld-Dirac formulas for the energy levels precisely. It also gives good results for the amplitude and phase of the nonrelativistic unbound Coulomb wave functions at infinity. It is expected that the method will have application in high energy radially symmetric scattering problems.

C7. Radiative Corrections to the Distribution of Nuclear Recoils from Electron Scattering. L. I. SCHIFF, *Stanford University.**—The scattering of fast electrons by nuclei can be investigated experimentally by measuring the distribution of the recoil nuclei with respect to their angle and energy. Only momentum transfers large in comparison with mc are significant if the recoil nucleus is to be detectable. If both recoil angle and energy can be measured, a comparison can be made with the Mott-Rutherford formula corrected for nuclear size and for the emission of low energy photons. If only the recoil angle can be measured, a correction for the emission of higher energy photons must also be applied. This effect has been estimated on the basis of the Bethe-Heitler formula, and is correct within a factor in a logarithm that is so chosen that the low energy photon cutoff cancels between low and high energy photon corrections. The calculation shows that for large momentum transfers, the photon tends to emerge close to the direction of either the incident or the scattered electron. The analogous result in pair production is that either the electron or the positron tends to emerge close to the direction of the incident photon when the momentum transfer is large.

* Assisted by the joint program of the ONR and AEC; a fuller account of this work will be published as a Microwave Laboratory report.

THURSDAY AFTERNOON AT 1:30

Room 3, Le Conte Hall

(F. A. JENKINS presiding)

D1. Electronic States of Molecular Crystals. N. W. BLAKE,* D. S. MCCLURE, AND H. WINSTON,† *University of California, Berkeley.*—It has been found possible to classify electronic levels of molecular crystals as "scatterer" or "absorber" levels (Peierls[1]), by studying emission and absorption spectra at low temperatures, and the emission lifetime as a function of temperature. Scatterers have narrow emission and absorption bands because of the κ (electronic wave number) selection rule, whereas absorbers have broad bands because κ is not quantized. In case the lowest allowed κ level of a scatterer is above the lowest forbidden K level, a long-lived temperature dependent emission should be observed (trapping). Mixed crystals of scatterers should display the emission spectra of both components, while for absorbers, only the component having the state of lowest energy will emit. These and other criteria have shown that the 3130A state of naphthalene is a good scatterer, the 3500A state of phenanthrene is closer to scatterer than absorber and the 4000A state of anthracene is an absorber.

* Now at Columbia University, Department of Chemistry.
† Now at U.C.L.A., Department of Chemistry.
[1] R. Peierls, Ann. Physik **405**, 905 (1932).

D2. A Vibrational Analysis of the Fluorescence of Naphthalene Vapor. O. Schnepp and D. S. McClure, *University of California, Berkeley.*—The fluorescence spectrum of naphthalene vapor has been photographed and found, under suitable conditions, to consist of a number of discrete bands. Thirty-nine bands were measured and a vibrational analysis was carried out making use of assignments of infrared and Raman fundamentals. The analysis indicates that the transition observed is forbidden by symmetry and made weakly allowed by a molecular vibration of frequency 478 cm^{-1} belonging to the representation b_{2u}. This indicates that the wave function of the lowest excited singlet state of naphthalene belongs to the irreducible representation A_g or B_{1g} of the point group D_{2h}.

D3. Unusual Dispersion Aspects of Gypsum in the Near Infrared. R. M. Vanderberg, *University of California, Los Angeles.* (Introduced by J. W. Ellis.)—When a beam of infrared radiation is sent through a gypsum crystal section placed between crossed polarizers, no orientation is found at which extinction occurs for all wavelengths. This phenomenon results from a dispersion of the bisectrices, which has been known in the visible as a rotation of these axes of about one degree. In the near infrared this rotation increases to about 50° at 2.5μ. An anomaly occurs near 2.0μ, which is the region of an absorption band produced by the water of crystallization. The wave plate maxima spacings shown in the infrared spectrum depart markedly from the formula $\delta\lambda=(-\lambda^2/t\Delta\mu)\delta n$, derived on the assumption of constant $\Delta\mu$, as the wavelength increases beyond 2.0μ. This demonstrates a large dispersion of the birefringence.

D4. Structure of the 3μ-Band of $NaBr\cdot 2H_2O$. D. S. Webber and A. N. Baker, Jr., *University of California, Los Angeles.*—The 3μ absorption band of $NaBr\cdot 2H_2O$ was re-investigated with the same spectrometer used by Lyon and Kinsey.[1] The use of very thin single crystals, instead of the polycrystalline films previously studied, and some refinements of the instrument, reducing zero-drift and background radiation, revealed details of the structure not heretofore observed. The band shows four distinct components. The component at 3478 cm^{-1} is assigned to the fundamental asymmetric vibration of the water molecule, ν_3. The components of 3420 cm^{-1} and 3551 cm^{-1} are assigned to the fundamental symmetric vibration mode, ν_1, split by the crystalline field. This is in excellent agreement with the results of Nayar[2] in a study of the Raman effect. Since ν_3 is primarily infrared active, and ν_1 is primarily Raman active, most of the absorption of the band as a whole is caused by ν_3. The fourth component, at 3239 cm^{-1}, is assigned as previously to a polymer effect.

[1] W. Lyon and E. L. Kinsey, Phys. Rev. **61**, 482 (1942).
[2] P. G. N. Nayar, Proc. Indian Acad. Sci. **A8**, 479 (1938).

D5. Rotational Temperatures of OH in Several Flames. H. P. Broida, *National Bureau of Standards.*—Spectroscopic scans have been made using a high resolution grating monochromator with photoelectric detection through the various regions of several oxygen flames with the object of determining the contribution from each region to the intensity measurements. Hydrogen, acetylene, methane, and propane were used with variations of fuel to oxygen ratio from one-half to twice that necessary for stoichiometric mixture. The OH rotational temperatures have been measured as a function of position in each flame. The constancy of measured temperature for different fuel to oxygen mixtures with the same fuel and the higher than adiabatic temperature suggests a lack of thermal equilibrium in the inner cone. In the hot gases above the reaction zone evidence of rotational and electronic equilibrium is found. The concentration of thermally produced OH in the hot gases at atmospheric pressure is so large in oxygen flames near stoichiometric mixtures that it is difficult to use the emission from this radical for studies of the reaction zone.

D6. The Vibrational Spectrum of Dinitrogen Tetroxide. W. D. Perkins and M. Kent Wilson, *Harvard University.*—The infrared spectrum of dinitrogen tetroxide has been investigated between 240 cm^{-1} and 5000 cm^{-1} with confirmation of the previously reported bands. Two hitherto unobserved bands[1] have been found at 430 cm^{-1} and 684 cm^{-1} and shown by their temperature dependence to belong to dinitrogen tetroxide and not to nitrogen dioxide. From these data, together with existing Raman data,[2] it has been possible to assign the frequencies to normal modes as follows: $\nu_1(A_g)=1342$, $\nu_2(A_g)=811$, $\nu_3(A_g)=265$, $\nu_4(A_u)=70$, $\nu_5(B_{1g})=1722$, $\nu_6(B_{1g})=500$, $\nu_7(B_{1u})=684$, $\nu_8(B_{2g})=(1133)$, $\nu_9(B_{2u})=1747$, $\nu_{10}(B_{2u})=430$, $\nu_{11}(B_{3u})=1260$, and $\nu_{12}(B_{3u})=748$. The frequency ν_8 was calculated from a valence-type potential function. A consideration based on selection rules, together with a comparison of the Raman spectra of the liquid and the solid, indicates a planar, ethylene-type configuration in agreement with the structure proposed from x-ray diffraction measurements.[3]

[1] G. B. B. M. Sutherland, Proc. Roy. Soc. (London) **A141**, 342 (1933).
[2] J. D. S. Goulden and D. J. Millen, J. Chem. Soc. 2620 (1950).
[3] J. S. Broadley and J. M. Robertson, Nature **164**, 915 (1949).

D7. The Spectrum of Nd^{+++} in Crystals. Robert A. Satten, *University of California, Los Angeles.*—The tentative identification of transitions from the ground state to various quartet states of f^3 electrons is made possible partly on the basis of consistency among the following: (a) the expected relative positions of the electrostatic interaction energy terms; (b) extrapolation from identified terms of other rare earths; (c) empirical term diagrams, drawn for most of the groups of absorption lines between 9000 and 3500A in solid $Nd(BrO_3)_3\cdot 9H_2O$ at room and liquid N_2 temperatures, which aid in determining J by the crystal splitting; and (d) a value of the single-electron Lande interval factor[1] $\zeta_{4f}=900$ cm^{-1} which yields fair agreement among predicted and observed positions of certain intense groups of lines as well as with values of ζ_{4f} found by extrapolation from other rare earths. Terms assigned to observed groups of lines with various degrees of probability are ${}^4I_{15/2}$; ${}^4F_{3/2,5/2,7/2,9/2}$; ${}^4G_{5/2,7/2,9/2,11/2}$; and ${}^4D_{1/2}$. The latter term was calculated in intermediate coupling. The empirical term diagrams (c) yield the splitting of the levels of the free Nd^{+++} ion in the crystal field. The ${}^4I_{9/2}$ ground state is split into five levels at 0, 115, 184, 363, and 382 cm^{-1}.

[1] Condon and Shortley, *The Theory of Atomic Spectra* (Cambridge University Press, London, 1935).

D8. Relations between the Vibrational Intensities of Isotopic Molecules. J. C. Decius, *Department of Chemistry, Oregon State College.*—In some unpublished work, Crawford[1] has shown that there exist some very simple relations between the integrated intensities, A_k, of isotopic molecules. These relations have the form $\Sigma_k A_k/\lambda_k = \Sigma_k A_k^*/\lambda_k^*$, where $\lambda_k = 4\pi^2\nu_k^2$, ν_k is a fundamental vibration frequency, the summation is extended over a single symmetry species, and the starred quantities refer to an isotopically substituted molecule. These relations are, however, restricted to the case in which the species in question is *not* one in which a component of rotation occurs. In the general case, where the species of the fundamentals may be the same as that of a rotation, the foregoing formula must be replaced by $\Sigma_k(A_k/\lambda_k) = \Sigma_k(A_k^*/\lambda_k^*) + \Phi$, in which Φ is a function of the mass changes, $\Delta m_\alpha = m_\alpha^* - m_\alpha$; the moments of inertia; the equilibrium geometry of the molecule; μ_x^0, μ_y^0, μ_z^0 the components of the dipole moment, and the corresponding dipole derivatives, $[(\partial\mu x)/(\partial Qk)]_0$, etc.; and of certain force constants. Symmetry may be used advantageously to simplify the function Φ. Moreover, Φ vanishes when the molecule has no permanent dipole moment.

[1] B. L. Crawford, Jr. (private communication).

THURSDAY AFTERNOON AT 3:30

Room 310, Le Conte Hall

(F. A. JENKINS presiding)

Invited Papers

E1. Molecular and Atomic Spectra Associated with the Solid State. J. W. ELLIS, *University of California, Los Angeles.* (45 min.)

E2. Absorption Spectra of Simple Radicals in Thermal Equilibrium. K. WIELAND, *University of Zürich.* (30 min.)

FRIDAY MORNING AT 9:00

Room 4, Le Conte Hall

(E. M. McMILLAN presiding)

F1. Neutron Spectrum from $B^{10}(\alpha, n)N^{13}$, N^{13*}. MARGUERITE ROGERS, F. K. ODENCRANTZ, AND G. J. PLAIN, USNOTS, *Inyokern.*—The neutron spectrum from separated B^{10} bombarded by polonium particles was recorded on Eastman HTA film. The tracks of recoil protons in the forward direction were measured by a B-and-L microscope using a filar micrometer eyepiece at total magnification 1000. Recoil proton groups at 0.90, 0.96, 1.01, 1.13, 1.27, and 1.32 Mev were observed. A total of 1000 tracks were measured.

F2. High Energy Electron-Electron Scattering. CHARLES E. VIOLET, F. C. GILBERT, ROBERT W. DEUTSCH AND WALTER H. BARKAS. *University of California, Berkeley.*—Eradicated electron sensitive nuclear emulsions were exposed to 200-Mev electrons obtained by magnetic analysis of pairs converted in the synchrotron beam. By following primary electron tracks in the emulsion, 427 electron-electron scattering events were recorded in which the scattered electron of lower energy, or knock-on electron, had an energy greater than 30 kev. The knock-on energy was determined by measuring either the range or the angle between the knock-on and primary tracks. The observed absolute differential cross section, as a function of knock-on energy, was found to be consistent with Møller's theoretical cross section. At this primary energy, a sufficient number of events of large fractional energy transfer could not be observed to detect exchange, spin, and retardation effects, and actually only the classical relativistic theory was verified. Two pairs initiated by primary electrons and two cases in which primary electrons vanished in the emulsion were also observed in 102.6 cm of track. No heavy particle events were observed.

F3. Physical Measurements on Nuclear Photographic Emulsion. A. J. OLIVER AND WALTER H. BARKAS, *University of California, Berkeley.*—Calculations of the stopping power of nuclear photographic emulsion and of the volume of emulsion at the time of exposure may be made with more accuracy if the dependence of density and thickness upon relative humidity were known in more detail than is available in published specifications. A device has been developed for measuring the expansion of emulsion with measured increases of relative humidity, both for unprocessed and for processed plates. The measurement of thickness without distorting soft emulsion at relative humidities from 10 percent to 90 percent was the primary contribution of this work. A second project was the measurement of average thickness and weight for the derivation of a density *vs* relative humidity relationship. A third measurement was a check of the refractive indices of emulsion and of the immersion oil employed, so that depth measurements with the microscope are calibrated properly. Measured shrinkage factors were found to vary between 1.8 and 3, depending on humidity conditions. The emulsion measured was Ilford type C-2, and the processing included fixing and hardening in Kodak Acid Fixer. A chart has been worked out to be employed in determining thickness at exposure, given final thickness and the relative humidities before and after processing.

F4. Electron Pickup by Fast C^{12} Nuclei in Emulsion. PETER C. GILES AND WALTER H. BARKAS. *University of California, Berkeley.*—C^{12} particles, accelerated in the 60-inch cyclotron to about 120 Mev, were detected by D-1 nuclear emulsion plates which were subsequently developed in D_{19} developer. Measurements were taken of the gap density,[1] as a function of the residual range, on 223 particle tracks. It was noticed that the gap density passed through a minimum at a residual range of about 35 microns, where it is assumed that electron pickup begins. By comparing points on the terminal side of the electron pickup point with points on the initial side of the pickup point of equal gap density, the charge on the particle was estimated as a function of the residual range. It was assumed that the rate of energy loss may be determined from $dE/dR = Z^2 f(V)$, where $f(V)$ is determined from proton data, E is the particle energy, R the residual range, and Z the instantaneous value of the charge carried by the ion.

[1] P. E. Hodgson, Phil. Mag. **41**, 725 (1950); also Bowker, Green, and Barkas, Phys. Rev. **81**, 649 (1951).

F5. Detection of Azimuthal Polarization in Double N−P Scattering at 150 Mev.* L. F. WOUTERS, *University of California, Berkeley*.—In order to circumvent the accidental background in the double scattering experiment, the first scattering is performed inside the 184-inch cyclotron tank. LiD and LiH targets are compared in order to obtain the D-neutron contribution to the polarization caused by the $p-n$ interaction. The second scattering is performed as an orthodox $n-p$ scattering experiment by paraffin-carbon difference, in the well-collimated neutron beam emerging outside the cyclotron shielding. Four scintillation counter telescopes are arranged in an azimuthal array observing the second scatterer. Each telescope consists of two photomultiplier-liquid phosphor units; these are operated from a pulsed H.V. source which is keyed in synchronism with the cyclotron beam pulse. Using selected 1P28 photomultipliers, the counter behavior is indistinguishable from normal dc operation, when using 100 microsecond keying pulses at 2 to 2.4 kv. Five to ten volt signal pulses are obtained from incident protons, and these are mixed in a current-biased crystal diode coincidence circuit. The system shows an over-all resolution time of 5×10^{-9} sec. This work was performed under the auspices of the AEC.

* D. Swanson and L. F. Wouters, Phys. Rev. (to be published).

F6. Fast Protons from 270-Mev N−D Scattering.* W. HESS, J. B. CLADIS, AND J. HADLEY, *University of California, Berkeley*.—The differential cross section for production of high energy protons in N−D scattering, using the 270-Mev neutron beam of the 184-inch cyclotron, has been measured at scattering angles between 4° and 58°. For normalization, yields of protons from N−P scattering were measured at each scattering angle. In all cases, only protons have a cut-off energy of 200-Mev $\cos^2\Phi$ were accepted by the counter system. In addition, through the use of a magnetic analyzer, energy distributions of the N−D protons were measured at 4° and at 22.5°. The energy distributions closely resembled, in shape, the energy distributions of N−P protons at the same angles, confirming the similarity in nature of collisions of high energy neutrons with free protons and with protons bound in deuterium. Total yield of protons above the cut-off energy is lower for N−D than for N−P collisions; however, the ratio of the two being about 0.7 at all angles observed. Effects of the exclusion principle, of the internal momentum distribution of the deuteron, and of the difference in average potential energy between the dineutron and the deuteron will be discussed as possible courses of the lowering of the N−D proton yield below that from N−P scattering.

* This work was performed under the auspices of the AEC.

F7. Nuclear Cross Sections for High Energy Neutrons and Protons. R. JASTROW AND J. E. ROBERTS, *University of California, Berkeley*.—An earlier study[1] of nuclear cross sections for neutrons at energies up to 270 Mev has been continued. We find that it is desirable to modify the customary assumption on the density of nuclear matter in order to account for the neutron cross sections over the full energy range from 14 Mev to 270 Mev. As usual, we take the density of nucleons in the nucleus to be uniform within a region whose radius increases roughly as $A^{\frac{1}{3}}$. However, outside this core a diffuse region is assumed in which the nucleon density falls off in a distance of the order of the range of nuclear forces. In the light elements the diffuse region is comparable with the core of constant density, while small compared with this core in the heavy elements. At moderately low energies, of the order of 25 Mev, the diffuse tail is relatively opaque. The increase in total cross section resulting from the tail is greater, relatively, for the light elements than for the heavy elements, and brings the calculated neutron cross sections into better agreement with the observed values at energies between 14 Mev and 40 Mev. At the same time the presence of the diffuse region destroys the diffraction pattern in the elastic cross sections of the light elements while only blurring slightly the diffraction patterns of the heavy elements. This result is also fn agreement with recently reported experimental results.[2]

[1] R. Jastrow, Phys. Rev. **82**, 261 (1951).
[2] Richardson, Ball, Leith, and Moyer, Phys. Rev. **83**, 859 (1951).

FRIDAY MORNING AT 9:00

Room 1, Le Conte Hall

(E. O. LAWRENCE presiding)

G1. Mechanism of Fission. GLENN T. SEABORG, *Department of Chemistry and Radiation Laboratory, University of California, Berkeley*.—An empirical correlation of the known data on spontaneous fission seems to point to an important effect of the nuclear type (or radius) on the rate. A plot of the logarithm of the "half-life" *versus* the fissionability parameter, Z^2/A (or Z^2/r^3), indicates that on the average the spontaneous fission rate is greater or an even-even nuclide than one with an odd number of nucleons. Extrapolation of the straight line representing the even-even nuclei to theregion of instantaneous rate (10^{-20} seconds) of spontaneous fission gives the expected value of about 47 for Z^2/A. The higher rates may result from the higher zero point energy of the modes of vibration which lead to fission associated with even-even nuclei because of their expected smaller radii. Similar considerations may be useful in interpreting the results of slow neutron and photofission. Thus the small fission cross section of Cm^{242} and relatively high photofission thresholds of U^{235}, U^{233}, and Pu^{239} may be associated with the odd nucleon intermediate nuclei, in contrast to the large fission cross sections of U^{235}, U^{233}, and Pu^{239} and the relatively low photofission threshold of U^{238} all represented by even-even intermediates.

G2. Alpha-Activity in Bi^{203} as Detected with Nuclear Emulsions. DEAN C. DUNLAVEY AND GLENN T. SEABORG, *Department of Chemistry and Radiation Laboratory, University of California, Berkeley*.—Alpha-emission of particle energy about 4.85 Mev has been observed in the bismuth fraction produced by the bombardment of lead with 60-Mev protons in the 184-inch cyclotron. The observed alpha-decay has a half-life approximating 12 hours. Correlation with the accompanying decay of the other radiation as measured with a Geiger counter[1] and with the alpha-systematics indicates the emitting isotope to be Bi^{203} with a partial alpha-half-life of 2×10^4 years. Following chemical separation, the carrier free bismuth was placed in a solution of pH about 4 and, for time intervals appropriately spaced following bombardment, impregnated into freshly eradicated Ilford C-2 nuclear emulsion plates. The associated gamma-conversion electron activity determined the maximum concentration of bismuth which could be tolerated by the emulsion without producing excessive fogging. Aliquots equal to those placed in the emulsion were counted in a windowless proportional counter to enable association of the alpha-abundance found in the emulsion with the number of known over-all disintegrations. The alpha/K branching ratio was found effectively constant and reproducible at about 10^{-7} over a series of experiments.

[1] H. M. Neumann and I. Perlman, Phys. Rev. **78**, 191 (1950).

G3. Complex Alpha-Structure of the Heavy Elements. Frank Asaro, Fred L. Reynolds, and I. Perlman, *Department of Chemistry and Radiation Laboratory, University of California, Berkeley.*—A study of complex alpha-energy spectra was undertaken in the hope that a correlation with alpha-systematics might promote a better understanding of nuclear states and their influence on the alpha-decay process. A 75-cm radius of curvature 60° symmetrical analyzer with photographic plate detection of alpha-particles was used for the energy discrimination. The complex alpha-particle energy spectrum of Cm^{242} comprises two groups: one at 6.110 ± 0.003 Mev, 73 ± 1 percent abundant; and one group 45.9 ± 1.0 kev lower in energy, 27 ± 1 percent abundant. The complex alpha-particle energy spectrum of Am^{241} comprises six groups: 5.544 Mev, 0.23 ± 0.06 percent abundant; 5.533 Mev, 0.34 ±0.06 percent abundant; 5.502 Mev, 0.21 ± 0.02 percent abundant; 5.475 Mev, 84.2 percent abundant; 5.433 Mev, 13.6 ± 1.4 percent abundant; 5.378 Mev, 1.4 ± 0.2 percent abundant. The identification of the experimentally observed alpha-groups with the alpha-emission spectra of the indicated nuclides is conclusively proved by the constancy of the respective energy differences and abundance ratios over wide ranges of sample activity prepared from different sources of material. In every case studied of even-even nuclei all groups lie very close to the alpha-systematic half-life *vs* energy curves for even-even nuclides.

G4. Isomeric States of Bi^{210}. Harris B. Levy and I. Perlman, *Department of Chemistry and Radiation Laboratory, University of California, Berkeley.*—In 1950 Neumann, Howland, and Perlman[1] reported finding a possible isomer of RaE. Bismuth was irradiated at high neutron flux to produce Bi^{210}. After the RaE had decayed out, a residual long-lived alpha-activity was found in the bismuth fraction. This alpha-activity was assigned to Bi^{210} on the basis of experiments in which the Tl^{206} daughter was milked out. The alpha-particle energy was determined at that time to be 5.03 ± 0.05 Mev, indicating that it was an excited state of RaE. Recently some of this bismuth fraction was electromagnetically separated, and the mass fractions 208, 209, and 210 were examined. The increase in the specific activity of the 210 mass fraction and the corresponding decrease in the specific activity of the 208 and 209 mass fractions confirmed the assignment of the alpha-activity to Bi^{210}. The energy of the alpha-particle was redetermined to be 4.93 ±0.02 Mev. The disintegration energy is therefore 5.03 ± 0.02 Mev. Comparison with the latest calculated alpha-disintegration energy of RaE, 5.06 Mev, leaves considerable doubt as to whether the long-lived alpha-emitter or RaE is the ground state of Bi^{210}.

[1] Neumann, Howland, Jr., and Perlman, Phys. Rev. **77**, 720 (1950).

G5. On the Semiempirical Correlation of Alpha-Decay Rates. J. O. Rasmussen, *Department of Chemistry and Radiation Laboratory, University of California, Berkeley.*—The decay rate data for the even-even type nuclides of the heavy region can be well correlated by a "many body" formula based on the experimental value of the "effective nuclear radius for alpha-particles" of Th^{232}. The experimental value $r=10.27\cdot10^{-13}$ cm was determined by Jungermann[1] from the alpha-induced fission cross section excitation function on Th^{232}. The simple decay rate expression used is of the form $\lambda=fP$ where λ is the decay constant in $\sec^{-1}$, f is the hypothetical "decay constant without barrier," and P is the penetration factor, calculated by the WKB approximation. The experimental decay data for 27 different even-even type alpha-emitters were used to calculate f. Excluding only the four nuclides with 126 or less neutrons, the average of $\log f$ is 18.84 ± 0.15. It is pointed out that f is very nearly equal to D/h, where D is the average level spacing for the ground states of the alpha-emitters as deduced from the energy spacing of alpha-fine structure groups. The orbital electron screening correction to the alpha-decay energy is also discussed.

[1] J. Jungermann, Phys. Rev. **79**, 640 (1950).

G6. L X-Rays and Low Energy Gamma-Radiation in the Decay of Am^{241}. C. I. Browne and I. Perlman, *Department of Chemistry and Radiation Laboratory, University of California, Berkeley.*—The L x-rays and low energy gamma-rays given off following the alpha-decay of Am^{241} have been studied on a 10-inch bent crystal x-ray spectrometer. Eight gamma-rays have been observed in the spectral region 12–85 kev, with energies ranging from 14.23 ± 0.06 to 59.78 ± 0.02 kev. The $L\alpha_2$, $L\alpha_1$, $L\eta$, $L\beta_2$, $L\beta_4$, $L\beta_1$, $L\gamma_1$, and $L\gamma_6$ x-rays of neptunium from gamma-ray internal conversion have been observed. They were identified by comparing the observed energies with extrapolations of the Moseley relationship and assuming the identities, the agreement in energy was close. Estimates of relative intensity have been made on both the gamma- and x-radiation, and lead to the conclusion that the ratio of vacancies produced in the L shell by internal conversion is $L_I:L_{II}:L_{III}=6:5:2$. A partial decay scheme is suggested and a number of the gamma-ray transitions are shown to be in good agreement with known spacings from alpha-particle complex structure.

G7. Alpha-Radioactivity in Elements below Lead. S. G. Thompson, J. O. Rasmussen, and A. Ghiorso, *Department of Chemistry and Radiation Laboratory, University of California, Berkeley.*—In a continuation of the survey for alpha-activity among cyclotron-produced, neutron deficient isotopes of the medium heavy elements, alpha-activity was found in a number of rare earth nuclides with atomic number greater than 62 (samarium). Element assignments were usually made by chemical separations and the mass numbers of several were assigned either by mass spectrographic determination or by means of excitation functions. Alpha-radioactivity caused by traces of heavy element ($Z>82$) contamination even in the purest samples was nearly always produced and discrimination by means of alpha-energy determination or by chemical separations was necessary. Alpha-energies in the rare earths ranged from 2.7 Mev in long-lived Gd^{150} to 4.2 Mev in a 7-minute dysprosium isotope. The alpha-emitting rare earth isotopes are of neutron number 84 or greater and their instability toward alpha-decay is interpreted as being caused by the influence of 82 neutrons.

G8. The Production and Assignment of Ra^{230} and Ac^{230}. William A. Jenkins and Glenn T. Seaborg, *Department of Chemistry and Radiation Laboratory, University of California, Berkeley.*—The bombardment of thorium metal with 180-Mev deuterons in the 184-inch cyclotron, followed by extensive chemistry, has demonstrated the presence of a new isotope of radium. This isotope proved to decay by beta-particle emission with a half-life of one hour and is best assigned to Ra^{230}. Attempts to milk the actinium daughter were unsuccessful and consequently the upper limit of the actinium half-life is set at one minute. The beta-particle energies were measured by

Feather analysis of aluminum absorption curves and by Fermi analysis of a beta-particle spectrograph plot which indicated two beta-distributions with maxima at 2.2 and 1.2 Mev. From the disintegration energies predicted by closed decay energy cycles, it seems most probable that the 1.2-Mev beta is associated with the one-hour decay of Ra^{230} and the 2.2-Mev beta, with Ac^{230}. This assignment was strengthened by the recent discovery by Harvey and Depocas[1] of a 67-minute activity which they assigned to Ac^{229}. This half-life of Ac^{229} has been recently confirmed by the reaction $Ra^{226}(\alpha, p)Ac^{229}$ in this laboratory.

[1] B. G. Harvey (private communication, September, 1951).

Friday Morning at 9:00

Room 3, Le Conte Hall

(J. Kaplan presiding)

H1. Postive Ion Energies in a Point-to-Plane Corona. Mark Schindler and G. L. Weissler, *University of Southern California.*—In a negative point-to-plane corona the energies with which positive ions strike the point electrode are of interest. In order to obtain an estimate of these energies an experiment was undertaken using as a corona point the junction of a thermocouple which had been shaped to conform with previously used electrode configurations.[1] Pure N_2 was used to avoid pulsating corona currents such as Trichel pulses in air, and the thermocouple deflections were noted for various corona currents at three N_2-pressures. These deflections were correlated in a separate calibration of the corona thermocouple with the amount of power from a small heater element necessary to produce the observed deflections. Heat energy losses resulting from conduction, radiation, and convection were taken into account, and energy transfer from positive ions to neutral N_2 molecules in the neighborhood of the point considered. The ion energies were thus estimated to be of the order of 100 ev.

[1] G. L. Weissler, Phys. Rev. **63**, 96 (1943).

H2. Electrical Fields in the Crooke's Dark Space of Low Pressure Glow Discharges by Electron Beam Probes. Robert P. Stein, *University of California, Berkeley.**—An electron beam probe of 10^4 volts and up was made to traverse the Crooke's dark space of 3-cm diameter glow discharges in air and N_2 at from 2×10^{-2} to 1.5×10^{-1} mm pressure, both at various distances from the cathode in the dark space as well as at other points in the glow discharge. The deflections of the beam were calibrated by known fields and thus registered the fields existing. Fields ranging from 400 volts/cm down to 2 volts/cm could be measured. The curves obtained as functions of pressure and current were reproducible and clean cut. Superficially the curves generally confirm the form of variation observed once by Aston with a linear fall in the abnormal region tending to concave upward as the normal region is approached. The data obtained and their interpretation will be presented.

* Supported by the ONR.

H3. Spray Electrification of Liquid Drops. E. E. Dodd, *University of California, Berkeley.**—A determination of the simultaneous size and charge of individual liquid spray drops has been made by the Hopper and Laby method. The statistical ion fluctuation charging theory of Natanson[1] is found to hold for nonconducting liquids in the investigated drop diameter range of about 2 to 30 microns, i.e., the charging probability is Gaussian with the average charge zero and the mean square charge proportional to the drop volume. Contact effects render the charging probability of clean mercury asymmetric, the average charge being positive and increasing with drop size.

* Supported in part by Research Corporation and ONR funds.
[1] G. L. Natanson, Doklady Akad. Nauk. **53**, 115 (1946).

H4. Positive Wire Corona Mechanisms in Hydrogen and Argon. Eugene J. Lauer, *University of California, Berkeley.**—Mechanisms in the corona discharge from a fine platinum wire at a positive potential along the axis of a hollow nickel cylinder have been investigated by using the oscilloscope to analyze the pulses caused by α-particles passed through the low field region parallel to the wire. The most important secondary electron generating mechanism in the hydrogen discharge is the photoelectric effect at the cathode. γ_p the secondary coefficient for the photoelectric effect has values from 70×10^{-5} at 100-mm to 5×10^{-5} at 650-mm pressure. γ_i for the hydrogen ions at the cathode is less than 10^{-6}. The mobility of the positive hydrogen ions is 13.4 ($\pm$0.4) cm²/volts $\times$sec at 760 mm and 20°C. γ_i for the argon positive ions is about 9×10^{-4} extrapolated to zero pressure and decreases with increasing pressure. The photon γ_p is less than 1/10 the ion γ_i. Most of the ions are A_2^+ with a mobility of 1.94 ($\pm$0.08) cm²/volt$\times$sec.

* Supported by the ONR.

H5. Some Experiments Confirming the Existence of Electrical Phenomena during the Freezing of Dilute Aqueous Solutions. Marvin E. Backman, *U. S. Naval Ordnance Test Station, Inyokern.*—Workman and Reynolds[1] have reported the discovery of an electrical effect accompanying the freezing of dilute aqueous solutions. This effect has been confirmed for several solutions by a simple experimental method. During the orderly freezing of dilute aqueous solutions of ionic solutes a potential is developed across the ice-water interface. A plot of the potential *versus* time is characteristic of the solute and concentration used.

[1] E. J. Workman and S. E. Reynolds, Phys. Rev. **78**, 254 (1950).

H6. Further Measurements of Electron Drift Velocities in a Grid Ionization Chamber. W. N. English, *Pacific Naval Laboratory, Esquimalt, B.C.**—The method used to obtain electron drift velocities in argon-CO_2 mixtures and in methane, in the low X/p range 0.05 to 0.5 volt per cm mm Hg, has been described.[1] Data have now been obtained for neon, krypton, and xenon with CO_2, for argon and krypton with CH_4, and for argon with N_2. Two interesting features have been noted. The first is a maximum in the drift velocity which moves up in X/p as the amount of polyatomic gas is increased. This maximum is tentatively identified with the maximum in the Ramsauer free path. The second is a marked variation in the shape of this maximum with the particular polyatomic gas used. This seems to indicate a surprising sensitivity to the arrangement of the molecular energy levels which are responsible for "moderating" the electrons.

* The measurements were made in the Chalk River Laboratory, in large part by O. W. Schwer.
[1] W. N. English, Phys. Rev. **83**, A889 (1951).

H7. On the Theory of Condensation of Gases. R. J. RIDDELL, JR., *University of California, Berkeley*.—The problem of treating the condensation of a gas is intimately related to the asymptotic behavior of the virial coefficients in the equation of state. According to Mayer,[1] the virial coefficients, for a gas in which the intermolecular forces are additive, are obtained as the sum of "irreducible integrals," in which the integrands may be conveniently represented by linear graphs of i points and k lines of a certain type which will be called "stars." Thus the problem of obtaining the virial coefficients is separated into two parts: (a) to find the number of stars of a particular type (a purely combinatorial problem), and (b) to calculate the value of the integral associated with them. The first problem was studied in detail and an exact equation for the generating function of the number of stars was obtained. This may be solved asymptotically in i and k. The first approximation gives the result that all graphs are stars. The evaluation of the integrals for rigid spheres was also investigated but with little success. The asymptotic contributions to the virial coefficient for $k=i$ and $k=i+1$ were obtained.

[1] Mayer and Mayer, *Statistical Mechanics*, Chapter 13.

FRIDAY MORNING AT 11:00

Room 310, Le Conte Hall

(E. O. LAWRENCE presiding)

Invited Papers

I1. Radioactivity of the Heaviest Elements. I. PERLMAN, *University of California, Berkeley*. (30 min.)

I2. The Fine Structure of Hydrogen. WILLIS E. LAMB, *Stanford University*. (30 min.)

FRIDAY AFTERNOON AT 1:30

Room 1, Le Conte Hall

(R. T. BIRGE presiding)

J1. The Decay of Ag^{105} and Ag^{106}. RAYMOND W. HAYWARD, *National Bureau of Standards*.—Using a magnetic lens and a scintillation spectrometer, studies were made on the K-capture activities of Ag^{105} and Ag^{106} which were produced by (α, n) and $(\alpha, 2n)$ reactions on rhodium and by (d, n) and $(d, 2n)$ reactions on palladium using the Department of Terrestial Magnetism sixty-inch cyclotron. Conversion and photoelectron peaks were found corresponding to nineteen different transitions. By following the decay rate of each peak over a period of three months the isotopic assignment of each transition was made. The observed transition energies in Ag^{105} are 62, 112, 154, 180, 281, 321, 343, 393, and 444 kev and in Ag^{106} the energies are 222, 399, 409, 511, 620, 717, 815, 1040, 1220, and 1550 kev with a probable error of approximately one percent. Gamma-gamma coincidences were observed in both isotopes and also specifically coincidences between the 62- and 281-kev gamma-rays of Ag^{105} were measured with a scintillation spectrometer coincidence detector. The K and L conversion ratios were determined for the stronger radiations. The 511-, 620-, 1040-, and 1550-kev gamma-rays are among those observed by Alburger[1] in the decay of Rh^{106}. Decay schemes based on experimental information and on shell model considerations will be proposed for both Ag^{105} and Ag^{106}.

[1] David E. Alburger, Bull. Am. Phys. Soc. 26, No. 6, 38 (1951).

J2. Measurement of Gamma-Rays in the Reaction $C^{13}(p, \gamma)N^{14}$.* H. H. WOODBURY, R. B. DAY AND A. V. TOLLESTRUP, *Kellogg Radiation Laboratory, California Institute of Technology*.—A NaI scintillation spectrometer has been used to study the γ-rays produced at various resonances[1] in the reaction $C^{13}(p, \gamma)N^{14}$. The target, which was 20-kev thick at 1.7 Mev, was composed of carbon enriched to 60 percent C^{13} deposited on a tantalum backing. Preliminary results on the energies of the stronger γ-rays are summarized in Table I, where E_R is the proton bombarding energy at resonance and E_x is the excitation energy of the compound nucleus, N^{14}. Further efforts are being pointed toward improving the precision of these measurements as well as measuring the energies of several weak γ-rays that occur. Coincidence experiments are also being carried out to aid in determining the decay scheme.

TABLE I.

E_R(Mev)	E_γ(Mev)	E_x(Mev)
0.55	1.6, 2.3, 4.1, 8.0	8.05
1.16	1.6, 2.3, 4.0, 4.6	8.62
1.25	8.7	8.70
1.76	9.2	9.18
2.1	4.5, 5.0	9.49

* This work was assisted by the joint program of the ONR and AEC.
[1] Seagrave, Day, and Perry, Jr., Phys. Rev. 81, 661 (1951).

J3. A New Gamma-Ray from $C^{12}+p$.* A. V. TOLLESTRUP, R. B. DAY, AND H. H. WOODBURY, *Kellogg Radiation Laboratory, California Institute of Technology*.—The γ-radiation from the reaction $C^{12}+p$ has been investigated with a NaI scintillation spectrometer. A new γ-ray has been observed in addition to the 2.4- and 3.5-Mev γ-rays produced at the 0.46- and 1.70-Mev resonances, respectively. Its assignment to the C^{12} reaction was made by comparing the yield from thin targets of normal carbon with a thin carbon target enriched to 60 percent C^{13}. This γ-ray has been observed for proton bombarding energies from 1.2 to 2.5 Mev. Preliminary estimates indicate that the yield does not vary by more than a factor of five in this region. Within the experimental error of ± 4 percent the γ-ray energy is given by $E\gamma=0.92\ (E_p-0.46)$ Mev. Since no 2.4-Mev γ-radiation is found with this γ-ray we conclude that it occurs in a transition to the 2.4-Mev state of N^{13}, which subsequently decays into a proton and C^{12}.

* This work was assisted by the joint program of the ONR and AEC.

J4. Investigation of the Reaction $B^{11}(p, \lambda)C^{12}$.* TORBEN HUUS AND ROBERT B. DAY, *Kellogg Radiation Laboratory, California Institute of Technology.*—The excitation curve for the reaction $B^{11}(p, \gamma)C^{12}$ has been investigated by means of a NaI scintillation counter in the region of proton bombarding energies from 0.14 Mev to 2.7 Mev. Besides the well-known resonance at 0.162 Mev, two other resonances were found, one at 0.67 Mev with $\Gamma=0.31$ Mev, and another at 1.37 Mev with $\Gamma=1.15$ Mev. An estimate of the cross sections is given in Table I. The γ-ray energies were obtained from the pulse

TABLE I.

E_p in Mev	σ in 10^{-28} cm²	$E\gamma$ in Mev		
0.162	1.1	4.45	11.6	
0.67	0.4	4.44	12.0	16.4
1.37	0.4	4.45	12.7	16.9

height spectrum by comparison with the 2.62-Mev ThC″ γ-ray. They confirm the existence of a cascade transition through the well-known level in C^{12} at 4.45 Mev. The cascade transition was found to be resonant only at the two lower resonances, and the ground-state transition only at the 1.37 Mev resonance, but in none of the cases can a small amount of the alternative transition be completely excluded. The results are consistent with the interpretation that the two broad resonances are an inverted doublet formed by s-wave protons.

* Assisted by the joint program of the ONR and AEC.

J5. Elastic Scattering of Li^7+p and $C^{12}+p$. WILLIAM D. WARTERS AND EDMUND A. MILNE, *Kellogg Radiation Laboratory, California Institute of Technology.*—A double focusing magnetic proton spectrometer[1] has been so mounted as to permit observations over a continuous range of scattering angles from 0 to 160 degrees. A fluxmeter and current control system have also been built, allowing spectrometer settings accurate to well within 0.1 percent. This equipment is being used to study the elastic scattering of protons from Li^7 and C^{12}. Data have been taken for Li^7 near the 440-kev resonance at 50, 70, 90, 145, and 160 degrees in the center-of-mass system. The cross sections at 90 and 145 degrees agree with previous results from this laboratory.[2] Analysis of the data is currently in progress. Data have been taken for C^{12} near the 456-kev resonance at every 10 degrees from 40 to 160 degrees. Preliminary analysis, confirming the previous work,[3] indicates that the 456-kev level is probably a $^2S_{\frac{1}{2}}$ state in N^{13}.

* Assisted by the joint program of the ONR and AEC.
1 Snyder, Ruben, Fowler, and Lauritsen, Rev. Sci. Instr. 21, 852 (1950).
2 Brown, Snyder, Fowler, and Lauritsen, Phys. Rev. 82, 159 (1951).
3 G. Goldhaber and R. M. Williamson, Phys. Rev. 82, 495 (1951).

J6. Cross Section of the $D(d, p)H^3$ Reaction.* W. A. WENZEL AND WARD WHALING, *Kellogg Radiation Laboratory, California, Institute of Technology.*—The cross section of the $D(d, p)H^3$ reaction has been determined over the deuteron energy range 25–550 kev from the yield of protons from a thick target of D_2O ice and the stopping cross section of ice given in the previous abstract. The angular distribution over the deuteron energy range 200–550 kev was obtained from measurements of the yield of protons from a thin ice target at 10° intervals between 80° and 170° in the laboratory. At lower energies the asymmetry factor[1] $Y(\theta)=Y(90°)[1+(0.175+0.0031\ E_{\text{kev}})\cos^2\theta]$ was used to calculate the total cross section from the observed yields at $150_{\text{lab}}°$. The total cross section is given in Table I. The 16-inch double focusing magnetic analyzer was used to measure the cross section at energies above 200 kev by observation of both protons and tritons. Values obtained by this method fall below the values given in the table by at most 20 percent.

TABLE I.

E_{D^2}(kev)	25		50		100		200		300		400		500	
σ(barns)	6.4	10^{-4}	4.3	10^{-3}	1.7	10^{-2}	3.3	10^{-2}	4.7	10^{-2}	5.7	10^{-2}	6.5	10^{-2}

* Assisted by the joint program of the ONR and AEC.
1 Bretscher, French, and Seidl, Phys. Rev. 73, 815 (1948).

J7. The Stopping Cross Section of Ice.* WARD WHALING AND W. A. WENZEL, *Kellogg Radiation Laboratory, California Institute of Technology.*—The stopping cross section $\epsilon=(1/N)dE/dx$ for protons in D_2O ice has been measured over the proton energy range 50–550 kev. The 16-inch double-focusing magnetic analyzer was used to determine the energy E_P of protons scattered at $\theta_{\text{LAB}}=90°$ from a clean Cu target and then the change of energy ΔE_P of the scattered protons when a thin (≈ 5 kev) layer of ice was condensed on the surface of the copper. Relative values of ϵ as a function of proton energy are calculated from the variation of ΔE_P with E_P. Absolute values of ϵ were determined from the yield of protons scattered from the 0 in the ice, which is a known[1] function of ϵ and the scattering cross section for protons on oxygen. Taking this scattering cross section as given by the Rutherford formula we have determined ϵ in terms of the thick target yield over the energy range 250–500 kev. Using these results and the relative values we find the following values for the stopping cross section. Evidence that the scattering

E_P(kev)	20	50	100	200	300	400	500
ϵ(10^{-15} ev-cm²)	19	25	26	22	17	14	12

from 0 should be described by the Rutherford formula will be presented.

* This work was assisted by the joint program of the ONR and AEC.
1 Snyder, Rubin, Fowler, and Lauritsen, Rev. Sci. Instr. 21, 866 (1950).

J8. Low-Lying Levels in Be^7 and B^{10}.* ROBERT B. DAY AND TORBEN HUUS, *Kellogg Radiation Laboratory, California Institute of Technology.*—The γ-radiation produced by bombarding B^{10} with protons has been investigated with a NaI scintillation spectrometer in a search for low energy levels in Be^7 that are excited by the reaction $B^{10}(p, \alpha)Be^{7*}$. In the region below 1 Mev we find γ-rays of the following energies: 178 ± 10 kev, 432 ± 2 kev, and 718 ± 5 kev. The energy of the first is rendered somewhat uncertain by the presence of a nearby γ-ray that is produced in the tantalum target backing, but its energy and intensity are consistent with the interpretation that it is Compton scattering of the 432-kev γ-ray from the surroundings. The second γ-ray is from a well-known level in Be^7, while the third is probably produced by inelastic scattering in B^{10}. Excitation curves for the last two γ-rays have also been investigated up to bombarding energies of 2.7 Mev. The 432-kev radiation has a single broad resonance at 1.52 Mev. The cross section ($4\pi\cdot\sigma_{90°}$) for the 718-kev radiation increases monotonically from $5\cdot10^{-4}$ barns at 1.52 Mev to 0.02 barn at 2.65 Mev.

* Assisted by the joint program of the ONR and AEC.

FRIDAY AFTERNOON AT 1:30

Room 4, Le Conte Hall

(F. BLOCH presiding)

K1. On the g Factor of Metallic Na.* Y. YAFET, *University of California, Berkeley.*—The spectroscopic splitting factor that one would observe in a microwave experiment on solid Na is calculated. On account of the strong coupling between electronic spins, it is assumed that in most of the transitions only the component of the total spin along the applied field changes. Correlation effects do not play a role in such transitions and the one-particle approximation may be used. The conduction electrons at the top of the Fermi band are practically free ($m^* = 1.069$),[1] so that one expects a g close to g_{spin}. Departures from this value will arise, because of spin-orbit and spin-nuclear effects. The latter is found to be comparable to the first one only at temperatures low enough to have a large nuclear alignment, $\sim 1°K$. The spin-orbit effect has been treated as a perturbation and the resulting inhomogeneous equation solved numerically to the first order by a development of the Bardeen method.[1] The angular momentum is quenched as long as spin-orbit interaction is not taken into account. The admixture caused by spin-orbit interaction is mainly from a p term and depends on the angle θ_0 between the propagation vector and the applied field, resulting in $\Delta g = -3.7 \times 10^{-4} \sin^2\theta_0$. The corresponding broadening is of the same order of magnitude as the relaxation line width.[2]

* Assisted by the ONR.
[1] J. Bardeen, J. Chem. Phys. **6**, 367 (1938).
[2] A. W. Overhauser, thesis, University of California.

K2. Spin-Echo Measurements of Nuclear Spin-Spin Coupling,*,† E. L. HAHN‡ AND D. E. MAXWELL, *Stanford University.*—Molecules which contain nuclear magnetic moments as close, nonequivalent neighbors exhibit the spin-echo envelope modulation effect.[1] Resonant H and F^{19} nuclei indicate on the echo envelope (1) a frequency δ, proportional to the dc magnetic field H_0, which corresponds to the chemical shift between like nuclear species, and (2) a second frequency J, which is independent of H_0. Echo measurements for two protons in liquid dichloroacetaldehyde (CCl_2HCHO) give $J/2\pi = 2.8$ cps and $\delta/2\pi = 104$ cps. The envelope shape is predicted if the Hamiltonian operator

$$\mathcal{H} = -\hbar[\gamma\sigma_{2z}(H_0+h_1)+\gamma\sigma_{2z}(H_0+h_2)+J/4\bar{\sigma}_1\cdot\bar{\sigma}_2]$$

is chosen to describe the system. h_1 and h_2 are absolute chemical shifts in gauss of nuclei 1 and 2, respectively, and $\delta = \gamma(h_1 - h_2)$. The possibility that J has its origin in the magnetic coupling of spin-to-spin via electrons has been considered.[2]

* Supported in part by the ONR.
† Independent work on this coupling effect has been done by McNeil, Slichter, and Gutowsky at the University of Illinois.
‡ National Research Council Post-doctoral Fellow.
[1] E. L. Hahn, Phys. Rev. **80**, 580 (1950).
[2] Suggested independently by Gutowsky, McCall, and Slichter, Phys. Rev. **84** (in press). E. M. Purcell and N. F. Ramsey (private communication) have calculated J for the HD molecule on the basis of a spin-electron-spin coupling mechanism which can account for large values of J.

K3. Nuclear Magnetic Resonance Absorption in Glycine. T. M. SHAW, R. H. ELSKEN, AND K. J. PALMER, *Western Regional Research Laboratory,* Albany, California.*—The magnetic resonance absorption of protons in a polycrystalline specimen of glycine has been observed in a magnetic field of approximately 4600 gauss for temperatures ranging from 25°C to −160°C. The line width of the resonance[1] is found to undergo a transition centered near −70°C. For temperatures above the transition (25° to −65°C) the observed line width is 9.5±0.5 gauss. For temperatures below the transition (−80°C to −160°C) the observed line width is 16.6±1 gauss. Calculations of the theoretical second moment of the absorption line for a rigid lattice yield a value of about 44 gauss[2] if a $H_3N^+CH_2COO^-$ (zwitter-ion) configuration[2] is assumed (the actual value depends upon the assumed position of the third proton on nitrogen) and a value about one-half as large for the uncharged form (NH_2CH_2COOH). Experimental values of the second moment compare favorably with the theoretical value for the zwitter-ion configuration.

* Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture. Report of a study made under the Research and Marketing Act of 1946.
[1] H. S. Gutowsky and G. E. Pake, J. Chem. Phys. **16**, 1164 (1948).
[2] G. Albrecht and R. B. Corey, J. Am. Chem. Soc. **61**, 1087 (1939).

K4. Nuclear Magnetic Resonance in Metallic Rb and Cs. D. F. ABELL AND W. D. KNIGHT, *University of California, Berkeley.*—A check on the validity of the formula[1] for the shift of nuclear magnetic resonance absorption frequencies in metals should be found in the consistency of experimental results in simple metals. We report here the results for Rb and Cs, and compare them with previously published values for Li and Na. General agreement is good, although reliable independent values for χ_p and $\langle|\psi_F(0)|^2\rangle_{\text{Av}}/|\psi_a(0)|^2$ are not available, except perhaps for Na. The measured values of $\Delta H/H$ are 0.02, 0.1, 0.6, and 1 percent, respectively, for Li*, Na, Rb, and Cs, at room temperature of about 25°C. The product of χ_p and the ratio of wave functions above, evaluated in terms of formula (1), reference 1, is a smoothly decreasing function of atomic number, following very closely a plot of Pauli's formula for χ_p. The significance of this is not clear, in view of the wide range of independent theoretical and experimental values for χ_p.

[1] Townes, Herring, and Knight, Phys. Rev. **77**, 852 (1950).
* The value given in reference 1 is incorrect.

K5. Properties of Transition Metals V and Nb by Nuclear Magnetic Resonance. W. D. KNIGHT, *University of California, Berkeley.*—The magnetic properties and the electronic structures in the transition metals are of considerable interest.[1,2] We report here concerning line shifts and line widths of nuclear magnetic resonance absorption signals in V* and Nb metals. The products $\chi_p\langle|\psi_F(0)|^2\rangle_{\text{Av}}/|\psi_a(0)|^2$, evaluated in terms of the line shifts, are 0.38×10^{-6} and 0.22×10^{-6} cgs/gm for V and Nb, respectively. Assuming a spin susceptibility χ_p given by Pauli's formula for one s-electron per atom, the ratios of the wave functions as above are 2.5 and 2.2. This is in general agreement with the idea of contraction of the s-wave functions when free atoms condense to the metallic state. These values are only approximate, since formula (1), reference 1 in preceding abstract, includes hyperfine structure interval factors for atomic s-states, and these are not known very accurately. The line widths between points of maximum slope are 16 gauss and 12 gauss for V and Nb. These are about two orders of magnitude greater than would be expected to result from simply nuclear magnetic dipolar coupling, and are probably caused by quadrupolar coupling with the crystalline field and to anisotropy of the line shift because of lattice strains at the powder particle surfaces.

* Measurements on V made by the author at Brookhaven National Laboratory under the auspices of the AEC.
[1] C. Zener, Phys. Rev. **81**, 441 (1951).
[2] Hume-Rothery, Irving, and Williams, Proc. Roy. Soc. (London) **A208**, 431 (1951).

K6. Theory of the Nuclear Quadrupole Interaction of Nb^{93} in $KNbO_3$.* M. H. COHEN, *University of California, Berkeley.†*—Optical hyperfine structure measurements have shown that the spin of Nb^{93} is 9/2 but have failed to show any quadrupole coupling, $KNbO_3$, a ferroelectric, has a twinned orthorhombic structure at room temperature. At 220°C a transition to tetragonal symmetry occurs. The electric field-gradient tensor is axially symmetric in a crystal of tetragonal symmetry but not in one of orthorhombic symmetry. A crude estimate of the gradient of the local field was made from the measured values of the maturation polarization and the lattice distortion. An approximate value of the quadrupole moment was taken from Townes' empirical plot. Combined these yield an estimated order of magnitude of 1 mc for the Stark splitting in the crystalline field. Second-order perturbation calculations of the energy levels for spin 9/2 in a strong magnetic field have been carried out for an axially symmetric field gradient and for an unsymmetric field gradient.

* Assisted in part by the ONR.
† AEC predoctoral fellow.

K7. Chemical Effects in Nuclear Induction. J. T. ARNOLD, *Stanford University.* (Introduced by F. Bloch.)—Using a carefully shimmed magnet and small samples, we have been able to resolve nuclear induction signals having a separation of approximately two milligauss in 7600 gauss. This degree of resolution has facilitated the observation of temperature and dilution dependence of the absolute chemical shifts of the OH groups of methyl and ethyl alcohols[1] and a slight splitting of hydrogen and fluorine signals in certain chemical compounds.[2] The absolute chemical shift of the OH group of ethyl alcohol was measured as a function of temperature in the interval, 150°K to 350°K.[3] Dilution experiments were made with chloroform and carbon tetrachloride. Two of the lines of ethyl alcohol and numerous lines of fluorine-substituted compounds show multiplicity under slow passage observation. In the case of ethyl alcohol, to within the limit of resolution, the CH_3 line consists of three, and the CH_2 line of four components.[4] The multiplet splitting of the fluorine lines is about ten times that of the hydrogen lines.

[1] J. T. Arnold and M. E. Packard (to be published in J. Chem. Phys.).
[2] M. E. Packard and J. T. Arnold, Phys. Rev. **83**, 210(A) (1951).
[3] Two possible explanations have been proposed by N. F. Ramsey and U. Liddel in a letter to be published in the J. Chem. Phys.
[4] A rule from which these numbers of components could have been expected has been given by H. S. Gutowsky and D. W. McCall, Phys. Rev. **82**, 748 (1951). It is also in agreement with the phenomenological theory of E. L. Hahn.

FRIDAY AFTERNOON AT 3:30

Room 310, Le Conte Hall

(R. T. BIRGE presiding)

Invited Papers

L1. Energy Loss of Fast Particles. ROBERT F. CHRISTY, *California Institute of Technology.* (30 min.)

L2. High Energy Proton-Deutron Scattering. OWEN CHAMBERLAIN, *University of California, Berkeley.* (30 min.)

SATURDAY MORNING AT 9:00

Room 1, Le Conte Hall

(H. E. WHITE presiding)

M1. Design and Operation of a High Geometry Electrostatic Time-of-Flight Mass Spectrograph. WILLIAM E. GLENN, *Department of Electrical Engineering and Radiation Laboratory, University of California, Berkeley.*—A mass spectrograph has been designed and constructed which measures e/m by measuring the time-of-flight of ions that have been accelerated and bunched by electrostatic fields. This instrument is similar to the Smyth and Wilson "Isotron." It has been able to collect about 30 percent of the ions formed of a given isotope. The resolution is such that the width of the intensity *versus* mass peaks is $\frac{3}{4}$ of a mass unit wide at 1 percent of the maximum intensity for all masses. The stability and linearity of the mass calibration is accurate to less than 1/10 of a mass unit. Experimental determinations of the geometry, resolution, and calibration were made with rubidium, cesium, and thallium. Methods of detection include the use of an electron multiplier and vibrating reed electrometer. Methods of eliminating the direct, neutral beam and ions of the wrong transit time have been devised. The instrument can be used for the isolation of individual artificially produced radioactive isotopes and some preliminary experiments of this type have been performed.

M2. Microscopy by Reconstructed Wave-fronts. HUSSEIN M. A. EL-SUM AND PAUL KIRKPATRICK, *Stanford University.*—Holograms produced by the method of Gabor[1] produce good reconstructions even when the illuminating radiation is far from monochromatic. White light may be used successfully, even with panchromatic film. This result is evidence of the great relative importance of the low order fringes. A homogram of a collection of object features not lying in the same plane normal to the illuminating beam admits of reconstruction so that any desired plane of the distributed object may be brought into focus. Examples are presented. Holograms may be produced with x-rays and reconstructed with visible light. A hologram made from a published x-ray diffraction pattern by Kellstrom yielded a good reconstruction corresponding to the published description of the object. Methods have been developed for getting rid of nearly all of the hologram noise resulting from dirt, defects in glass parts, and optical non-uniformity of the photographic film base.

[1] D. Gabor, Proc. Phys. Soc. (London) **BL14**, 449 (1951).

M3. Use of Successive Diffractions to Double or Quadruple the Resolving Power of a Grating. F. A. JENKINS AND L. W. ALVAREZ, *University of California, Berkeley.*—The availability of blazed gratings suggests the possibility of reflecting the light back to the grating one or more times to obtain increased dispersion and resolving power. One method utilizes a plane mirror which is placed in a parallel beam from the grating.[1] Greater intensity for a given dispersion was obtained thereby, but no increase in resolving power. By using two mutually perpendicular plane mirrors as a reflex combination in the focal plane of a concave grating, an arrangement similar to that suggested by Walsh[2] for prism monochromators, we have succeeded in doubling the resolving power hitherto obtainable with this grating. Spectra of Hg and I_2 corresponding to the fourth order of a 30,000 line/in grating were photographed, whereas only the second order of the same wavelength is observable in single diffraction. The astigmatism is annulled in an even number of diffractions, yielding a saving in intensity. Since it can be shown that the width of the line is not increased in successive diffractions, the resolving power is proportional to the dispersion and to the number of diffractions.

[1] E. Hulthén and E. Lind, Arkiv Fysik, **2**, 253 (1950).
[2] A. Walsh, Nature **167**, 810 (1951).

M4. Resolution and Sensitivity of Microwave Spectrographs.* H. R. Johnson, *Research Laboratory of Electronics, Massachusetts Institute of Technology*.—Obtaining narrow lines in microwave spectroscopy is important, since it determines whether or not fine structure can be resolved and the accuracy with which it can be measured. Sensitivity determines whether or not weak lines can be observed at all. We have used a Stark modulation spectrograph in our laboratory for over a year; in K-band it yields line half-widths at half intensity of 50 kc/sec and has a limiting sensitivity of 10^{-8} cm^{-1} with a Stark cell 1 m long and a 5-sec time constant. The factors responsible for this line width will be discussed, and an equation from which the ultimate sensitivity of our Stark spectrographs can be predicted will be presented. This discussion will include the effect of detector crystal noise and Stark modulation frequency. It will be shown that for most purposes a Stark modulation frequency of about 6 kc/sec is optimum, and that the generally accepted expression for optimum cell length is incorrect for our spectrographs. The optimum length is greater by a calculable factor that is typically about 5 or 10.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and the ONR.

M5. The Reflection of X-Rays and the X-Ray Microscope. L. M. Rieser, Jr., *Stanford University*.—A large number of accurate measurements on the reflection of x-rays from evaporated films have recently been made, stimulated in part by the development of the x-ray microscope. Applications of some of these results to this instrument are discussed. Among the important features of a satisfactory reflector for x-rays are small particle size to reduce scattering and relation of absorption to refractive index. Results of measurements at $\lambda = 1.54$A and $\lambda = 2.28$A indicate that beryllium, aluminum, nickel, gold, and perhaps iridium are suitable reflectors when deposited on glass, while chromium, copper, and silver are not. Silver, used so frequently in the early version of this instrument, has little to recommend it other than ease of evaporation. Knowledge of the ratio of reflected to incident intensity becomes increasingly important in the design of the compound microscope described in paper M7. In this instrument the x-rays appearing in the final image undergo four reflections, emphasizing the importance of a reflector, such as glass or aluminum to insure uniform distribution across the field and sufficient total intensity. Mere striving for high critical angle in the choice of x-ray mirrors is not sufficient.

M6. The Structure and Stability of Thin Evaporated Metallic Films. Marsden S. Blois, Jr., *Stanford University*.—The dependence of the structure and stability of thin (10A–1000A) evaporated metallic films upon the nature of the metal, nature of the substrate, and the evaporation parameters has been investigated using electron microscopy, the optical absorption spectra, and density measurements. The absorption spectra of thin ($\sim$10A) silver films was found to depend upon the particle sizes of these particulate deposits, and the absorption maximum characterizes them in a convenient manner. The change of structure undergone by these films as the evaporation parameters are varied, is thus indicated by gross color changes of the films. These structural changes are also observed with the electron microscope. The densities of a series of silver and copper films were measured using a thickness determination given by a Tolansky multiple beam interferometer, the mass being determined directly with a semimicro balance. The plot of density *vs* thickness gives evidence for the strong migration of these metals in the early stages of film formation while the outer layers to be deposited form on top of the underlying metal to build up an apparently normal solid structure with the result that for thick films the density asymptotically approaches that of the bulk metal.

M7. The Compound X-Ray Microscope. H. H. Pattee, Jr., *Stanford University*. (Introduced by Paul Kirkpatrick.)—A simple x-ray microscope using a pair of crossed concave mirrors has been described by Kirkpatrick and Baez.[1] Limitations on resolution, speed, and width-of-field are discussed. A method is described for designing a compound x-ray microscope using two pairs of crossed mirrors giving great improvement over the simple system in resolution, speed, and width-of-field. Mirrors must be aspherical surfaces, with extremely precise contours and smooth metallic coating to realize optimum theoretical performance. Multiple-beam interferometry allows determination of average contours of mirrors to about $\pm$10A. Smoothness of metallic coats may be observed by electron microphotographs of replicas. A compound x-ray microscope has been constructed using only spherical mirrors. This has several advantages over a simple system using spheres, but will not approach the capabilities of an aspherical compound system. A technique for producing extremely small, intense, focused beams of x-rays at a known location on a specimen is being developed. This would allow microdiffraction and microabsorption measurements to be made on volumes of the order of 10^{-15} cm^3.

[1] P. Kirkpatrick and A. V. Baez, J. Opt. Soc. Am. **38**, 766 (1948).

M8. Acceleration of Multiply Charged Nuclei.* Cornelius A. Tobias, *University of California, Berkeley*.—A method is proposed for cyclotron acceleration of nuclei ${}_zA$ to high energies without limitation in their atomic number z. A low voltage external ion source is used in which an intense beam of ions with low multiplicity of charge, e.g., ${}_zA^{(++)}$ is made. These ions are "preaccelerated" in a linear accelerator to a velocity which is somewhat higher than the velocity of the K-electrons of ${}_zA$. Only those ions remain usable which retain their charge $(++)$ during the entire preacceleration, without electron exchange. If the gas pressure of the accelerator is low enough a large fraction of ${}_zA^{(++)}$ is retained and can be injected in a frequency modulated cyclotron tangentially to a cyclotron orbit for ${}_zA^{(z+)}$. When the cyclotron orbit is reached, the ions ${}_zA^{(++)}$ are passed through the edge of a thin metal foil which strips them of all their electrons, forming ${}_zA^{(z+)}$. If the ions arrive in proper phase, they will be accelerated in the cyclotron without much further loss because of electron exchange. A similar preaccelerator can be used for tangential injection of the stripped ions ${}_zA^{(z+)}$ in the bevatron.

* This work was supported by the AEC.

M9. Relative Spectral Sensitivity Calibration of Electron Multiplier Phototubes in the 2500A–3500A Region. E. H. Gilmore and R. H. Knipe,* *U. S. Naval Ordnance Test Station, Inyokern*.—The utility of the electron multiplier phototube is enhanced in certain studies if its relative spectral sensitivity curve can be determined. The 1P-28 type extends the useful spectral range to about 2200A in the ultraviolet; however, relative spectral sensitivity determinations at wavelengths shorter than 3500A are in general considerably more difficult than those at longer wavelengths. The authors have calibrated some of these tubes by a comparison of the phototube response with that of a thermopile. Two methods of accomplishing the required nonselective attenuation have been employed: the standard method of increasing the separation of the source from the monochromator used, and a method whereby the attenuation is accomplished by use of a diffusely reflecting surface. In general the standard deviation from the mean curve obtained is less than eight percent. Calibration by the use of the diffuse reflector proved to be the more rapid method of the two, and is, in the opinion of the authors, freer of pitfalls.

* Now at Duke University.

M10. Precision Measurement of Uniformity of Materials by Gamma-Ray Transmission.* JOHN N. HARRIS AND ARTHUR I. BERMAN, *Los Alamos Scientific Laboratory.*—The uniformity of the product of thickness and density (i.e., mass per unit area) of materials of constant mass absorption coefficient is determined by measurements of the variation in gamma-ray transmission. The radiation is detected with a scintillation detector and vibrating-reed electrometer. For a given incident intensity, maximum sensitivity is attained when a source is chosen which emits gamma-rays whose mean free path in the material under investigation equals the thickness. This optimum condition for cobalt-60 radiation obtains for thicknesses of 3, 1, and $\frac{1}{2}$-in. of Al, Fe, and U, respectively; using a 1-curie source, variations of 0.01 percent in the uniformity of plates of these thicknesses have been measured. The method may be applied also to the scanning of curved surfaces and extended materials where the source and detector cannot permanently be fixed with respect to each other. For this latter case, the problem of compensating for the effect of source-detector misalignment is considered.

* Work performed under the auspices of the AEC.

M11. Ion Trajectories in the Omegatron. CLIFFORD E. BERRY, *Consolidated Engineering Corporation.*—The Omegatron is a mass spectrometer in which an alternating electric field acts normal to a uniform magnetic field.[1] Ions having a cyclotron resonant frequency equal to the frequency of the applied electric field travel in unbounded spiral orbits. Ions out of resonance pursue bounded orbits.

For a strictly two-dimensional system, the equations of motion are readily solved to give the ion trajectories. The general solutions including both arbitrary phase angle and initial velocity vector will be given. From these solutions, the resolving power and path length are readily derived, and, in addition, the following conclusions can be drawn: (a) The phase angle between the time of origin of an ion and the exciting voltage has only a minor effect on the path length. (b) At any given time, all resonant ions lie within a narrow band on a rotating radial spoke. (c) At any given time, all nonresonant ions of a given mass lie within a narrow band about a circle intersecting the origin and rotating about the origin. That diameter of this circle which passes through the origin is always normal to the radial spoke of the resonant ions.

[1] Sommer, Thomas, and Hipple, Phys. Rev. **82**, 697 (1951).

M12. Effect of Chemical Structure on Stopping Powers for High Energy Protons. T. J. THOMPSON. *University of California, Berkeley.*—The stopping power of various organic compounds relative to copper is being measured for protons of mean energy 270 Mev. The compounds selected consist of C, H, N, O, and Cl in various combinations so that possible structural effects on the stopping power may be observed. The sample thickness is selected so as to reduce the energy of the beam from 340 Mev to approximately 200 Mev. The remainder of the proton range is dissipated in copper absorbers of variable thickness. Ionization chambers before and behind the absorber column are used to obtain Bragg curves of absorber thickness *vs* relative ionization in the usual manner. It is known that the stopping power of a compound is very nearly an additive function of the stopping power of the elements making up the compound. The relative stopping power at 270 Mev, while not strictly additive, is, in the case tested, additive within the accuracy of most nuclear experiments. There appears to be, however, a measurable deviation from additivity. Preliminary results, which must be further verified, indicate that unsaturated compounds (e.g., benzene) have slightly higher stopping power than would a mixture of graphite and saturated compound (e.g., cyclohexane) of the same atomic constitution. Details will be discussed. Experiments with other compounds and solutions and the liquid gases are being carried out.

SATURDAY MORNING AT 9:00

Room 4, Le Conte Hall

(R. T. BIRGE presiding)

N1. Theory of the Angular Width of Cerenkov Radiation from a Particle Undergoing Multiple Scattering. K. G. DEDRICK, *Stanford University.*—A theoretical formula is being developed to describe the Cerenkov radiation from a fast particle traveling through a substance consisting of screened Coulomb potential centers. The procedure is to calculate the radiation from a series of short connected segments with angles between them corresponding to single scattering. This expression is then averaged over the single scattering angles to obtain the distribution of radiated power in terms of the viewing angle. It will contain contributions due both to the average change in direction of the scattered particles, and to the partial incoherence of the radiation from the individual path segments.

N2. Cerenkov Radiation from Positrons. T. C. WILFONG, JR., AND J. E. HENDERSON, *University of Washington.*—Preliminary results indicate that Cerenkov radiation has been obtained using positrons from copper 64 and zinc 63, both of which were prepared in the University of Washington Cyclotron. Intensity considerations required the design of equipment in which a large fraction of the positrons emitted from a broad source are focused by a magnetic field upon a special Lucite target. Shields serve to eliminate any electrons that might be present. In addition two nearly symmetrical lucite paraboloids of revolution with the target at their joint apex serve to gather the radiation over a large solid angle. One paraboloid collects radiation in the direction of motion of the positron and the other collects radiation going in the opposite direction. Asymmetry between the radiation in the two directions is taken as indication that Cerenkov radiation exists. Gamma-rays were distinguished from the Cerenkov radiation by thin obstacles over portions of the films used to detect the radiation. Although no intensity measurements have been made as yet, our results indicate that the efficiency of production is approximately the same as that of ordinary electrons.

N3. A New Type Cerenkov Counter.* ROBERT W. BIRGE, *University of California, Berkeley.*—A new type Cerenkov counter has been built that uses ideas similar to those suggested by I. A. Getting.[1] In our counter the center portion is cut out to reduce the amount of light due to scintillations. Previous tests of Getting's counter by R. H. Dicke[2] were not conclusive, mainly because of the lack of a fast coincidence circuit to eliminate phototube noise. However, the recent experiments by John Marshall[3] indicate that a Cerenkov counter can be made to work. The counter to be described was tested in coincidence with a stilbene crystal using a circuit with a resolving time of about 10^{-9} seconds, developed by Lee Neher at the Radiation Laboratory. Transition curves were taken using the gamma-rays from π^0-meson decay in the target of the 184-inch cyclotron. Evidence will be given to show that Cerenkov radiation from the resulting electrons can be detected with reasonable efficiency.

* This work was performed under the auspices of the AEC.
[1] I. A. Getting, Phys. Rev. **71**, 123(L) (1947).
[2] R. H. Dicke, Phys. Rev. **71**, 737(L) (1947).
[3] J. Marshall, Phys. Rev. **81**, 275(L) (1951).

N4. High Energy Photoprotons from Carbon.* J. W. ROSE AND W. S. GILBERT. *University of California, Berkeley.*—A study is being made of the high energy protons ejected from carbon by the 322-Mev bremsstrahlung of the Berkeley synchrotron. The protons are detected by means of a counter telescope consisting of three liquid scintillators each viewed by two or three 1P21 photomultiplier tubes connected in parallel. The protons are required to stop in the second counter, and pulse-height analysis in the first counter is used to differentiate between protons and mesons. $d\sigma/d\Omega$ per equivalent quantum, Q, has been measured at 90° in the lab. Preliminary results indicate a variation with energy of $1/E^{2.8}$ from 85 Mev to 200 Mev.

* This experiment was performed under the auspices of the AEC.

N5. Photodisintegration of the Deuteron. W. S. GILBERT AND J. W. ROSE. *University of California, Berkeley.*—Photons of a maximum energy of 312 ± 15 Mev in the "spread-out" bremsstrahlung beam of the Berkeley electron synchrotron have been used to disintegrate deuterium. The gas was bombarded in a high pressure, low temperature target at a pressure of 136 atmospheres and at a temperature of 77°K. The protons from the $D(\gamma, n)p$ reaction were detected by the scintillation counter telescope system described in the preceding abstract. Since the photoeffect, in the absence of meson production, is a two-body problem, knowledge of a proton's energy and angle in the laboratory system uniquely determines the energy of the x-ray responsible for the disintegration. Using this fact, absolute values of $d\sigma/d\Omega$ at several angles were determined for x-ray energies of 200 Mev and 250 Mev in the center-of-mass system, and total cross sections were determined for these energies. $\sigma_t(200 \text{ Mev}) = (9.5\pm30 \text{ percent}) \times 10^{-29}$ cm^2 and $\sigma_t(250 \text{ Mev}) = (13\pm40 \text{ percent}) \times 10^{-29}$ cm^2. The indicated probable errors are based on counting statistics alone and give an indication of the limits on the relative cross sections. The absolute cross sections may be in error by as much as a factor of 2. These cross sections are far greater than any smooth extrapolation based on the calculated cross sections at lower energies[1, 2, 3] could yield. One therefore concludes that above the meson threshold, the cross section rises sharply with increasing energy.

[1] J. F. Marshall and E. Guth, Phys. Rev. **76**, 1881 (1949).
[2] L. I. Schiff, Phys. Rev. **78**, 734 (1950).
[3] J. F. Marshall and E. Guth, Phys. Rev. **78**, 739 (1950).

N6. Internal Momentum Distributions from Scattering Experiments. J. B. CLADIS, W. HESS, AND B. J. MOYER. *University of California, Berkeley.*—The mean free path in nuclear material and the de Broglie wavelength of a 340-Mev proton are such that a single collision with a nucleon of a light nucleus is expected when the proton is scattered. Thus, at scattering angles greater than about 25°, where interference terms are small, the proton energy spectra reflect the momentum distribution of the nucleons in the target nucleus. An expression for the spectra as a function of momentum distribution and scattering angle has been given by Wolff.[1] Energy spectra of protons scattered from H, D, and C have been obtained at scattering angles of 30° and 40°. These spectra are obtained by deflecting the protons by a magnetic field into channels defined by proportional counters and a bank of 35 Geiger-counters. Spectra calculated by inserting the theoretical momentum distribution for the deuteron and the gaussian distribution[2] for carbon into Wolff's formulas fit the data fairly well at both angles. The Chew-Goldberger distribution contains too many high momentum components.

[1] P. A. Wolff, UCRL-1410.
[2] E. M. Henley and G. H. Huddlestone, Phys. Rev. **82**, 754 (1951).

N7. Nuclear Momentum Distributions. PETER A. WOLFF. *University of California, Berkeley.*—Using the impulse approximation, a formula has been obtained which gives the energy distributions, at several angles, of fast protons that have been scattered from nuclei. The formula involves an integral over the nuclear momentum distribution and can, therefore, be used to extract information about this distribution from experimental data on scattering. The fitting of the experimental curves is most sensitive to the high momentum components in the nuclear wave function; in particular, it will be shown that long tailed momentum distributions such as that proposed by Chew and Goldberger[1] are not suitable, whereas a Gaussian with average energy of about 25 Mev fits the data well at several angles of scattering. The final theoretical energy distributions contain corrections, calculated by the Monte Carlo method, for the effects of multiple scattering of the proton within the nucleus. These distributions will be compared with those obtained by Cladis[2] experimentally and a discussion will be given of the error inherent in the method, which is estimated to be about five percent for protons of 340 Mev.

[1] G. F. Chew and M. L. Goldberger, Phys. Rev. **77**, 470 (1950).
[2] Previous abstract.

N8. The Long-Lived Phosphorescence of Potassium Iodide-Thallium Iodide. BERNARD SMALLER AND EUGENE AVERY, *Argonne National Laboratory, Chicago.*—The long-lived phosphorescent decay of KI–TlI has been investigated using Co^{60} gamma-rays as the stimulating agent.

Analyses of the complete decay curve for the temperature range 255–360°K permits resolution into several exponential decay periods ranging from 1–10^4 sec. Determination of the frequency factors, s, and activation energies, ΔH, for the various trapping levels gave agreement with the absolute rate

TABLE I.

Trap No.	Log$s$	ΔH(ev)	$\sigma\times10^{17}$ cm^2
1	12.81	0.92	1.8
2	11.83	0.84	1.7
3	11.25	0.76	2.4
4	10.01	0.65	1.0

theory[1] which predicts for the decay time, τ

$$1/\tau=(kT/h)\exp(\Delta S/R)\exp(-\Delta H/RT)=se^{-\Delta H/RT}$$

Discrepancies exist, however, with the glow curve phenomenon, previously reported,[2] which may be attributed to the low capture cross sections calculated for the process. The various constants of the reaction are given in Table I.

[1] Glasstone, Laidler, and Eyring, *The Theory of Rate Processes* (McGraw-Hill Book Co., Inc., New York, 1941).
[2] Smaller, May, and Freedman, Phys. Rev. **79**, 940 (1950).

N9. New Technique for the Determination of Photonuclear Cross Sections.* Lester L. Newkirk, *Iowa State College.*—A new technique for measuring photonuclear cross sections has been developed and applied to the $Cu^{63}(\gamma, n)Cu^{62}$ and $C^{12}(\gamma, n)C^{11}$ reactions up to 60 Mev. The results are in good agreement with other results obtained by different methods. Radioactivity is used to monitor the synchrotron beam. A mechanical "oscillator" slides a test sample and an identical monitor sample alternately into the beam. As the oscillator moves to and fro, the electron energy of the synchrotron is switched back and forth between two values. From one run to another the monitor sample is irradiated at the same electron energy, but the test sample is irradiated at various energies. Since conditions of irradiation and counting are always the same, any random or long time changes in beam intensity will show up in the monitor sample activity. The required photon distribution was determined by obtaining with the oscillator an activation curve for the $Ag^{107}(\gamma, n)Ag^{106}$ reaction, whose cross section is known;[1] the results were then applied to the bremsstrahlung spectra of presumed known shape.

* Work was performed at the Ames Laboratory of the AEC.
[1] B. C. Diven and G. M. Almy, Phys. Rev. **80**, 407 (1950).

N10. Recent Developments with the Mass Synchrometer.* Lincoln G. Smith, *Brookhaven National Laboratory.*—Recent work on an instrument for comparing accurately the cyclotron frequencies or periods of ions of nearly equal mass and thus measuring their mass differences will be described. As originally arranged[1,2] this device has yielded higher resolution than most conventional mass spectrometers and required less critical alignment of component parts. However intensity obtainable for given resolution is materially lower because of a much lower duty cycle and greater loss of ions per unit path over the longer path used. In recent modifications the velocities of ions are modulated at 180° from the source in a short rf field rather than one pulsed at a considerably lower rate. Moreover, ions make only two or possibly a few more rotations between source and detector. Thus intensity for given resolution is quite comparable with that of conventional instruments. In fact, with the detector just behind or below the source rather than between it and the modulator, materially larger intensity may be obtainable. It appears, however, that obtaining it requires use of a square wave rather than a sinusoidal modulating field. Comparison of this instrument with others for measuring cyclotron frequencies or periods and with deflection-type spectrometers will be discussed.

* Research carried out under contract with AEC.
[1] L. G. Smith, Rev. Sci. Instr. **22**, 115 (1951).
[2] L. G. Smith, Phys. Rev. **81**, 295(A) (1951).

N11. Slow Neutron Crystal Spectrometer. R. G. Allen, C. P. Stanford, T. E. Stephenson, and S. Bernstein, *Oak Ridge National Laboratory.*—The use of a crystal spectrometer as a source of monoenergetic neutrons has been, in general, limited to the region of energies greater than about .03 electron volts because of the presence of higher-order reflections from the crystal. However, by making use of the total reflection properties of mirrors for neutrons incident at very small glancing angles, order-free reflections from the crystal have been obtained and the useful range of a crystal spectrometer extended to around .005 electron volts. In practice, the lower energy limit of usefulness is determined only by the intensity available in this energy range. With this arrangement total neutron cross section measurements as a function of energy have been made for the strong capturing substances, gold, indium and silver in the region between .02 to .005 electron volt. Total cross section measurements of the strong scatterers nickel and nickel oxide have also been made in this energy region. Values for the coherent scattering cross sections were obtained from the heights of the discontinuities in the total cross section at wavelengths satisfying the Bragg law for ninety degree glancing angles for the various sets of crystalline planes. Detailed results for these substances will be given and compared to results of other observers obtained by the use of other techniques.

N12. The University of Washington 60-in. Cyclotron. F. K. Donnelly, H. J. Engebretson, J. E. Henderson, T. J. Morgan, F. H. Schmidt, and J. F. Streib, *University of Washington.*—Successful operation of a new conventional type cyclotron has recently been achieved. Internal D and H_2 beams $>100\mu a$ are obtained with 100-kv peak dee to ground at $\sim$60-kw input. An rf deflector will be installed shortly. Although patterned after the Berkeley 60-in. cyclotron, the instrument has several new features. The grounded grid oscillator uses one ML 354 triode, 75-kw plate dissipation. The plate is at dc ground; hence, no insulated water supply is required. A 2-kw frequency doubler "booster" oscillator drives the main oscillator over the low voltage tank discharge. The system is extremely stable and will "ride-thru" almost continuous sparking. Bake-out time is short. The tube is cathode-biased and no constant current network is required. Although the machined gasket surfaces of the aluminum alloy vacuum chamber included several welded areas, the structure was vacuum tight at first test. The chamber is joined to cylindrical dee stem tanks by a single transition section, below which is located a 20-in. diffusion pump. The electrical terminations of the dee stems (spiders) are adjustable from outside the vacuum. The cyclotron is housed in a 40-ft-diameter room built into a natural ravine for earth shielding. An opening leads through a shielded passage; the deflected beam will be utilized in a low background laboratory. Generous assistance was given by staff, graduate students, and technical personnel.

* Jointly supported by the University of Washington, the ONR and the AEC.

N13. The Determination of the Height and the Diurnal Variation of the Night Airglow.* Edward V. Ashburn, *U. S. Naval Ordnance Test Station, Inyokern.*—A critical analysis has been made of the method given by Roach and Pettit[1] for determining the intensity, height, and diurnal variation of the night airglow. In particular, this method, involving separation of the airglow from the total light of the night sky, has been put in analytical form. The analysis indicates in general that their evaluation of the intensity of the airglow can be appreciably improved by more rigorous techniques. It also indicates that the large scale features of the relative diurnal variation of the 5577A airglow as obtained by Roach and Pettit are essentially correct, although it suggests the desirability of additional data in support of their hypothesis of the semifixed isophot pattern. Their two techniques for determining the height of 5577A airglow yield, as they stated, results whose accuracy is relatively low.

* ONR Project NR 082-045 (in part).
[1] F. E. Roach, and Helen Pettit, Geophys. Research (September, 1951).

SATURDAY MORNING AT 9:00

Room 3, Le Conte Hall

(V. F. LENZEN presiding)

O1. Considerations of the Elastic Constants of Copper.* J. A. BRINKMAN, *North American Aviation, Inc., Downey, California.*—The potential used by Fuchs[1] in calculating the elastic constants for copper does not satisfy the condition required on the forces to maintain lattice stability:

$$12\frac{\partial W}{\partial r}\bigg|_{r=r_0}+6\frac{\partial W}{\partial r}\bigg|_{r=\sqrt{2}r_0}+24\frac{\partial W}{\partial r}\bigg|_{r=\sqrt{3}r_0}+12\frac{\partial W}{\partial r}\bigg|_{r=2r_0}+\cdots=0.$$

This condition demands that $\partial W/\partial r|_{r=r_0}=0$, if only nearest neighbor interactions are important. However, this derivative must have a nonzero value to explain the observed elastic constants. Hence, $\partial W/\partial r|_{r=\sqrt{2}r_0}$ must be of the same order of magnitude and opposite sign. Thus, the contribution from next nearest neighbors is not negligible when compared with the first derivative term resulting from nearest neighbors. An attempt has been made to satisfy the foregoing stability condition as well as the observed elastic constants by using a Morse potential to explain the compressibility, and a modification of this potential to explain the two shear elastic constants. The necessity for this modification arises from the dependence of compressibility on volume forces, while the shear constants are independent of volume forces.

* This work is based upon studies conducted for the Atomic Energy Commission under Contract AT-11-1-GEN-8.
[1] K. Fuchs, Proc. Roy. Soc. (London) **A151**, 622 (1936).

O2. A Theoretical and Experimental Investigation of High Temperature Graphitization.* W. P. EATHERLY, *North American Aviation, Inc., Downey, California.*—The high temperature graphitization process has been studied using samples of index rod, a gas-baked petroleum coke. The various electrical and magnetic properties change only slightly at temperatures below 1800°C, which variations are attributable to the binder material. In the range from 1800° to 2700°C rapid changes occur, coupled with growth in crystallite size and the evaporation of impurity atoms. The electrical conductivity, magneto-resistance, and magnetic susceptibility increase monotonically, but both the Hall coefficient and thermoelectric power pass through sharp maxima. The thermal conductivity shows a much more gradual increase which extends over the entire temperature range investigated. Employing the band energies calculated from the tight-binding approximation,[1] analytic expressions can be computed for the various electronic phenomena. These expressions agree qualitatively with the experimental data, and indicate that the electric and magnetic changes induced by graphitization are due primarily to the freeing of electrons trapped by crystal defects and impurities. The mean free path of the conduction electrons is limited by scattering from crystallite boundaries and defects rather than from lattice oscillations. The data and theory both indicate the unusual electronic characteristics of graphite are caused by the prominent action of a Brillouin zone boundary.

* Work performed under AEC contract.
[1] P. R. Wallace, Phys. Rev. **71**, 622 (1947).

O3. Magnetic Susceptibility of Polycrystalline Anisotropic Materials, and Observations on Artificial Graphites.* J. D. MCCLELLAND AND J. J. DONOGHUE, *North American Aviation Inc., Downey, California.*—A study of the anomalous diamagnetism of graphite provides a sensitive index of the role of the Fermi energy, of interest in the theory of conduction phenomena. However, the extreme anisotropy of graphite makes single observations on a specimen have a questionable significance. An invariant measure was therefore sought, and found in the sum of any three mutually perpendicular susceptibilities observed on the same cubical specimen, termed the "total" susceptibility. An experimental verification of the invariance is presented for polycrystalline artificial graphites of differing anisotropy. The "total" susceptibility of artificial graphites is -21.0×10^{-6} per g, only ten percent less than natural graphite. The method has been applied to observe the growth of the dimagnetism of carbon during graphitization. Index rod carbon was raised to successively higher temperatures up to 2800°C for two minute periods, and the room-temperature susceptibility determined between anneals. The results indicate the removal of impurities below 2000°C, and a steady growth in dimagnetism as crystallite perfection and growth proceeds.

* Work performed under AEC contract.

O4. Deformation and Fracturing of Thick-Walled Steel Cylinders under Explosive Attack. JOHN PEARSON AND JOHN S. RINEHART, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.*—Tests have been conducted on annealed heavy-walled cylinders of low carbon (1020) steel internally loaded by explosive charges. The purpose of these tests was to obtain basic information on the manner and type of fracturing and plastic flow obtained by extremely high pressures acting for short durations. It was observed that all of the cylinders tended to fracture in long fragments in the same basic pattern, but with variations because of wall thickness and manner of loading. Experimental results indicate that the radial cleavage type of fracture is initiated within the cylinder wall and propagated to the surface, while the shear type fracture associated with the inner portion of the cylinder wall appears as an independent energy relieving process. Microstructure analysis of the cylinder fragments shows a definite relationship between the type of fracture and the amount of distortion of the grain boundary. Considerable shock twinning is present in the cylinder fragments, and the grain structure near the inner surface shows severe distortion and flow. Strain measurements indicate that considerable plastic strain occurs during the explosive loading and cleavage fractures were always observed to occur in association with considerable plastic deformation.

O5. Some Tensile Fractures Generated in Metals by Impulsive Compressional Loading. JOHN S. RINEHART AND JOHN PEARSON, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.*—One aspect of the part that high intensity stress waves play in the fracturing of metal cylinders subjected to internal explosive loading has been studied. It has been found that tensile type fractures will result from the interference of reflected tensile stress waves whenever the resulting tensile stress exceeds the critical normal fracture stress of the material. The magnitude of this resulting tensile stress and its location within the body are largely dependent on the geometry of the metal-explosive system. Stress wave velocities have been measured for low-carbon steel, brass, copper, lead and aluminum alloy from the geometry of fracture. These velocities are in reasonably good agreement with accepted values for the velocities of dilatational waves in these metals.

O6. The Measurement of Young's Modulus and Internal Friction in Metal Specimens Suitable for Uniform Cyclotron Irradiation.* F. E. BOWMAN AND M. TARPINIAN, *North American Aviation, Inc., Downey, California*.—Theoretical considerations suggest that a study of the effects of cyclotron irradiation upon the elastic constants of metals should lead to further understanding of the nature of radiation damage. A technique has been developed for obtaining Young's modulus on samples that are suitable for such irradiations. Cyclotron characteristics enforce stringent limitations upon specimen size. Through necessity for uniform irradiation the specimen diameter is limited to about 0.005 inch by the particle range. The dimensions of the cyclotron beam fix a specimen length of about one-half inch. In order to meet these requirements, an apparatus was developed that employs the specimen as a vibrating cantilever beam. The beam modulates a light that falls on a photocell. The signal is impressed on a scaler, and thus the characteristic frequency of the sample is determined to about one part in one thousand. From this frequency the modulus can be computed. By photographing an oscilloscope pattern of the photocell signal as the vibration excitation is interrupted, a free decay curve is obtained and an internal friction value determined.

* This work is based upon studies conducted for the AEC under Contract AT-11-1-GEN-8.

O7. Interactions of Shock Waves in Air with Three-Dimensional Surfaces, I. RICHARD I. CONDIT, *Broadview Research and Development, Burlingame, California*.—Existing information on the interaction of shock waves in air with rigid surfaces has been largely limited to one- or two-dimensional surfaces. Extension to three-dimensional surfaces seems promising with an experimental procedure which records in sequence the positions of the leading edge of the region of interaction of shock wave and surface. These contours of interaction are photographed in a direction normal to the general orientation of the surface with the source of the shock waves between the motion picture camera and the test surface. The test surface must have an indicator coating which is deformed or altered by the passing shock wave in a manner that will allow photographic registration. Examples of such indicators will be given. The time sequence of photographs allows the determination of shock wave velocities and peak pressures at the surface. Thus at any point on the surface, the influence of the shape of the surface on the peak pressure can be evaluated. The results are most readily analyzed when the surfaces only suffer gradual changes in shape—as with natural topography. The procedure is equally adaptable to studies of full-scale explosions or accurate small-scale model shots.

O8. Growth of Single Crystals of Tantalum and Their Surface Structure. M. H. NICHOLS,*,† *California Institute of Technology*.—Single crystals of tantalum of centimeter length have been grown in tantalum wire by a moving temperature gradient technique.[1] Qualitative examination of the thermionic electron projection tube pattern shows it to be identical with that of tungsten single crystals.[1] This is another indication that the anisotropy of thermionic emission from these metals is a surface rather than a volume effect.[2] The tantalum crystals so grown exhibited a plateau-like surface structure normal to the (110) direction extending approximately 2 degrees of arc around the wire either side of the (110) direction after approximately $4\frac{1}{2}$-hours vacuum heating at 2500°K. After this amount of heating, a plateau-like structure normal to the (100) direction was just visible with a microscope magnification of 100. After sufficient vacuum heating to evaporate approximately 5 percent of the wire diameter, the plateau normal to the (110) direction extended over 10 degrees of arc, and the plateau normal to the (100) direction extended over approximately 5 degrees of arc.

* This work was sponsored by the ONR.
† Now at the University of Michigan.
[1] M. H. Nichols, Phys. Rev. **57**, 297 (1940).
[2] C. Herring and M. H. Nichols, Revs. Modern Phys. **21**, 185 (1949).

O9. One-Dimensional Flow with Mass Addition. EDWARD W. PRICE, *U. S. Naval Ordnance Test Station, Inyokern*.—Analysis has been made of flow in a straight channel with mass addition along the channel corresponding to the case of a typical solid propellant rocket motor. One-dimensional, steady-state, adiabatic flow with chemical equilibrium and constant stagnation enthalpy was assumed. It was found that, when the mass addition was a known function of the variables of state of the stream (as is the case in a rocket motor), the entire (one-dimensional) flow field could be computed for any given upstream pressure using conventional numerical methods. When the discharge characteristic of the rocket nozzle was known, the upstream pressure (and hence the flow field) could be specified as a function of two variables, one depending on the mass addition function and one depending on the ratio of the nozzle throat area to the flow channel area. When this area ratio is $\geqq 1$, the flow reaches sonic speed at the downstream end of the channel, and the flow field in the straight channel is dependent only on the mass addition function. In the event that the gas composition is unchanging in the stream, the form of solution of the flow problem is independent of upstream pressure.

O10. Time-Resolved Spectroscopy of the Incandescence Associated with Ultraspeed Pellets. EARLE B. MAYFIELD, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern*.—Improved time-resolved spectra of the luminous trails associated with 5 km/sec ultraspeed pellets[1] have been obtained and reduced. Improved optical instrumentation was used, including an O'Brien drum spectrograph with a writing speed of 0.1 mm/sec and provided with a millisecond timer. Quantitative studies of the spectra indicate that about 90 percent of the emitted light can be identified with the atomic lines of the metals and the molecular bands of their oxides. Very little of the superimposed continuous spectra can be attributed to ballistic or air shock. Pellets have been fired into a chamber that contained gases at reduced pressures. The effect of gas pressure on the time-resolved spectra has been determined.

[1] Allen, Rinehart, and White, Phys. Rev. **83**, 889 (1951).

O11. Transient Waves through Steel Produced by Impulsive Loading.* WILLIAM A. ALLEN AND CLYDE L. McCRARY, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern*.—The transient behavior of a thick circular plate deforming under explosive attack has been investigated. An experimental technique, based upon the principle of the optical lever, has been used to measure surface oscillations as small as 10μ in amplitude. A long focal-length sweeping-image camer with a writing speed of 3 mm/μ sec was used to obtain time resolution as short as 0.1 μsec. Measured particle velocities on the free surface indicate the presence of elastic and plastic waves. Particle velocities determined by this method are not inconsistent with reported values.[1] Measured transit-times of the waves through the steel plate confirm reported values.[2] For most of the plates tested, permanent strain developed within 20 μsec. The permanent strain of each recovered plate was found to a limiting configuration of the transient deformation.

* Work supported by Armament Branch, ONR.
[1] J. S. Rinehart, J. Appl. Phys. **22**, 555 (1951).
[2] Pack, Evans, and James, Proc. Phys. Soc. (London) **60**, 1 (1948).

O12. Successive Approximations in a Theory for Critical Stability of Fluids. H. L. MORRISON, *U. S. Naval Ordnance Test Station, Inyokern.*—The theory[1] for conditions of critical mechanical stability of fluids at nonconstant temperature in porous media involves the solution of two simultaneous differential equations in mixed variables: w, the vertical component of flow velocity; and θ, the alteration of temperature distribution by incipient flow. In starting the solution by the method of Picard, w has been taken $w_1 = w_m \sin \pi z/D$ (in the notation of reference 1), and from the predominantly-θ equation a first approximation, θ_1, to θ has been obtained by quadratures. At this juncture, the w-equation has been used (by numerical integration) to solve the critical stability problem in two ways: (a) directly, and (b) after multiplication[1] by the spatial derivative of temperature. It has been found that the latter calculation produces numbers in better general accord with experiment than the former. This conclusion is interpreted to mean that a much better w_1 can be had, of the general nature of $\exp(-\varphi s/D) \sin \pi z/D$; detailed examinations of solutions of approximate differential equations bear this out.

[1] Morrison, Rogers, Jr., and Schilberg, J. Appl. Phys. (1951, in press).

O13. Variational Approach to a Theory for Critical Stability of a Fluid. F. T. ROGERS, JR., *U. S. Naval Ordnance Test Station, Inyokern.*—In reference 1 are derived two simultaneous linear differential equations in mixed variables and nonconstant coefficients, which, with suitable boundary conditions, define the thermal environment at critical stability of a fluid (heated from below) in a porous medium. For the special case ($\varphi = 0$) of an environment linear in the vertical spatial variable and independent of the other two, we have established that these equations are the Euler-Lagrange conditions that $\int_0^D [(-\beta_c/h^2) \exp(\nu\beta_c z)(w'^2 + Aw^2) + A\lambda(\theta'^2 + A\theta^2) - (2A\lambda\beta_c/h^2)\theta w] dz$ assume an extreme value with respect to "weak" variations, and furthermore, that for w and θ eigenfunctions and for β_c eigenvalues of the problem, this extremum is zero. Notation here is precisely that of reference 1. It has not as yet proved feasible accurately to extend these relationships to the case of $\varphi > 0$, though approximate relationships can be devised for $\varphi > 0$ with an accuracy decreasing with increasing φ.

[1] Rogers and Morrison, Proc. Fourth Annual Heat Transfer and Fluid Dynamics Inst. (Stanford, 1951), p. 45.

SATURDAY AFTERNOON AT 2:00

Room 1, Le Conte Hall

(J. KAPLAN presiding)

P1. Electrodynamics as a Basis for Special Relativity. ARTHUR E. RUARK, *Institute for Cooperative Research, The Johns Hopkins University.*—The Lorentz transformation is usually derived from the symmetry of the physical experiences of two observers on inertial frames, and the assumption that both observers obtain the same value of c, no matter how the source is moving. Suppose we replace the second postulate by the statement that the Maxwell equations and the Lorentz force are valid for the "resting" observer. We can discuss a simple clock,—a negative charge, rotating around a heavy positive charge in a plane perpendicular to the X axis. Setting this system into uniform motion, it becomes the clock of the moving observer. The resting observer can use the retarded potentials to discuss its behavior. A few lines suffice, to derive the mass increase and the decrease of angular velocity which occur when the clock is set into motion. The expansion of times associated with a moving body, the constancy of light velocity for the moving observer, the Lorentz contraction of a moving body, and the Lorentz transformation follow in order, with ease. This attack makes these matters so readily understandable, on the basis of retardation of electrical forces, that it appears to possess didactic value.

P2. The Surface Ionization of Lanthanum. JOHN H. REYNOLDS, *University of California, Berkeley.*—A modified ion source of the surface type has been constructed in which the ionizing surface is a bare tungsten ribbon which intercepts 1.5 percent of the neutral vapor from a secondary tungsten ribbon located in the plane of the first defining slit. The secondary filament is coated with the solid sample under investigation, in this case La_2O_3. Accelerated ions from the bare filament are analyzed with a 60° sector mass spectrometer by standard techniques. The stability of the source is adequate. Thus for a fixed secondary-filament voltage setting, the emission is a reproducible function of the ionizing-filament voltage setting over periods of several hours. For source pressures of 10^{-7} mm or less, it is found that the character of the ion emission differs significantly from that observed from La_2O_3 using a conventional surface ionization source in that a strong La^+ component is present, sometimes without competing LaO^+ emission. Reasons for this will be discussed. For pure La^+ emission, the variation with surface temperature of the ion current, i, is in good agreement with that predicted by the Saha-Langmuir equation, namely, $d \ln i/d(1/T) = -(e/k)(V_i - V_w)$, where V_i is the ionization potential of lanthanum and V_w is the work function of the ionizing surface.

P3. Photomesons from Deuterium. R. STEPHEN WHITE, MARK J. JAKOBSON, AND ALVIN G. SCHULZ. *University of California, Berkeley.*—Hydrogen and deuterium gases have been bombarded in a high pressure, low temperature target by photons from the Berkeley synchrotron to produce charged mesons. The π_+-mesons were detected by trans-stilbene scintillation crystals using $\pi\mu$, $\pi\beta$, and $\pi\mu\beta$ coincidence detection, and both π^+ and π^- mesons were detected with nuclear emulsions. At angles to the beam direction of 135±16°, 90±16°, and 45±16° the ratios of the number of π^- to π^+ mesons were 1.21±0.17, 1.07±0.13, and 0.96±0.11, respectively. No variation of the ratio with meson energy, within statistics, was observed. Absolute values for the π^+-meson energy distribution

TABLE I.

	45±16°		90±16°		135±19°	
$\left[\frac{d^2\sigma(\bar\theta, \bar E_\pi)}{dE_\pi d\Omega}\right]_D \Big/ \left[\frac{d^2\sigma(\bar\theta, \bar E_\pi)}{dE_\pi d\Omega}\right]_H \equiv$	$\frac{D}{H}$	$\bar E_\pi$(Mev)	$\frac{D}{H}$	$\bar E_\pi$(Mev)	$\frac{D}{H}$	$\bar E_\pi$(Mev)
	0.84±0.17	43	1.04±0.31	42	0.81±0.10	42
	0.86±0.13	57	0.75±0.08	55	0.80±0.07	56
	0.78±0.14	87	0.78±0.11	70	0.60±0.15	76
	···	···	0.68±0.05	75	···	···
	···	···	0.58±0.09	94	···	···
$\left[\frac{d\sigma(\bar\theta)}{d\Omega}\right]_D \Big/ \left[\frac{d\sigma(\bar\theta)}{d\Omega}\right]_H$	0.81±0.10		0.75±0.05		0.80±0.06	
$[\bar\sigma T]_D/[\bar\sigma T]_H$	0.78±0.03					

functions from hydrogen and deuterium in cm^2, per proton, per equivalent quantum, per Mev, per steradian have been measured, and the differential and total cross sections have been obtained by integrating over energy and angle, respectively. The ratios of the cross sections in the lab system from deuterium and hydrogen at each of the detection angles are given in Table I. Errors given are standard deviations resulting from statistics only. The statistics of the data are not sufficient to compute the proton spin-flip probability from the theory of Chew and Lewis.

P4. Capture of μ^- Mesons in Nuclear Emulsions. D. F. SHERMAN, HARRY H. HECKMAN, AND WALTER H. BARKAS. *University of California, Berkeley.*—The behavior of μ^- mesons produced in the cyclotron has been investigated to verify deductions from cosmic-ray studies. A beam of μ^- mesons has been obtained inside the 184-inch cyclotron by bombarding a Be target with the proton beam. Because many of the π-mesons so produced disintegrate near the target, the target region acts as a diffuse source of μ-mesons. A channel was constructed to select a beam of negative mesons of momentum 130 ± 3 Mev/c. An absorber which stops the π-mesons of momentum up to 140 Mev/c was placed in this beam, and an Ilford C-2 emulsion in a wedge absorber was placed behind it to detect μ^- mesons which penetrated the absorber. μ^- mesons were found ending in the plate with a density of about 4000 per cc in the energy interval 54 to 70 Mev. About 6 percent of these form one prong stars of low energy. This agrees with results of George and Evans.[1] An additional 35 percent show evidence of nuclear capture in the form of two pronglets, each about a micron long, or a "blob" at the end of the track.

[1] E. P. George and J. Evans, Proc. Phys. Soc. (London) **A44**, 193 (1951).

P5. Scattering of Negative π-mesons in Aluminum, Copper, and Lead. HARRY H. HECKMAN AND WALTER H. BARKAS. *University of California, Berkeley.*—A new technique is being used to measure nuclear scattering cross sections of π^--mesons as they traverse a semi-infinite scatterer. A stripped nuclear emulsion is embedded in the scatterer, exposed to an incident beam of 50_{-5}^{+15} Mev π^--mesons, and scanned. Most of the mesons stop at the expected distance from the absorber edge as determined from the range-energy relation. A few mesons are found at smaller depths of penetration and are attributed to large angle scattering. Mesons traveling opposite (90°–180°) to the direction of the incident beam are attributed to nuclear scattering and are used in the cross section calculation. The assumptions in this calculation are: (a) spherically symmetric nuclear scattering, and (b) nuclear scattering cross section independent of meson energy from 30–60 Mev. There is no geometrical correction factor, i.e., the cross section is proportional to the ratio of the backward flux to incident flux, both of which are observed in the same strip of emulsion. The analysis does not distinguish between elastic and inelastic scattering. The total (elastic and inelastic) nuclear scattering cross section for π^--mesons in the energy interval 40_{-10}^{+20} Mev is being studied for Al, Cu, and Pb. A preliminary value for Cu is 560 ± 160 mb.

P6. Photo Production of Negative Pions from Deuterium. R. E. LELEVIER, *University of California, Berkeley.*—The meson energy spectrum for fixed recoil angles of meson and proton in photo-π^- production from deuterium was calculated using the impulse approximation[1] and a phenomenological spin dependent interaction.[2] The spectrum is peaked near the unique energy which results at given free neutron production angles. The main portion of the spectrum is essentially given by $\phi_0^2(\mathbf{k})$ where $\phi_0(\mathbf{k})$ is the Fourier transform of the deuteron wave function, and $\mathbf{k}$ is the momentum of the original proton in the deuteron. For a given meson energy the conservation laws determine $\mathbf{k}$. If the final protons are in a singlet spin state there is a sharp rise in the spectrum at the maximum possible meson energy. This is because of a large increase in the phase-space factor and the ^1S proton-proton interaction. The experimental ratio of the height of the "spike" to that of the central peak would provide a measure of the spin-flip process, since there is no spike if the final protons are in a spin triplet state.

[1] G. Chew, Phys. Rev. **80**, 196 (1950).
[2] M. Lax and H. Feshbach, Phys. Rev. **81**, 189 (1951).

P7. Range Straggle of μ^+-Mesons. F. M. SMITH, W. BIRNBAUM, AND W. H. BARKAS, *University of California, Berkeley.*—The present study is being conducted on the mono-energetic μ^+-mesons arising from decay of π^+-mesons stopping in photographic emulsion. In 200-micron emulsion $\sim$17 percent of these μ's will lose all of their kinetic energy in the film. The track lengths of those μ-mesons which visibly stop are measured with regard to *total* range. The shrinkage factor of the processed film has been determined in order to find the proper depth component of the range. Preliminary results on the range distribution of 260 tracks are in good agreement with the predictions of straggling theory: The standard deviation of the range is found to be 4.4 percent, and the distribution is not inconsistent with an assumption of normality. Recent reports[1–3] indicate the existence of μ-tracks of very short range. Although some of these might conceivably lie within the tail of the distribution, others are too far out to be included and presumably must be attributed to another process.

[1] W. H. Barkas, Phys. Rev. **83**, 236(T) (1951); also U.C.R.L., 1285.
[2] W. F. Fry, Phys. Rev. **83**, 1268 (1951).
[3] E. Gross (private communication).

P8. Analysis of Neutral Meson Gamma-Ray Spectra from Carbon. W. E. CRANDALL, K. CROWE, B. J. MOYER, W. K. H. PANOFSKY, R. PHILLIPS, AND D. WALKER, *University of California, Berkeley.*—The gamma-ray spectra for angles of observation of 0°, 47°, 90°, 133°, and 180° from carbon targets bombarded by 345-Mev protons have been measured with a multi channel pair spectrometer,[1] and the spectrum obtained by averaging over all angles is compared with the expected spectrum arising from the decay of a neutral pion into two gamma-rays. Uncertainties in the low energy portion of the spectrum make a precise assessment of the symmetry properties difficult, but the contribution to the spectrum from nonneutral pion decay radiation does not need to be more than 2 percent of the observed radiation. If it is assumed that only decay of neutral pions contributes to the radiation observed, then the energy distribution of the neutron pion is derivable from the spectrum. The spectra for lower energy proton bombardments have been measured for two supplementary angles of view of the target and, based on the observed angular dependence of the spectra for 345-Mev protons, the excitation function for neutral pion production is deduced.

[1] Aamodt, Hadley, and Panofsky, Phys. Rev. **81**, 565 (1951).

P9. The Photoproduction of Negative Mesons from Deuterium. RICHARD MADEY, KENNETH C. BANDTEL, AND WILSON J. FRANK, *University of California, Berkeley.*—Evidence will be presented for the observation of the photomeson production process $\gamma+n\rightarrow\pi^-+p$. The photon source is the 322-Mev bremsstrahlung of the Berkeley synchrotron. Pion-proton coincidences were observed at pion laboratory angles of 90° and 120°. Correlated proton angles are predicted from the conservation laws for the photoproduction of a pion from a free neutron at rest. The predicted pairs of correlated meson and proton angles remain very nearly the same over all photon energies in the region of interest. Furthermore, the upper energy limit of the bremsstrahlung spectrum restricts the protons to an angular region in the forward direction within less than about sixty degrees from the beam direction. The effect of the loose binding of the neutron in deuterium imparts a calculable smearing of the angle and energy correlations. When the angle of the proton telescope is varied to seven degrees on either side of the associated correlation angles, the difference in the counting rates between heavy water and ordinary water shows a well-defined peak at the predicted proton angles of 31.5° and 20°.

P10. Angular Distribution of π^+-Mesons Produced in $P-P$ Collisions.* MARIAN WHITEHEAD AND CHAIM RICHMAN. *University of California, Berkeley.*—The energy spectra of π^+-mesons produced by 341-Mev protons striking H' have previously been measured at 0°, 18°, and 60° [1,2] to the proton beam. In order to determine the angular distribution of the mesons more accurately a careful measurement of the production at 35° has been made. As at 0° and 60° the hydrogen cross section was found by taking a polyethylene carbon difference. The mesons were separated from the proton beam by a magnetic field and were detected at the end of their range, by nuclear emulsions embedded in an aluminum absorber. The characteristic peak, which is assumed caused by the reaction $p+p\rightarrow\pi^++d$,[3] is observed at a meson energy of 48 Mev with a width at half-maximum of 4 Mev. The finite width is the result of the beam's energy variation and the resolution of the detector. Previously the angular distribution in the center-of-mass system was assumed to be of the form $d\sigma/d\Omega=a(b+\cos^2\theta_{\mathrm{cm}})$, and values of the constants were calculated from the 0° and 60° data.[4] These data in conjunction with the present results enable one to fix the constants with greater precision.

* This work was sponsored by the AEC.
[1] Cartwright, Richman, Whitehead, and Wilcox, Phys. Rev. **78**, 823 (1950), and Phys. Rev. **81**, 652 (1951).
[2] V. Z. Peterson, Phys. Rev. **79**, 407 (1950), and Peterson, Iloff, and Sherman, Phys. Rev. **81**, 647 (1951).
[3] Crawford, Crowe, and Stevenson, Phys. Rev. **82**, 97 (1951).
[4] Marian Whitehead and Chaim Richman, Phys. Rev. **83**, 855 (1951).

P11. The Production of Photo-mesons from Helium. MARK J. JAKOBSON, ALVIN G. SCHULZ, AND R. STEPHEN WHITE, *University of California, Berkeley.*—A study has been made of the mesons produced from helium and hydrogen by bombarding a low temperature, high pressure target with the 318±10-Mev bremsstrahlung beam of the Berkeley synchrotron. π^+-mesons were detected by scintillation counters, using $\pi-\mu$, $\pi-\beta$, and $\pi-\mu-\beta$ delayed coincidence detection. Ilford C-2, 200μ nuclear emulsions were used to obtain the π^-/π^+ ratio. Measurements were made at angles of 45°, 90° and 135° to the photon beam direction. The minimum energy detected was about 27 Mev resulting principally from the energy loss of the mesons in the target walls. The mean values of the minus-plus ratio from helium at 45°, 90°, and 135° are: .99±.15, 1.09±.14, and 1.00±.12, respectively. Differential and total cross sections for π^+-production were evaluated extrapolating from the minimum energy detected to zero meson energy. The results are presented in Table I (not corrected for nuclear absorption in the absorbers).

TABLE I.

Gas	$\frac{d\sigma(\theta)}{d}$ cm² (steradian)$^{-1}$	(equivalent quantum)$^{-1}$ (proton)$^{-1}$		σ cm² (equivalent quantum)$^{-1}$ (proton)$^{-1}$
	45°±16°	90°±19°	135°±20°	
Helium	$2.5\pm0.2\times10^{-30}$	$4.0\pm0.3\times10^{-30}$	$3.2\pm0.2\times10^{-30}$	$4.1\pm0.2\times10^{-2}$
Hydrogen	$5.5\pm0.5\times10^{-20}$	$7.4\pm0.5\times10^{-30}$	$5.4\pm0.4\times10^{-30}$	$7.8\pm0.4\times10^{-29}$
Ratio $\frac{\text{Helium}}{\text{Hydrogen}}$	0.45±0.06	0.54±0.05	0.59±0.06	0.53±0.04

P12. Nonlinear Pseudoscalar Meson Theory. E. M. HENLEY, *Stanford University.*—A nonlinear term has been introduced into the usual meson wave equation in order to account for nuclear saturation and shell structure.[1] Experimental evidence from meson production, absorption, and scattering favors a pseudoscalar meson with pseudovector coupling, rather than the scalar meson previously investigated. A study has been undertaken to determine the effect of a nonlinearity which corresponds to a point-contact repulsion[1] on such a neutral meson field, making use of classical field theory. For an isolated nucleon, at rest, a particular angular dependence is chosen for the meson field, similar to that for the linear case, so that separation of the angular part of the wave equation becomes possible. The total source strength is found for this case. A variation principle for an arbitrary source is also investigated, together with various nuclear models. It is hoped to carry this analysis further, to the case of charged mesons and more realistic nuclear models than the simple ones chosen to date.

[1] L. I. Schiff, Phys. Rev. **84**, 1 (1951).

P13. Classical Meson Fields. I. D. FOX AND JAMES R. WILSON, *University of California, Berkeley.*—Dirac[1] derived an equation of motion for a point electron in a classical electromagnetic field by equating the flux of field energy-momentum leaving the particle to the rate of change of the particle's energy-momentum. The usual divergence associated with the field of a classical point electron was identified as a relativistically invariant mass renormalization term. A similar procedure was used by Bhabha[2] in treating the problem of the point nucleon in a classical neutral vector meson field, and by T. D. Lee[3] for the case of the neutral scalar field. The method has been extended by the present authors to the treatment of the symmetric and charged scalar fields. The equation of motion of the nucleon was developed as described previously. In addition, conservation of charge was used to derive the equation of motion of the isotopic spin. Both the neutral and the symmetric scalar theories were applied to scattering problems.

[1] P. A. M. Dirac, Proc. Roy. Soc. (London) **A167**, 148 (1938).
[2] H. J. Bhabha, Proc. Roy. Soc. (London) **A172**, 384 (1939).
[3] Private communication.

SATURDAY AFTERNOON AT 2:00

Room 4, Le Conte Hall

(W. B. FRETTER presiding)

Q1. The Latitude Effect of Cosmic Rays between Geomagnetic Latitudes 54° and 88°N.* H. V. NEHER, VINCENT Z. PETERSON, AND EDWARD A. STERN, *California Institute of Technology, Pasadena.*—In the summer of 1951, balloon flights with ionization chambers were made, from shipboard going north from Boston, and from Thule, Greenland. The four flights from shipboard were made at geomagnetic latitudes, λ_m, 55°, 57.5°, 62.5°, and 67.5°N. These flights as well as five of those at Thule ($\lambda_m=88$°N) were made simultaneously with similar flights at Bismarck, N. D. The data show that the daily fluctuations at high altitudes occur simultaneously at these widely separated places and further that these fluctuations are larger than the total latitude effect between Bismarck and Thule. An examination of the records of the magnetic field of the earth both from Mt. Wilson and the Danish station at Thule, shows that, during the times flights were made, there was no appreciable magnetic disturbance.

* Supported in part by the joint program of the ONR and the AEC.

Q2. The Mean Free Path of the High Energy Nuclear Component.* ROBERT R. BROWN, *University of California, Berkeley.*—The mean free path of the charged particles that produce penetrating showers has been measured in carbon, sulfur and iron. The measurements were carried out at Lake Sabrina, California (2765 m). A hodoscope arrangement similar to that of Walker, Walker, and Greisen[1] was used. In order to reduce the background due to the extra nuclear interactions of mu-mesons a producing layer of 50 gm/cm^2 of graphite was used. Events in which one charged particle entered and three or more charged particles left, the graphite producing layer were recorded as a function of the absorber thickness. Analysis of the data obtained gives mean free paths in carbon, sulfur and iron of 65 ± 5, 76 ± 7, and 115 ± 12 gm/cm^2, respectively. The results are consistent with collision mean-free paths determined by the nuclear geometric cross section.

* Assisted by the joint program of the ONR and the AEC.
[1] Walker, Walker, and Greisen, Phys. Rev. **80**, 546 (1950).

Q3. Angular Distribution of the Decay Tracks of Neutral *V*-Particles.* W. B. FRETTER AND M. M. MAY, *University of California, Berkeley.*—An investigation was carried out into the angular distribution of the decay tracks of neutral *V*-particles.[1] The angles θ_1, θ_2 which the decay tracks make with the proposed path of the *V*-particle (line drawn from the apex of the *V* to the probable initial event) were measured. Only cases where the coplanarity of the three paths could be established were considered (27 out of 35). Under a two particle decay scheme, there are two independent variables once mass values are assumed. From θ_1 and θ_2 were calculated, on the one hand, the ionizations of the daughter particles, and, on the other, the angle ϕ^* which their momenta in the rest system of the V^0-particle make with the velocity of the V^0-particle. Assuming two decay processes:[2] $V^0\rightarrow p+\pi^-$, V^0 mass = 2350 e.m., $V^0\rightarrow\pi_++\pi^-$, V^0 mass = 800 e.m., fair agreement was obtained with the observed ionizations and with a sine distribution function for ϕ^*. Three or four anomalous cases were noted.

* Assisted by the joint program of the ONR and the AEC.
[1] W. B. Fretter, Phys. Rev. **83**, 1053 (1951).
[2] Armenteros, Barker, Butler, and Cachon, "The Properties of Neutral V-Particles," to be published, Phil. Mag., October, 1951.

Q4. A Cloud-Chamber Study of Penetrating Showers in Light and Heavy Elements.* W. D. WALKER,† N. M. DULLER, and J. D. SORRELLS,‡ *Rice Institute.*—Penetrating showers were studied using a large rectangular cloud chamber containing carbon and lead plates. The chamber was operated in conjunction with an extensive hodoscope placed beneath it. The apparatus was operated during the summer of 1951 at Echo Lake, Colorado. Star production (i.e., elastic scatterings) by primary particles capable of producing penetrating showers was investigated. There were extremely few pictures of particles that produced a star in the chamber and also a penetrating shower detected in the hodoscope. It is concluded that the elastic scattering cross section for high energy primaries is very small compared to the geometric cross section, as would be expected from Fermi's statistical theory. A comparison has been made between penetrating showers starting in carbon, lead, paraffin, and iron. The rate of showers, per mean-free path of generating material, with *n* penetrating secondaries appears to be almost the same for light and heavy elements with *n* ranging from 2 to 20 particles.

* Supported in part by grants from the Research Corporation and R.E.S.A.
† Presently on leave of absence at the University of California, Berkeley.
‡ Now at California Institute of Technology.

Q5. Zenith Angle Effects for Cosmic-Ray Protons and Mesons.* C. E. MILLER, J. E. HENDERSON, GERALD GARRISON, AND WAYNE SANDSTROM, *University of Washington.*—A magnetic cloud chamber has been used to determine the distribution in momentum of those charged particles stopping in fifteen cm of lead absorber as a function of zenith angle. Observations were made at an altitude of 3.3 km for vertical incidence and for angles of 45° east and west. The method gives the intensity of low energy mesons (momentum below 400 mev/c) and, because of nuclear reactions in the absorber, the intensity of protons to 2.5 bev/c. For these low energy mesons the intensity is found to decrease by a factor of three in going from the vertical to 45° east or west. Within statistics, no change in the positive to negative ratio is found. The decrease in intensity at 3.3 km in going from zero to 45° zenith angle is the same as that found for vertical observation in going from this altitude to sea level. This one would expect from the effective atmospheric depths involved. For low energy protons the intensity also decreases by three from zero to 45° at the altitude 3.3 km which is not at all the same as the factor of about twenty between vertical observations at this altitude and at sea level. For higher energy protons (momentum above 1 bev/c) a pronounced east-west asymmetry is found. Observations are still continuing.

* Supported in part by the ONR.

Q6. Energy Loss of Cosmic-Ray μ-Mesons.* ROBERT HOFSTADTER AND ALVIN M. HUDSON, *Department of Physics and Microwave Laboratory, Stanford University.*—A triple-coincidence telescope, consisting of three NaI(Tl) crystals, has been used to measure the energy loss of μ-mesons in the cosmic rays at sea level. Six inches of lead above the telescope absorbed most of the soft component and three inches of lead between the middle and lower crystals absorbed slow mesons. The middle crystal, of thickness two inches, has been viewed by an RCA C7157 photomultiplier. Energy loss calibration was obtained by measuring the well-resolved gamma-ray lines in the C^{12*} (4.4 Mev) spectrum and the gamma lines of the thorium spectrum. The observed curve is presented in the form of a 70-channel differential energy loss spectrum and shows a sharp peak close to 27.5 Mev. The theoretical energy loss distribution has been computed on the basis of Landau's straggling theory with the Bethe-Bloch energy loss formula and the cosmic ray μ-meson spectrum.[1] The experimental curve is slightly narrower than the theoretical curve. The possible significance of these results will be discussed.

* Aided by the Joint Program of the ONR and AEC.
[1] B. Rossi, Revs. Modern Phys. **20**, 537 (1948).

Q7. Protons and Mesons at 9000 Feet.* A. Z. ROSEN, *University of California, Berkeley.*—An apparatus[1] consisting of three cloud chambers arranged so as to measure the angular deviation of a particle in a magnetic field and its range in Cu has been operated during the summer of 1951 at 9000 ft. Data were obtained on the spectra of single protons and mesons having ranges between 34.1 g/cm^2 and 117.8 g/cm^2 of Cu after having traversed from 0 g/cm^2 to 345 g/cm^2 of Pb-absorber over the apparatus. The use of a tray of counters above the Pb-absorber to operate a neon light in coincidence with the triggering telescope, made possible the counting of protons originating from neutral particles incident on the absorber, and also allowed some estimate of the neutron intensity to be made. The absolute differential intensities of the protons will be detailed and also the intensities relative to those for the mesons which are corrected for reduction in acceptance angle because of the large angular deviation of the mesons in the magnetic field. The results will be compared to those obtained at sea level with the same apparatus.

* This work has been assisted by the joint program of the ONR and AEC.
[1] R. B. Brode, Revs. Modern Phys. 21, 37 (1949).

Q8. Penetrating Cosmic-Ray Showers in Water.* GEORGE W. ROLLOSSON,† *University of New Mexico, Albuquerque.*—Penetrating showers produced locally by neutral radiation were studied using counter techniques. The collision length in water of the neutral, penetrating, shower-producing component was found to be (98 ± 13) g/cm^2. A comparison of this collision length with that obtained by others in carbon[1] and aluminum[2] seems to indicate that the hydrogen nuclei in water have a rather small cross section for the production of penetrating showers by neutral radiation. Measurements taken at two elevations show the absorption length in air of the neutral, penetrating, shower-producing component to be (115 ± 19) g/cm^2.

* Supported in part by a grant from the Research Corporation.
† Now at Sandia Corporation, Albuquerque, New Mexico.
[1] Walker, Walker, and Greisen, Phys. Rev. 80, 546 (1950).
[2] E. P. George and A. C. Jason, Proc. Phys. Soc. (London) A63, 1081 (1950).

Q9. Knock-On Secondaries from Penetrating Particles in Carbon. JOHN R. GREEN, *University of New Mexico.*—Cloud-chamber pictures obtained to investigate penetrating showers produced in carbon* have been re-examined for knock-on particles accompanying individual penetrating particles (mostly mu-mesons) emerging from carbon plates. The probability that a penetrating particle leaving a one-inch carbon plate will be accompanied by a knock-on is about ten percent. The angular distribution of secondaries relative to the parent particles is approximated by $\cos^n\theta$, with n between 2 and 3. Ten percent of the secondaries scatter noticeably in the one-half inch of gas between plates and have energies below 1 Mev. Eighty percent traverse the gas without scattering but cannot penetrate the following one-inch carbon plate; these have energies of a few Mev. The remaining ten percent traverse one or more carbon plates. One to two percent produce additional ionizing particles in the carbon plates or in the one-half inch lead plates that identified the penetrating particles; these particles possess energies of 100 Mev or higher. The general behaviour of the secondaries is consistent with that expected of electrons. Agreement was found between observations at sea level and at 12,000 feet.

* The pictures were obtained while the author was at the University of California, Berkeley, with the Cosmic Ray Group on a project supported in part by the ONR and AEC. See Phys. Rev. 80, 832 (1950).

Q10. Absorption Cross Sections for 19.5-Mev Quanta.* ARTHUR I. BERMAN, *Los Alamos Scientific Laboratory.*—Total cross sections for 19 elements, from hydrogen to uranium, were found by a photonuclear detector method[1] which measured the C^{11} activity induced by betatron bremsstrahlung. The penetration of the radiation (maximum energy, 20.4 Mev) through the absorbers was detected by the $C^{12}(\gamma, n)C^{11}$ reaction (threshold, 18.7 Mev) in polyethylene. The use of high counting rates and dual monitor-detector Geiger counters, which completely or partially canceled errors due to timing, intensity fluctuations, and uncertainty in counter, resolving-time theory, reduced most random probable errors to approximately 0.4 percent. Systematic errors added about 0.4 percent to this. The narrow band width permitted a determination of the proportion of counts due to secondary effects. If the approximate high-energy validity of the Klein-Nishina Compton cross section (verified here to within 7 percent) is assumed, together with recent photonuclear data, then the theoretical (essentially Bethe-Heitler formula including screening) and experimental pair cross sections are related by $(\sigma_t-\sigma_e)/\sigma_t=(1.6\pm0.2)\times10^{-5}Z^2$.

* Work performed under the auspices of the AEC.
[1] G. D. Adams, Phys. Rev. 74, 1707 (1948).

Q11. The Aeroballistics Laboratory of the U. S. ARTHUR L. BENNETT, IVAR HIGHBERG, ERNEST BARKOFSKY, AND LUCIEN M. BIBERMAN, *Naval Ordnance Test Station, Inyokern.*—The U.S.N.O.T.S. is completing a facility for the accurate experimental evaluation of the parameters (such as lift, overturning moment, and drag) required for the prediction of the behavior of a new projectile design. The Laboratory is an enclosed range for the measurement of the trajectory of models in free flight. Since safe extrapolation to full scale requires that the model exceed the critical Reynolds number, the range is designed for models at least 3 inches in diameter. The configuration to be studied is projected through the range by a suitable gun. The laboratory building is 480 ft long, 40 ft wide, and 30 ft high; a clear radius of 10 ft about the trajectory is provided to avoid wall interference at velocities near Mach 1. The position and orientation of the model is recorded photographically at frequent intervals by multiple photographs taken by pairs of cameras at 20 ft spacing. The microsecond flash lamps, which provide the light for the photographs, are precisely timed by a submultiple of the frequency of a crystal clock. Measurement of the photographs provides the position and orientation (hence yaw) of the model at known time intervals. From these data the aerodynamic and ballistic characteristics of the model are determined. Auxiliary equipment for shadowgraph, schlieren, and interferometer photographs will be added as needed for study of flow about the models. Photographs of the building and the instruments are presented and the operating technique described.

Q12. The Differential Cross Section for the Scattering of 9.5-Mev Protons from Helium. T. M. PUTNAM, *University of California, Berkeley.*—The angular distribution of 9.5-Mev protons scattered from helium nuclei has been measured with photographic emulsions. The 20-Mev molecular hydrogen beam from the 60-in. cyclotron in Crocker Laboratory was the source of protons. The scattering chamber was the nuclear multiplate camera of Allred, *et al.*, developed at Los Alamos.[1] Forty angles from 10° to 172.5° were measured. The scattered particles passed through a two-slit collimating system which, together with the beam collimation system, determined the scattering volume. The geometry was such that the angle of the nuclear plate with the slit axis did not enter into the solid angle determination. Approximately 2500 tracks were counted at each angle using suitable acceptance criteria to establish the identity of the scattered particles. The construction of the multiplate camera was such that the relative accuracy for a group of points from a given run is espected to be within the counting statistics. An absolute standard error to be assigned to the data is five percent for the angular range of 10° to 25° and 2.9 percent for the range of 25° to 172.5°.

[1] Allred, Rosen, Tallmadge, and Williams, Rev. Sci. Instr. 22, 191 (1951).

Q13. Electron-Electron Scattering at 6.1 Mev. W. C. BARBER, G. E. BECKER, AND E. L. CHU, *Stanford University.*—The absolute differential cross section for the scattering of 6.1-Mev electrons by the electrons in a beryllium foil has been measured at 90° and 109° in the cm system. Electrons from a linear accelerator were first magnetically analyzed and then collimated to form the incident beam. Electron-electron scattering events were detected by end-window Geiger counters in coincidence. The counter with the defining aperture was connected in coincidence (1) with a counter at the conjugate scattering-angle, lying in the plane determined by the incident beam and the scattering direction to the defining counter; and

(2) with another counter at the conjugate-angle but lying outside this plane, thus counting only accidental coincidences. The number of $e-e$ coincidences was then given by the difference between (1) and (2), with appreciable corrections arising from asymmetry in the background and from dead-time losses. These corrections required measurements of single and coincidence count rates with the scatterer in and out of the beam. The average result at each angle is somewhat lower than that predicted by the Møller theory, but the discrepancy is not greater than the present experimental uncertainty of the order of ± 10 percent. Possible systematic errors are being investigated.

SUPPLEMENTARY PROGRAMME

S1. Eigenfunctions and Landé Interval Factors for Terms of f^3 Electrons. Selection Rules Applicable to Rare Earth Bromates.* ROBERT A. SATTEN, *University of California, Los Angeles.*—The eigenfunctions corresponding to the Russell-Saunders terms of f^3 electrons were calculated by the method of Gray and Wills[1] as linear combinations of products of single-electron eigenfunctions. Also the Landé interval factors $\zeta(LS)$ for the various Russell-Saunders terms arising from f^3 electrons were computed in terms of the single-electron spin-orbit interaction[1] "parameter" ζ_{4f}. The diagonal sum rule was used to calculate all the $\zeta(LS)$ values whose LS values occur only once. To obtain the remaining ζ's, the Russell-Saunders eigenfunctions for LS values which occur twice were used. Selection rules were derived by the usual group theoretical means for electric and magnetic dipole as well as electric quadrupole radiation for an atom in an electric field of symmetry C_{3v}. These selection rules do not agree with the corresponding rules given by K. H. Hellwege.[2] The results apply to rare earth bromates. Thus it can be determined that the 8600A group of absorption lines in $Nd(BrO_3)_3 \cdot 9H_2O$, identified as a transition to $^4F_{3/2}$, cannot arise solely from electric dipole, or solely from magnetic dipole, or electric quadrupole radiation alone.

* To be given after Session D if time permits.
[1] Condon and Shortley, *The Theory of Atomic Spectra* (Cambridge University Press, London, England, 1935).
[2] K. H. Hellwege, Ann. Physik **4**, 95 (1948).

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